THE TECHNOLOGY OF LUMBER DRYING:
RECENT PROGRESS AND CURRENT PROBLEMS

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SUMMARY

Technological progress in the seasoning of wood is described. Such progress includes unit package handling in the yarding of lumber for air drying and improved forced air circulation dry kilns that have made kiln drying most softwood lumber sizes green from the saw economically feasible. Opportunities are discussed for research and development to further advance drying technology, particularly in accelerating free-water reduction.

INTRODUCTION

The technology of lumber drying has made significant advances in the last 25 years, and the contributions that the research technicians, dry kiln companies, engineers, and the lumber-producing industries have made to create these accomplishments are not often recognized and properly credited. I, as one of you, have been associated, although some might think rather remotely, with what I would like to call the great "changeover" in lumber seasoning practices. My experiences started with the operation of natural circulation progressive dryers that had practically no automatic control of drying temperatures. Now most softwood species are kiln dried green from the saw in forced-air circulation dry kilns with reliable instruments that record and control dry and wet bulb temperatures automatically, and at the same time control venting. This change in dry kiln equipment did not develop quickly. It is difficult to believe that the internal fan type of dry kiln design had to fight its way into actuality, but the improved performance that could be obtained as compared with the natural circulation kiln was demonstrated, and real progress was made when some of the dry kiln companies decided to design, build, develop, and improve the basic principles.

Although a remarkable advance in the technology of kiln drying lumber has been made there is still much to be done to further develop and improve our drying processes.

WHY IS ROUGH LUMBER DRIED?

This may seem like a strange question to ask of a group of men who are earning their livelihood in this phase of the lumber processing business. However, we occasionally need to remind ourselves that the objectives of the drying process, which is an expensive phase of lumber production, are important and are justifiable. The drying of lumber is more than weight reduction to cheapen the cost of transportation—it is an aspect of wood processing that improves dimensional stability in use, or it might well be considered as a process of preshrinking wood while it is still in the rough form so that lumber size standards really mean something. To me, this matter of drying and shrinking wood before machining or factory processing far outweighs the importance of all of the other advantages of drying. We know that dry wood is less apt to stain, mold, or decay, or be infested with insects. We know that fasteners perform better. We know that it is stronger. We know that better retention of preservatives and fire retardants is obtained. We know that the electrical resistance increases and we know that dry wood is a better insulating material than wet wood. But of all of the advantages gained by drying rough-sawn products before machining and processing, the removal of all of the free water and most of the hygroscopic water to allow shrinkage is, in my opinion, by far the most important. Once dried to the moisture level of the in-use environment, the seasonal dimension changes are most often of minor consequence.

Those of you who are responsible for the lumber seasoning process, the quality-incorporating process, must face up to the realization that moisture content standards must be sharpened, the process
must be kept in control to these standards and, at the same time, production needs to be increased with reduced losses that are due to seasoning degrade and with no significant impairment of the mechanical properties of the wood. A challenge? Why certainly it is a challenge, but with the application of the knowledge that we now have and with an expanded research and development program in wood drying, I am confident that further significant advances in drying technology can be achieved.

IMPROVEMENTS IN LUMBER-DRYING PROCESSES

What have been some of the significant improvements in the seasoning processes in recent years? Before discussing dry kiln equipment, I want to talk briefly about what has happened in the field of air drying lumber. You are all familiar with the switch from hand stacking to unit package handling. This advance came about because of the need to reduce lumber stacking and handling costs. I believe that the western kilns led the way in this development. The changeover came fast after World War II, and now practically all softwood and hardwood lumber-producing mills yard lumber for air drying in unit packages. The unit package handling system has no doubt had some influence on the improvements in sorting and stacking.

The use of carriers and forked lift trucks for unit package handling in yarding for air drying has often required site improvement. Paved yards, better pile foundations, increased pile spacing, and other factors conducive to better air drying have been effective in increasing the output of better air-dried lumber per acre. The accomplishments in this area of lumber seasoning that have been experienced by the redwood industry are outstanding. I am confident that the members of the Redwood Seasoning Committee, the California Redwood Association, and the owners of mills producing and air drying redwood feel that the research studies that have been conducted were productive and that the changes that have been made are definitely beneficial.

Some of you will recall how the industry formerly air-dried much of the sawmill production. It is now economical to kiln dry softwood lumber of most species and items green from the saw. What has brought about this change in lumber-drying processes? The development of the forced-air circulation ventilated dry kiln had much to do with this change. But this kiln type was only developed when the wet and dry bulb controller was made available.

During the World War I era, Tiemann and his coworkers at the Forest Products Laboratory developed designs of superheated steam kilns, and by the simple method of controlling the temperature of the superheated vapor, regulated the equilibrium moisture content conditions in the dryer. To control equilibrium moisture content conditions in a dryer operating at more moderate temperatures, they developed the water-spray dry kiln. Equilibrium moisture content conditions in this dryer were maintained by controlling the dew point temperature of the air moving through the lumber by natural draft. When the instrument companies provided the wet and dry bulb controller and the relationship of the wet bulb depression to wood EMC was better established and realized, a basis was founded for the rapid commercial development and acceptance of the forced-air circulation dry kiln, and particularly the internal fan kiln. Although the Forest Products Laboratory takes great pride in having created the basic principles of the internal fan lumber dry kiln, we recognize that the modern ventilated dry kiln of this type is the product of the engineering development by the dry kiln companies.

In discussing the improvements in kiln drying that have taken place in recent years, I first want to talk about the dry kiln itself. Remember the days when air circulation rates of 100 to 150 feet per minute across the loads were considered fantastic? Now the dry kiln engineers are thinking in terms of designs to produce rates as high as 1,000 feet per minute or more. High circulation rates, coupled with frequent fan reversal, are conducive to reduced drying time, but probably more important is the lowered variation in final moisture content between boards of the kiln charge. The opposed fans and the fan baffles that go along with it probably were one of the more important improvements in the long shaft kiln design. The end drift problem was practically eliminated when this change was made. The long
shaft kiln design has featured large diameter fans delivering large volumes of air at low shaft rpm.

Similar large diameter fans that are being driven at the lower rpm through reducing transmissions are now being used in so-called short shaft kilns. Some designers prefer to use a smaller diameter fan directly connected to the driving motor. In any case, higher circulation rates are being designed into the new dry kilns. Incidentally, I might add that these stepped-up air circulation rates are being included in the package-loaded trackless-type dry kilns, as well as in the conventional track-type kilns.

Have heating systems been improved? Well, we are still using steam for heating in most of our dryers, and the heating systems certainly have been changed for the better. In long kilns we now have split heating systems with independent zone control of temperature. Coils of fin-type pipe have replaced countless runs of plain black iron pipe and the resistance to air flow has been reduced. The coils are subdivided so that the dry-bulb temperature fluctuates less. Coupled with split heating systems and subdivided coils, we often find automatic steam pressure-reducing equipment to further refine steam flow to produce better temperature control.

What has been accomplished in venting systems on dry kilns? I have already mentioned that venting is now controlled through instrumentation associated with wet-bulb temperature control. In kiln drying some woods with high initial evaporation rates, auxiliary hand-controlled vents can be opened. There is little excuse now for using steam to maintain the desired wet-bulb temperature during the drying process. With a tight kiln and tight vent caps, excess venting is eliminated with automatic control. This is certainly an improvement over the manual vent operation of a few years ago. An associated improvement for wet-bulb temperature control is the increasing use of desuperheaters on the steam spray supply line.

I do not believe that an experienced dry kiln operator would attempt drying a charge of lumber today without having the dry kiln equipped with an automatic controller for dry- and wet-bulb temperatures. These instruments are indispensable. They are invariably of the round chart recording type, and this chart is one of the records of the drying process. Our modern instruments are greatly improved over the earlier models and we now have great confidence in their reliability. I must admit, however, that the requirements of wet-bulb thermometry haven't changed much. They still require good water of an adequate quantity and the wicks must be changed often. Although most control instrument installations are air operated, these same types of instruments can be made all electric. Recently the thermoelectric recorder controller has been installed by some kiln designers. Some designers also prefer to install instrumentation so that the proportioning control on the steam lines can be obtained.

Before completing this discussion on improvements in dry kiln equipment, I want to at least mention that structural building improvements have been made and are being made. We certainly have better roof designs and roofing materials than existed some years ago. The installation of overhead fans and heating systems is a distinct improvement over the below-the-rails system. I remember the days when the arguments for and against the overhead equipment sometimes were particularly heated. I have seen overhead operating rooms that are virtually living rooms compared with the dark, dank, dirty, hot, and stinking pits of my kiln operating days.

It is difficult for me to ascertain why some of our dry kiln manufacturers decided to make prefabricated dry kilns. I argued their economy with some of the dry kiln manufacturers for years, but I suspect that the success of some of the German manufacturers in building small prefabricated units was the real stimulation. We now have them and time will tell whether they are an improvement over the conventional wood, brick and tile or concrete block structures.

Although the dry kiln itself has been greatly improved in recent years, the changes that have taken place ahead of the kilns and behind the kilns are quite significant. The need to improve stacking and yet reduce stacking costs created a situation that produced our present-day automatic and
semi-automatic stackers. The installation of this equipment has led to greater engineering attention to developing better sorters. Mechanical unstackers with better handling and storage of stickers is a vast improvement over some of the methods previously used.

Before leaving this subject, I want to pay tribute to the dry kiln operator. He has improved too! He has improved drying schedules to the benefit of the industry. He has used his ingenuity to get good drying results from poor kiln equipment. He has associated with other operators and obtained additional knowledge to solve some of his operational problems. He has attended dry kiln courses to receive technical information on the properties and physical characteristics of wood and how it dries. He has sweated out the demands of management to accomplish the almost impossible. But above all, he has stimulated the dry kiln manufacturers and engineers to design better equipment, and has posed the questions that require the research for information that is now going on.

SEASONING PROBLEM OF TODAY

With improved drying equipment supervised by more technically trained kiln operators, we have come a long way toward the goal of producing a superior dried sawmill product. My recitation of improvements might make you think that the lumber drying process is as efficient as possible and that we can rest on our laurels until a method of dimensionally stabilizing green wood is developed and then all that we will have to do is remove water to reduce the weight for transportation purposes. Unfortunately, this is not the situation. It has been said that 20 percent of the cost of the finished lumber product is invested in the seasoning process. The industry has always been interested in possibilities of reducing this expense. The ventilated forced-air circulation dry kiln seems to be the most economical type of dryer that is available at the present time, but definite opportunities to improve these kilns and perhaps to develop a radically new drying process certainly exist. It is going to take more fundamental and applied research and development to bring them about.

Before discussing some of the problems needing solution, I want to stress the need to make good use of the knowledge and experiences that are now available. The exchange of information at meetings such as this is one way whereby this can and is being done. The success of the dry kiln club concept is based on this matter of extension of information. Research accomplishments at the laboratories or equipment improvements and developments by the engineers are of little value to the overall industry unless they are put into use at the individual plants.

The production of kiln-dried lumber is generally dependent upon good sorting for drying classifications. Species and thickness classifications are standard, but one problem is to have to sort for green moisture content so that better advantage is made of the faster drying items to increase kiln output. Drying costs are related to kiln time and kiln output is generally dependent upon having charges of lumber with like drying characteristics. Some progress is being made in developing equipment that will identify, mark, or segregate green lumber into drying classes. After the lumber is sorted into various classifications including lengths, the next task is to get it stacked. A problem here is the stacking stick. These often cause trouble in the automatic stacker. Someday a lumber layer separator is going to be developed that will replace the sticker, and, in addition to a greater ease in handling for stacking and unstacking, the layer separator could reduce spacing to not only increase kiln holding capacity but to increase the circulation rate and, in addition, increase the uniformity of air distribution. Perhaps another important benefit will be a better restraint to warp.

In spite of the fact that a commercial drying process has not turned up to be competitive with the ventilated dry kiln, we must admit that this kiln type is wasteful of energy. The evaporated moisture that was in the wood is expelled as vapor and carries with it heat that somehow should be reclaimed. Economizers to preheat incoming fresh air just have not worked out. Even though excess venting has been reduced by putting vents under control, the heat lost per pound of water evaporated from the wood is considerable and increases as the absolute humidity of the vented air is reduced.
Someday the engineers will develop dehumidification equipment that will enable us to economically recover most of the latent heat of evaporation and discharge water from the kiln rather than vapor. Another energy consumer is the heat lost by radiation. These heat losses can be reduced by better insulation, and more attention is being given to this matter by the kiln designers. Although some dry kiln designers are not greatly concerned with the increased horsepower input in the fan system as circulation rates are stepped up, this energy consumption aspect of kiln drying can often be an appreciable factor in the total energy required to evaporate a pound of water from the lumber. As I see the problem, increasing the circulation rate without greatly increasing power input will require research and development in the general field of dry kiln aerodynamics. Actually but very little work has been done in this direction, and I feel that a good opportunity exists to improve kiln design features.

Are dry kiln control instruments a problem? I believe that we have good instrumentation and it is automation in the sense that the instrument takes on the job of controlling the set wet- and dry-bulb temperatures. The problem here is that the instruments must be set manually in accordance with a predetermined schedule. Where we are using time schedules, why aren't we using more program controllers so that once started, the kiln run is carried through the complete cycle without further attendance? The next step in more complete automation is instrumentation that is tied in with some physical drying property that automatically speeds up or slows down the drying rate to produce a quality-dried product yet providing a way to generally reduce the overall drying time.

The energy required to heat the wood, evaporate the water, and overcome hygroscopic forces is fixed, and therefore the total energy required for drying lumber in a ventilated kiln is directly related to the time that the charge is in the kiln. The influential factors increasing the total energy consumption per kiln charge are mainly radiation losses, excessive ventilation losses, and fan horsepower requirements. To keep these energy requirements to a minimum involves kiln drying schedules. The shorter the drying time, the less will be the energy requirements for these factors. What is the basic problem here? In my opinion, it is the time required to evaporate the free water. It is during this stage of the drying process where damaging influences occur; but if we are to reduce overall drying time, it is in this stage of the drying process where the possibilities of accomplishment are greatest. I suspect that the solutions are going to come from predrying treatments rather than from radical modifications of kiln drying schedules.

I could talk about the problems facing us in the machining of kilndried lumber and the control of moisture content in storage at the mill, during transportation, at the lumber yard or fabricating site or factory. Encouraging progress is being made here, yet the sawmill industry must recognize that good wood performance at the consumer level is a responsibility that must be shared with the wholesaler, retailer, contractor, or woodworking factory owner.

RECOMMENDATIONS FOR RESEARCH AND DEVELOPMENT

I have decided not to discuss the engineering problems of developing new and less costly methods of sorting, stacking, unstacking, and the storage of dry lumber. Opportunities for developing methods to reduce costs exist and progress is being made. In the remaining time that I have, I want to outline some of the fields of research and development that I feel are essential to provide information to solve some of our drying problems.

(1) Dimensional stabilization. The shrinkage of wood is the physical property that creates so much trouble for us. Examples are end checking and splitting, surface checking, honeycomb, ring separation, collapse, and warp. The control of these degrading defects increases kiln time. Although almost complete stabilization would eliminate almost all of the dimensional change problems in the use of wood, we who are concerned with the seasoning process only need a partial stabilization in order to carry out major changes in the drying process conducive to drying cost reduction. If the surface layer of a green board had a greatly reduced shrinkage characteristic, we could create a very
moisture gradient to accelerate free water removal. The research that is being conducted in this field is very limited.

(2) Movement of moisture in wood. I suspect that most wood technologists accept the theory that moisture moves through wood in response to a concentration gradient. With a given gradient, the drying rate is dependent upon temperature. Another factor that appreciably influences the drying rate, however, is the permeability characteristics of the species being dried. Permeability is tied in with the structure of the wood and if we are to devise methods to accelerate free water reduction, we should be studying ways and means of modifying this structure before drying is started. Presteaming some of the eucalypts is effective in reducing the time required to evaporate the free water. Ellwood has shown that presteaming redwood was beneficial in accelerating free water reduction. Fundamental research on the movement of moisture in wood needs encouragement, and emphasis should be placed on the development of processes and treatments of green wood that will modify permeability.

(3) Heat and mass transfer and boundary layer effects. The transfer of heat from the circulated air to the wood and the water vapor from the wood takes place through a zone called the boundary layer. The greater the turbulence of the moving air stream over the board surface, the thinner will be the boundary layer, and presumably its influence on the overall drying rate will be lessened. Thus, high circulation rates not only reduce the temperature drop across the load but also, we believe, effectively increases the turbulence in the air space between layers of boards. Research for information on the influence of the boundary layer on drying rates has been too long neglected. The effectiveness of jet air streams perpendicular to the board face or air impingement systems of handling the air is being studied. Veneer dryers based on this principle have been developed. I have no idea as to how a lumber dryer would be designed for such an air-handling method, but if research shows that the overall drying rate can be greatly increased, our mechanical engineers will find a way to do the job.

(4) Properties of wood as influenced by the drying process. If laminators are concerned with the possibility that the lumber drying process reduces strength characteristics and thereby the properties of built-up beam, we need to collect data to assure them that our conventional drying methods are satisfactory and if they are not, we must develop processing schedules that retain the inherent strength characteristics of the wood. Likewise, we need to learn a lot more about how to redry lumber treated with waterborne chemicals, such as preservatives and fire-retardant salts, without further reducing the strength properties of this treated wood. As our drying processes are sharpened up and modified to reduce costs, mechanical and physical properties of the dried wood must be better known to determine drying process limitations and to assure the users of our lumber products that quality characteristics have been enhanced rather than deteriorated by the drying process.

(5) Seasoning degrade and volume loss investigations. How many of you have conducted kiln performance studies that show the losses attributable to the drying process? Are the grade losses and footage losses due to mismanufacture in the sawmill, seasoning, or planer mill processing? The identification will indicate where research and development attention is required. The moisture content quality of the dried lumber also needs to be given greater study. The causes of excessive variation or the inability to consistently meet the requirements of the average need to be determined and remedial measures put into operation.

Other fields that merit investigation are:

(1) Electrical properties of wood, particularly above the fiber saturation point.
(2) Biochemistry of color changes.
(3) Moisture content changes in transit.
(4) Evaluation of special drying methods.
(5) Drying of poles, railroad ties, small timbers, and thick lumber.
(6) Air drying, forced-air drying, and predrying of lumber.
(7) Drying schedule development.
Other opportunistic fields of research and development will have occurred to you as I have briefed those areas that I believe are important.

CONCLUSION

Although I feel that the drying processes for lumber are characterized as having made significant technological advances in the last 25 years, we cannot afford to be complacent and assume that some experimenter is soon going to come up with a different approach and develop a radically new drying process that solves all our problems. We must conduct the basic research on how wood dries at our Federal, State, university, and industry laboratories so that our present methods can be improved. The applied research and development must be conducted by the kiln company engineers and the technologists at the producing sawmills. The opportunities for accomplishment merit greater attention by all concerned with the production of timber and its utilization.