FREQUENCY CONTROL -- A NEW TOOL IN DRYING

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It's been my pleasure to give a number of talks on the use of fan frequency control to dry kiln groups and lumber associations around the country. I must admit that most of these people have been in the hardwood field, and the feeling is that fan frequency control is only for the hardwood industry. This is certainly not the case. While we think of drying oak as taking 21, 24, 25 days or even longer, in that same period of time in many cases, you can have seven or eight loads of softwood go through conventional temperature kilns, and of course in your high temperature units, many more loads than that.

When we first worked with Allan Bradley on the development of the frequency control, and had installed the first dozen or so kilns, I really thought we had a "tiger by the tail". I thought in the hardwood industry all I had to do was waltz around from one 20 year old kiln to another, install fan frequency control and spend my winters in Florida or the Caribbean.

Nothing could have been further from the truth. We found that of the thousands of kilns out there, most of them do not have enough air speed now, let alone installing a frequency control to lower the air speed at the end of the drying. We still feel that it is the most significant improvement to come down the pike in the lumber drying industry, and are very excited about it.

A kiln of modern design, unlike the hardwood units that were designed to dry air-dried lumber or the early line shaft kilns out here, should have a modern air circulating system to dry the lumber as fast as possible without causing degrade. Because electricity is expensive, we should only be using this high velocity air when it's needed. I don't have to tell you that for each species, thickness, and moisture content there is a very definite prescribed condition of temperature and humidity. The one thing that the government services and most of the universities have left out is the air velocity. The air velocity plus the temperature and humidity are related to the safe rate of moisture loss.

We are now able to affect that rate of loss in high moisture content situations by regulating the air velocity through the load, both at the green stages when high velocity is beneficial and at dry stages when the low velocities are adequate. This allows us to minimize the drying time, protect the lumber quality, and, most importantly, conserve on energy. There is no need to pay for more electricity than is necessary to produce the air volume that is beneficial. This may seem pretty simple, but what we want to illustrate is the relationship of "air velocity to the drying rate".

The closer the lumber temperature is to the wet bulb temperature, the greater the effect of air velocity. The closer the lumber temperature is to the dry bulb temperature, the less effect air velocity has on the drying rate. Figure 1 shows the effect of air velocity at high relative humidities when the EMC condition of the air is very high. It certainly has a marked effect. Figure 2 is even more revealing and shows the tremendous effect that air velocity has at different moisture contents. At 60% moisture content and greater, the higher the air velocity, the faster the drying rate. As the moisture content decreases, air velocity has less effect. From 40% on down, you certainly don't need the same velocity that you do above that

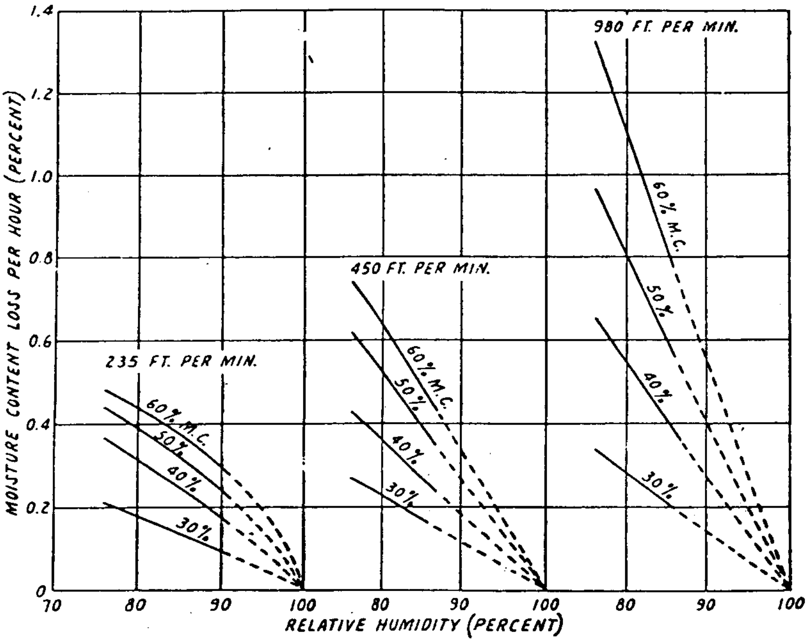

Figure 1. Effect of relative humidity, air velocity, and moisture content on the rate of moisture loss.

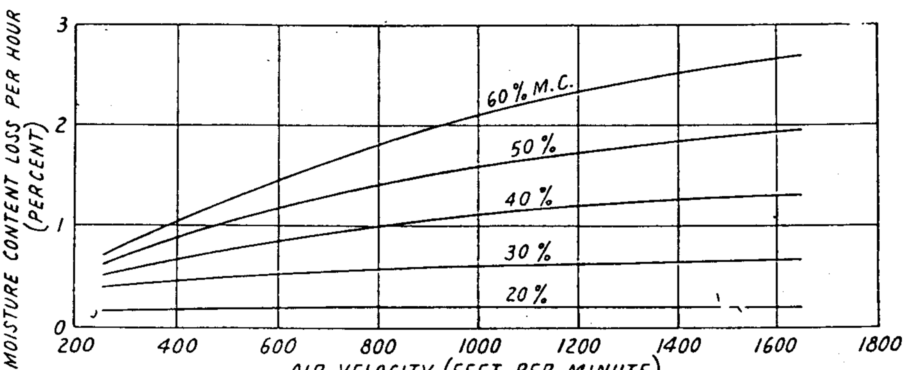

Figure 2. Effect of air velocity on drying rate at various moisture contents.

point. At 30%, it's a waste of electricity and energy and dollars to use this high velocity. From 30% on down, air velocity has little or no effect on the drying rate. At this rate, air velocity is used primarily to maintain the uniform conditions in the chamber.

I don't have to tell you that certain species are subject to brown stain and if you have enough air velocity, you can certainly eliminate that. Our Eastern White Pine, for the first two days or until the moisture content is less that 50%, we use 750 ft/min. From 50 to 30%, we use 600 ft/min, and then 200 ft/min when we're below 30%. Frequency control really puts an added tool into the hands of the operator to fine tune the kiln schedule by controlling all three elements, temperature, relative humidity, and air velocity.

Up to now, we have been talking about the drying advantages of using frequency control. Now, let's talk about what it does to the pocketbook. There are a lot of equations and laws of electricity to establish the results that we're going to look at, but let me explain that I'm not necessarily an engineering marvel in electricity. What I do know is that you have to pay for it, you have to pay too much for it, and it does not pay to fool around with it. Get your pencils out because you're going to have a hard time believing this. If we adjust the speed of the fan, the horsepower will go up or down as the cube of the speed. To put it in a little plainer English, let's take a 10 hp motor at 100% speed and using the full ten hp. If you reduce the speed to 50% or 30 cycles instead of 60, the fan manufacturers say that you get half the air velocity. The cube of the speed operating at 50% is 0.50 x 0.50 x 0.50 x 10 hp or 1.25 hp. This means you are running at 12 1/2% of the original 10 hp motor and getting 50% of the air volume. If we use 746 Watts per motor hp and 6 1/2 cents per kw rate, we can show that it costs $11.64 per day to run the 10 hp motor at 100% speed. It would cost $1.45 per day to run that same 10 hp motor at 50% speed, a reduction of 84 1/2% in electrical consumption. Reduction of the flow and the pressure as the fan speed is reduced does not change the efficiency of the fan as a completely new fan curve is generated at each different speed. If we think back at the air velocity required at the different stages of drying, we can see that the opportunity to save on energy by cutting down on the speed of fans as the lumber dries is very real and there can be a substantial saving. Time and the chance of implosions are reduced with variable frequency control because when reversing, the fans slow down within an adjustable 10 or 15 seconds and turn immediately back on in the reverse direction. We eliminate that three to six minute period where heat builds up at the top of the kiln chamber. Next, I would like to present data for a typical hardwood installation of drying oak. The same percentages apply to units I have installed for drying Southern Pine as well as in pressure treating plants where the schedule is a three to four day drying cycle.

These next four figures are based on a 28 day cycle of drying oak in a 30,000 bf package kiln. The final figure will show the remarkable savings that you can have by a little study on the installation of the size and number of motors and fans in your kiln.

In Figure 3 we have shown the species to be 4/4 green oak, 28 days are required to dry, the initial moisture content 75%, the stack is 96 4/4 layers high with 3/4" sticks, and the total volume of space for the air to travel is 176 ft^2. The latter was obtained by multiplying the width of the kiln times the combined thickness of the sticker and bolster openings.

In this first study, it was determined that all the air we needed to maintain the drying rate could be provided by four, 5 hp fans producing 31,842 cfm at 1/2" static pressure. The operating efficiency of the motor was .87 so we have divided

MFCF ELECTRICAL CONSUMPTION OF FANS 4/4 GREEN OAK

Days 28 Initial Moisture Content 75

4/4 LBR LAY.HIGH 96 STK SIZE .75 LBR WIDE 24

SQ.FT. OF STK.SPACE 176.0000

No. Of Fans/Kiln 4

H.P./Fan 5 (48") 31842 CFM

Operating Eff. ,87

Factor for Eff. 1.149425

Total H.P. 22.98851 H.P.

K.Watts/H.P. .746 Watts

KW Reqd./HR. 17.14943

Hrs./Day 24

No. Days/Charge 28

TOTAL KW/CHARGE 11524.41

KW RATE .065

Temperature Service Factor .9

TOTAL COST/CHARGE $ 674.1782

CHARGE SIZE 30000 bd.ft.

TOTAL COST/M bf.ft. $ 22.47261

TOTAL CFM				
127368	100% SP			
89157.6	70%	FREQUENCY SAVING %	.343	$ 7.708104
76420.8	60%		.216	4.854083
63684	50%		.125	2.809076
50947.2	40%		.064	1.438247
38210.4	30%		.027	.6067604
25473.6	20%		.008	.1797809

	AV. FPM	WITH NO LOSS		TOTAL	%
100%	723.6818	28 DAYS MC LOSS/DAY	2.4	67.2	674.1782
70	506.5773	0	0	0	0
60	434.2091	0	0	0	0
50	361.8409	0	0	0	0
40	289.4727	0	0	0	0
30	217.1045	0	0	0	0
20	144.7364	0	0	0	0
		28		67.2	

INIT.MC 75% FINAL % 7.8 TOTAL COST 674.1782

COST/M BD.FT. 22.47261

Figure 3. Operating cost for four, 5 hp motors without frequency control.

the four, 5 hp motors by that factor for efficiency and come up with 23 hp. The kilowatts per hp is 0.746. Multiplying that by the 23 gives 17.15 kw required. This times 24 hours per day times 28 days gives a total kilowatt usage per charge of 11,524. The kw rate is 6 1/2 cents and the temperature service factor is 0.9 so we have a charge cost of $674.18. This means that our cost per thousand was $22.47. This is without frequency control. We have figures with no losses that the kiln would give us a velocity of 723', but after years of experience in package loaded kilns, we find that if you multiply that 60%, you will be more accurate, so we really think we're getting about 434' a minute which is adequate for drying oak. In Figure 4 we have changed things. We're using the same four, 5 hp motors, but we have determined that in the later stages of drying we don't really need as much air. We have run eight days at 100% and 7 days at 70% capacity. Without going through all the mathematics again that 70% would be about 34% original horsepower. The moisture content was then low enough so we could operate the remaining 13 days at 40% speed. To summarize, we have changed the energy usage of the fans from the original $22.47 per thousand to $9.00 per thousand. Remember, we haven't done this without spending some money. Figure 5 shows four, 7 1/2 hp motors with frequency control. We start out at running eight days at 70%, seven days at 60% and thirteen days at 30%. Once again that means that we have come down with a substantial saving. Our drying cost for energy usage of the fans is down to $5.46 per thousand compared to the original cost of over $22.00. In Figure 6 we show four, ten hp motors. We find that our cost is down to $4.34 per thousand. The same would be true if we used 15, 20, or 25 hp motors.

What we have done in Figure 7 is put the dollars and cents down for each of the four options to see which is most favorable. Over and above the original kiln proposal where we said we would use four, 5 hp motors without frequency, we have come back now and said here is the additional money that we will save by adding frequency control and here is the cost. For the four, 5 hp motors without frequency the operating cost per year would be $8,764.00. By spending $10,500.00, you reduce that cost to $3,516.00 for a saving per year of $5248.00. If we add four, 7 1/2 hp motors with frequency control, the additional equipment cost is only $856.00. Your operating cost is $2,163.00, but your saving is actually $1353.00 over that of the four, five hp motors with frequency control. Again, I am perfectly willing to go over the rest of the chart with any of you, but it's pretty obvious to see that by spending $11,300.00 to get a return of $6,601.00 is the best expenditure among these three alternatives. Putting in the four, 10 hp and spending an additional $5,600.00 and only getting a return of $468.00 wouldn't make much sense.

This is factual information. It's a valuable tool whether your drying schedule is three days or 30 and has been used in Europe for a number of years where it is tied into the moisture content. The only problem there has been the accuracy of the probes used to signal the frequency control as to when to lower the air velocity. This can be done either manually or through micro-processor control.

MFCF ELECTRICAL CONSUMPTION OF FANS 4/4 GREEN OAK
Days 2d Initial Moisture Content 75
4/4 LBR LAY.HIGH 96 STK SIZE .75 LBR WIDE 24
SQ.FT. OF STK.SPACE 176.0000

No. Of Fans/Kiln	4	
H.P./Fan	5 (48")	31842 CFM
Operating Eff.	.87	
Factor for Eff.	1.149425	
Total H.P.	22.98851 H.P.	
K.Watts/H.P.	.746 Watts	
KW Reqd./HR.	17.14943	
Hrs./Day	24	
No. Days/Charge	28	
TOTAL KW/CHARGE		11524.41
KW RATE	.065	
Temperature Service Factor	.9	
TOTAL COST/CHARGE		$ 674.1782
CHARGE SIZE	30000 bd.ft.	
TOTAL COST/M bf.ft.		$ 22.47261

TOTAL CFM

127368	100% SP			
89157.6	70%	FREQUENCY SAVING %	.343	$ 7.708104
76420.8	60%		.216	4.854083
63684	50%		.125	2.809076
50947.2	40%		.064	1.438247
38210.4	30%		.027	.6067604
25473.6	20%		.008	.1797809

	AV. FPM WITH NO LOSS	DAYS	MC LOSS/DAY	TOTAL %	
100%	723.6818	8	3.2	25.6	192.6223
70	506.5773	7	2.9	20.3	57.81078
60	434.2091	0	0	0	0
50	361.8409	0	0	0	0
40	289.4727	13	1.7	22.1	20.03272
30	217.1045	0	0	0	0
20	144.7364	0	0	0	0
		28		68	

INIT.MC 75% FINAL % 7 TOTAL COST 270.4658
COST/M BD.FT. 9.015528

Figure 4. Operating cost for four, 5 hp motors with frequency control.

MFCF ELECTRICAL CONSUMPTION OF FANS 4/4 GREEN OAK
Days 28 Initial Moisture Content 75
4/4 LBR LAY.HIGH 96 STK SIZE .75 LBR WIDE 24
SQ.FT. OF STK.SPACE 176.0000

No. Of Fans/Kiln	4	
H.P./Fan	7.5 (48")	38688 CFM
Operating Eff.	.87	
Factor for Eff.	1.149425	
Total H.P.	34.48276 H.P.	
K.Watts/H.P.	.746 Watts	
KW Reqd./HR.	25.72414	
Hrs./Day	24	
No. Days/Charge	28	
TOTAL KW/CHARGE		17286.62
KW RATE	.065	
Temperature Service Factor	.9	
TOTAL COST/CHARGE		$ 1011.267
CHARGE SIZE	30000 bd.ft.	
TOTAL COST/M bf.ft.		$ 33.70891

TOTAL CFM			
154752	100% SP		
108326.4	70%	FREQUENCY SAVING % .343	$ 11.56216
92851.2	60%	.216	7.281125
77376	50%	.125	4.213614
61900.8	40%	.064	2.157370
46425.6	30%	.027	.9101406
30950.4	20%	.008	.2696713

	AV. FPM WITH NO LOSS	DAYS	MC LOSS/DAY	TOTAL %		
100%	879.2727	0	0	0	0
70	615.4909	8	3.2	25.6	99.10420
60	527.5636	7	2.9	20.3	54.60843
50	439.6364	0	0	0	0
40	351.7091	0	0	0	0
30	263.7818	13	1.7	22.1	12.67696
20	175.8545	0	0	0	0
		28		68	

INIT.MC 75% FINAL % 7 TOTAL COST 166.3896
COST/M BD.FT. 5.546320

Figure 5. Operating cost for four, 7.5 hp motors with frequency control.

MFCF ELECTRICAL CONSUMPTION OF FANS 4/4 GREEN OAK
Days 28 Initial Moisture Content 75
4/4 LBR LAY.HIGH 96 STK SIZE .75 LBR WIDE 24
SQ.FT. OF STK.SPACE 176.0000

No. Of Fans/Kiln	4	
H.P./Fan	10 (54')	48469 CFM
Operating Eff.	.87	
Factor for Eff.	1.149425	
Total H.P.	45.97701 H.P.	
K.Watts/H.P.	.746 Watts	
KW Reqd./HR.	34.29885	
Hrs./Day	24	
No. Days/Charge	28	
TOTAL KW/CHARGE		23048.83
KW RATE	.065	
Temperature Service Factor	.9	
TOTAL COST/CHARGE		$ 1348.356
CHARGE SIZE	30000 bd.ft.	
TOTAL COST/M bf.ft.		$ 44.94521

TOTAL CFM

193876	100% SP			
135713.2	70%	FREQUENCY SAVING %	.343	$ 15.41621
116325.6	60%		.216	9.708166
96938	50%		.125	5.618152
77550.4	40%		.064	2.876494
58162.8	30%		.027	1.213521
38775.2	20%		.008	.3595617

	AV. FPM WITH NO LOSS			TOTAL %	
100%	1101.5'?	0 DAYS MC LOSS/DAY	0	0	0
70	771.0' 77	0	0	0	0
60	660.9409	8	3.2	25.6	83.21285
50	550.7841	7	2.9	20.3	42.13614
40	440.6273	0	0	0	0
30	330.4705	0	0	0	0
20	220.3136	13	1.7	22.1	5.008181
		28		68	

INIT.MC 75% FINAL % 7 TOTAL COST 130.3572
COST/M BD.FT. 4.345239

Figure 6. Operating cost for four, 10 hp motors with frequency control.

	Additional Equip. Cost	Operating Cost per year	Savings per year
4-5 hp. without frequency[1]	-	$8,764.34	-
4-5 hp. with frequency	$10,500.00	$3,516.11	$5,248.23
4-7.5 hp. with frequency	$11,356.00	$2,163.20	$6,601.27
4-10 hp. with frequency	$16,978.00	$1,694.68	$7,069.79

[1]base case

Figure 7. Cost and savings involved in changing to frequency fan control in new kilns.