Casehardening Stress Relief of Ponderosa Pine

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Hot Lumber 24 Hours Conditioning, 19200 lbs. steam used.

Cool Lumber 12 Hours Conditioning, 10 hours cooling, 9600 lbs. steam used.

Hot Lumber, 12 Hours Conditioning, Water injection, 600 gals. water used, 9600 lbs. steam used.
SUMMARY

The purpose of this study was to determine efficient means of conditioning Ponderosa Pine to relieve case hardening stresses. Comparative tests revealed that conditioning time could be reduced from 24 hours to 4 hours by cooling lumber prior to conditioning, by injecting water into the steam spray line and by increasing the quantity of steam. Cooling lumber and injecting water are two effective means of achieving saturated conditions at high temperatures during conditioning. Both methods result in savings of steam as well as time. The relationship of steam quantity to the effect on stress relief reaches an economical proportion within the range of 80 to 100 lbs./hr/M. Water injection devices are inexpensive, or easy to build and install in the spray line of each kiln. The devices tested are sketched within the report.

Introduction

The spraying of lumber with generous amounts of steam to relieve the casehardening stresses developed during kiln drying has been generally practiced for many years. Stress removal by conditioning is an important step in producing quality stock for resawing or ripping during further manufacture. Recommendations without basic study of the effect of temperature, relative humidity and length of time have been made to promote effective conditioning. Various methods of techniques and equipment have been devised by trial and error methods. Therefore, a study was needed to test recommendations and obtain data for the design and operation of devices and equipment.

Several variable factors such as the rate of drying, texture of stock, moisture content and kiln construction do affect the intensity of stresses and the relief of them. A study of these variables is not included for this report.

The factor of greatest influence is steam for the use of conditioning. Steam will vary from mill to mill in pressure, quality and quantity. A low pressure steam system supplies steam of saturated qualities which will provide high relative humidity and equilibrium moisture conditions at high temperatures. A high pressure steam system supplying steam at higher pressures is dry in quality which will provide high temperatures, but low humidities. In W.P.A. Research Note No. 45222 it is pointed out:

"While it is easy to heat the lumber by the use of steam jets, merely turning on high pressure steam for a few hours frequently fails to get desired results in the way of stress relief. The reason is that high pressure steam expanded to atmospheric pressure seldom yields kiln humidities higher than 70% and at 170° kiln temperature the surface fibers would not rise above 9% moisture content. While saturated steam is used at most mills, boiler pressure steam is no longer saturated when its pressure is dropped to that of the atmosphere without work being done, but rather is highly superheated. If only superheated steam is available, the superheat at atmospheric pressure is correspondingly greater. Means must be found then to absorb this superheat so that the humidity may be high enough to cause a rather large surface pick up in moisture content."

A recommended practice for conditioning is to close all the vents, close all heating coils and open the spray line for a maximum steam flow. This technique will rarely produce relatively high humidities. Therefore, what means could be used to obtain the high relative humidities? The means were directed toward the size of the spray line and orifice openings for steam quantity and pressure reduction, the possible cooling of lumber prior to the
final conditioning and the mixing of cold or hot water with the steam to reduce pressure and superheating. Some or all of these ideas may be useful in absorbing the superheat to produce saturated conditions. The purpose of this study, therefore, was to determine the degree of effect which these various methods had upon the efficiency of conditioning to relieve casehardening stresses.

Casehardening stresses and their development have been explained in many research bulletins and textbooks. Several references are listed on page 40.

Test Procedure

A test program was planned which simulated equipment, material, methods and sampling techniques used in kiln drying of softwood species.

Equipment

The Western Pine Association test kiln at the Brooks-Scanlon Lumber Co., Bend, Oregon, was used for this study. The kiln is of standard cross section, but only one crib long, approximately, 16’ W x 22’ H x 25’ L inside dimensions. The load rests on a scale for continuous weighing during a test period.

A spray line with thermocouple wells and pressure gauges was installed to record temperature and pressure of the steam. Steam flow was recorded with a steam flow meter or computed at controlled pressures for three sizes of orifice openings into the kiln air. Steam flow through an orifice to the atmosphere was computed by Napier’s Formula:

\[ W = \frac{Pa}{70} \]

- \( W \) = Steam flow in lbs/sec.
- \( P \) = Pressure in psia
- \( a \) = Orifice size in sq. in.

Thermocouples were placed inside the kiln for data of dry bulb, wet bulb and lumber surface temperature. The scale recorded the increase in weight due to moisture absorption during each test run. The following devices were installed in the spray line for injection of water into the steam spray line before entering into the kiln: (1) Venturi, (2) Tee siphon, (3) Desuperheater. (Sketches Fig. 2).
Other devices were tried but the steam flow was limited because of orifice sizes. Therefore testing was centered around the 3 listed devices. Water flow, pressure and temperature were recorded with instruments in the water supply line.

**Material**

Test material was 6/4 Shop, Ponderosa Pine, 16 feet long in quantities of 10,000 bd ft. The stock was dried in the mills cross-circulation kilns to a moisture content of 6%-10%. The schedule used for drying the test material was one which controlled the rate of drying for desired speed and resulting quality in the region.

**Sampling**

The test crib was pulled from a kiln charge and sample boards, 6/4 x 12 x 16 were selected for control and test samples. Four stress samples were cut from the selected boards before each test. A total of 10 stress samples were selected to obtain results of stress relief across the width of the test loads. All samples were surfaced to standard finished thickness and width. Moisture content of core and shell was determined with a moisture meter. Each sample was resawn into two pieces of equal thickness designated pith side and bark side. They were laid on a flat surface, the cupped face down and measured to an accuracy of .01 inch at the greatest curvature. The measurements of the pith and bark sides were added for the total amount of cup and divided by two for the average cup. The percent of stress relief was computed from these measurements of the average amount of cup for each piece. Calculations were as follows:

\[
\text{Control sample } \frac{.40}{2} = .20'' \text{ avg. cup}
\]

\[
\text{Treated sample } \frac{.16}{2} = .08'' \text{ avg. cup}
\]

\[
\text{Stress Relief} = \frac{.20-.08}{.20} \times 100 = 60\%
\]

**Test Method**

The following practice was maintained throughout all tests. All heating coils were closed, all vents were closed, and the spray line was opened full. The only control was on steam pressure to maintain a desired steam flow. Therefore, maximum humidity and E.M.C. were reached as governed by the condition of the steam at the given pressure and the quantity which the orifice openings would exhaust to the atmosphere.

The following factors and methods were tested to determine their effect upon the relief of stresses in relation to time: (1) Steam volume, (2) Lumber temperature, (3) Water injection, (4) Air Circulation.

**Results**

**Steam volumes**

An increase in steam volume directly influenced the rate and final relief of stresses. An indication of the effect of increased steam quantities on stress relief and time is shown by three tests of cooled lumber. (50 lbs of steam /hr/M gave 55% stress relief in 14 hours; 80 lbs/hr/M gave 80% stress relief in 9 hrs; and 340 lbs gave 72% in four hours.) The conditioning time was reduced and the stress relief was equal or better at increased steam quantities. Although this fact is true, the use of steam over 100 lbs/hr/M appears to be impractical for efficient conditioning.

**Conditioning Methods**

The accompanying graphs, Fig’s. 5, 6, 7, demonstrate the results of three conditioning methods; hot lumber, cool lumber and water injection, at the indicated steam and water quantities. The graphs demonstrate the effect of the
conditioning method on temperatures and gain in weight in relation to time.

The methods of cooling lumber and injecting water reduced the superheating effect of the steam to provide more moisture for absorption. This is indicated by the comparative rate of gain in weight and higher relative humidity. The total weight gain was less, yet more effective because of the increased rate of weight gain during the time of increasing wet bulb temperatures. The rate of moisture absorption is more effective than the maximum temperatures attained. The per cent of stress relief for Test No's. 1, 2, and 3 are compared in relation to time, Fig. 11. The results show that for shorter periods of time, cool lumber and water injection methods produced as well a stress relief as hot lumber tests of 24 hours. Cooling time added 5 hours to the actual conditioning time for a total of 14 hours to effect the same stress relief. Whereas a water injection method effected the same stress relief in 12 hours.

Larger quantities of steam were used in other studies to determine maximum limits of economical steam use in relation to time and stress relief. This resulted in higher temperatures, more rapid moisture absorption and a faster rate of stress relief. The following Figures 8, 9, and 10 demonstrate the results of three conditioning methods: hot lumber, cool lumber and water injection at a steam quantity of 340 lbs/hr/M.

Cooling of lumber and injection of water reduced the superheating effect of the steam. This provided more moisture for absorption as the wet bulb temperature increased. This is indicated by the increased rate of weight gain due to higher relative humidities at higher temperatures. The per cent of stress relief for these Test No's 4, 5, 6, are compared in relation to time, Fig. 12. The results show that for equal periods of time and larger steam quantities, the per cent of stress relief is improved by cooling the lumber or injecting water into the steam. But, the use of steam quantities as great as 340 lb/hr/M is not economical in proportion to the rate of stress relief. Therefore, for economical limits of steam use to efficient stress relief, a maximum of 80-100 lbs/hr/M is more reasonable.

**Cold Versus Hot Water Injection**

The use of hot water simulated a system to collect and inject condensate from other kilns into the steam spray line or the use of a separate heating process for this purpose. The results show that water at 63°F effected a stress relief of 48%, whereas, water at 177°F effected a stress relief of only 56%. All other variables were the same for this comparative test. The extra
equipment to supply hot water would be unnecessary for such a small improvement in stress relief.

**Effect of Air Circulation**

Variation of the uniformity in stress relief across the width of test loads 9’ wide was notable due to air circulation direction. The trends affected by one way circulation, no circulation, and reverse circulation are demonstrated by the graphs of Fig. 13.

One way circulation revealed a high to low stress relief from the entering to the leaving side of the load. (Left to right). This indication was general with most of tests using one way circulation. No circulation produced a high-low-high per cent of stress relief across the width of test loads. Although this simulates the use of a steam chamber for conditioning, the trend is not serious enough for adequate uniformity of stress relief. Reversing circulation produced a much more uniform stress relief across the width of a load. Air
circulation should be reversed midway of the total conditioning time.

**Conclusions**

1. Steam volume, pressure and the resulting temperature are primary factors for efficient relief of drying stresses. The free flow of steam with a minimum of back pressure must be provided by orifice openings which will exhaust the maximum steam flow for the installed spray line pipe. The total area of the orifice openings should be slightly greater than the internal area of the spray pipe. The steam flow of 60 to 100 lbs of steam/hr/M bd ft at a pressure of 30 psig near the outlet is an economical quantity of steam use for efficient relief of casehardening stresses. Where more steam is available conditioning time will be shorter, but at a rate of over 100 lbs/hr/M the use of greater quantities becomes less economical.

2. The highest temperatures obtainable by continuous spraying is recommended rather than controlled temperatures for specific relative humidities and equilibrium moisture content. The high temperatures of 160° to 180° are practical to attain by continuous steam flow at 60 to 100 lbs of steam/hr/M.

3. Cooling of lumber reduces the conditioning time to approximately one-half of the time necessary for hot lumber. Cooling inside the kiln to a temperature of approximately 115° or complete cooling outside for more than 5 hours will provide uniformly low lumber temperatures for uniform stress relief, save conditioning time and steam. Cooling appears to have no adverse affect upon grade.

4. Mixing of water with high pressure superheated steam will reduce conditioning time by one-half of the time needed for conditioning of hot lumber. Devices installed in the spray line system for water injection eliminates cooling time, effectively raise the humidity and save steam. Hot water is slightly more effective than cold water. Extra equipment to supply condensate or to heat water would be of small advantage. The use of approximately 2 to 5 gallons of water per hour per M bd. ft. mixed with the 80 to 100 lbs of steam/hr/M would be sufficient water to produce saturated conditions and prevent excessive wetting. Redrying time is unnecessary because the release of heat evaporates all of the moisture absorbed during conditioning.

5. All three types of water injection devices used in the tests are satisfactory. Most important are pressure differences between water and
steam. The venturi device operates well at pressure differences of approximately 40 psig if the narrowed portion is one-half the diameter of the upstream and downstream pipe diameter. Or if the downstream pipe diameter is half again as large as the upstream pipe diameter. The same requirements for the tee-siphon. The desuperheater device must exhaust the mixed steam and water into a spray line pipe twice the diameter of the supply line. If the initial water and steam pressures are the same, the design corrections are unnecessary except that these corrections do induce pressure reduction.

6. Reversing of air circulation during conditioning is needed for uniform stress relief regardless of the method employed.

Acknowledgment

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References

Western Pine Association, Research Note No. 4.5222, Casehardening of Lumber.

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