RESTRAINT APPLICATION DURING DRYING OF HEM-FIR LUMBER

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BACKGROUND

The use of small log hem-fir lumber for residential and commercial applications has been hindered by the excessive degrade associated with warp during kiln drying. The high percentage of juvenile and compression wood found in small log lumber results in a greater number of pieces having both normal and abnormal (compression and juvenile) wood in the same piece. This results in differential longitudinal shrinkage between the abnormal and normal wood components, with subsequent warpage.

Efforts to reduce warp during kiln drying have included drying schedule changes, presteaming, and restraint of the load. The application of "dead-load" restraint has been successful, while presteaming and drying schedule modification have been of limited success. The ability to apply "dead-load" restraint to existing drying systems is very difficult due to inadequate load bearing capacity of the foundations, handling difficulties of the "dead-loads," and loss of kiln capacity. Because of these problems, the search for a successful mechanical system was undertaken.

Criteria for success of a mechanical restraint system includes: a large reduction in warp, ease of application and removal, low maintenance requirements, safety design of the system, and a high benefit/cost ratio. Prior studies using the commercially available "Tim-Kiln-Tie" spring and cable restraint system (Figure 1) manufactured by Timber Conversion, Inc. of Portland, Or., were unsuccessful in significantly reducing warp during kiln drying. This was mainly due to the inability of the system to conform to the load during drying. The system selected for these tests was a patented Weyerhaeuser leaf spring system (Figure 2) which conforms to the load and restrains the entire package.

The major value loss due to warp is associated with kiln drying at the operational site. However, additional value loss occurs with on-grade material shipped to low humidity markets when subsequent drying occurs before application. For this reason, the final average moisture content of the kiln charge is also critical in obtaining an acceptable product.

PROCEDURES

Control of the drying process and a sufficiently large sample size are important criteria in obtaining statistically significant results. For these reasons, a 20,000BF gas-fired kiln used for experimental purposes was selected for this study. This kiln was designed with uniform drying, excellent control of dry and wet bulb temperatures, and a kiln car weighing system for assistance in determination of end point. Conventional stacking of the 16ft mill run hem-fir lumber produced four-12x22 packages on each of the two kiln cars (Figure 3), for a total of over 2000 boards per test charge.

Two of the top four packages were restrained, while the other two packages were unrestrained. The bottom packages were considered controls since they were weight restrained by the top packages and had minimum warp. Nine Weyerhaeuser leaf springs were applied on two foot sticker spacing for each of the top-restrained packages. This number of restraints produced an initial, equivalent dead load of over 250lb/sq ft. Previous tests using only five leaf spring restraints on four foot sticker spacing indicated an inadequate reduction in warp.

To determine the effects of final moisture content on warp during drying, two final target moisture levels were chosen 9% and 12%. A mild CRT (Continuously Rising Temperature) drying schedule (Figure 4) with 400fpm air velocity was used for all the tests. The material from the 12%MC tests was solid piled and placed back into the kiln at 4%EMC conditions to simulate low humidity market conditions. After one week at these low humidity conditions, the lumber was reevaluated for warp. The evaluation process involved a single Western Wood Products Association certified grader who evaluated each piece of lumber. The grading criteria are shown in Table 1, and include a more stringent warp requirement for MSR (Machine Stress Rated) candidate stock.

Each piece of lumber was measured with a Delmhorst Moisture Meter at three locations using a 2-pin electrode with 7/16in pins. If there was a large discrepancy in the three values, at least two other measurements were taken to obtain an average moisture content for each board. The average moisture content for each package and the kiln charge was then determined.

In addition to warp and moisture content information, the amount of juvenile wood in the piece was also determined visually by growth rate and the presence of pith or near-pith material. Pieces that had a fast growth rate and "pith-included" had a high percentage of juvenile wood. Pieces that were slow growth and had "pith-included" had a low percentage of juvenile wood. Each piece was then allocated to a growth rate and "pith-included" or "no-pith" category to determine the quantitative effects of juvenile wood on warp.

RESULTS

Data Analysis - The data was separated into three categories: top unrestrained, top restrained, and bottom packages. Data included the incidence and severity of warp, moisture content, juvenile wood percentage, visual grade, and final length.

If the piece was trimmed, the piece trimmed-off was valued as chips. Average 1980 realization prices for random length hem-fir 2x4's (Table 2) were used to determine the value of the kiln dried stock.

Juvenile Wood - The influence of juvenile wood on warp is shown dramatically in Figure 5. A piece that has a high percentage of juvenile wood has a probability greater than 50% of being degraded for warp. A piece that has even a low percentage of juvenile wood has a probability of about 20% of being degraded for warp. This is in contrast to those pieces void of juvenile wood which have less than a 15% probability of being degraded for warp.

Restraint - The effectiveness of the Weyerhaeuser leaf spring is shown in Figure 6. While the unrestrained top packages had nearly 30% of the material degraded for warp, only 20% of the top restrained packages was degraded for warp. This was equivalent to the warp degrade associated with the bottom packages, which were weight restrained by the top packages. The restraint appeared to be more effective in reducing warp in excess of the allowances for Standard and Better lumber. The warp degrade percentage associated with MSR candidate stock appeared to be unchanged from unrestrained to bottom packages. This is indicative of the difficulty in eliminating a small degree of warp entirely during kiln drying.

Final Moisture Content Level - As the final moisture content level is reduced from 12% to 9%, the amount of warp degrade increases substantially. Figure 7 shows that the warp degrade at 9%MC in all categories is almost double that at 12%MC. With unrestrained packages, over 60% of the pieces are degraded for warp. Even with restraint, over 30% of the pieces are degraded for warp, with most of those falling out of the MSR grade. With a final moisture content of 9%, the restraint system is less effective due to the additional shrinkage and reduced spring forces.

The effect of final moisture content on warp degrade is shown graphically in Figure 8 using the grade distributions for each test and the pricing table (Table 2). The non-linear increase in drying degrade with lower moisture contents is well substantiated with other data.

Low Humidity Exposure - When kiln dried material is solid piled and shipped to low humidity markets, additional drying continues. This additional drying also means additional warp and degrade. A measure of this additional degrade was determined using solid piled, finished lumber from the 12%MC tests. The material was exposed to 4%EMC conditions for one week at air velocities of 100fpm in the experimental kiln. This was assumed to be equivalent to three weeks of normal market conditions exposure. At the end of this period, all the lumber was remeasured for warp degrade, and moisture content as before. The final average moisture content was reduced to 8% during this period.

The resulting degrade of kiln dried MSR stock is shown in Figure 9. Nearly 40% of the MSR stock was degraded due to warp after exposure to the 4%EMC conditions. About one-third of this material dropped two grades during the low humidity exposure. It was interesting to note that the material restrained during kiln drying also had less degrade after low humidity exposure. There appears to be some carry-over effect of restraint during kiln drying. Obviously, the material in the bottom packages had the least amount of degrade after low humidity exposure.

The value loss accompanying the warp degrade of the MSR stock is shown in Figure 10. An average of $25/MBF is lost when kiln dried MSR stock (top and bottom packages) is exposed to low humidity conditions for an extended period. If restraint of the top packages is part of the kiln drying process, the expected value loss is reduced to $22/MBF.

The degrade loss of only Standard and Better lumber after exposure to low humidity conditions is shown in Figure 11. The percentage of unrestrained material degraded for warp is double (20%) that of the bottom packages (10%), while the top restrained material had a 15% reduction in grade after low humidity exposure. This again confirms the benefits of restraint during kiln drying on product value after sales.

CONCLUSIONS

If typical mill run, hem-fir lumber is kiln dried to a 12%MC average using a conservative drying schedule, the expected grade loss due to warp is about 15% for Standard and Better lumber, and about 20% if MSR grades are also included. This grade loss due to warp can be reduced by one-third if the top packages can be adequately restrained during kiln drying. With MSR grades included, this amounts to about $20/MBF value loss due to drying degrade.

The application of mechanical restraint to the top packages during kiln drying is effective in reducing warp if the system is capable of continuously applying restraint during shrinkage of the lumber. The Weyerhaeuser leaf spring system was able to reduce the amount of warp degrade equivalent to the bottom weight restrained packages when kiln dried to a final moisture content level of 12%. If the final moisture content level is less, the Weyerhaeuser leaf spring system has a reduced effectiveness due to excessive shrinkage of the lumber and a loss of restraining force. This could probably be offset with a higher spring force.

Two major factors contributing to warp during kiln drying are: (1) the presence of a high percentage of juvenile wood in the piece, and (2) the final moisture content level. Pieces with a high percentage of juvenile wood have over a 50% probability of being degraded at least one grade for warp. Those pieces without juvenile wood or a low percentage of juvenile wood have a 10-15% probability of being degraded for warp. If the final moisture content level is reduced from an average of 12% to 9%, the amount of warp degrade is almost doubled.

If material is kiln dried, graded and shipped to low humidity conditions, additional drying degrade will occur on site. This amounts to about a 15% loss of Standard and Better stock, and as much as a 35% loss of MSR stock if the exposure time is sufficient to reduce the average moisture content by at least 4%.

ABSTRACT

The application of the Weyerhaeuser leaf spring to hem-fir 2x4's during kiln drying results in a significant reduction in warp degrade. The uplift in grade quality is equivalent to the bottom "weight-restrained" packages when the final average moisture content is 12%. When the average moisture content of the charge is reduced to 9%MC, the amount of warp degrade is doubled. The presence of juvenile wood in the piece is a major factor contributing to warp development during kiln drying. Pieces with a high percentage of juvenile wood were found to have a 50% probability of degrade due to warp. Material that was on-grade after kiln drying to 12%MC, was significantly degraded when exposed to low humidity conditions (4%EMC) for an equivalent of three weeks. The downfall in grade was most critical for MSR (Machine Stress Rated) material which has a limited tolerance to warp.

Table 1. Warp Allowances

Warp Type	Maximum Warp (inches)			
	MSR	Standard	Utility	Economy
Bow	1.6	3.2	5.0	5.0+
Crook	0.5	1.0	1.5	1.5+
Twist	0.5	1.0	1.5	1.5+

Table 2. Value Table
16 ft. 2x4 Hem-Fir

Grade	$/MBF
MSR	240
Standard	190
Utility	130
Economy	115
Chips	50

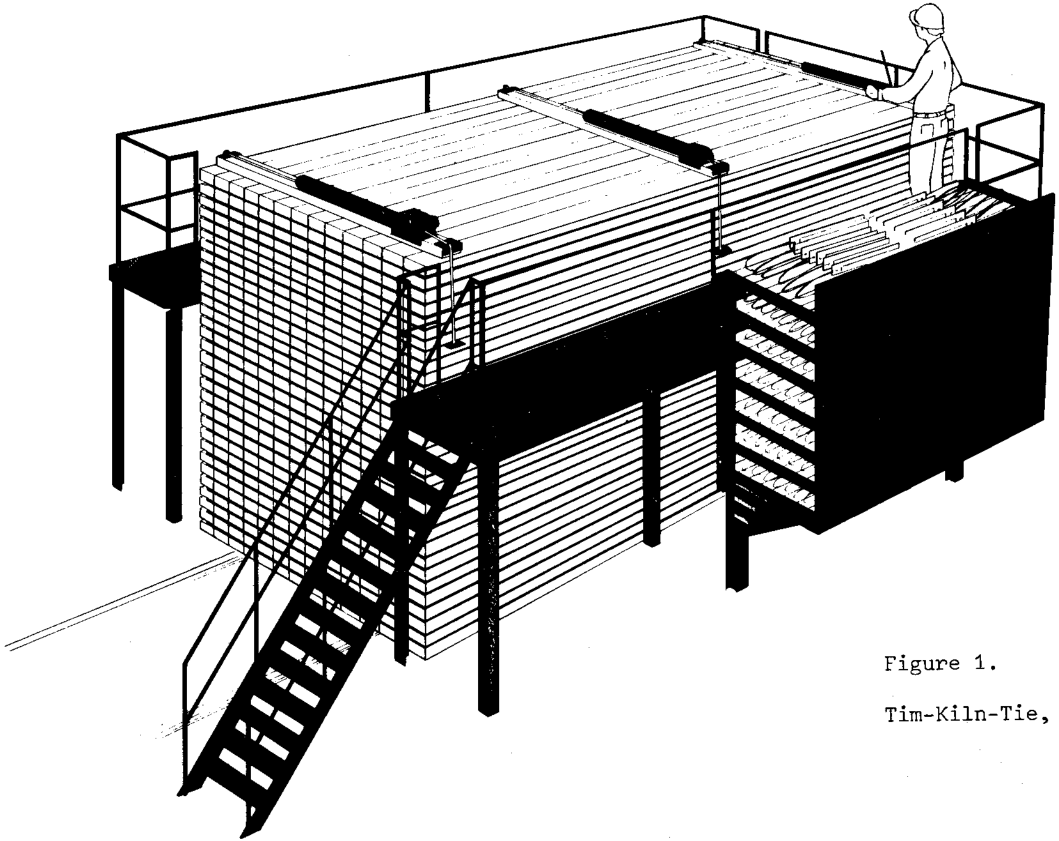

Figure 1.

Tim-Kiln-Tie, System

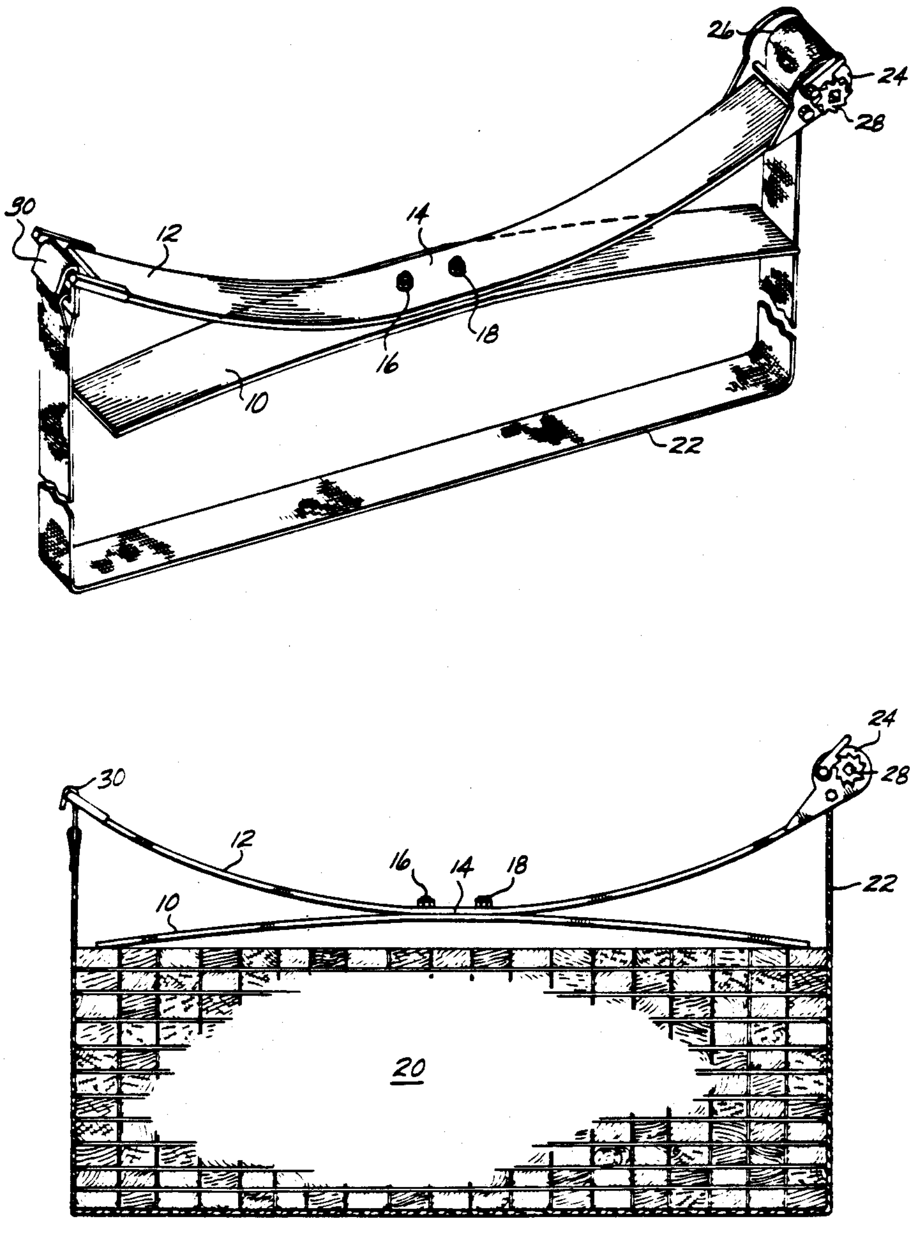

Figure 2. Weyerhaeuser Leaf Spring System

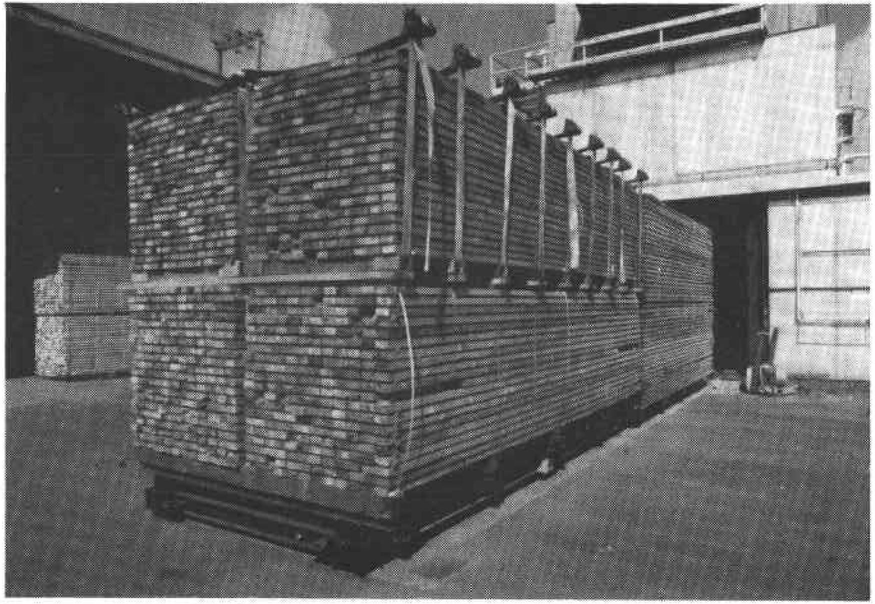

Figure 3. Partially restrained kiln charge ready to be dried in 34ft. Experimental Gas-fired Dry Kiln

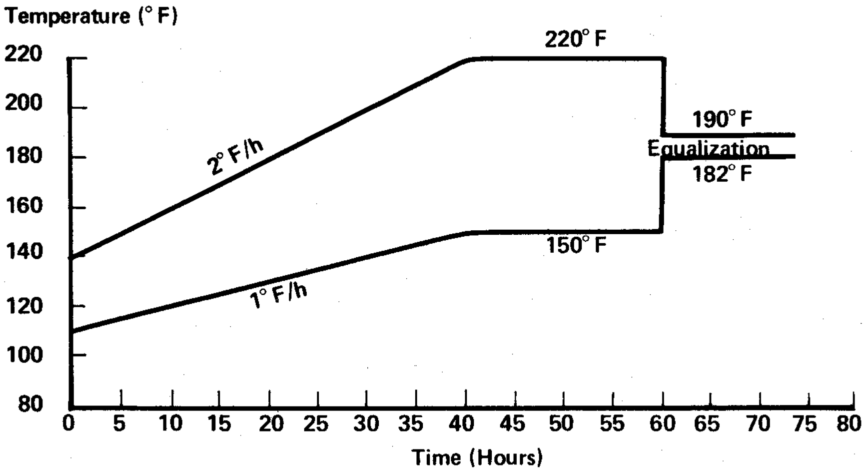

Figure 4. Hem-Fir 2x4 Drying Schedule

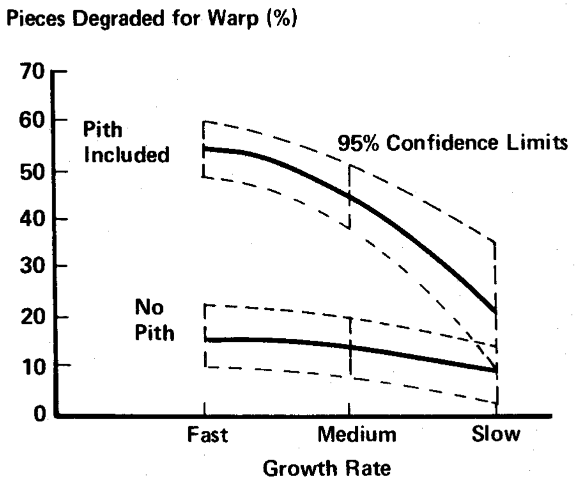

Figure 5. Material Characteristics

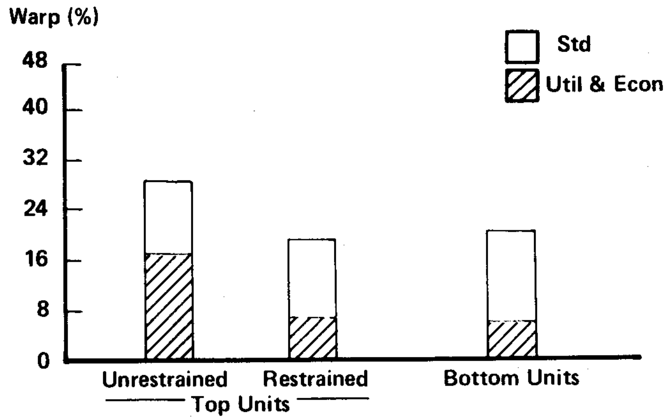

Figure 6. Weyerhaeuser Leaf Spring Restraints 12% MC Average

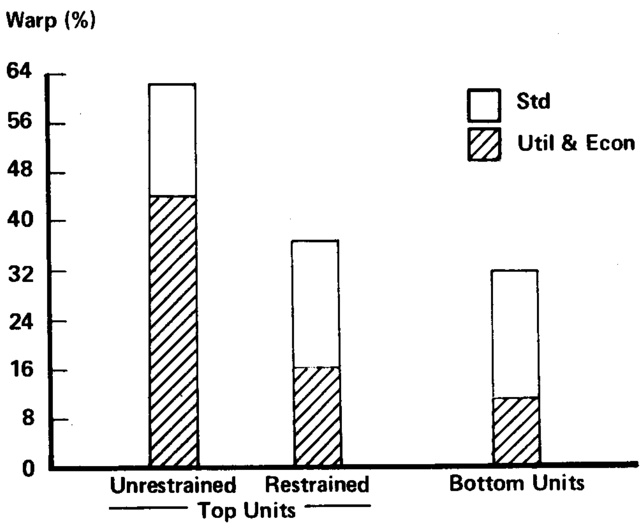

Figure 7. Weyerhaeuser Leaf Spring Restraints 9% MC Average

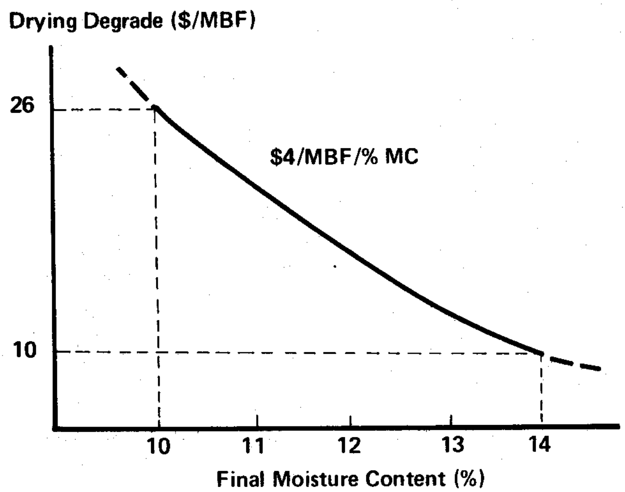

Figure 8. Average Moisture Content Effects on Warp Degrade

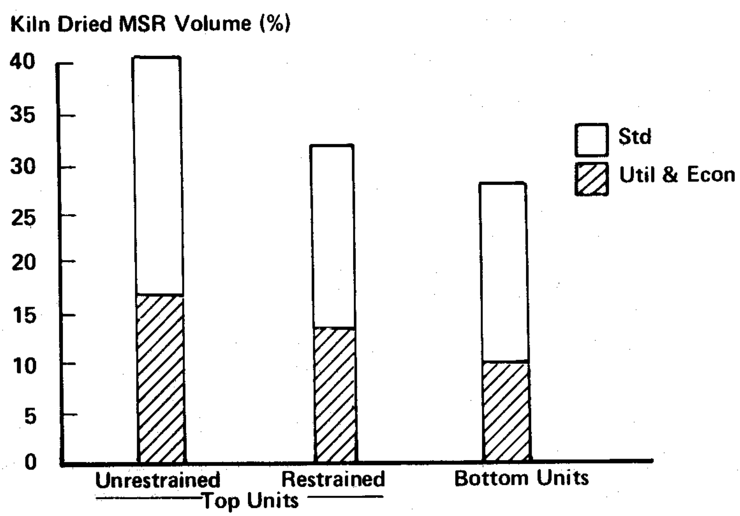

Figure 9. MSR Stock Exposed to Low Humidity Conditions (4% EMC)

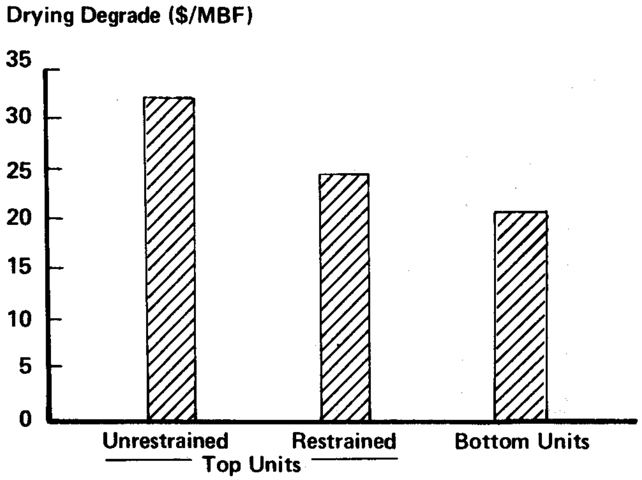

Figure 10. MSR Stock Exposed to Low Humidity Conditions (4% EMC)

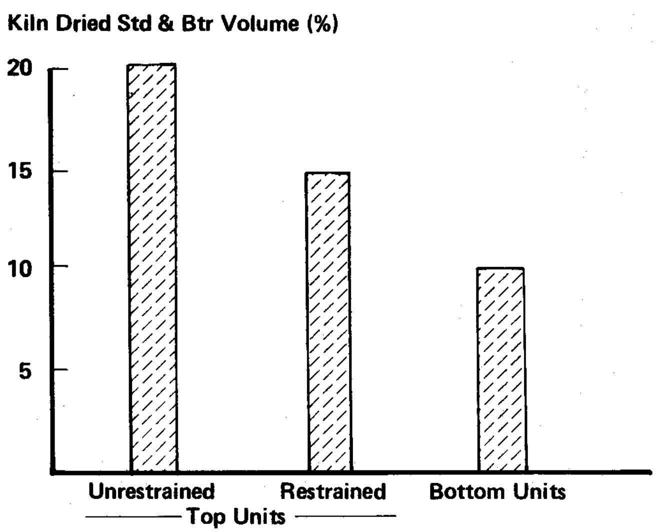

Figure 11. Standard and Better Stock Exposed to Low Humidity Conditions (4% EMC)