WHY IS THERE A NEED FOR MORE ACCURACY IN DRY KILN CONTROL

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INTRODUCTION

Section A Parameters for Measurement and Control

The following is a list of parameters or items that need to be measured and controlled which affect the rate that lumber dries in a lumber dry kiln. Air flow in a conventional kiln is shown in Figure 1.

Table 1. Basic kiln

Steam flow per kiln	Steam flow per system
Steam priorities	Steam pressure
Steam valve position	Spray valve operation
Dry bulb (quantity n)	Wet bulb (quantity n)
Wet bulb depression	Fan sensors: on/off, direction
Fan reversals	

Table 2. Enhanced kiln for a final EMC of ± 1%

Heat loss	Energy balance
Air temperature per crib	Zone control
Air flow: CFM, FPM	Air flow: distribution
Air balance: internal/ external	Relative humidity: internal/ external
Condensate flow rates	Trap function via temperature

The following functions must also be addressed in an advanced dry kiln control system.

Table 3. Basic kiln

Data viewing and reporting
Reliability: fully distributed controls plus local and manual alarms
Training

Enhanced kiln

Boiler control feedforward/feedback
Fan line shaft brakes
Automated schedule compensation/adjustment/flexibility
Production data base for management

Section B The Effect of Major Parameters on Final EMC

Old style controls told very little about what was happening in a kiln. Even advanced electronic moisture meters only identified when something had happened, not what caused it to happen.

Future dry kiln control systems must be able to quickly identify all out of tolerance conditions which can cause more than a 1% variation in final EMC.

This section shows the probable effect on final EMC for some of the major parameters (factors) listed in Section A.

1. Non Uniform Air Flow Through Stacks

Desired highest velocities in first third of schedules, 500 ft/min in middle third and 200 ft/min during final third of drying.

Probable typical variation 80 to 800 ft/min.

Assumptions: Charge is 5/4 PP (1 1/2") with 3/4" stickers, in each cross section of 1x1 there will be:

$$\frac{6 \times .75'' \times 12''}{144} \text{ or } .37 \text{ sq ft of opening}$$

Sensitivity of final EMC to velocity variation: A one percent variation in EMC equals 0.013 lbs moisture per board ft.

Three cubic ft of saturated air at 160°F contains approximately 0.013 lbs moisture. If we assume that at 20°F depression (which is a very gentle and slow schedule) it requires 15 minutes for each unit of air to absorb its load of water vapor. Then for a 10 FPM variation through .37 sq ft of opening on one hour, there can be a variation of 0.65 lbs water removed which equals 1% EMC per each 1' x 1' cross section of lumber. Fortunately, wetter sections lose moisture faster than dryer sections. Therefore, the actual sensitivity of EMC to airflow is greater than ± 10 FPM in any given hour. There is considerable evidence that a ± 50 FPM variation in any given hour causes measurable changes in final EMC. For measurement purposes the sensors should be able to identify a change no larger than 1/2 of the allowable variation around the desired control point.

NEED: Measure air flow through the stack within ± 25 FPM or better in any given hour and ± 10 FPM for long periods of time.

2. Non Uniform and Lack of Adequate Venting of Water Vapor

Assumptions: 104 ft kiln, 13 vents each side, each 2' x 2'

.3 lb water removal per cubic ft of wood per/hr; 460 ft/min avg kiln velocity @ 50% of maximum water vapor load in exhaust.

Almost all kilns are semi-natural draft, i.e., dependent upon the circulation fans, internal pressure build up and hot vapor (chimney effect). Also the location of vents and internal air flow patterns tend to not allow a uniform or well-controlled rate of venting during the critical transition time between stages B and C. (See Figure 2). The following is for the future kiln to dry all boards to ± 1 EMC. If one half (one side) of vents lets fresh air in and the other half exhausts water vapor, then the estimated effect due to temperature difference (chimney effect) is 20% of the total. Unfortunately, internal pressure build-up tends to force air out of all vents. A 0.01" change in differential air pressure vs. atmospheric pressure can result in a 30% change in amount of air vented which may or may not be saturated.

NEED: Measure difference between internal and external air pressure within ± 0.01" water column. Flow direction, i.e., is air flow in or out? Velocity measurement through vent, 0-500 FPM ± 2%.

3. Variation in Desired Relative Humidity (Depression)

The EMC is fairly linear with depression between 150°F and 180°F dry bulb. For small depressions, each 1°F change in depression results in approximately .8% changes in EMC if all other factors are held constant.

Based on this, then the "controllability" of the depression should be ± 1°F which at 160°F DB is ± 2% RH for a target EMC of 12%. From this it can be seen that a RH measurement is twice as sensitive as depression or wet bulb measurement. In actual practice, the wet bulb and dry bulb are totally independent measurements. Example:

180°F DB ± 1/2% of full scale (400°F) measurement system = ± 2°F

The same parameters exist for the wet bulb even if the wick is working perfectly. There is a 25% chance that the error in depression will be 4°F, which translates into a variation in RH of 8%. In addition, typical wet bulb wicks add from 1 or 2°F to over 10°F additional error.

NEED: Relative humidity sensor accurate to ± 1% RH over the temperature range 120°F to 170°F.

4. Variation in Internal Air Flow

Typical fans in lumber dry kilns operate between 1/4" to 1/2" static pressure (SP). Many older style fans can have a 30-40% drop off in air flow when the SP goes up by as little as 1/4", if the fan is already operating at the top of the performance curve. Even modern fans have a 20% change in air flow when the SP changes from 1/4" to 1/2". In fairly good kilns, up to 50% of the air doesn't go through the lumber. Air will always attempt to go to the path of least resistance. In any given kiln, the by-pass areas tend to remain more or less the same from one load to the next or until something gets fixed. High variation in air flow can result from how the lumber is stacked and placed on the trucks and positioned in the kiln. Also see item 1.

NEED: Delta P (T) across fans 0-1" H20 accurate to 0.05"

Delta P (T) across each crib 0-1" H20 accurate to 0.05"

5. Energy Flow Into Kiln

The thermodynamic characteristics of each kiln will identify how well a kiln is performing. Once a kiln's behavior is plotted, variation off this "norm" can be used to identify problem areas. Things that typically go wrong are:

Traps not working
Leaks in piping
Coils flooded due to condensate malfunction
Low steam pressure and high condensate back pressure
Valves not opening or closing as expected
Spray valve not closed
NEED:

Table 4. Energy flow measurements

Steam/Condensate System	Units	Range	Accuracy
Steam flow each kiln	#/hr	500 to 15,000	±50 lbs/hr under 5,000 lb/hr flow
Condensate flow each kiln	#/hr	500 to 15,000	±50 lbs/hr under 5,000 lb/hr flow
Traps	°F	100 to 400	±5°F ±1°F Delta T
Steam pressure	PSIG	10 to 150	±2 PSI except ±.5 PSI under 30 PSI
Condensate pressure	PSIG	0 to 10	±.5 PSI if H/pressure ±.1 PSI if L/pressure

6. Condition of Lumber (Moisture Content)

Moisture in wood can be in three major modes. They are "surface" water, "free" water under the surface but not bound with the cells and "bound" water. The methods and driving forces of surface and free water movement is fairly well understood. There is still a great deal of uncertainty on just how bound water gets out of the cell and what happens if it tries to exit "too fast." (See Figure 2).

There needs to be two abrupt changes in a typical schedule in addition to any conditioning and/or stress relieving. (See Figure 2). The first of these is when the surface water has been removed and any "frozen" lumber has been thawed and brought up to a uniform temperature within at least 5°F of the kiln wet bulb air temperature. After this point, the kiln dry bulb temperature and depression can be increased at a more rapid rate. Most theories state that this rate must not exceed the rate the free water will migrate to the surface. After the free water has reached a low level, probably under 30% EMC--maybe under 20%, the depression can be increased to the maximum ability of the kiln. Some theories state that towards the end of this phase, the temperature and depression should be reduced to help equalize difference in lumber EMC.

The reason for this uncertainty is that production kilns so far have not been precisely controlled and conventional controls have only measured two or three parameters. Therefore the necessary data has not been available to change lumber drying from an operator's "feel" to a science.

NEED:

Table 5. Temperature measurements

Kiln Temperature	Units	Range	Accuracy
Across coils (T)	$^{\circ}$F	T 0 to 50	$\pm$.5°F/each coil
Inlet air (T)	$^{\circ}$F	-20°F to 100°F	$\pm$ 1°F
Space air temp (T)	$^{\circ}$F	50°F to 200°F	$\pm$ 2°F accuracy $\pm$.5°F repeatability
Lumber (T)	$^{\circ}$F	T 50°F	$\pm$.1°F

7. Effect on Lumber Drying of Fan Reversal

Work done in drying of other similar products shows frequency of fan reversal should be varied depending on the condition of the lumber and which part of the schedule you are in. This may be especially true during conditioning and stress relieving.

NEED: Calculation of information from other sections to ascertain optimum interval for fan reversals.

SECTION C A typical ponderosa pine rate moisture removal rate is shown in Figure 2. Next are shown possible DB, WB, RH and potential EMC for each drying stage.

Table 6.

DB = Dry Bulb
WB = Wet Bulb
RH = Relative Humidity
EMC = Equilibrium Moisture Content

GOAL 13.8% EMC

Stage in Schedule		A				B				C				D			
		DB	WB	RH	EMC hot	DB	WB	RH	EMC hot	DB	WB	RH	EMC hot	DB	WB	RH	EMC hot
AIR	High Ideal Low	100F	100F	100%		140F	130F	75%		180F	140F	35%		160F	153.5F	84.5%	
LUMBER	High Ideal Low	35 F (Start)			50	120 F (S)			22	175 F			15	165 F			13.8

Airflow effect on moisture removal

A. Air becomes "Sat." before exiting stack
B. Drops below rate necessary to remove rate of internal migration, 100 FPM after 24 hours
C. Drops below amount necessary for uniformity

The final table of this section shows how accurate you would need to make the listed measurements if you really needed to control final EMC with ± 1%.

Table 7.

MEASUREMENTS

STEAM/CONDENSATE SYSTEM	Units	Range	Accuracy
Steam flow	#hr	500 to 15,000	± 50 lbs/hr under 5,000 lb/hr
Condensate flow	#hr	500 to 15,000	± 50 lbs/hr under 5,000 lb/hr
Traps	°F	100 to 400	± 5°F
			± 1°F T
Steam pressure	PSIG	10 to 150	± 2 psi except ± .5 psi under 30 psi
Condensate pressure	PSIG	0 to 10	± .5 psi if high pressure steam
			± .1 psi if low pressure steam
KILN AIR BALANCE			
Internal vs. atmosphere P	ΔP "H_2O	-1" to +1" H20	± 0.05
Air flow in/out	ΔP "H_2O	-1" to +1" H20	± 0.05 (one each vent)
INTERNAL AIR FLOW			
Across fan(s)	ΔP "H_2O	0 to 1" H20	± 0.05 each fan
Across lumber	ΔP "H_2O	0 to 1" H20	± 0.05 each crib
KILN TEMPERATURE			
Across coils (ΔT)	°F	ΔT 0 to 50	± .5 F each coil
Inlet air (T)	°F	-20 to 100	± 1 F high flow
Space air temperature (T)	°F	50 to 200	± .5 F near wall each crib
Lumber (ΔT)	°F	ΔT 0 to 50	± .1 F each crib

Relative Humidity at 25% of the DB space air temperature points.
104 ft kiln needs a minimum of 9 coils, may require 18 coils.

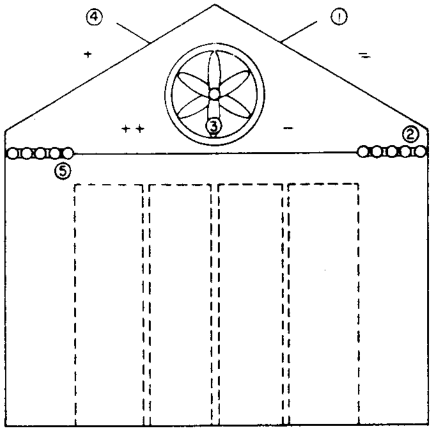

Figure 1

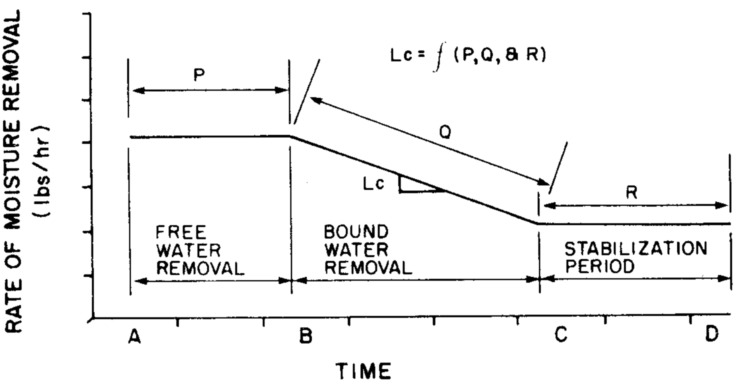

Figure 2

KILN TEMPERATURE DISTRIBUTION

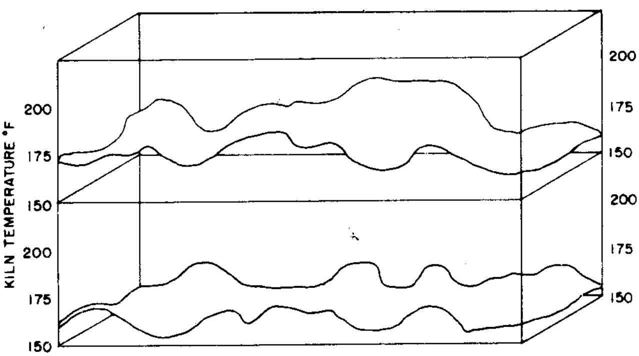

Figure 3