A NEW APPROACH TO MANAGEMENT AND CONTROL OF THE TRADITIONAL LUMBER DRYING PROCESS

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Substantial increases in the market value of lumber products and a decreasing supply of quality timber have made the kiln drying process an ideal candidate for the application of modern process control technology. For this reason, The Foxboro Company assembled a team of control and application specialists in 1983 to identify the process control related needs of the industry and to develop a state-of-the-art control system designed to improve profitability by addressing those needs.

This paper reviews the progress of this effort, starting with the identification of issues affecting the profitability in kiln drying process. Next, it describes the major features of a proposed solution, reviews key design considerations, and concludes with a discussion on the test and final system implementation phases. The Appendix contains technical data including the derivation of wood moisture content from process temperatures, a plot of an evaporative-rate drying cycle, and samples of operator displays.

SURVEY RESULTS

After surveying major kiln operations in the Pacific Northwest, the team evaluated the needs of the industry in terms of improved profitability as follows:

Product Quality Issues

- Improve grade recovery by reducing wood damaged in drying.
- Improve final product moisture uniformity by consistent drying.

Process Management Issues

- Increase kiln throughput by improved process management and control.
- Automate drying procedures to reduce operator workload. Also provide better tools for analyzing and troubleshooting the drying process.
- Smooth steam use to prevent boiler trips and save energy.
- In co-gen plants, coordinate kiln steam use with boiler house needs while minimizing impact on drying quality.

Initial estimates revealed that a 3-4% reduction in degrade could justify the cost of a control system, over an 18-month payback period. Satisfying other needs (particularly increased throughput) would provide additional ROI.

According to our survey, dry kiln installations in the Pacific Northwest operate from 3 to 50 kilns (sometimes more) which range in age from brand new up to 40 years. Newer installations typically have fewer, more efficient kilns.

Nearly all kilns are set up for two independently controlled heating zones (ranging in length from 40 to 50 feet). Most are heated by low pressure steam supplied by burning wood waste. Larger installations having a fuel surplus are considering implementing or have already implemented co-gen projects.

Kilns are almost universally controlled by large-case pneumatic controllers utilizing a time-proven mechanical design. These instruments contain two dry bulb temperature controllers plus single wet bulb controllers. Steam valves are typically on-off, and control is off-on or narrow-band proportional which results in cyclical steam demand spikes. Bulbs are the filled-thermal type and are connected to the controller by capillary tubing. Response is very slow since the kilns are often more than 100 feet long. Some instruments include an automatic cam-setting feature, but the majority of the cams are disconnected. Consequently nearly all setpoints are adjusted by the operator. Most locations provide both saturated steam spray and roof vent operators for wet bulb control.

In all kilns heated air is forced through the load by fans. Older kilns often use a reversible line-shaft fan and manifold arrangement. Newer installations use a battery of large, adjustable pitch fans. Air flow rates (through the wood) range from 200 to 600 cfm, with 350-400 being an acceptable range. Fans are automatically or manually reversed, with reversal periods ranging from 2 to 6 hours or more. Implosion protection interlocks are often provided to hold vents open while fans are off.

Steam heat is distributed through overhead finned tubing arranged for independent zone control. Air is heated both on entering and leaving the load. In double-track kilns, a vertical re-heat section is often added between the two tracks.

In older-style kilns with line-shaft fans, an air flow manifold surrounding the fan blades directs inlet air to one side or the other of the kiln, depending on the direction of shaft rotation. We noticed while walking along the inlet side of this type kiln in operation, that the air temperature entering the load often varied $\pm$ 5 degrees depending on its position under the manifold and roof vents. We also noticed many instances where baffles were inadequate or were not properly secured. We also noticed obvious irregularities in the placement and even the quantity of finned tube sections.

It was also evident at every location that the day shift operator(s), in particular were extremely busy with enormously varied tasks. These tasks ranged from measuring kiln usage, building loads on a fork lift, and loading and unloading the kilns; to running the boiler and selecting and executing a wide mix of drying schedules for a variety of wood products. Operator duties also included troubleshooting and repairing a wide variety of mechanical equipment, as well as maintaining and calibrating delicate instrumentation.

The typical kiln soft wood drying cycle, we determined, starts with a 4-6 hour warmup period with spray optionally added along with dry heat to bring the load to a nominal operating temperature. This is typically followed by an extended period (ranging from a day to several weeks) during which wetbulb-drybulb setpoints are changed every 4-8 hours based on a fixed schedule. When the wood reaches the dryness target, the operator turns off the steam and (optionally) cools the load and conditions it for a variable period (4-8 hours). Lastly, he cools the kiln (may let it "soak" for a while) and pulls the load. The operator gauges when the load is acceptably dry based on several factors: length of run, vent position, in-kiln wood moisture meters, and hand operated moisture probes.

Based on this information, we determined that drying quality problems can be traced to one or more of the following sources:

1) Inadequate sorting on initial moisture content. Also stacking problems (holes between cribs or missing/broken stickers) which prevent an even distribution of heated air through the load.
2) Problems related to Drying Control Technique; control mechanisms, end point determination, and drying consistency.
3) Equipment malfunctions: missing baffles, air and steam leaks, and sticking valves or vents.
4) Kiln Design: Inadequate air velocity or poor circulation, limited heating capacity and distribution, oversized heating control zones, and interruptions in steam supply.
5) Use of busy operators to diagnose or compensate for all of the above.

PROVIDING A SOLUTION--FUNCTIONAL OBJECTIVES

Not all quality-related problems can be addressed directly with a new control system. Kiln design deficiencies, wood handling, and maintenance problems require equal attention. Yet a properly designed digital control system can resolve most of the measurement and control problems. It can also provide the operator with the tools to diagnose and resolve other issues detrimental to product quality and kiln performance. Specifically, we determined that a truly useful system should perform the following functions:

1) Manage and control drying processes from a centrally located CRT Operator's Console and printer. This equipment would:
   - Display an overview of all kilns with respect to current operating status, steam consumption, expected out time; such that the operator could scan the entire operation at a glance and schedule his own activities more productively.
   - Provide an easy-to-use technique for kiln startup and operation control.
   - Provide stored drying schedules.
   - Display detailed information on control execution (zone temperatures, valve and vent positions, steam usage, and moisture readings) to aid the operator in detecting minor problems, such as steam leads and fouled steam traps.
   - Alert the operator when the steam is unable to maintain control targets for any reason.

- Aid in process management by printing detailed end-of-run reports and equipment malfunction alarms.

2) Fully automate the entire drying process, and thereby eliminate chart changing, setpoint adjustment, fan reversing and manual moisture sampling. Also, automatically take protective action in the event of a fan failure or dried out wetbulb, or any other event which could damage the lumber.
3) Eliminate the need for instrument calibration and provide more precise and responsive control.
4) Smooth out steam consumption on per kiln basis by means of improved control action, throttling valves and overriding logic.
5) Monitor, or if desired, manage kiln house steam use by means of manual or automatic steam limiting.
6) Lastly, prevent technical obsolescence by providing the means to modify and test control strategies on site.

SYSTEM DESIGN CONSIDERATIONS

Now that we had established functional objectives, our next steps were first to select hardware, and then to design, implement and evaluate the resulting system at a test site. For a final system, we selected a Foxboro Fox 300 (TM) microprocessor-based control system which provided built-in (configurable) control and display capability plus the means to add custom displays and computations in BASIC. For temperature sensors, we chose matched-pair platinum resistance temperature detectors (RTDs) over thermocouples to obtain the greatest possible accuracy and reliability. Also, the requirement for smoother, more precise control meant that proportional valves would have to be used.

We decided to use a small, portable system with limited display capability to prove out our control design at a test site before implementing the final design in the Fox 300.

Key issues in our system design were to:

- Create a system that is easy to use and will be readily accepted by the operators.
- Provide a wide range of operating capability--from manual to fully automatic (computer control).
- Select a drying control strategy with the greatest potential for reducing degrade and providing a uniform moisture content.

Operator Interface

Designing a control system display for the operator that is "easy to use" is a tough issue. It must provide quick access to essential information, reduce data entry to a minimum, and above all be consistent and self-prompting. We choose in our design to use a layered approach where the top layer provided an overview and subsequent layers revealed increasingly detailed information. We also reduced display call up procedure to single key stroke (plant overview or a specific kiln).

Once a given kiln was selected, the operator would be presented with legitimate actions on labeled "Function Keys," such as STOP, TEST, SCHD, etc. Illogical choices would be eliminated based on kiln status. Potentially detrimental selections such as STOP (which would void the run) were to be protected by keylock. We also insured that stored schedules were described by load type, not just a number to avoid costly errors.

We also included sufficient time in our design schedule for the test site kiln supervisor to review and test all operating procedures before the system was commissioned.

Operational Flexibility

We realized from the beginning that a successful kiln control design must provide a wide range of operating flexibility, from manual valve control to a fully automatic drying cycle. A simple RUN-STOP pushbutton approach would not work. Too many things can (and do) go wrong in a drying cycle. The operator must have the means to override the "system" at any time to minimize his losses when problems such as steam loss or other mechanical breakdowns occur.

For these various reasons, we selected a traditional set of operating phases (START, WARM, DRY, COOL, CONDITION, and END) which would normally execute in sequence, but which could be stopped and selectively restarted at any time with minimal impact on product quality. The phases would also be "self seeking" such that if a run were restarted on "WARM," and the wood was not only WARM but actually dry, the system would rapidly advance to the "COOL" phase. We also provided backup control modes (MANUAL AND OPERATOR-SET AUTOMATIC) to allow the operator to override the system, and the means to place the kiln in a "safe-to-enter" state at the press of a single button.

For operator convenience, the system would store pre-defined control settings for temperatures, fan reversal periods, and other adjustments in "Schedules" identified as to species and dimension (4/4 P. Pine, for example). Each schedule would be designed by the Kiln Superintendent. He would also specify a range of adjustment permitted on a per-run basis to compensate for minor load variations.

In order to aid in kiln management, the system would also require the operator to select a unique run number for each load and also to enter species, width, length and board feet. This information would appear on the operator display and be printed in a report when the load was completed.

The critical issue in achieving full automation is sensing when the load has reached the moisture target and is ready for optional cooling and conditioning. This means the system must either have access to an external moisture meter (measurement or shutdown contact), or include the means to measure moisture content on its own. The author decided to test the merit of deriving lumber moisture content from process temperatures, based on published work by F.G. Shinskey on batch food driers (1), before making a final design decision. This approach proved satisfactory and is summarized in the Appendix.

Control Strategy Selection

Our next design issue was to select a drying control strategy with the greatest potential to improve product quality and moisture uniformity.

We determined there were two good candidates for the control strategy. One was to automate the traditional time-temperature profile approach and hope to improve product quality by means of greater sensor accuracy and tighter control. The second strategy, promoted and eventually patented by Tom Kinney from our Applications Development Group, provided something new with great potential: EVAPORATIVE RATE CONTROL. We decided to test evaporative rate control first, and if it did not match our expectations, we could fall back to the traditional approach. In either case, we had the capability to add more control zones if the additional expense could be justified by improved quality.

Evaporative rate control uses the drop in air temperature through the load as a measure of the rate at which water is being removed from the wood, and it automatically throttles steam flow to maintain a desired rate. The resulting dry bulb-wet bulb temperature set represents the driving force required to sustain a desired evaporation rate for any given moment in time. As the wood dries out, more force is required. If the wet bulb remains constant, this will cause a gradually increasing dry bulb temperature. The significance of this strategy is that feedback from the wood (not a fixed schedule) automatically generates the profile of the driving force. This wood-generated temperature profile will vary from load to load and even between zones in a given load since the control scheme responds to actual zone loss content. Furthermore, if a drying run is interrupted by the operator or a steam loss, use of process feedback guarantees appropriate drying forces will be reapplied when drying resumes.

NOTE:

The author's reason for expecting better quality drying is that evaporative rate control should minimize drying stress. The scenario goes as follows: Once the wood is warmed up and water starts to migrate to the surface, the rate of water removal is held constant, and remains constant until the kiln temperature is driven to a preset high limit. This normally occurs about midway through the run, but would depend on load content and the specified drying rate. From this point on, the driving force is held constant and the rate of drying falls off very gradually until the load is sufficiently dry. In both stages of drying, sudden or inappropriate changes in the rate of evaporation are held to a minimum, thus reducing stress on the wood. Additionally, maintenance of a suitably low evaporation rate in the early stages of the drying run should allow excellent wetbulb control and thus aid in preventing stain. In contrast, a "fixed" wet-dry bulb schedule is a "best guess" approach based on past experience. A "fixed" schedule approach has no ability to compensate for the drying characteristics for the actual load being dried or, for that matter, differences in zone content. For this reason, excessive or insufficient drying forces may occur and result in product degrade.

Moisture Uniformity Achieved Through Drying Balancing

The final issue to be addressed is the design of a strategy to ensure product moisture uniformity.

Evaporative rate drying aims at reducing degrade caused by stress and staining through gentle and consistent drying. In order to do so, it must treat each drying zone as a separate drying process. Boards are dried within a given zone in a fashion that suits the aggregate, not the individual. Moisture uniformity within a given zone is achieved by the natural tendency of wood to give up water in proportion to its moisture content. Thus, if a proper drying regime is enforced, all boards within a given zone will reach a suitable uniform final moisture content, assuming reasonable sorting and stacking practices are employed.

In a multi-zone kiln, however, each zone will respond in a slightly different fashion, unless zone load content and zone physical properties are identical. We know this is not the case. Thus, the wood in one zone must reach the target moisture content first and end up being over-dried unless prevented from doing so by the control system. Furthermore, the addition of more zones to provide tighter control throughout the kiln might tend to aggravate the disparity in completion time.

For these various reasons, the control system should include, as a minimum, the means to sense zone moisture content plus the ability to halt or reduce drying in each zone to minimize "overdry." A more complete solution which we included in our design also "biases" zone drying rates, based on the relative dryness of their contents, such that all zones reach the target dryness at the same time.

An analogy to a perfect solution can be observed in action by watching a horse race film run backwards. Regardless of their relative "starting" positions, all horses "back" into the "ending" gate at the same time.

Effect on Operations

From an operational viewpoint, full automation and use of the EVAPORATIVE RATE strategy should reduce the operator work load. The operator need not specify or implement a complex time-temperature schedule; instead, he will merely specify the number of a pre-built "schedule."

Length of run will now vary with the actual characteristics of load. Loads with lower overall initial moisture content than the norm will dry more quickly and thereby increase production rate. The system also enables the kiln foreman to experiment with evaporation rates and different maximum temperatures to see if production rates can be increased without affecting product quality.

TRIAL PHASE

At the invitation of the Boise Cascade Corporation, we conducted a system trial at their Emmett, Idaho, facility in three separate phases during the Spring and Fall of 1984. Collectively, the tests ran for a total of 16 weeks and provided results for approximately 2-1/2 drying runs per week. The final test runs (Fall of 1984) were conducted in controlled experiment basis using two "identical" 30+ year old kilns, one serving as a test bed for the new drying strategy and the other using conventional temperature-based controls for comparison. A majority of the runs were conducted by Boise personnel without any supervision from The Foxboro Company. Boise Cascade evaluated and retained the results of these tests.

Tests were run on "matched" and marked loads of lumber. These loads included both dimensional and shop grades, primarily Ponderosa Pine. A few runs were also made with local varieties of fir and spruce.

Right from the start, comments from the shift operators and the planer led us to believe that we were on the right track. According to them, the controlled rate of drying was causing an obvious improvement in brightness and texture. During the entire testing period, the shift operators and kiln foreman, Cloyce Bentley, were especially cooperative and helpful. Many of their observations and suggestions led to improvements in the test system as well as the final design. Of particular value was Cloyce's guidance in setting up drying schedules to improve quality and throughput.

While the author was not involved in the evaluation process, Boise Cascade personnel indicated that they evaluated test results based on the dollar value of improvements in grade recovery, moisture uniformity, brightness, knot quality, texture, and drying time. They also weighed in observable, but intangible benefits derived from the system's ability to sense and call attention to minor equipment problems such as miscalibrated valves, dried out wetbulbs, and steam or spray leaks.

At the end of the final testing period, Boise Cascade was sufficiently confident in dollar payback of the new drying technique to purchase a Fox 300 system configured to control all 17 kilns at their Emmett facility.

FINAL SYSTEM INSTALLATION

Control Equipment installed at the 17 kiln-Emmett facility includes a Fox 300 Process Computer, 19-inch Color Operator's Display Terminal, typer, Field I/O Subsystem, recorders, vent operators, on-off spray valves, throttling steam valves, Platinum RTD sensors and fan motor starters. The original Pneumatic Controllers provide backup in the event of system failure. Manual switchover is accomplished in seconds by air switches.

The Fox 300 provides total control of operation, including fan reversal. The kilns (16 single, and 1 double track) include two (2) separate fin-tube heating zones which have recently been reworked to balance heat distribution. Adjustable pitch fans provide a very high air velocity. Steam is provided by an on-site co-gen power plant facility.

Species dried at Emmett are Pine 65%, White Fir 25%, Red Fir 3% and Spruce 7%. Pine runs about 50% 5/4 and 6/4 shop.

The Fox 300 system was installed and commissioned in December, 1985. It controls lumber drying using the evaporative rate control and the dryness measurement and drying rate biasing techniques described in this paper.

Schedules for 15 different load types (differing species and dimension) have been constructed by the Kiln Superintendent. It takes approximately 30 seconds to start the drying operation from the operator's console, and once started, the total drying cycle is totally automated. On completion, an end-of-run report is printed which describes load statistics, the length of the run, steam use/bd. ft., and final moisture content.

Primary operator displays include plant overview, kiln status, kiln startup, schedule builder, and temperature-moisture historical plot. (Refer to the Appendix for examples similar to these displays.) The Emmett system includes a manual limit control over system-wide steam valve position. This feature is periodically used to throttle back on kiln steam use in favor of co-gen power production during peak demand periods or when fuel supply is limited. The effect on drying quality is minimal, since the cutback normally only affects kilns being warmed up (which demands 100% valve position). Within 4 hours, the steam valves close to 40% or less.

The system also provides the means to delay kiln startup to even out steam consumption. The overview display lists kilns like an airline arrival display; i.e., in order by expected "due" time. This display lists operational status (COMP, STOP, RUN) load content, steam use, run time, and due time. Operators use a printout of this display to schedule their own activities with respect to pulling and charging the kilns.

The kiln status display serves primarily for startup and for process troubleshooting. Comparative analysis of temperatures and control deviations combined with zone moisture content, valve positions and run averages, quickly reveal the source of process problems such as faulty steam traps and leaks.

While this paper must not be considered a product endorsement by Boise Cascade, letters received from Cloyce Bentley and Ralph Russell (Quality Control) at Emmett indicate that the System has (over the past 16 months):

- Increased production by 15% or more and set new drying production records.
- Improved grade recovery of #2 common Pine boards by 3%.
- Improved brightness and texture.
- Improved knot quality and minimized cracking in large knots.
- Improved texture has been partly responsible for new planer production records.
- Produced a consistent and uniform moisture content.

In the summer of 1986, Boise Cascade purchased a second Fox 300 system for their Kettle Falls, Washington mill. This facility runs 8 tracks in 5 kilns (3 double track, 2 single track). These kilns have been partitioned into 4 heating zones, and are controlled in essentially the same fashion as those at Emmett.

Operator displays on this system have been updated based on experience gained at Emmett. The Kettle Falls system was commissioned in November, 1986.

SUMMARY

The various strategies described in this paper: Evaporative Rate Control, temperature-based moisture measurement and dryness balancing have proven effective in improving wood texture and grade, moisture uniformity, and kiln throughput. It is difficult to assess the contribution of less tangible system features, such as alarm and end-of-batch reporting, failure mode protection, simplified operating procedures and detailed process displays.

These features are included to aid the operator in managing the drying process and to protect lumber from equipment failure. Their overall intent is to give the operator the opportunity to pay close attention to issues which seriously impact both quality and production rate, but which are beyond the scope of any control system. These issues include modifying schedules to accommodate weather changes, suppliers, and customers; ensuring kilns are maintained at peak performance levels; and lastly, keeping a close watch on sorting-stacking operations.

ACKNOWLEDGEMENTS

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Ron Perez (Applications Engineer)
Jim Noel (Sales)

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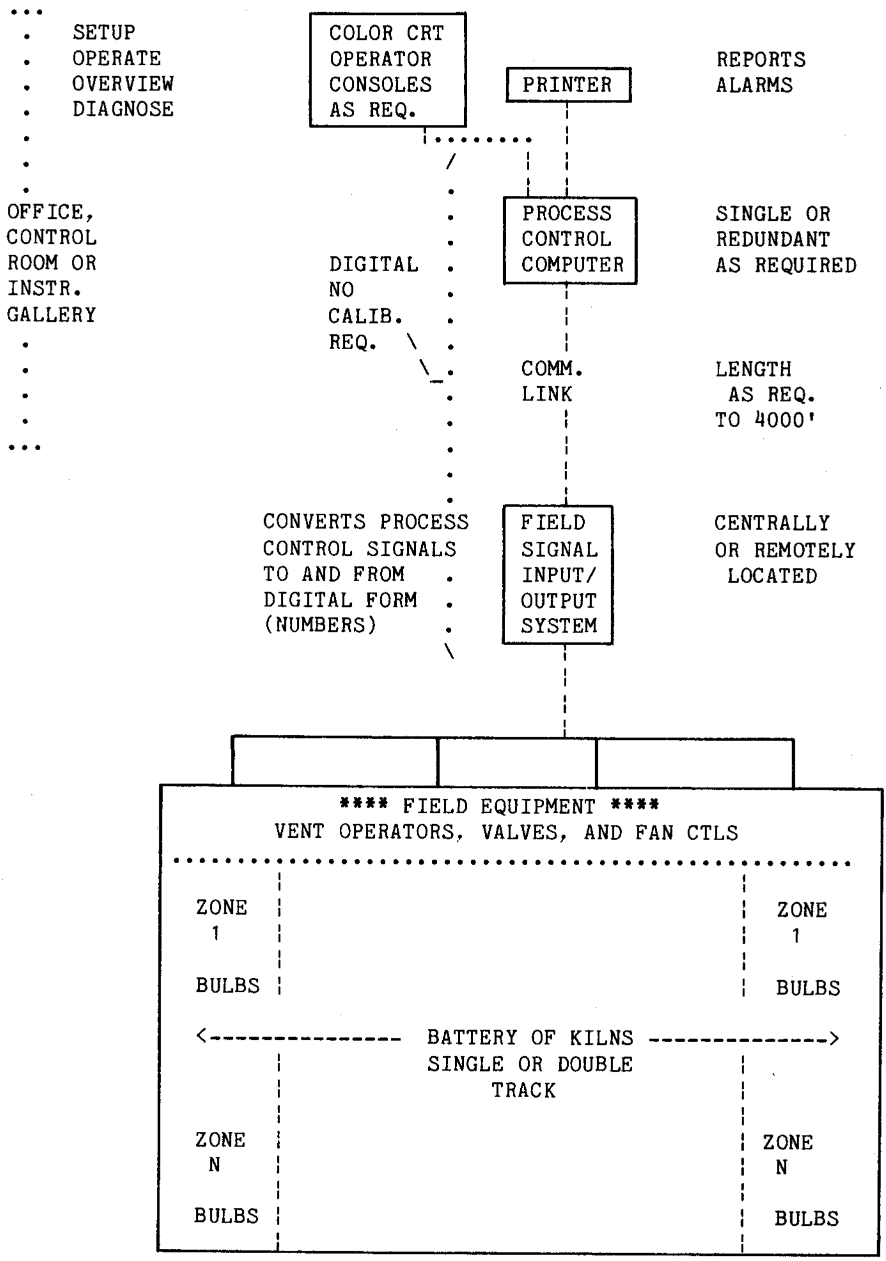
Jim Spenser (Emmett Plant Engineer)
Nancy Wood (Test Results Evaluation), and most especially
Cloyce Bentley (Kiln Superintendent, for his lumber drying savey and persistent optimism)

LITERATURE CITED

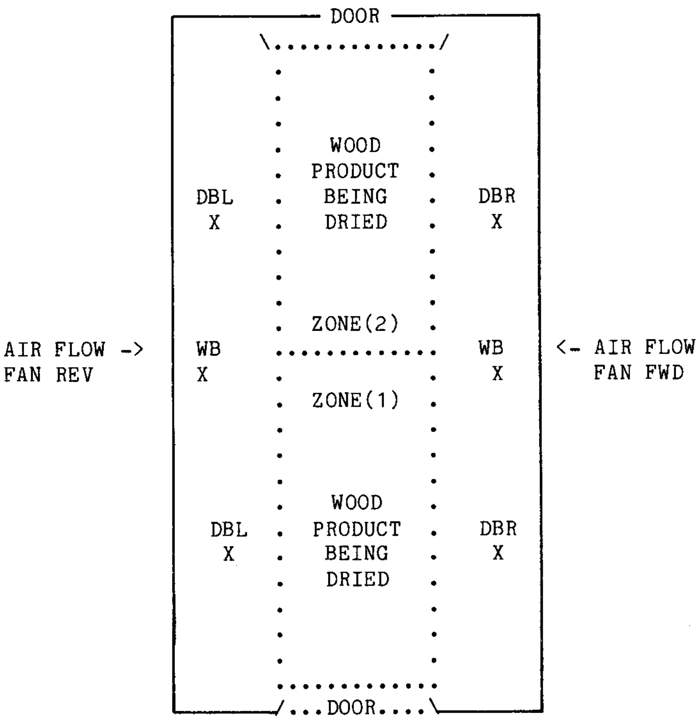
1. Hildebrand, Robert (1970). Kiln Drying of Sawn Lumber. Printed by Richard Schorindofer Buch-und Offsetdruk, Plochingen, Widdumstr. 3-7, Germany.

2. Shinskey, Frances G. (1978). Energy Conservation Through Control. Academic Press.

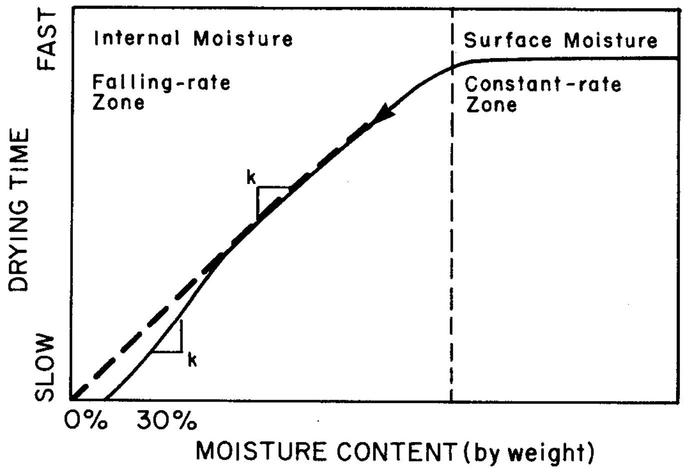
APPENDIX



TYPICAL COMPUTER-BASED KILN CONTROLLER SYSTEM LAYOUT



BULB ARRANGEMENT FOR A 2-ZONE SINGLE TRACK KILN



Repeatable rate-of-drying vs. moisture slopes for specific wood types permit moisture content to be calculated with sufficient accuracy to balance drying and determine end point (1).

MC(%) = K ln((Ti-Tw)/(To-Tw))
where K = CG/akAHv (Per-product calibration constant)

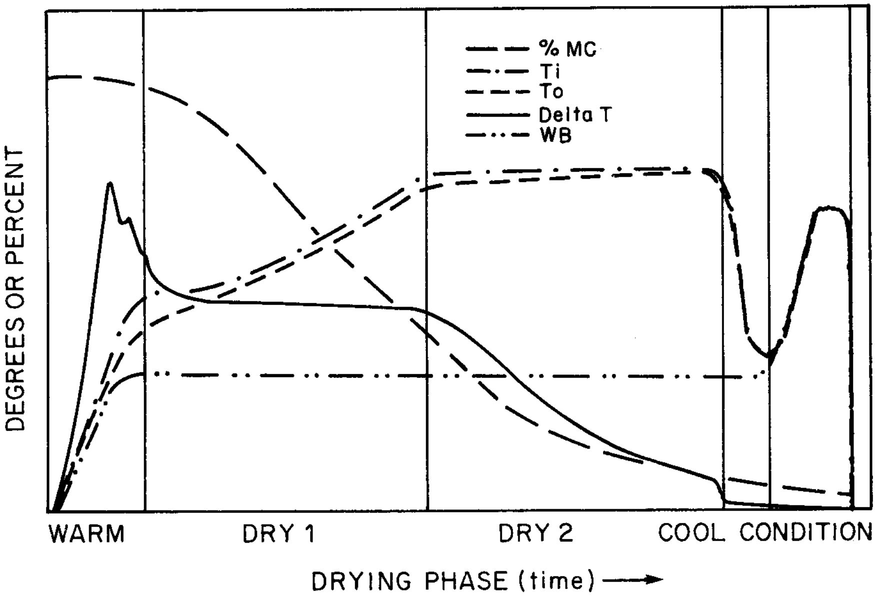
G = Mass flow of air	Hv = Latent heat of evap.
C = Heating coef. of air	A = Product surface area
a = Mass transfer coef.	Ti = Inlet temperature
K = d-rate/d-M%	To = Outlet temperature
	Tw = Wet bulb temperature

```
                            ...
            Air Flow       |F|
                 - - < - - |a| - - < - -
Heating-> ooooo            |n|        ooooo
Coils       |              | |          |
            |        ______     ______  |
            |       |               |   |
            - ->    |    Lumber     |  ->-
   Inlet    Ti      |    Being      |  To (Outlet)
            Tw      |    Dried      |  Tw
                    |_______________|
```

Diagram of Drying Process

(1) Plot and equations are derived in the following source: Shinskey, Francis G. (1978). Energy Conservation Through Control. Academic Press.

DERIVATION OF MOISTURE CONTENT FROM PROCESS TEMPERATURES



SCALE: WB,Ti,To 50-250 DEGF
Delta T 0-20 DEGF
Moisture 0-150 %

Ti = Temperature at load inlet
To = Temperature at load outlet
Delta T = Ti - To
WB = Wet bulb temperature

TEMPERATURE-MOISTURE PLOT DURING EVAPORATIVE RATE DRYING PHASES

KILN OVERVIEW

KILN	STAT	SCHEDULE	KBDFT	STM FLOW KLBH	TIME AND DATE START DATE	TIME	HRS-REM
7	COMP	P.PINE 4Q	XX.XXX	X.XXX	04/10/87	18:45	2:15
4	COMP	HEM FIR 6Q	XX.XX	X.XXX	04/11/87	01:10	5:20
3	COMP	S.PINE 6Q	XX.XXX	X.XXX	04/09/87	08:20	18:50
2	TEST	P.PINE 6/Q	XX.XXX	X.XXX	04/10/87	08:13	22:15
1	AUTO			X.XXX			
5	MAN			X.XXX			
6	OFF						
N							
		TOTALS:	XXX.XXX	XX.XXX			

Steam Press Is: xxx.xxx (lbs)
Cur. Steam Limit Is: xx.xxx Valve Limit Is: 85%
Cur. Steam Flow Is: xx.xxx Auto Limit Is: Off
Diff: x.xxx (KLBH)

(Optionally kilns can be listed by number, see L1)

L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
BY-K								LIMIT				PRNT

KILN STATUS DISPLAY

```
                                                                        TIME AND DATE
                                          KILN (NN)
STAT     RUNNO     SCHD     PHASE     PHZTM     CMPTM     RUNTM     STRT     DATE-TIME     HRS-REM
OFF
MC TARG =          0.0%     0       100     200                            0        50          100
ZONE DIR %MC                +-------+-------+    EMC VALVE          PCT    +--------+-----------+ AVG
NO. 1    FWD       0.0                           0.0 STEAM          0.0                           0.0
         REV       0.0
NO. 2    FWD       0.0                           0.0 STEAM          0.0                           0.0
         REV       0.0
NO. 3    FWD       0.0                           0.0 STEAM          0.0                           0.0
         REV       0.0
NO. 4    FWD       0.0                           0.0 STEAM          0.0                           0.0
         REV       0.0
%MC      FWD       0.0                               VENT           0.0                           0.0
%MC      REV       0.0                               SPRY           0.0                           0.0
%MC      EST       0.0                               FAN:     OFF      PER:     0    DUE:     0  (MIN)
```

DRYING RUN SETUP

SCHD: 16	ITEM	QTY	QTRS	WID	LENGTHS	SPECIES	GRADE	KBDFT	TOTAL
P. PINE 4/4	1	2	4	10	14/16	P. PINE	SAP	6.233	12.466
	2	4	4	12	10/12	P. PINE	SAP	4.100	16.400
OPR: 7	3	1	4	6	14/16	P. PINE	SAP	2.987	2.987
	4	2	4	..	../..	....	...	.....	.....
RUN: 12031	5				/			.....	.....
	6				/				
								TOTAL:	65.840

SCHED	DESCRIPTION	SCHED	DESCRIPTION	GRADE	DESCRIPTION
1	SHOP 5/4	16	P. PINE 4/4	1	SAP
2	....	17	....	2	....
3	....	18	....	3	....
..	....	..	....	..	....

(Available Schedules & Grades Listed for Reference)

<--------FUNCTION KEYS VARY WITH KILN STATUS-------->

L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
STOP		TEST	MAN	AUTO	COMP		SCHD			COMM		PRNT

NOTES:
Select schedule by no., enter operator and run no., fill in load details, press COMP to start run...or first press SCHD to modify schedule for this run...then press COMP.

```
                                        KILN STATUS DISPLAY              TIME AND DATE
                                          KILN (NN)
STAT    RUNNO    SCHD    PHASE    PHZTM    CMPTM    RUNTM    STRT    DATE-TIME    HRS-REM
COMP    1245     21      DRY2     4:20     32:15    32:15    04/13/87  12:45        6:21
MC TARG =        12%  0        25       50                      0          50          100
ZONE DIR   %MC        +---------+-------+   EMC VALVE    PCT    +---------+-----------+ AVG
NO. 1 FWD  40.7        AAAAAAAAAAAAAA       9.6 STEAM    28.6   #####                   38.5
      REV  36.5        IIIIIIIIIIII
NO. 2 FWD  43.5        AAAAAAAAAAAAAAA      9.4 STEAM    38.1   ######                  65.7
      REV  40.1        IIIIIIIIIIIII
NO. 3 FWD  41.4        AAAAAAAAAAAAAA       8.6 STEAM    27.1   #####                   55.7
      REV  37.2        IIIIIIIIIIII
NO. 4 FWD  39.6        AAAAAAAAAAAAAA       9.1 STEAM    44.6   #######                 47.2
      REV  35.2        IIIIIIIIIIII
%MC   FWD  41.3        AAAAAAAAAAAAA            VENT     18.3   ###                     42.4
%MC   REV  37.2        IIIIIIIIIII              SPRY      0.0                            4.8
%MC   EST  39.2        ############             FAN:  FWD     PER:  270   DUE:  241 MIN
           ***PRESS MODE KEY***
                   FOR
              CONTROL DETAILS
                                                                OPERATOR NOTEBOARD
                                                                 Check spray leak
                                                                SYSTEM MESSAGES
                                                                 LEFT WB DRIED OUT

                   <--------FUNCTION KEYS VARY WITH KILN STATUS-------->
 L1      L2      L3      L4      L5      L6      L7      L8      L9      L10      L11      L12      L13
STOP            TEST     MAN    AUTO                    SCHD                      COMM              PRNT
```

NOTES:

The successive characters represent color bar graphs. Also the moisture scale drops from 200 to 50 when all values are below 50.

The (A) active moisture measurements are displayed in green, (I) inactive in blue.

Function keys permit the operator to place kiln in auto, man, test modes as well as to print the display, examine or modify the schedule.

KILN STATUS DISPLAY

```
STAT    RUNNO    SCHD    PHASE    PHZTM    CMPTM    RUNTM    STRT     DATE-TIME     HRS-REM
COMP    1245     21      DRY 1     4:20    14:17    16:25     04/10/87  18:45        23:21
MC TARG = 12.0%          0       100      200                         0        50        100
ZONE DIR   %MC           +--------+--------+ EMC VALVE        PCT     +---------+---------+ AVG
NO. 1 FWD  140.8         AAAAAAAAAA         10.9 STEAM        65.9    ###########          68.5
      REV  136.8         IIIIIIIII
NO. 2 FWD  165.9         AAAAAAAAAAA        11.6 STEAM        86.1    #############        85.7
      REV  147.9         IIIIIIIIII
NO. 3 FWD  138.5         AAAAAAAAAA         11.1 STEAM        50.0    ##########           55.7
      REV  132.6         IIIIIIIII
NO. 4 FWD  154.9         AAAAAAAAAA         11.5 STEAM        70.1    ############         75.8
      REV  137.9         IIIIIIIII
%MC   FWD  150.3         AAAAAAAAAAA             VENT        100.0    ##################   98.1
%MC   REV  138.9         IIIIIIIIII              SPRY          0.0                          4.8
%MC   EST  144.6         ###########             FAN:  FWD       PER:  270    DUE:  248   MIN

Z VAR    TEMP    SETPT    DIFF    SCHD    TRIM
  DT      9.7    10.0     -0.3    10.0    0.0
1 IN    149.8   165.0    -15.2   165.0    0.0
  OUT   141.1   140.0      1.1   140.0
  DT     11.4    11.5     -.01    10.0    1.5
2 IN    153.4   165.0    -13.2   165.0    0.0
  OUT   142.6   140.0      2.6   140.0
  DT      8.5     8.5      0.0    10.0   -1.5
3 IN    150.0   165.0    -15.0   165.0    0.0          OPERATOR NOTEBOARD
  OUT   141.0   140.0      1.0   140.0                 spray leak fixed!
  DT     10.0    10.0      0.0    10.0    0.0          SYSTEM MESSAGES
4 IN    152.0   165.0    -13.0   165.0    0.0          DRYING TO MAX TEMP
  OUT   142.0   140.0      2.0   140.0

WT  LO  130.0   130.0 (L)   131.1 (R)   130.1

                <--------FUNCTION KEYS VARY WITH KILN STATUS-------->
 L1     L2     L3     L4     L5     L6     L7     L8     L9     L10     L11     L12     L13
 STOP          TEST   MAN    AUTO                 SCHD          COMM                    PRNT
```

NOTES:

Trim is automatically added to adjust the drying rates of the slowest and fastest zones to promote uniform moisture content.

SCHEDULE BLDR

SCHEDULE NO. 16
P. PINE 4/4

ITEM	DESCRIPTION	ABS LIMITS LO	ABS LIMITS HI	USR LIMITS LO	USR LIMITS HI	CURRENT VALUE
1	Delayed start time hrs	0.0	10.0	0.0	10.0	0.0
2	Max expected run hrs	0.0	100.0	36.0	45.0	42.0
3	Maximum temp setpt	0.0	200.0	170.0	180.0	175.0
4	Fan reversal per #1 hrs	0.2	10.0	2.0	4.0	3.0

NOTES: Approximately 30 values for the full schedule.
Absolute (ABS) limits are fixed. User limits must be within ABS limits and are set by supervisor.
Schedules are set up for each common wood type and dimension. Once assigned to a kiln the setup operator can vary the schedule within the limits established by the supervisor.

<------FUNCTION KEYS VARY WITH USE OF DISPLAY------>

L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13
MENU	SAVE	EXIT										PRNT