POST DRYING OPERATIONS — DEFECT ANALYSIS AND SCHEDULE ADJUSTMENT — KEYS TO QUALITY CONTROL

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Introduction

Several recent trends have added to the importance of the post drying operations to be discussed in this paper, i.e. defect analysis and schedule adjustment. The first of these trends is the ever spiraling increase in the value of sawtimber and hence the value of any given charge going into and out of a kiln. As an example of this the stumpage value of Douglas-fir logs in California sold on National forests has increased from $62 per thousand board feet in 1969 to $187 in 1979 (Rudermann, 1980). The second trend is a continued desire for shorter kiln residence times caused by a need for greater productivity and reduced inventories due to increased interest rates. To this one can add the decreased use of air drying in the western states. These trends are to an extent in conflict, since in many cases one can expect greater fall down or degrade development the shorter the drying time. The difficulty the kiln operator faces from this is readily evident: how does he dry an ever increasingly valuable material in shorter times while maintaining the same level of fall down, or more preferable, reducing it? Clearly this is not easy to do.

Faced with this dilemma a kiln operator can take several approaches. One is to simply heave a sigh of relief when a charge comes out of the kiln and think "There's another one done. I hope nothing went wrong and I don't get any complaints about it." Hopefully this paper will show that this is not the way to think and that during charge breakdown, dry grading and surfacing, the kiln operator and his management have a unique opportunity to assess fall down and further to evaluate the problems of the drying system. To do this I would like to discuss several aspects of the post drying operation and review the different drying defects that occur and how we can adjust our kiln schedules to reduce them.

Unloading and Unstacking

Unloading and destacking are, for the most part, rather routine and straightforward, but still merit several comments. The stickers at many mills frequently represent a sizeable investment, for example, when straight grained clear Douglas-fir material is used for stickers. Assuming 5 stickers per course x 50 courses times 6 trucks per kiln, the total value of these 1500 stickers at $0.60 per sticker is $900. Clearly these are worth taking care of. These stickers serve to help restrain the lumber from developing excessive warp. For this reason it is necessary to insure that the stickers are reasonably uniform in thickness; stickers that are too thin or too thick should be discarded. During unloading one should also verify that good sticker alignment was initially used and not destroyed by excessive handling roughness during the charge loading.

Dry End Moisture Measurement

Those mills that have a moisture meter on the dry chain have the perfect opportunity to check on their drying efficiency without a great deal of trouble. It is probably worth noting that drying to a very low final moisture content or a very low redry level is probably costing that mill a good deal of money. There isn't time here to discuss the question of redry in detail, but there is some good evidence (Berry, 1969; Bassett, 1973) that a redry level between 20 and 30 percent is actually more profitable than a low redry level because it:

1. has lower overall degrade development
2. leads to greater kiln throughput

The lower degrade results from the fact that use of a higher redry level leads to a higher final charge average moisture content. This is particularly important for those species where warp is a serious problem. The importance of final moisture content and warp is illustrated in the data of Figure 1, which shows warp development in young growth ponderosa pine 2x4's (Arganbright _et al_. 1978).

Recent developments now permit a mill to have a dry chain meter that will tally the number of pieces of every unit, if that is desired, that are

1. too wet
2. too dry
3. within the mill's acceptable moisture content range.

By simply resetting the meter counters back to zero after each unit or crib, you now have a perfect record of that kiln's ability to dry to the proper final moisture content with a given schedule. Once data has been developed over a sufficient number of runs to be considered truly valid, one can:

1. Establish which kilns work best or the differences between however many kilns there are;
2. Identify within kiln problems, for example, slow drying zones will show up consistently;
3. Have a tool to use in evaluating any change made in a kiln whether it be a schedule change, adding baffles, changing sticker design, etc.

The cost of dry chain meters is not large and installation of one should pay back itself in a short time.

Grading of Surfaced/Unsurfaced Lumber and Planing

The dry chain and outfeed end of a mill's planers are without doubt the most efficient points at which most drying defects can be appraised. Once the type and frequency of defects occurring in the different species, thicknesses and grades are known, then appropriate steps to correct them can be taken. It takes, however, a good deal of time and patience at these two points to do this.

The Schedule

Before discussing a number of the common different types of drying defects that plague kiln operators, it seems worthwhile to briefly review what a kiln schedule is and break it down into its main parts. A typical schedule is represented schematically in Figure 2. A kiln schedule is an established set of dry- and wet-bulb temperatures which an operator can use to dry a specific product at a satisfactory rate with an acceptable level of degrade. Schedules are most simply classified as being either time based or moisture content based. That is, the temperatures at any given point in a schedule are made upon time elapsed since the start of the charge or an estimate of the actual moisture content of all or a portion of the charge. Most softwood lumber is dried using time-based schedules while higher valued hardwood stock utilizes moisture content type schedules.

As indicated in Figure 2, a typical schedule, whether time or moisture content based, can be divided into three distinct phases or periods which are:

1. An initial period of defect control
2. A subsequent period of accelerated drying rate
3. A final period of quality control

The initial period of defect control is characterized by lower dry bulb temperatures and higher wet bulb temperatures. These milder conditions are maintained because for many species it is during this early initial drying that many drying defects occur, such as surface and end checking and collapse.

Once stress reversal has occurred, the damage period for the defects just mentioned is over and the rate of drying can be greatly accelerated without fear of defect development. To do this the dry bulb temperatures are increased and wet bulb temperatures decreased. The purpose is now to dry as rapidly as possible. This is continued until the average moisture content of the charge is near the desired final value. At this point, the period of quality control commences. The final period ideally consists of two distinct separate steps which are

a. an equalizing step
b. a conditioning step

The purpose of the equalizing step is to reduce excessive between board variation in final moisture content. The schedule is adjusted to prevent the more rapidly drying boards from being over dried while the slower drying pieces continue to dry in order to prevent an excessively high redry level. By preventing over drying one reduces excessive shrinkage and therefore losses due to warp, planer split and scant material. Machining defects are also minimized.

The conditioning step has an entirely different goal when it is used and that is to reduce or ideally eliminate any residual (casehardening) stresses that are present in the lumber which will cause fall down due to dimensional instability later on when the piece is surfaced, resawn or patterned. Conditioning is really not necessary for lumber that is not going to be remanufactured in some way.

These two steps are frequently confused and often incorrectly referred to. It is important to bear in mind their very distinctly different goals.

Drying Defects

The purpose of this section is to review the various types of drying defects, what causes them, and what kind of schedule changes are most likely to reduce their severity or occurrence.

1. Surface Checks--arise during the first stage of drying as a result of excessive shell tensile stresses. They indicate that the drying rate during the early portion of the schedule was too rapid. To reduce or eliminate surface checks maintain the same dry bulb temperatures, but raise the wet bulb temperatures. Remember that surface checks can close in the second stage of drying (after stress reversal) and thus are not always visible at the end of drying. They will become apparent after surfacing and/or other remanufacturing. Surface checking is more severe the thicker the stock.
2. End Checks and Splits--these defects also occur as a result of excessive tensile stresses not at the surfaces, but at the ends of boards or logs. They are also caused by too rapid drying during the first stage. As in the case of surface checks the recommended practice for reducing their occurrence is to maintain the same dry bulb temperature, but increase the wet bulb temperature. With thick stock or very valuable material the use of an end seal ought to be considered. End splits frequently occur in the log decks prior to kiln drying, a problem that should not be placed on the kiln operator. Efficient water spray on the ends of the logs will, of course, prevent this problem.
3. Honeycombing--this is also a stress caused defect and it takes place after stress reversal, that is, during the second stage of drying. It occurs when the tensile stresses on the inside of the piece (core) exceed the tensile strength of wood. It is extremely important to remember that while it appears during the second stage of drying it is controlled by the amount of tensile set established in the outer core during <u>the first stage of drying</u> and therefore to correct it schedule adjustments must be made during the first stage. It is best corrected by reducing the early drying rate, hence increase the wet bulb temperature.
4. Casehardening--at the end of drying boards that have a residual compressive stress in the outer shell and tensile stress in the inner core are said to be casehardened. This is a normal consequence of wood's shrinkage and the fact that lumber dries from the outside inward, i.e., from the surface to the center. If lumber is casehardened after drying it indicates that the conditioning treatment was not sufficient. The time used should, therefore, be

lengthened and the kiln equilibrium moisture content during conditioning reevaluated.

5. Reverse Casehardening--in this case the conditioning portion of the schedule was too long. The boards now have tensile stresses in the outer shell and compressive stresses in the inner core, similar to the first stage of drying. Once it occurs in a given charge of lumber it cannot be removed. To prevent its recurrence shorten the conditioning treatment.
6. Collapse--this defect is observed in species that have a high initial moisture content and/or water streaks or high extractive content, that is, "sinker stock" type of material. It occurs as a result of a high capillary pull on those cells saturated with water or in combination with a large internal compressive stress on the core. It is thought to occur early in drying. To reduce it decrease the dry bulb temperature to keep the wood as strong as possible and to retard drying rate.
7. Warp--this is the general problem of excessive dimensional change and includes bow, cup, crook, twist, kink and diamonding. It is caused by differential shrinkage within the piece, such as radial/tangential shrinkage differences, the presence of juvenile, compression or tension wood. Since shrinkage increases the lower the final moisture content is, it can be best controlled by drying to as high a final moisture content as possible. Good stacking, sticker alignment and box piling all also help. It will be worse if there is considerable between board thickness variation (thick-thin lumber) which is not the responsibility of the kiln operator. This defect will become more and more of a problem as log size decreases due to the fact that small logs contain a higher proportion of juvenile and compression wood. The equalizing portion of a schedule is very significant here since it helps reduce over drying.
8. Knot Checking--this defect is almost impossible to prevent. It occurs due to the fact that the knot shrinks differently from the wood tissue surrounding it. To reduce it use higher relative humidities and dry to as high a final moisture content as possible.
9. Loose Knots/Knot Fall Out--this occurs for the same reason that was discussed under knot checking. It also can be reduced by drying to higher final moisture contents.
10. Unset Pitch--the presence of excessive sticky resin on the surface of boards indicates that either the maximum dry bulb temperature used was too low or it was not used for a long enough period of time. Pitch will generally be set if dry bulb temperatures of 160°F or higher are used.
11. Blue Stain--this form of lumber stain is caused by mold and stain fungi that are present in and around every sawmill. Since it cannot occur in wood when the moisture content is below around 25 percent, it is best prevented by rapid surface drying. Once the outer surface is dry it generally will not occur within the board. It can also be effectively prevented by the use of commercial anti-stain dip or spray solutions. Kiln operators should be aware

that it can also occur in the log decks, particularly hot decks or cold decks where the water is not reaching the log ends. To prevent it through schedule adjustment, increase early drying as much as possible without causing excessive surface checking or later honeycombing; this is most effectively done by decreasing the wet bulb temperature but only during the first stage of drying.

12. Brown Stain--this stain, common in sugar pine and eastern and western white pine, is created by an enzymatic reaction of the extractives in these species at appropriate temperatures and moisture contents in the presence of atmospheric oxygen. Brown stain is particularly prevalent in lumber from logs that have been in log storage for long periods or lumber that has been solid piled, particularly during the summer months. In addition to shortening log storage time and not solid piling, it can be reduced by:
    a. Using an initial dry bulb less than 130°F.
    b. Keeping the relative humidity as low as possible without causing surface checking.
    c. Using a wet bulb temperature below 120°F throughout drying.
13. Planer Split--this defect occurs in boards that have excessive cup. It is more severe in flat sawn boards, thinner and/or wider stock. To reduce it one needs to decrease cup, hence dry to a higher final moisture content and reduce over drying. Good stacking practices and having little thick/thin material are also necessary for its control.
14. Chipped and Torn Grain--these machining defects are generally a sign that the moisture content of the lumber was below 8 percent. They are caused by having too brittle surface fibers, and become a real problem when the surface moisture content is below 5 percent. To reduce their occurrence, make sure that the moisture content is above 8 percent or increase the conditioning treatment to add more moisture to the surface layer.
15. Raised Grain--this is just the opposite of chipped and torn grain since it indicates that the surface of the lumber is at too high a final moisture content. It is induced by dull planer knives forcing the stronger latewood portion of the annual ring into the weaker earlywood on <u>flat sawn</u> boards. It generally does not occur at moisture contents below 13 percent.
16. Scant Material--lumber that is not completely cleaned up during surfacing may occur for one of two reasons: the sawmill is sawing too thin or over drying is occurring during drying. The latter can be best controlled by adjusting or lengthening the equalizing portion of the schedule and/or adjusting the target final moisture content to a higher value. The problem of scant lumber should become more and more prevalent as the industry strives for smaller green lumber target thickness sizes.
17. Excessive Variation in Final Moisture Content--while this is not a drying defect per se, it is one of the common problems kiln operators encounter. It can be caused by a number of different factors including within kiln

temperature, humidity and air velocity non-uniformity. Most frequently it arises from the natural variability in drying rate within certain species. Hemlock, sugar pine, white fir and redwood are species that have large drying variability. It is also caused by between board thickness variation since thinner boards dry considerably faster than thicker boards. As a general rule the shorter the kiln schedule the greater the problem. The primary purpose of the equalizing portion of a schedule is to reduce final moisture content variability. I also feel that the use of higher wet bulb temperatures is effective as this increases the internal board temperature which in turn increases moisture diffusivity. When this problem is encountered the kiln operator should first try increasing the length of the equalizing treatment.

Summary

Today's kiln operators are faced with the difficult problem of drying faster and with less degrade. Although drying technology continues to evolve, the operator still needs to understand why, how, and when different types of drying defects occur. With this knowledge the kiln schedule being used can be modified to minimize the most common forms of fall down. This, together with data on the average value for and variation in final moisture content of his charges, gives the kiln operator the necessary quality control tools to maximize his effectiveness.

Literature Cited

Arganbright, D. G., Venturino, J. A. and Gorvad, M. R. 1978. Warp reduction in young-growth ponderosa pine studs dried by different methods with top load restraint. For. Prod. J. 28(8):47-52.

Basset, K. H. 1973. A look at redry. Proc. 24th Ann. Mtg. Western Dry Kiln Clubs. p. 31-39.

Berry, W. S. 1969. An example of operations research in dry kilns. Proc. 20th Ann. Mtg. Western Dry Kiln Clubs. p. 18-21.

Ruderman, F. K. 1980. Production prices, employment and trade in Northwest forest industries, first quarter 1980. USDA For. Serv. PNW For. Range Exp. Station Report.

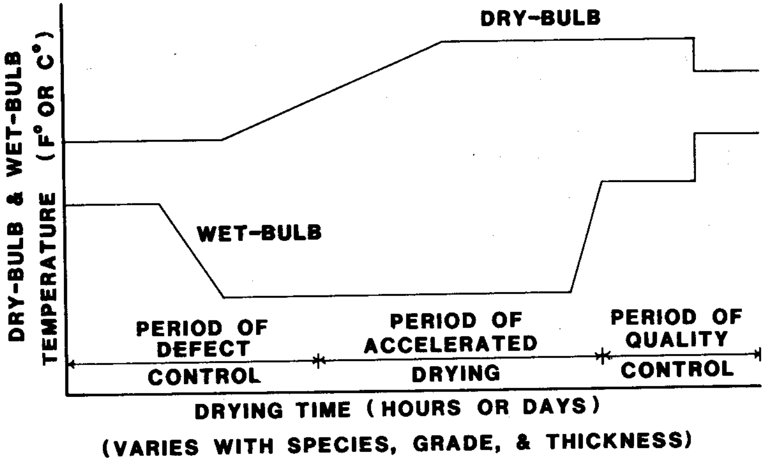

Figure 1. The effect of average final moisture content on warp development in young growth ponderosa pine 2 x 4's.

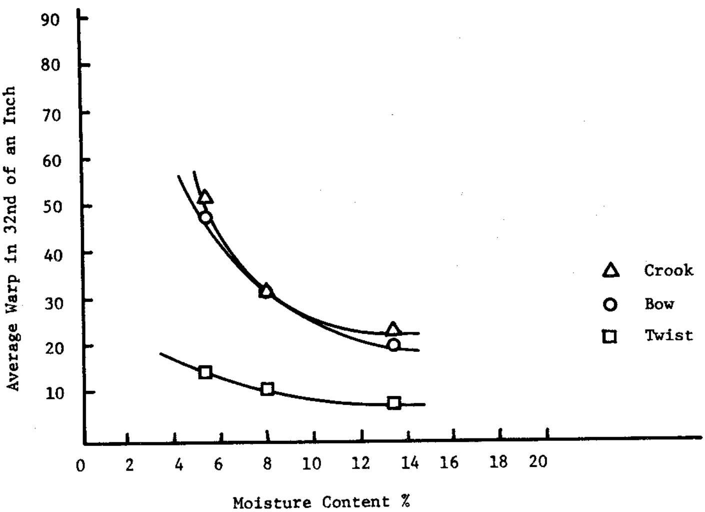

Figure 2. Schematic representation of a time based schedule for drying lumber.