

## UNDERSTANDING THE MECHANICS OF A DRY KILN TO REDUCE COSTS AND INCREASE EFFICIENCY

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In lumber drying, as in all business, the ultimate objective is profit. Mill management invests money in kilns and related equipment, hires people, and carries out the drying process with the conviction that ultimately more money will be received than was spent.

Lumber drying is a complex unit process in which a raw material, green lumber, is modified both physically and chemically to produce a new product which has greatly different properties. The goal is to obtain maximum yield of product having the desired properties and maximum value at the lowest processing cost.

Some of the economic factors of drying are obvious because they involve short range one-time expenditures such as the capital cost of a kiln or the continuing costs of kiln supervision. Some mills shop for kilns on the basis of selling price, apparently on the assumption that all heated boxes of a given size are alike.

Other economic factors are less obvious unless detailed records (which are seldom found) are kept. The profitability potentials of many of these less obvious processing factors far outweigh such items as capital cost and supervision.

It is the purpose of this presentation to call attention to some of these factors and to point out the magnitudes of their contributions to total profit. Achievement of optimum results can come only from a detailed knowledge of kiln operation and drying mechanism and from the application of this knowledge. In order to introduce the topic some simple questions are asked.

### Some Questions

1. What is the value of a 2 X 8 by 2 feet board if the product sells for \$150/MBF?
2. What is the value of a 2 X 8 by 16 feet board if the product sells for \$150/MBF?
3. What is the difference in value between a 16 feet 2 X 8 which sells for \$150/MBF and one which sells for \$100/MBF?
4. Many kilns use more than three pounds of steam to evaporate one pound of water. Ideally, one pound of water can be evaporated by the use of less than two pounds of steam. With steam at fifty cents per thousand pounds what is the difference in energy cost to dry one thousand board feet of hemlock from 85% to 15% moisture content using three pounds and two pounds of steam per pound of water?
5. Many kilns use as much as 2000 pounds of steam for each 1000 BF of lumber for heat-up and for maintaining set point humidity. At this rate of usage what is the steam spray cost for a kiln charge of 160 MBF? (Assume steam costs \$.50/M - lb).
6. What is the cost of operating a one horsepower motor continuously for one year assuming power sells for \$0.005/KWH.

7. Assume that one kiln sells for \$200,000 and another for \$100,000. If both kilns perform equally and dry 160 MBF each 36 hours for 20 years (8400 hours per year) what is the added drying cost due to the additional cost of the higher priced kiln?

These are just sample questions which are asked solely to get the reader to think seriously about some phases of the economics of kiln drying. The answers are given below together with some comments.

#### Answers

- Question 1: A 2 X 8 by 2 feet board contains 2.667 board feet at \$150/MBF is worth \$0.40 if it is a part of a usable piece. This may appear to be a trifling amount but if drying could be conducted in such a manner that one 2 feet end trim could be prevented for each 1000 board feet in a 160 MBF charge the increased value of the charge would be \$64. If kiln residence time is 36 hours, the increased profitability would be \$1.78 per hour or \$14,933 per 8400 hours year. If the lifetime of the kiln is 20 years, the lifetime increase in product value would be \$298,667.
- Question 2: A 2 X 8 by 16 feet board is valued at \$3.20 on the basis of \$150/MBF. If a drying process could be followed which would prevent one such board per crib (12 boards per charge) from being sent to the hog the improved product value would be \$38.40 per charge, \$1.067 per hour (36 hour basis), \$8,960 per year or \$179,200 per kiln lifetime of 20 years.
- Question 3: A 2 X 8 by 16 feet board is worth \$3.20 at \$150/MBF and \$2.13 at \$100/MBF. The difference is \$1.07 per board. Assume, now that a drying process were followed which would prevent the degrade of one board per thousand board feet from a grade of \$150/MBF to \$100/MBF. The increased product value would be \$171.20 per charge, \$4,755 per hour (36 hour basis), \$39,947 per year or \$798,933 in a 20-year kiln lifetime.
- Question 4: The drying of 1000BF of hemlock (oven dry density of 23.712 pounds per oven dry cubic foot or 1.976 pounds per oven dry board foot) from 85% to 15% involves the removal of 1383.2 pounds of water. In a kiln charge of 160 MBF, 221,312 pounds of water is evaporated. If 3 pounds of steam is used for each pound of water removed, 663,936 pounds of steam worth \$331.97 is required. If the job can be done with 2 pounds of steam per pound of water the steam requirement per charge is 442,624 pounds which cost \$221.31. The steam saving is therefore \$110.66 per charge, or \$3.07 per hour (36 hour schedule basis), \$25,821 per year or \$516,413 in a 20 year kiln lifetime.
- Question 5: The answer is obviously \$160 per charge. Some processes get along with no spray steam by starting at low temperature (CRT is such a process) and utilizing the moisture driven from the wood to control humidity. In this case the profit is \$4.44 per hour, \$37,333 per year or \$746,667 for a 20-year kiln lifetime.
- Question 6: The cost of operation of a 1-horsepower motor for one year (8400 hours) using 5-mill/KWH power is \$31.33 (this becomes about \$100 per year in many regions). Assume that one kiln operates with 50 coupled horsepower and another with 112.5 horsepower

(i. e. 15-7.5 HP motors). The difference in power cost alone is \$1,958 per year or \$39,162 in a 20 year kiln lifetime.

Question 7: Over a period of 20 years a kiln drying 160 MBF every 36 hours will produce 746,667 MBF of dried lumber. The additional cost per thousand board feet for the assumed absurd difference kiln cost would be \$0.139/MBF or \$21.42 per charge. Obviously no one is going to be so foolish as to spend an extra \$100,000 for a new kiln that performs only as well as a cheaper kiln. The question is asked and answered only to impress upon the operator the relatively small impact of even large differences in capital cost, which is a principal criterion used by most mill operators when purchasing a kiln. (The writer is well aware of the fallacy in this answer because he has not taken into account the fact that the \$100,000 which was not spent for a kiln would be invested and that a 6% compounded annually for 20 years would amount to \$320,710 or the equivalent an additional effective \$0.43/MBF or a total of about \$0.51/MBF).

Based on the above hypothetical questions, assume now that a kiln having capacity of 160 MBF of hemlock is operated in such a manner that the improvements which were calculated above, were obtained.

Increased Value or Profit

	per charge	per year	per 20 years
Prevention of one 2' end trim/MBF	\$64.00	\$14,933	\$298,667
Prevention of one 16' board/crib being sent to the hog	38.40	8,960	179,200
Prevention of one 16' board/MBF degrading from 150-\$100/MBF	171.20	39,947	798,933
Improvement of steam efficiency	110.66	25,821	516,413
Elimination of spray steam	160.00	37,333	746,667
Reduction in horsepower from 112.5 to 50	8.39	1,928	39,162
	\$552.65	\$128,982	\$2,579,042
TOTALS			
	or		
	3.45/MBF		

The above discussion is, of course, hypothetical. But it is in no sense improbable. In reality many of the examples used are highly conservative. Well documented data on product values on matched samples dried by two different methods to the same moisture content in the same kiln show a difference of approximately double the \$3.45/MBF figure indicated above. This means that the mill operator who produces 50 M MBF per year may be pocketing \$150,000 to \$300,000 per year less than he could.

Improved drying economics of the order of magnitude indicated are within the reach of many mill operators. What is required is first, valid information concerning the costs of the elements of present practice; second, the recognition that lumber drying is a highly complex chemical engineering process involving dependable equipment which provides the desired processing conditions; third, complete understanding of equipment and its functions and of the process being carried

out on a particular item to produce a given product; fourth, continual vigilance to insure that both equipment and process are performing as desired; and fifth, continuous detailed records.

It has been the experience of this writer that few mill owners or kiln operators know with certainty what their drying costs for various lumber items are. It would appear that many operators take for granted there will be wet boards, deformed boards that will not pass through the planer, end trim, roller split, surface checking, collapse, and loss in grade result from the drying process. However, few operators know precisely the magnitudes of these effects or exactly how much they change with changing drying conditions.

Too frequently one encounters the attitude that drying can still be accomplished satisfactorily even though one or more fans are not turning, a bank of heating coils is inoperative, or baffles are not functioning. Recently a kiln was visited in which three of fifteen fans had been out for several weeks. In another kiln it was found that one fan was rotating in the opposite direction from adjacent fans. Steam leaks, faulty traps and ill-fitting vents are also commonly found. It is a basic principle that if identical materials are treated in identical manners, identical results will be obtained. Certainly the loss of fans changes the kiln condition and a change in product must result.

A dry kiln consists essentially of two separate interconnected units. One unit is a chamber into which the lumber is placed and is so sized that uniformity of conditions is maintained. The second unit is an air conditioner receiving the air which has passed through the charge of lumber, adjusts its temperature and humidity to the predetermined entering air conditions and readmits it to the kiln at the desired rate. Tradition, and perhaps economy in manufacture, have resulted in the combination of these two functions in a single unit which results in many operating complications. However, the more nearly the chamber and air conditioning unit can be separated and treated as individual units the more efficient the drying process will be. It is necessary for the kiln operator to know the temperature changes that take place in the drying chamber. One temperature condition that should be known but seldom measured is the dry bulb temperature on the leaving air side of the charge which is a measure of the drying rate the lumber is experiencing. The difference between the dry bulb temperatures is the indication of whether drying is taking place across the full width of the charge of lumber.

By far the most valuable tool on the desk of the kiln operator is a pad of psychometric charts in the dry and wet bulb temperature range used in the kiln. When the charge and kiln data are plotted on a psychometric chart, drying rates, venting requirements, and overall kiln efficiencies are immediately obvious. If the kiln operator has had the good fortune of attending a kiln school or a drying short course he is, of course, familiar with the use of the chart. If he is unfamiliar with the technique any kiln manufacturer or manufacturers representative will gladly give instructions for their use.

The kiln operator should understand and apply the best information available in his work. For example, degrade (end checking, surface checking, honeycombing and collapse) which is due to stresses caused by moisture content variations tends to take place during early

stages of drying and is aggravated by high temperatures. Therefore, items which are prone to such behavior should be treated gently and at low temperatures during the early stages of drying.

On the other hand degrade (cupping, bowing, twisting) which is caused by unequal shrinkage along and across the annual rings is increased as the moisture content is decreased because shrinkages are greater. Therefore care should be taken not to over-dry the lumber. Valid data have been gathered (Williston, Oberg, Abner and more recently Comstock and Bassett all working in Weyerhaeuser Company Research Division) which show Pacific Northwest softwood dimension lumber drying below 17-19% average moisture content results in a loss of product value of more than one dollar per thousand board feet for each per cent reduction in moisture content below this level. Thus, if the operator chooses to dry his charge to an average moisture content of 8% in order to reduce the number of wet boards in the load to specification level or if he fails to "pull" the charge at a higher moisture content he may be costing his company \$10-\$15 per thousand or \$1600-\$2400 per double track kiln charge. Recognition of this fact might well convince a mill manager to investigate the desirability of drying to a substantially higher moisture content and redrying the resulting wet boards. Serious attention is invited to the data and conclusions of Mr. Kendall Bassett of Weyerhaeuser Company in his paper given at this meeting.

Many kilns, including new installations, are not designed for maximum economy of operation. Many purchasers specify more fan delivery than is needed thus requiring more fans and more horsepower. Many kilns are equipped with fans which, because of nature and location, expend a great deal of energy merely churning air rather than delivering it to the lumber load (some fan systems deliver less than 50% of the air in a kiln as the same fans deliver in a test stand). Many kilns have plenums which do not permit uniform air delivery through all portions of the load.

The temperature sensing elements, which initiate the temperature control sequence frequently do not "see" the air temperature which actually enters the load. This is particularly true of the wet bulb sensors which require an air velocity of 600-1000 feet per minute over the wick in order to attain and maintain the heat and mass flow equilibria necessary for true humidity read-out. Consequently, the humidity in most kilns is actually substantially lower than the operator desires.

Many kilns do not employ the sequence of exhaust, humidify, and heat in the air conditioning unit. Because of this much more make-up air is required which must be heated with the result that heat energy is wasted in the exhaust air.

Proportionating controls on heaters and vents contribute markedly to economy of operation and product quality. Without proportional control on heaters the entering air temperature may suddenly rise as much as 20-30°F above set point and then gradually subside until the sensor calls for heat again. This results in substantial dollar loss.

Frequently, lumber charges are dried in kilns in which the top, bottom or end baffles do not contact the loads; the cribs do not touch; or short boards are piled on top of longer boards. All such practices result in a large cross-sectional area of low resistance which pass a disproportionately large amount of air not used for drying the lumber.

The list can be continued indefinitely to include failure to place sticks at the ends of the boards, placement of sticks in staggered or non-vertical rows, omission of sticks, failure to align sticks over bottom bunks, placement of packages in the crib so that air cannot circulate directly from one package to the other and so on, ad nauseum.

There are probably but few kilns that are performing as efficiently and effectively as they are capable of performing. Improvement comes from a thorough understanding of the kiln and its functions, knowledge of the principles of the drying process in general, optimum conditions which apply to the particular item being processed, prompt and effective maintenance, and continual alert attention to details.

The number of dollars which depend upon the skill and attention of the dry kiln operator demands that the operator perform as a professional. Few, if any, members of the processing team have such a great potential for determining the production economics of the plant. In order to live up to his responsibility as a professional man the kiln operator must know his processing, equipment, and be continually aware of how his lumber charges are reacting. This is obviously not a part time job.

The kiln operator must continually experiment in order to improve his performance. At the same time he must continually add to and refine his knowledge and techniques. There are many opportunities for accomplishing this. The dry kiln clubs offer excellent opportunities for picking up and evaluating new ideas. Kiln courses and drying short courses present the theories of drying in practical and easy to understand terms. Representatives of dry kiln manufacturing companies are well trained in the theories and practice of drying and are available for assistance. Questions addressed to kiln manufacturers headquarters will be gladly researched and answered.

In conclusion, there is opportunity for improvements in lumber drying economics which at first glance are mind boggling. These improvements result from a combination of kiln structural and operational factors, load stacking and applied kiln conditions. The economic gains which are achievable so far outweigh gains due to differences in capital cost that the use of selling price of the kiln as the sole or principal criterion for the selection of equipment cannot be justified.

The gaining and application of better knowledge concerning kilns and drying will certainly prevent an incident which was recently observed from happening. The new, but observant, kiln operator knew that the process which he was carrying out involved the removal of moisture from the lumber in the kiln. Therefore, with the best interest of his company in mind, when he discovered a small stream of water entering and overflowing a box on the wall of the kiln, he turned the water off!