THE CONSTRUCTION AND USE OF A Small-Scale Dehumidification Kiln

Kiln-drying small volumes of lumber (less than 1,000 board feet) is an available service many portable sawmill owners would like to have. Unfortunately, in most areas, no one offers this capability, but the ability to provide it could open new market opportunities.

Operating a small-scale dehumidification kiln is a simple and inexpensive process and has the potential to pay off construction costs quickly. The total construction cost for a recently-built dehumidification kiln with an 800 BF capacity was less than $3,200 (Figures 1 and 2). Considering that the average price of 4/4 green FAS Appalachian white oak is $1,005 per thousand board feet and that the average kiln-dry price is $1,570 per thousand board feet (*Hardwood Market Report*, June 18, 2011), a profit of $564 is possible. The daily power consumption for this kiln can range from $1 to $4. (Note: Power consumption for a kiln depends upon the size of the kiln, quantity of insulation, moisture content of lumber, and ambient temperatures outside the kiln. Any reported operating cost for this kiln would not be accurate for another kiln.) The dehumidification unit used by this kiln operates on 115v and is rated at 7 amps. No air is vented during the drying, thus the same air is continually reheated thereby lowering heating costs. The $4 per day used to calculate the operating cost of this kiln should be on the high side.

The cost to run the kiln at $0.10 per kilowatt for two weeks should be less than $56. These costs and sales values can result in a potential profit of $406 per 800 BF charge of

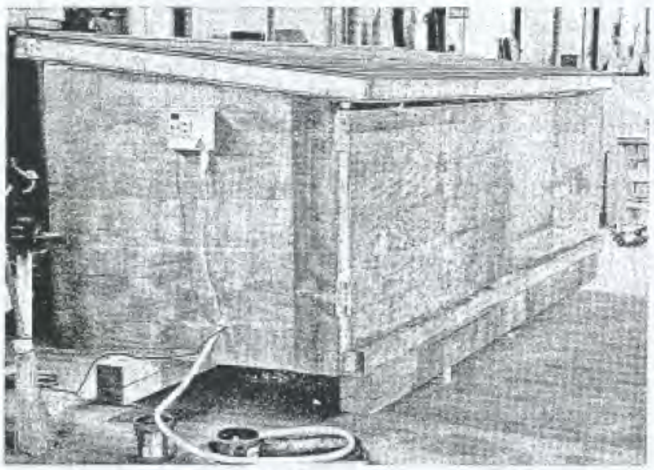

Fig. 1. Dry kiln.

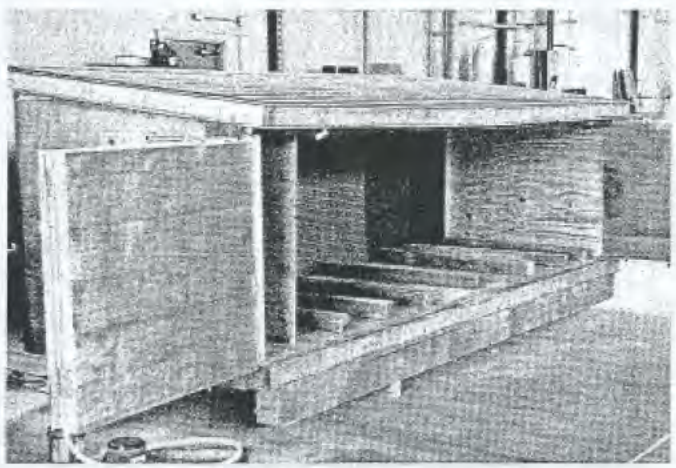

Fig. 2. Dry kiln with hinged bifold doors open.

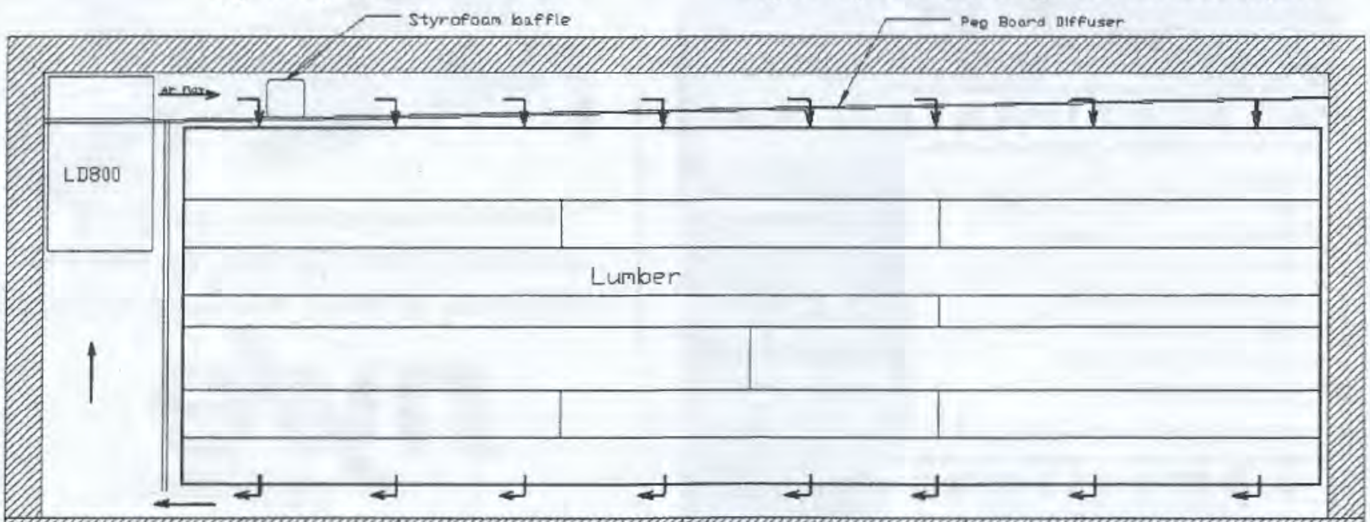

Fig. 3. Schematic top view of dry kiln.

FAS white oak, and the ability to pay off the kiln after only eight uses. If the operator dries custom-sawn or specialty lumber and species, the pay-off period could be even shorter.

After researching and pricing package kilns, I decided that the least expensive option was to use an EBAC LD800 dehumidifier that we already owned. (Note: The author or USDA Forest Service does not endorse the EBAC company. Any similar dehumidification unit provided by another company to dry lumber would work as well.)

This unit was being used to control humidity in a storage building containing lumber and various wood samples and was liberated from this duty with the intention of returning it to the storage building between dry-kiln runs.

CONSTRUCTION

The LD800 owner's manual includes plans for constructing kilns based on different sizes of lumber stacks. Our kiln is sized to dry a stack of lumber 12 feet long by 45 inches wide by 18 rows high of 4/4 boards. This size allows for approximately 800 BF to be dried in one charge. Walls are simple 2 x 4 constructions, filled with R13 fiberglass insulation. Sheeting inside and out is 1/2-inch exterior-grade plywood. Galvanized nails were used as fasteners. A sloped roof and shingles were added to allow outside storage when not in use. As recommended by EBAC, a layer of 4 mil plastic was placed between the insulation and inside sheeting to keep the insulation dry from condensate. Peg-Board was installed across the inside back of the kiln 4 to 6 inches from the rear wall to ensure even airflow through the lumber stack. A hole was drilled near the bottom of the kiln for electrical cables and a drain hose to pass through.

The EBAC LD800 dehumidifier has a fan rated at 460 cubic feet per minute (cfm). According to the company's dry kiln design (Figure 3), air is blown perpendicular to the face of the lumber stack past a Styrofoam baffle (provided by EBAC); the air must then turn 90 degrees through a Peg-Board diffuser before contacting the lumber stack. Airflow velocities of 20 to 50 feet per minute were measured at the front of the lumber stack.

An aspect of the kiln design not covered in the EBAC owner's manual is door design. Doors must open wide enough to allow lumber to be loaded into and removed from the kiln, to be easily opened to remove sample boards daily, and to have a tight seal to keep out the outside air.

Scrap plywood was used to sheet the outside of the kiln, resulting in material costs of $559 plus $2,469 for the EBAC LD800. Use of additional salvage materials or lumber sawn from your sawmill could further reduce the cost of the kiln.

Green weight	Oven-dry weight	Moisture content (%)
3.21	2.85	12.63
2.91	2.57	13.23
2.71	2.35	15.32
		13.7 Average

Table 1. Green MC samples –first charge.

KILN OPERATION

The EBAC LD800 includes a controller (Figure 4) that is mounted outside the kiln and displays actual kiln temperature. The only two settings to regulate are the temperature inside the kiln and the percentage of time that the drying compressor runs. Two simple tables are included in the owner's manual to guide you to the proper settings throughout the drying run.

PROCEDURES

Boards are stickered and stacked immediately after sawing. We do not have an edger so the bark remained on the jacket boards. Lumber stacks are stored in a heated shop. The first dry-kiln run was made up of boards that had been air-dried at least six months, accounting for relatively uniform MC readings from the three sample boards (Table 1). The second dry-kiln run was made of boards that had air-dried from three to six months, resulting in a greater range of MC readings obtained from 14 boards (Table 3, page 24). Air-drying defects and bark edges were removed by chop saw, and straight-line rip saw at the time the dry-kiln stacks were assembled using a stacking guide (Figure 5). Moisture content samples approximately 1 inch in length times the width of the board they were removed from were collected during this process to be oven-dried so that the average moisture content of the lumber could be determined before it was placed in the kiln. The second stack of lumber was weighed before and after drying. All water removed from the kiln by way of a drain hose was collected and weighed each workday. The weight reduction in the dried stack should equal the weight of the water collected. For each stack, a sample board was chosen. The sample board is an approximately 2-foot-long section cut from the center of one of the boards in the stack. Two approximately 1-inch-long samples were cut from the ends of the sample board and oven-dried. These smaller samples were used to calculate the actual moisture content of the sample board. The sample board was weighed and placed in the front face of the stack so it could be easily removed from the kiln daily and weighed. The daily measured weights of the sample board were used to calculate its decreasing moisture content and thus the moisture content of the stack being dried. Formulas used to calculate moisture content are included in the EBAC owner's manual. Airflow velocities were measured at the front and back of each stack with a hot wired anemometer.

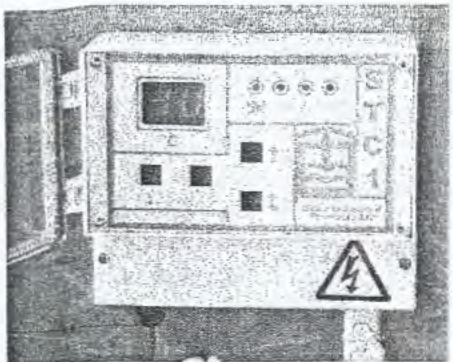

Fig. 4. S[illegible]1 Controller.

FIRST CHARGE

The first dry-kiln run was made up of 4/4 white oak boards that were air-dried with a range from 12.6% to 15.3% MC (Table 1). Drying to 6% MC required 11 days. After drying, 20 samples (at least one sample per tier) were gathered throughout the stack to check for uniform drying and drying stresses (see Table 2, next page).

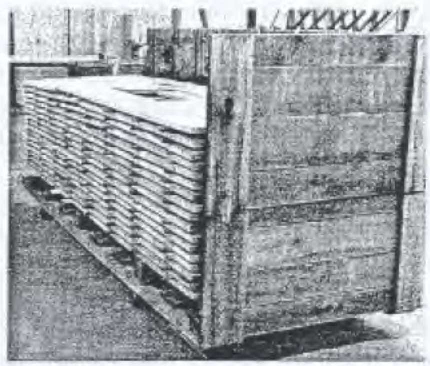

Fig. 5. Lumber-stacking guide.

RESULTS FOR FIRST CHARGE

Dry sample MC results ranged from 4.93% to 8.33% with an average MC of 6.01%. Prong tests and shell and core tests showed that samples were free of residual stress and that uniform drying had occurred throughout the thickness of the boards. Eight gallons of water were collected from the drain hose. No additional end-splits, honey-combing, or staining were observed in the lumber stack.

SECOND CHARGE

The second dry-kiln run was made up of 4/4 white oak boards that were air-dried with a range of 9.0% to 25.1% MC (Table 3). Average MC was 13.4%.The lumber stack was weighed before (2,769 pounds) and after drying (2,693 pounds). After 20 days of drying, 19 samples were gathered throughout the stack to check for uniform drying (Table 4, next page).

R1 – top tier of stack, I – inside of stack, O – end of stack, Front – face of stack toward front of kiln, Back – face of stack toward back of kiln			
Location	Wet weight	Oven-dry weight	Moisture content (%)
R11 O	2.63	2.48	6.05
R1	2.71	2.56	5.86
R13 O	3.21	3.03	5.94
R9 I	3.19	3.04	4.93
R7 I CORE	1.56	1.47	6.12
R14 I	1.58	1.5	5.33
R15 I FRONT	2.04	1.93	5.70
R15 O	3.46	3.27	5.81
R8 O	3.02	2.87	5.23
R12 I	2.91	2.76	5.43
R6 I	2.24	2.13	5.16
R10 I	4.73	4.49	5.35
R16 I	3.8	3.58	6.15
R4 O	3.99	3.77	5.84
R3 I	3.57	3.38	5.62
R16 I CORE	2.36	2.19	7.76
R2 I	2.88	2.73	5.49
R9 I BACK CORE	1.83	1.73	5.78
R7 I	3.12	2.97	5.05
R11 O CORE	1.6	1.5	6.67
R9 SHELL	0.8	0.76	5.26
R16 SHELL	1.04	0.96	8.33
R9 SHELL	0.59	0.56	5.36
R16 SHELL	0.75	0.7	7.14
R7 SHELL	0.67	0.63	6.35
R11 SHELL	0.7	0.65	7.69
R7 SHELL	0.78	0.74	5.41
R11 SHELL	0.73	0.68	7.35
			6.01 Average

Table 2. Samples collected after drying – first charge.

	Green weight	Oven-dry weight	Moisture content (%)
Sample bd. 1*	3.49	3.19	9.4
Sample bd. 2*	3.76	3.43	9.6
	5.07	4.53	11.9
	2.17	1.99	9.0
	4.6	4.1	12.2
	4.91	4.36	12.6
	3.23	2.96	9.1
	2.27	2.07	9.7
	3.47	3.02	14.9
	4.87	3.95	23.3
	5.44	4.35	25.1
	3.6	3.27	10.1
	4.8	4.04	18.8
	4.16	3.62	14.9
	4.17	3.8	9.7
			13.4 Average

*Samples taken from larger sample board that was weighed each day to moitor drying rate of change

Table 3. Green sample MC – second charge.

DRYING RESULTS FOR SECOND CHARGE

Dry sample MC results ranged from 4.35% to 6.86% with an average MC of 5.17% (Table 4). The volume of water collected from the drain hose was 11.7 gallons (97 pounds). No drying defects were observed. I chose one sample board while I was building the stack, but after oven-drying the MC samples, discovered that my sample board was one of the driest boards in the stack. I chose to use this board and tried to dry it to just under 6% MC to ensure the rest of the stack was dried sufficiently. The sample board reached 6.3% MC on a Thursday before a three-day weekend. By the following Monday the sample board had dried to 5.5% MC (Table 4). This resulted in the entire stack being slightly overdried, but all sample MCs were within a narrow range.

SUMMARY

The first stack of white oak dried remarkably well. The narrow range of green moisture contents undoubtedly aided the results.

In hindsight, I probably should have chosen a more representative sample board for the second stack even though it would have delayed the start of the dry-kiln run by a couple of days. Another problem encountered with the second kiln charge was that 97 pounds of water were collected from the dehumidifier drain, but the lumber only lost 76 pounds of weight. I attribute this to air leaking in around the doors which will be corrected with additional rubber seals. This was not detected during the first run because the lumber stack was not weighed. I will continue to compare the loss of weight in the lumber stack to the weight of water collected from the drain hose until I get the kiln as airtight as possible. Sealing the air leaks should reduce drying times. It is a good idea to collect water from the drain hose each day. You can compare volumes from day to day and gain a general

R1 – top tier of stack, I – inside of stack, O – end of stack, Front – face of stack toward front of kiln, Back – face of stack toward back of kiln			
Location	**Kiln-dried weight**	**Oven-dry weight**	**Moisture content (%)**
R1 I	4.21	3.99	5.51
R2 I	4.56	4.37	4.35
R3 I	4.43	4.2	5.48
R4 I Front	3.91	3.72	5.11
R5 I	4.45	4.25	4.71
R6I	3.51	3.35	4.78
R7 I	2.44	2.32	5.17
R8 I	3.53	3.36	5.06
R9 I	5.01	4.79	4.59
R9 O	4.67	4.45	4.94
R10 I Back	4.1	3.91	4.86
R11 I	5.53	5.28	4.73
R12 I	4.25	4.04	5.20
R12 O	4.44	4.23	4.96
R13 I Back	3.39	3.22	5.28
R14 I	3.59	3.4	5.59
R15 I	3.74	3.55	5.35
R16 I	4.43	4.19	5.73
R17 I	5.14	4.81	6.86
			5.17 Average

Table 4. Samples collected after drying – second charge.

References; HMR. 2011. Hardwood Market Report. June 18, 2011. Volume 89(25):40, 40p.

impression of how the drying process is progressing without opening the kiln doors.

Given the low cost of construction and operation, a short payback period, the simplicity of operation, and the narrow moisture content range of the dried boards, a dehumidification kiln of this type should provide small sawmill operators with a good method of drying lumber. Given my limited experience with dry kilns, I was pleased with the results from the kiln charges described here. The lumber dried for these tests had already air-dried substantially, which contributed to my success. The low air velocities likely reduced the chances of case-hardening. In the samples dried in these tests, there was no evidence of any drying defects caused by the kiln. In the future, the kiln will be tested with green hard maple lumber taken directly from the sawmill. ■

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