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Dehumidification Dry Kiln Construction Plans

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Abstract

Small, complete dehumidification dry kilns under 5,000 board-foot capacity are not available for sale. Dehumidification drying equipment is available, but an enclosure must be built to house the equipment and dry the lumber. A dry kiln needs to be operated completely filled with lumber. This forces airflow through the tiers of lumber instead of around the ends or over the top of the stack(s). This construction plan is for an 800 board-foot capacity dry kiln structure that is designed to work with an EBAC LD800™ dehumidification unit. This size is suitable for the small woodworking shop or for portable sawmill owners.

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Cover Photo

Completed 800 board-foot capacity dehumidification dry kiln. Photo by by Neal Bennett, USDA Forest Service.

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INTRODUCTION

Portable sawmill owners recognize the advantage to kiln-drying the lumber they produce. Having the ability to provide properly kiln-dried lumber opens new market opportunities and can increase profit margins. However, the construction and operation of a small dry kiln must be economical and simple. A small dehumidification kiln with an 800 board-foot capacity was constructed by the USDA Forest Service, Northern Research Station. Construction and initial use of the kiln were discussed in an article in *Independent Sawmill & Woodlot Management Magazine* (Bennett 2012). The cost of the dry kiln included \$2,500 for the dehumidification unit and controller and \$500 for construction materials. Scrap materials were used when possible in constructing this original model to keep material costs down. The performance of this first kiln constructed by the author as well as an accounting of electricity consumption measured during the drying of two stacks of hard maple (*Acer saccharum* L.) was documented in Bennett (2013).

Since the design and construction of the initial dry kiln, three additional kilns have been constructed for research use. Incremental design improvements were achieved between the first dry kiln and the fourth based on experience gained in usage. Among the improvements that are incorporated into the current version of the dehumidification dry kiln is a redesign of the doors to make them easier to open to check drying sample boards. Weather-stripping around and between the doors is improved to make the structure more air tight and thus more energy efficient. The plans provided in this report were developed to assist with construction.

Similar to the earlier versions of this kiln, the final dry kiln design is sized to dry approximately 800 board feet of 4/4-thickness hardwood lumber with board lengths up to 12 feet, 2 inches. While this construction plan is designed to work with an EBAC LD800™ dehumidification unit, other units are available to achieve similar results. The exterior dimensions of this kiln are 15 feet long × 5 feet, 5 inches wide × 5 feet high. This size is suitable for the small woodworking shop or portable sawmill owners. The length of the lumber stack of 12 feet, 2 inches was an arbitrary decision based on the average lengths of the logs we normally process in our wood shop. Also, commercially purchased lumber 12 feet in length is usually 12 feet, 2 inches long. This dry kiln is normally loaded with a forklift, so 4 inches of extra length was added to the drying chamber. Boards shorter than 12 feet can be mixed in with longer boards to construct a 12 foot, 2 inch-long lumber stack. It is important for the lumber stack to fill the drying chamber in order to force air through the tiers of boards and minimize airflow over and around the lumber stack. The EBAC LD800™ owner's manual (<http://www.ebacusa.com/downloads/manuals/TPC230.pdf>, pages 8-17) also provides basic guidelines for building a dry kiln. If a different-length lumber stack is preferred, then all of the dimensions in this plan would need to be altered.

Construction Details

The dry kiln walls are framed with 2 × 4s on 16-inch centers, insulated with R-13 fiberglass insulation, and constructed with ½-inch exterior plywood or T-111™ siding on the outside of the kiln and ½-inch exterior plywood on the inside of the kiln and on the roof. All nails or screws used are corrosion resistant. Plywood seams are caulked. Doors are constructed with ¼-inch plywood on the inside and 3/8-inch plywood or T-111™ siding to reduce weight. Doors are hinged to be bi-fold to ease opening and closing and loading of lumber (Fig. 1).



Figure 1.—Completed 800 board-foot capacity dehumidification dry kiln.

Table 1.—Dry kiln construction materials list.

Material	No. of units
½-inch plywood	19 sheets
¼-inch plywood	2 sheets
T-111™ 19/32 inches	5 sheets
T-111™ 11/32 inches	2 sheets
¼-inch peg board	4 sheets
6-inch x 6-inch x 16-foot timbers	3-4
2-inch x 4-inch x 8-foot timbers	49
2-inch x 4-inch x 16-inch timbers	10
Mortise hinges	14
Barrel latches	8
Shingles	4 bundles
Plastic 6 mm	10 feet x 100 feet
Caulk	6-10 tubes
Nails 16p and 8p	Corrosion resistant
Corrosion resistant screws #8	1½ inches and 2 inches long
Drip edge for roof	44 lineal feet
Lag screws 8 inches x ½ inch	12-15
Fiberglass insulation R-13	7 rolls

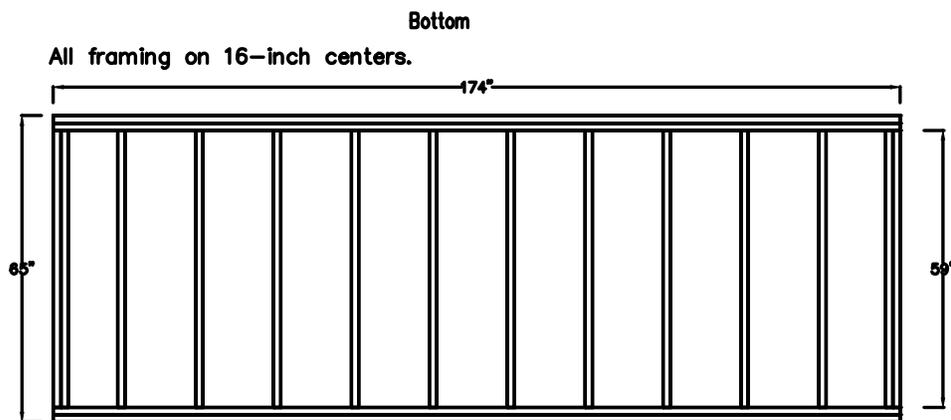
Cost savings realized from using scrap wood, etc., in the construction of the first dry kiln were not realized subsequently because scrap was no longer at hand. Material costs excluding the dehumidification drying units were about \$1,200 per dry kiln. All materials (Table 1) for each of the three latter dry kilns were purchased at a local home improvement store to reduce construction time. The dry kiln can be built with lumber produced by a portable sawmill to save money. In that case, the builder would have to exercise care in making sure all joints are sealed to prevent water from seeping in and wetting the insulation. Dimensions are given for almost every component; however, the builder will have to measure and compensate for any minor variances that occur during construction.

Bottom

Build the floor frame as shown (Fig. 2, Drawing 1). Nail $\frac{1}{2}$ -inch plywood to one side. The plywood will help square the frame. Flip the bottom over. If it is anticipated that the dry kiln will be moved, it is advisable to attach 6-inch \times 6-inch timbers long-ways under the bottom of the dry kiln. In this case, the timbers were spaced to accommodate the 48-inch long forks of our forklift. If the dry kiln is not going to be moved, then it must be elevated off the ground to keep the bottom dry. If 6-inch \times 6-inch timbers are used, attach them now (Fig. 3). Lag screws inserted through the bottom joists into the timbers are suggested. Add insulation with the vapor barrier turned up between the 2-inch \times 4-inch joists (Fig. 4). To protect insulation from water seeping through the plywood, add a layer of 6-mm plastic film (Fig. 5) and then the top layer of plywood, which will be the floor of the dry kiln (Fig. 6). Seal the plywood seams and nails in the floor of the dry kiln with construction caulk to further seal them from moisture seepage.



Figure 2.—Bottom of the kiln.



Drawing 1.



Figure 3.—Timbers in place under the dry kiln floor.



Figure 4.—Insulation installed in the bottom of dry kiln.



Figure 5.—Plastic (6 mm) stapled to frame covering insulation.



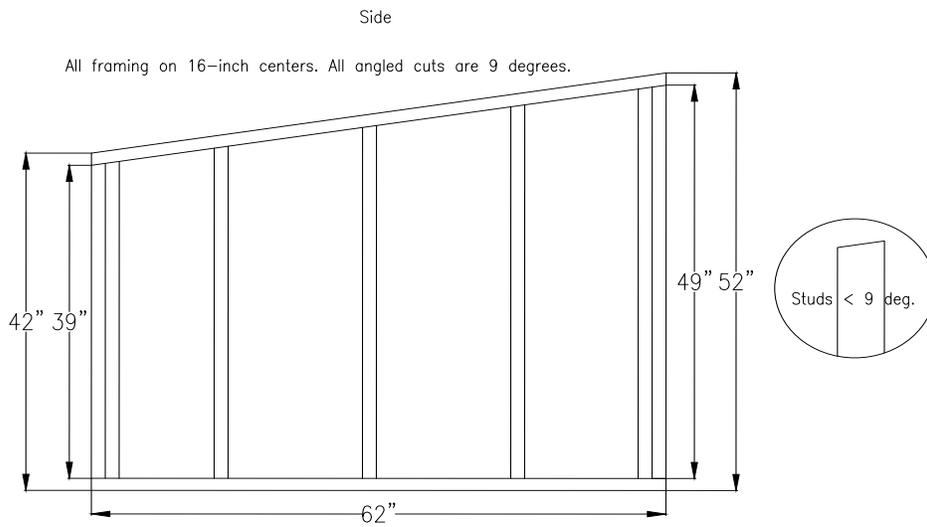
Figure 6.—Plywood installed over the plastic moisture barrier.

Sides

Build the frames of the sides as shown (Fig. 7, Drawing 2). Dimensions are given for the outside studs; the middle studs must be cut to fit. Nail the sides to bottom. The outside edges of the sides are flush with outside edges and back of floor.



Figure 7.—Sides attached to the floor of dry kiln.



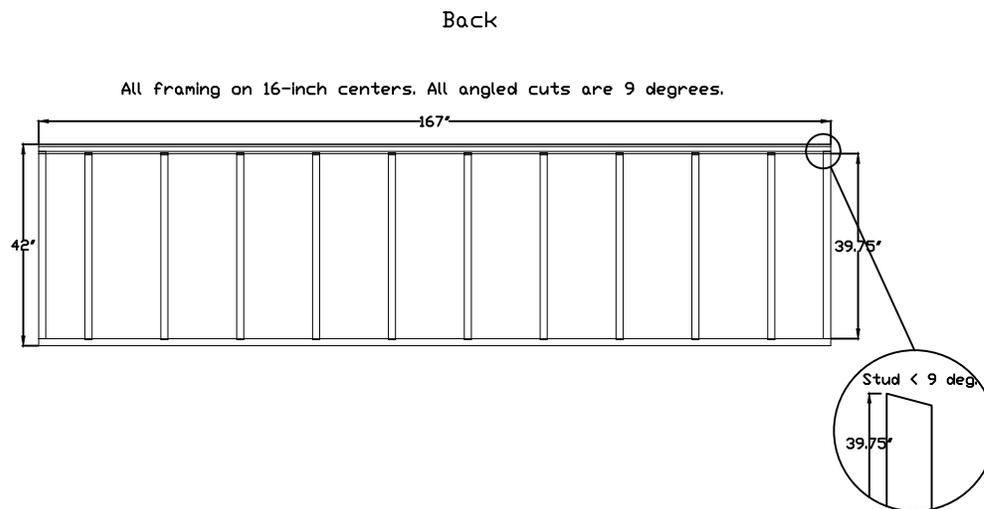
Drawing 2.

Back

Build the back frame as shown (Fig. 8, Drawing 3). Nail the back to dry kiln floor so it is flush with the rear of floor and the sides.



Figure 8.—The back and sides attached to the bottom of the dry kiln.



Drawing 3.

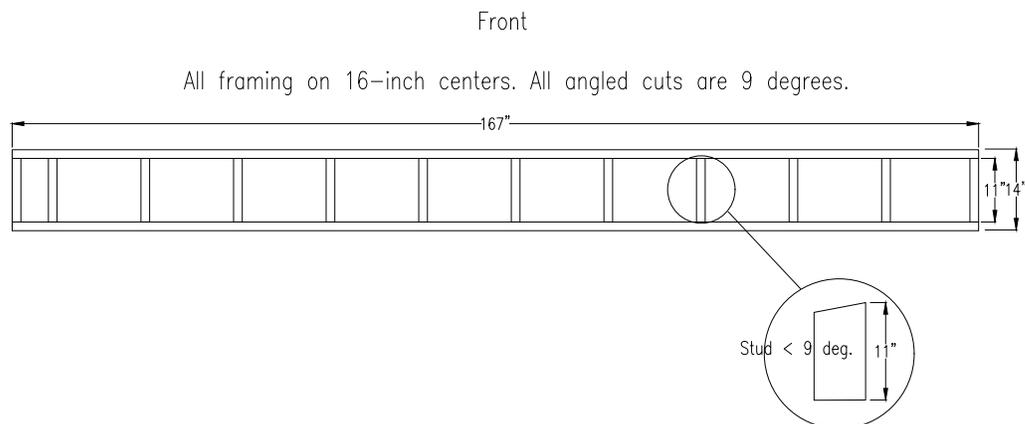
Front or Header

Build the frame of the header as shown (Fig. 9, Drawing 4). Nail the front to the top of the sides of the dry kiln. Make sure the front or header is level and is not sagging before attaching plywood. Prop it up into a level position or attach the plywood to one side of the header to keep the header from sagging before nailing it to the side walls.

Next, insulate all walls with the insulation vapor barrier facing the inside of the dry kiln. Nail ½-inch plywood to the inside of the dry kiln, and attach ½-inch plywood or T-111™ siding to the outside of dry kiln. Apply caulk to the seams between the sheets of plywood.



Figure 9.—The header attached to the front of the dry kiln.



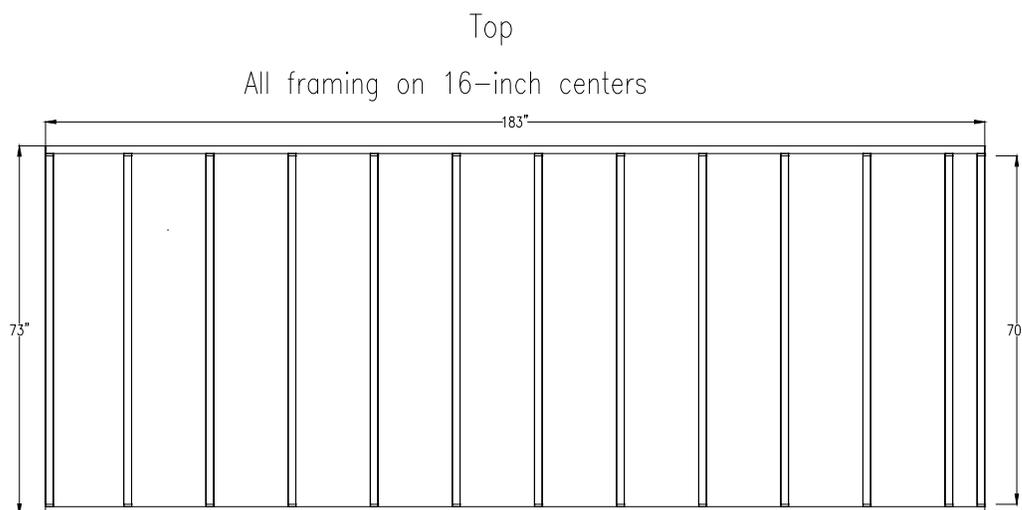
Drawing 4.

Top

Build the frame for the top as shown (Fig. 10, Drawing 5). Nail ½-inch plywood to one side. Use the plywood to help square the frame. Turn the top over and place it on top of the dry kiln. Apply caulk as a sealant between the top and the walls. Nail the top to the dry kiln walls, allowing an even overhang of all sides. It is best to toenail through the top joists into the top plate of the walls. Insulate the top with fiberglass insulation with the vapor barrier turned downward. We used R-13 but other R-values may be appropriate for different-sized chambers or climatic conditions (a guide is provided in the EBAC LD800™ owner's manual). Staple 6-mm plastic over the insulation and nail ½-inch plywood on top of it (Fig.11). If the dry kiln is to be stored or used outside, then roofing must be added. Steel roofing is not recommended due to the danger of cuts while loading and unloading the dry kiln. Consequently, shingles with drip edge are recommended.



Figure 10.—Framing for the top of the dry kiln.



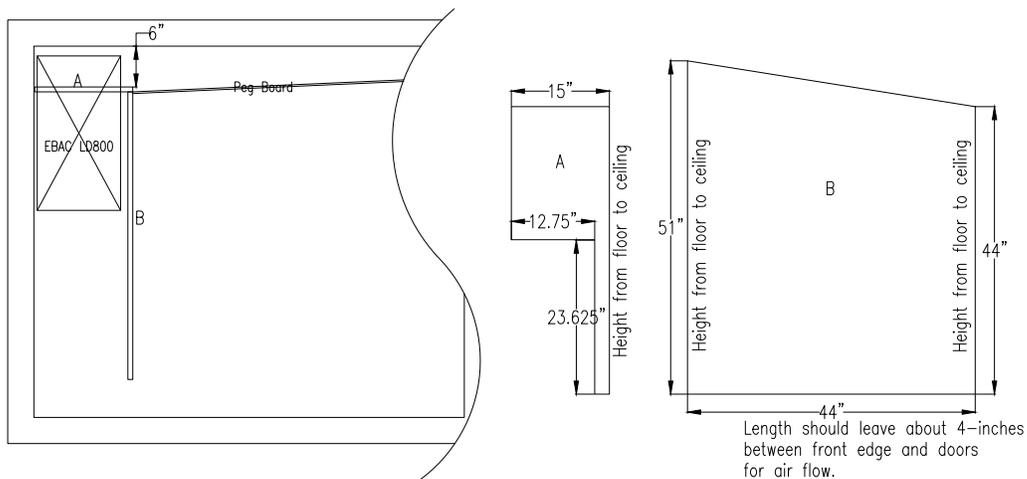
Drawing 5.



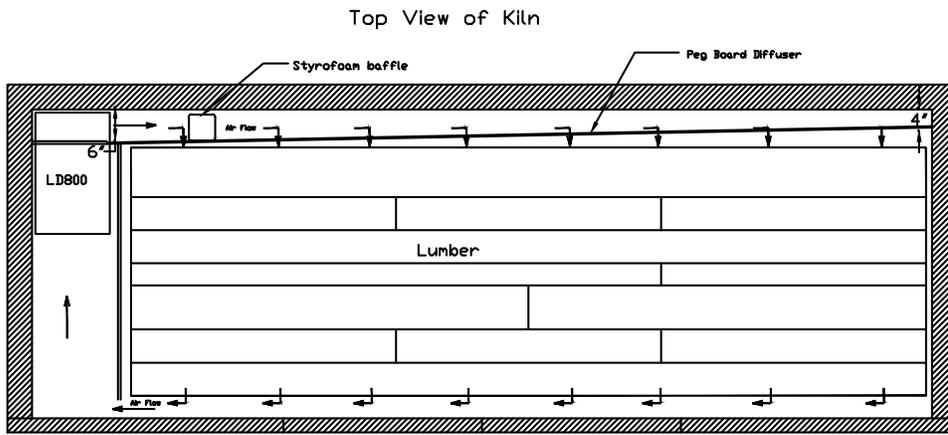
Figure 11.—The dry kiln with the top attached.

Inside Parts

The inside parts of the dry kiln are designed specifically for an EBAC LD800™ dehumidification (DH) unit. Instructions for the inside parts are also included in the EBAC LD800™ owner's manual. Cut out inside parts A and B (Drawing 6). Add ¾-inch square softwood stock to fasten parts A and B to the dry kiln wall, floor, and ceiling. Fig. 12 shows parts A and B installed with the EBAC LD800™ in place. Attach the peg board diffuser across the back of the dry kiln using ¾-inch square softwood stock (Drawing 7, Fig. 12). Also use ¾-inch softwood stock along the vertical seams between pieces of peg board. The DH unit is supplied with a foam baffle to reduce air velocity. Attach the baffle with glue or screws to the back of the first sheet of peg board (Fig. 13). It is to be mounted about 16½ inches from the DH unit and 7 inches above the floor.



Drawing 6.



Drawing 7.



Figure 12.—Inside view of dry kiln with EBAC LD800TM dehumidification unit in place.

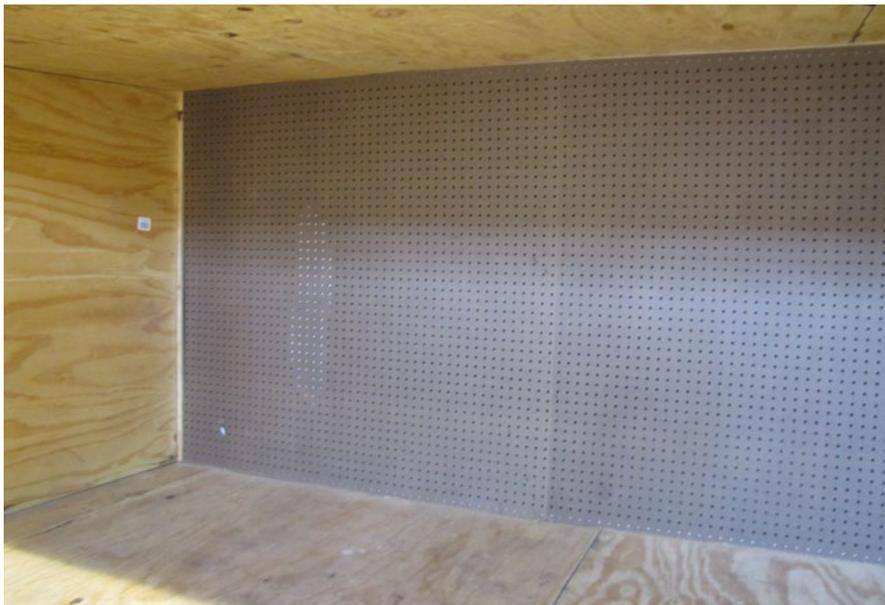
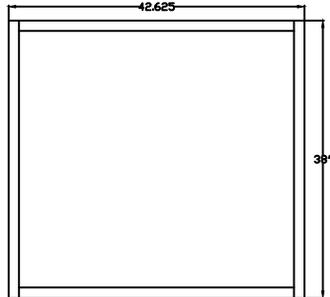


Figure 13.—View of the peg board diffuser after installation.

Doors

Dimensions of doors are approximate. Measure box opening, divide by 4 for door width. Deduct 1/4" for hinge gaps, Subtract 1/2-inch for height. Shim doors 1/4-inch from floor until hinges are mounted. Doors may have to be re-trimmed after hinges are installed.



Framing materials are 2X4's. Insulate and cover inside of doors with 1/4-inch plywood and outside of doors with 1/4-inch plywood or thin T-111™ siding. Outboard hinges are mounted on outside of doors and inboard hinges are mounted on inside of doors.

Drawing 8.

Doors

Build the door frames as shown (Drawing 8). Size the doors by measuring the total opening dimensions. For door height, subtract 1/2 inch from the opening height. Door width will be the total width of the opening divided by 4. Subtract another 1/4 inch from the width of each door for hinge clearance. The last door installed may have to be further reduced in width to allow clearance plus room for weather-stripping. Nail 1/4-inch plywood to inside. The plywood will help square the frame. Insulate with the vapor barrier turned toward the inside of the door and add plywood or T-111™ siding to the outside of the frame. The hinges on the outer doors are placed on the outside of the dry kiln and visible when looking at the kiln (Fig. 1), whereas the hinges that connect the inside doors to the outside doors are mounted on the inside of the dry kiln. This results in two sets of folding doors. To save money, hinges and latches used were not stainless steel. Corrosion was not an issue until a load of green red oak was dried. If acidic species such as red oak are going to be dried in the kiln, then it will be necessary to treat the hardware with a rust preservative or use much more expensive stainless steel hardware.

Shim the doors off the floor 1/4 inch before attaching hinges to facilitate opening and closing of doors. At this point, every effort has been made to build the dry kiln to provide a square door opening and to build the doors square to fit the opening. Nevertheless, the doors may have to be trimmed to fit the opening after the hinges are installed. Attach latches to the doors (Fig. 1) to keep them closed and add moderate pressure to the weather-stripping. Make sure any holes drilled for the barrels on the bottom latches do not penetrate through the plywood floor and expose the insulation. After the doors and latches are installed, add 3/4-inch stock softwood or aluminum angle across both the top and bottom of the kiln opening. This material serves as a stop for the doors and will need weather-stripping applied. Rubber weather-stripping works better here than foam weather-stripping. Add weather-stripping between the doors to seal gaps. For the gaps between the doors, foam weather-stripping is used because it is generally available in various thicknesses. Finally, add a pair of handles near the middle of the paired doors to assist with opening and closing the dry kiln doors (Fig. 1).



Figure 14.—Control box with the access hole through the side of the kiln.

Control Box, Cables and Drain

Mount the control box for the EBAC LD800™ DH unit on the outside end of the kiln near the DH unit location (Fig. 14). Drill a 2-inch-diameter hole through the side of the kiln to pass the drain hose and power cables to the outside of the kiln. **It is important to place the hole below the drain pan of the dehumidifier unit because drainage is by gravity.** The control box has a temperature probe that passes through the same hole to the inside of the kiln. Mount the probe loosely about 2 feet above the kiln floor to Part B (Fig. 12). After the cables are routed, the hole can be sealed with expandable foam. Any gaps should be caulked and moldings can be added for cosmetic improvement. Finally, paint or stain the outside of the dry kiln to protect it from the weather.

Upon completion, the DH dry kiln is now ready to use to dry lumber. Use the EBAC LD800™ owner's manual, or the owner's manual for whatever brand of dehumidification dry kiln unit is used, to begin operating the dry kiln. Reference some of the sources of information listed in the next section to refine your operations.

Additional Resources

Other DH drying units are available from EBAC and other companies that dry larger lumber charges (e.g., 3,000 to 15,000 board feet of 4/4-thickness lumber) but would require modification of the construction plan. In addition, a simple internet search of “dehumidification dry kiln kit” indicates there are options for kiln kits that include additional hardware such as vents, fans, and auxiliary heating required to improve drying results if a larger capacity kiln is needed. The dry kiln kit option typically requires the construction of the chamber for which the plans provided in this paper may be useful as a starting point.

One of the earliest efforts to document the construction and operation of a dehumidification dry kiln was based on an earlier version of the larger dehumidifier unit manufactured by EBAC (3,000 board-foot capacity when drying hardwood lumber with 4/4 thickness) (Boryen 1995). This is a highly recommended resource as it provides overview information on kiln drying, strategies for operating and monitoring the performance of a kiln, and information on factors that should be considered in planning a kiln construction based on location, available capital, and operational constraints.

A prior dehumidification dry kiln development project undertaken by the USDA Forest Service, Forest Products Lab with partners in the Wisconsin Department of Natural Resources and the Madison Area Technical College is described in Bowe et al. (2007). This kiln was built using a large home dehumidifier unit. The price cited for the materials used to construct this dry kiln is \$2,703 which equates to \$3,310 in 2018 dollars (using the CPI inflation calculator on the bls.gov site). This kiln model had some humidity control issues as it lacked the automated humidity control unit that allows for regular and timely adjustments of the dehumidifier. This issue and a few others noted by the authors are discussed in the “Lessons Learned” section of the Bowe et al. publication. A related publication by Bergmann (2008) details operating costs for the Bowe et al. kiln and provides useful background information on the fundamental components and principles of dehumidification drying.

A highly visited Sawing and Drying Forum that is curated by a renowned lumber drying expert, Dr. Gene Wengert, is found in the WOODWEB system and referenced in the literature cited section of this paper. The “kiln construction” section of the forum contains many discussion strings related to dehumidification kilns with insights provided by Dr. Wengert and other kiln users.

Finally, the hardwood lumber drying manual (Denig et al. 2000) is an excellent general reference that all kiln drying operations will find useful in making decisions about drying approaches and methods to optimize the quality and value of dry lumber.

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KEY WORDS: dehumidification, dry kiln

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