Automatic Programing and Control for Steam-Heated lumber Dry Kilns

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Abstract

An automatic dry kiln control for use on either new or existing kilns was designed that: 1) continually measures the wood moisture content in the kiln by weight, 2) determines automatically the desired dry- and wet-bulb settings for the measured moisture control, and 3) proportionally opens or closes valves or vents to obtain desired temperatures. Faster drying (as much as 10 percent faster) was achieved by automatic programing, and better temperature control, which implies less lumber degrade, was made possible by the sophisticated control system.

REDUCING THE OVER ALL COST of drying oak by 30 percent is one of the current research objectives at the U.S. Forest Products Laboratory. The first reported study in this effort dealt with the development and evaluation of accelerated kiln schedules for 4/4 northern red oak (3). Once such an accelerated kiln schedule is developed in which changes in kiln conditions are based on the average moisture content of the wood being dried, automation of the kiln drying process can more easily be accomplished. This paper deals with this automation.

In the earlier work presurfaced 1-inch northern red oak was experimentally dried from 87 to 5 percent average moisture content in 14-1/4 days (3). From these results, an accelerated schedule was postulated for careful commercial trial. This schedule involves nine changes in kiln conditions (Fig. 1). Clearly, if drying time is to be kept to a minimum, the changes in kiln conditions should be made as soon as the required moisture content level is reached. Because a specific moisture content level may be reached when no operator is present (during the night or on a weekend), automating the programing of the process should save time.

A second important way to automate kiln drying is to program changes in kiln conditions using many small, frequent changes in kiln conditions rather than the nine rather large changes suggested. The drying schedule would be nearly the same as is now used, except that the curve of moisture content *vs.* desired wet- and dry-bulb temperatures would be smoothed rather than stepped (Fig. 2).

The advantages from using a smooth program occur during the middle of the run – roughly from 45 to 18 percent moisture content – when kiln conditions are changing. This is also the moisture content range in which honeycomb is most apt to develop. It was hypothesized, therefore, that smooth programing would result in more rapid drying rates without an increase in honeycomb; in short, the wood would be treated more gently by gradual rather than step changes.

In addition to automatic programing, the control system – the system that opens or closes valves and vents to maintain the desired temperature – was also "automated" by using three-mode proportional control rather than off-on control. It was hypothesized

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that this sophisticated system would control kiln conditions very closely in the early stages of drying (above 45 percent moisture content). In this range, poor control can result in larger wet-bulb depressions than desired and thereby cause or increase surface checking. It was further hypothesized that more precise control of conditions in the kiln would permit a larger wet-bulb depression than normal to be used, thereby accelerating drying without increasing degrade.

Finally, the. flexibility of automatic programing will permit new hypotheses and new schedules to be evaluated with the goal of optimizing the kiln drying procedure.

Design Requirements

The design of the automatic dry kiln was separated into four sections (Fig. 3):

1) Determining the' wood's moisture content.
2) Programing the desired dry- and wet-bulb temperatures as a function of moisture content.
3) Measuring and recording the actual dry- and wet-bulb temperatures.
4) Controlling the steam heat, steam spray, and vents to obtain the programed or desired temperatures in the kiln.

Several design criteria were established. First, maximum. flexibility in the design and equipment was necessary at a minimum cost. Also, the equipment and design features must be fully capable of use on both existing or new hardwood dry kilns. Therefore, all equipment must be stock items available "off the shelf." Furthermore, the equipment must not require highly skilled personnel to operate it. It should be adaptable to other woods besides the oaks. Finally, it must cost no more than $5,000 to be worthy of consideration.

Determining Moisture Content

One of the easiest methods of determining the moisture content of wood is by weighing the wood green and ovendry and then calculating the value of the expression (green wt. – dry wt./dry wt. × 100%). This expression can be further simplified because (green – dry). = water. Therefore, if the weight of the water in a load of lumber and the dry weight of the lumber are known, the moisture content can be calculated, (water/dry) × 100% = moisture content.

The accelerated kiln schedule is based on the average moisture content of the load (or of the average of representative samples). In this work we decided to weigh the entire kiln charge, approximately 800 board feet, as a unit and to determine the average moisture content of the entire load, from this weight value and an estimated dry weight. (There is no reason why a smaller portion of the load could not have been weighed.)

A load cell, at any time during drying, measures the weight of the total load – the weight of the water in the wood plus the weight of the dry wood plus the weight of the stickers and cover boards plus the weight of the platform. (The platform was a convenient method for holding the lumber so that only one load cell would be required.) A computer tares out the "dead weight" that the load cell measures, everything except the weight of the water. Then the computer divides

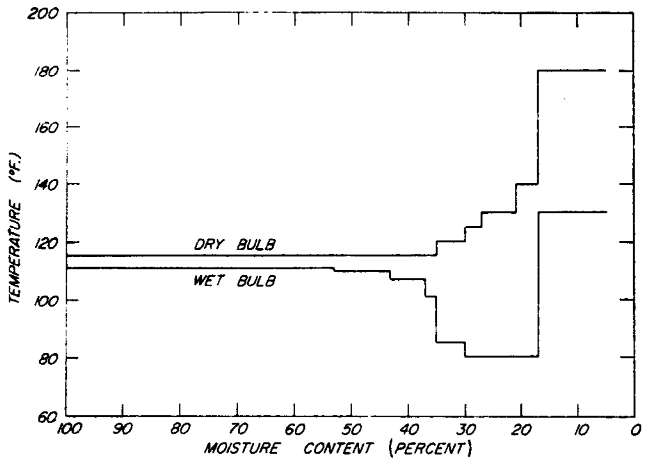

Figure 1. - Postulated kiln schedule for careful commercial trial of accelerated drying of presurfaced 1-inch northern red oak when initial moisture content is between 71 and 80 percent (3).

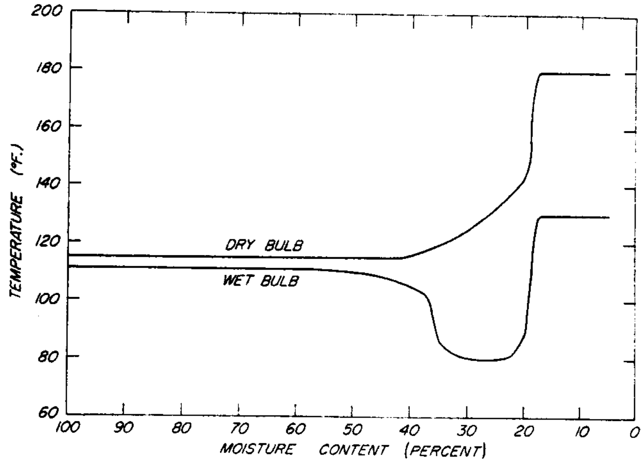

Figure 2. - Smoothly changing kiln schedules derived empirically from the schedule in Figure 1.

the weight of the water by the dry weight of the lumber (estimated by using ovendried samples) and multiplies the result by 100 percent to obtain the moisture content.

Of course, the load cell is always weighing, and therefore the computer is giving a value of the moisture content at all times. This output is a voltage.

The theory of operation outlined above may seem complex, but the outlined procedure (Appendix I) indicates its simplicity. The absolute calibration of the load cell is not required – in effect, the cell is recalibrated whenever the outlined procedure is followed.

Programing Desired Temperatures

If the moisture content is known, it is a straightforward procedure to determine the desired dry- and wet-bulb temperatures manually from the schedule (Figs. 1 and 2). However, the programing section of the automatic kiln must make this determination continually and automatically. It accepts the moisture content output from the load cell system and determines the dry- and wet-bulb temperatures that are desired. Of course, the initial determination of the kiln schedule and the entry of the ‘schedule into the programer is done by the kiln operator in advance.

Measuring Actual Temperatures

It is necessary continually to measure the conditions inside the kiln and record them. Resistance bulb thermometers were chosen for this work due to their speed of response. The temperatures were recorded on a 7-day circular recorder, as is typical in most kiln-drying operations.

Controlling Kiln Temperatures

The control section must control the dry- and wet-bulb temperatures inside the kiln by regulating the amount of steam heat, steam spray, and venting. The controllers (one independent controller for dry-bulb and one for wet-bulb) therefore first compare the actual temperatures in the kiln with the programed or desired temperatures and then open or close valves or vents to reach the desired temperature. A three-mode (proportional, reset, and rate) controller was used, providing very close control of kiln conditions at the point where the temperatures were measured. (See references 1, 2, and 4 for a more complete discussion of proportional controllers.)

Initial Evaluation

Six charges (800 bd. ft. each) of mill-run, 4/4, presurfaced northern red oak were dried using the schedules illustrated in Figures 1 and 2. No attempt was made to match the material in the various charges, so that no valid conclusions can be drawn as to the effect of automatic programing and control on drying rate or defect development.

However, not only were the kiln conditions closely controlled (± 1/2° F.) to those programed, but drying

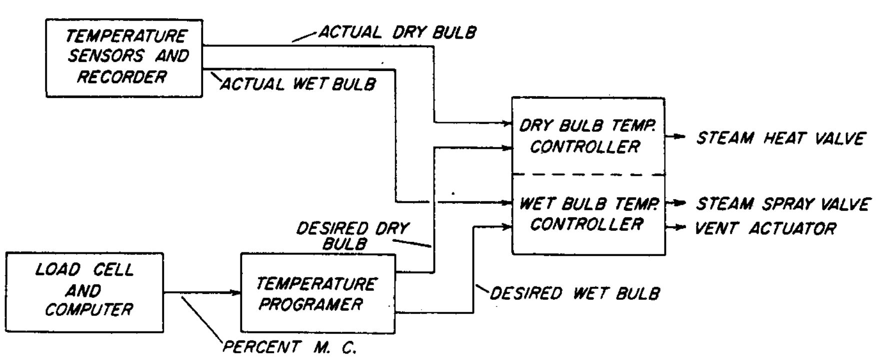

Figure 3. - Diagrammatic sketch of programing and control system for automatic kiln.

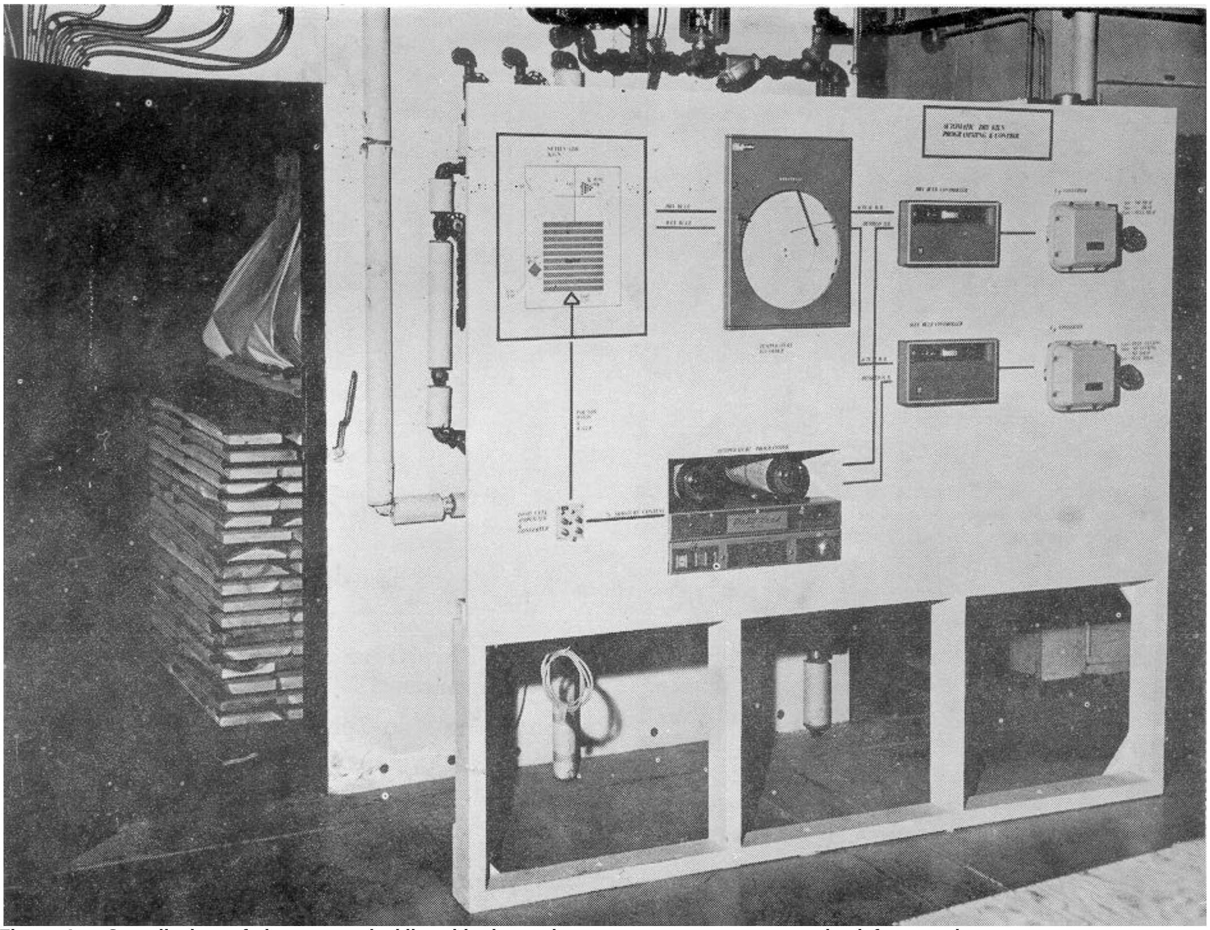

Figure 4. - Overall view of the automatic kiln with the moisture content computer on the left; recorder, upper center; programmer, lower center; dry-bulb controller and pneumatic converter, upper right; wet-bulb controller and converter, lower right.

results were acceptable. That is, checking and honeycomb were minimal or nonexistent; end splitting seldom occurred; and warping was very slight. Further, the drying time from 80 to 7 percent moisture content was about 14 days.

Another kiln run was made using schedule C as outlined by McMillen (3) except that the schedule was smoothed. Drying from 80 to 7 percent moisture content was accomplished in 12-1/4 days, with a 4-foot-wide load. McMillen, using a 2-foot-wide load, and the same schedule in steps, dried from 87 to 5 percent moisture content in 14-1/4 days. Again, reducing drying time by accelerating the dying schedule using the automatic equipment has not produced a noticeable increase in drying defects.

Future Research

We will be comparing manually and automatically programed step schedules, together with a smoothed schedule to get some picture of the advantages to be gained by automatic operation in terms of time saving for a specified schedule. We will then direct our work toward optimizing schedules to reduce drying time while maintaining virtual freedom from drying defects.

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Appendix I

Procedure for Initially Setting Load Cell and Its Computer

1) Tare out or zero the dead load (weight of stickers, platform, etc.)
2) Load the kiln with lumber and take several moisture content sections that will be used to determine the initial moisture content, *M*, in percent.
3) Read the output from the computer, A, in volts.
4) Tare out or zero the dry weight of the wood so that the output from the computer, *B*, is only representative of water, i.e.,

$$B = A \left[\frac{M}{100 + M} \right].$$

5) Adjust the span or amplification on the computer so that the correct value of moisture content is indicated on the programer.