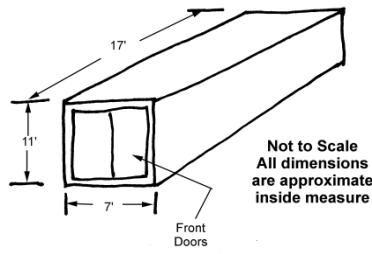


CHAPTER 7 – Kiln Structures to House Lumber Driers

Lumber drying equipment is sometimes supplied independent of a drying chamber; this is particularly true for dehumidification driers. In this case it is the customer's responsibility to provide the chamber. There are a few details to keep in mind when designing or purchasing a chamber for the unit. The basic criteria are described below.

1. **Kiln Capacity** – Capacity of chamber compatible with the size of the drying system.
 - a. Each 1000 board feet of lumber requires an energy capacity of about 2 million BTU's. This is roughly equivalent to about ½ horsepower of compressor capacity in a dehumidification unit.
 - b. **Chamber Dimensions** – The drying chamber needs to be sized so that it can easily accommodate the expected range of lumber sizes that will be dried and include ample plenum space to ensure uniform air flow during drying. Since lumber is usually handled in forklift packages measuring 4 feet wide x 4 feet high x varying lumber lengths the height and width of the kiln should be in multiples of 4 feet with additional space for equipment and plenum space where needed.
 - c. **Height** – The drying chamber can be any height but better results will be obtained if the lumber is stacked at least 8 feet high. The reason for this is that the more weight that is carried by a board from the boards stacked above it the flatter the board will be after drying. Boards kept flat during drying stay flat. The boards at the top of the stack are not carrying enough weight above them to keep them restrained and warp may occur. This is particularly important in high density species that are prone to warp when they dry.
 - d. **Width** – The width of the kiln must encompass the width of lumber package as well as a plenum space needed for uniform air flow through the lumber package. The minimum plenum is defined by at least a 1 foot clearance between the walls and both the entering and exit air sides of the lumber unit and a total volume equivalent to the sum of the sticker openings between boards. For example, each 1000 board foot unit of lumber measuring 8 feet long x 4 feet wide x 4 ft high with ¾-inch width stickers has a total volume of the air space between boards of about 55 ft³ feet. A 1.8 ft plenum space on each side of the lumber will provide 55 ft³ feet of air space.
 - e. **Length** – The long dimension of the kiln should be designed around the length of lumber most likely to be milled. For example if 8-foot lumber is being cut then the chamber length should be in multiples of 8 (8, 16, 24, etc.) plus an additional foot to account for board trim lengths and ease of loading.

An example of a kiln designed for 4,000 BF of 8-foot long lumber is shown in Figure 1 and an example of a kiln designed for 8,000 BF is shown in Figure 2.



This kiln holds 4 units of lumber for a total capacity of 4000 BF
 Each lumber unit measures approximately 4' x 4' x 8'

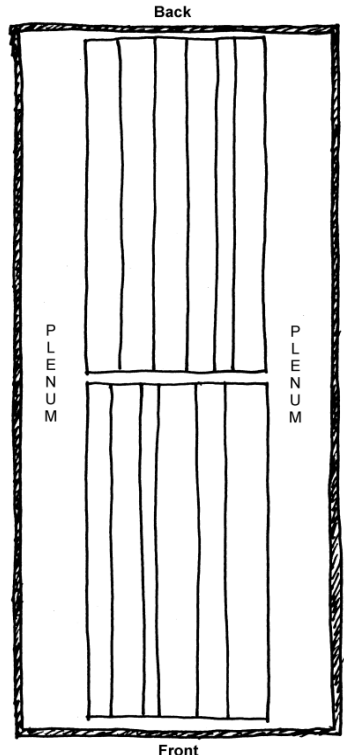
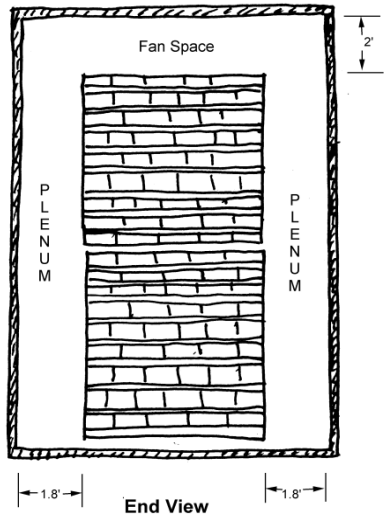
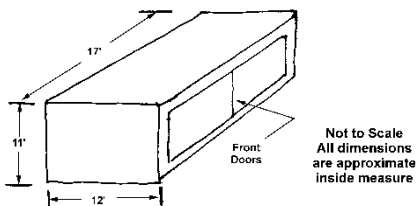


Figure 1. Track-loaded kiln with a capacity of 4,000 BF



Each lumber unit measures approximately 4' x 4' x 8'
 This kiln holds 8 units for a total capacity of ~ 8000 BF

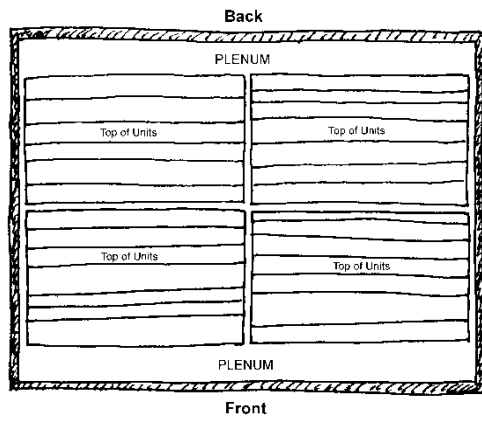
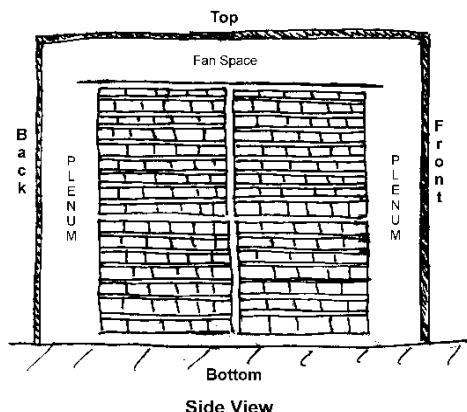


Figure 2. Forklift-loaded package kiln with a capacity of 8,000 BF

1. Large doors that open fully so lumber can be easily loaded into the chamber. Typically lumber dry kilns are designed to be fork lift – package loaded as in Figures 2 and 3, or track loaded as shown in Figures 1 and 4.
2. Walls, roof and floor need to be well insulated to minimize excessive heat loss and installed with vapor barriers to prevent moisture from moving into and condensing inside of walls. A minimum insulation rating of R19 is recommended for the walls and R30 for the roof and floor.

Lumber dry kilns come in a variety of sizes and shapes. One of the most important decisions to make early in the design process is to define the lengths of lumber that are expected to be put into the dry kiln. The kiln shown in Figure 3 was designed for a sawmill that only processed nominal 12 ft long sawlogs (actual length about 12-ft 6-in). The lumber produced was trimmed to 12 ft - 3 in. in length. The dry kiln chamber was designed with an inside dimension of 12 ft – 6 in. The extra three inches allow for ease of placement of the units in the kiln.



Figure 3. Two side-by-side forklift-loaded package lumber dry kilns. Each kiln houses a Nyle L200 Dehumidification unit and is designed for two units of 12 ft long lumber, one on top of the other (4,000 BF capacity each).



Figure 4. A track-loaded dry kiln manufactured by the Koetter Kiln Company, designed for lumber units 8 feet to 24 feet long. Kiln is shown here with 6 units of 8 foot lumber (6,000 bf capacity).

The kiln shown in Figure 4 is a standard size kiln provided by the Koetter kiln company. The inside length dimension is 25 feet allowing for three kiln carts of lumber 8 ft long plus a trim length of three to four inches each. Two kiln carts of 12 ft lumber or any other combination of lengths up to the maximum length of 25 feet can also be loaded into the kiln. The kiln carts are loaded with a forklift and carefully pushed into the kiln, either manually or with the forklift.



The kiln shown in Figure 5 is an 8,000 BF drying chamber built to the specifications of the kiln plans provided by the Nyle Corporation to house the Nyle L300 dehumidifier. The chamber has an inside dimension along the long axis (left to right) of 22 ft. This chamber was designed for 10 ft - 3 in. long lumber stacked two units deep, two units high, and 2 units wide. Note the service door along the back wall to allow for access to the drying chamber to check drying samples.

Converting a preexisting space into a dry kiln is an alternative to building a kiln from the ground up or purchasing a pre-fabricated kiln. One of the more popular conversion techniques is to modify a standard overseas shipping container. These containers are sized 8-feet wide and either 20 or 40 feet in length. If converted into drying chambers the capacity of the 20 ft container would be about 2000 BF and the 40 ft container would be about 4000 BF. The size of these containers and the fact that used/reconditioned ones can be readily purchased makes them a logical choice to consider for a lumber drying chamber. This can work well if the cost of conversion can be controlled and the four basic criteria for a lumber dry kiln defined above are met.

There are a few inherent disadvantages related to the size and shape of the shipping container which influence the cost of conversion as well as the quality of the dried lumber. The major disadvantages are:

- Container shape – The long, narrow shape of the container, with doors at one end dictates that lumber cannot be loaded with a forklift. The lumber will have to be either loaded by hand or put on kiln carts that can be pushed into the kiln. The use of kiln trucks requires the installation of a rail system for the movement of the trucks.
- Container height – The inside height of the container less the space needed for mounting the circulation fans overhead less the space needed for the kiln trucks leaves about 4 to 4-1/2 ft. of effective height for stacking lumber. If warp prone lumber is being dried in such short stacks than about on-half of the total charge of lumber is subject to warp because of the lack of restraint that would be provided by the weight of lumber in taller stacks (criteria 2a).
- Plenum size – The long narrow plenum spaces on each side of the lumber make it difficult to provide uniform air flow (criteria 2b) without adding additional fans, adding to the cost.

If a mechanical restrain system is provided and adequate fan power and plenum space can be provided for uniform air flow through the lumber than an effective drying chamber can be built from shipping containers. The cost to make the modifications must be analyzed carefully to make sure that the conversion will be less than building a chamber from the ground up that is designed specifically to meet the four basic kiln criteria.

Recommendations for Converting a Shipping Container to a Dehumidification Dry Kiln

Shipping containers are either 20 ft or 40 ft long and both are sizes are available in a standard or insulated (for refrigeration) design. The 40 ft long container is not a very good size for a lumber dry kiln as the resultant long narrow drying chamber is difficult to load and difficult to maintain uniform air flow. The insulated container is a better choice as it already will meet the insulation needs of the kiln discussed above in criteria 4. Standard containers, on the other hand, require adding insulation to meet the heat loss requirements. Thus, the recommended container to use for a lumber dry kiln conversion is a 20 foot, insulated container.

The inside dimensions of a 20 ft, insulated container are 7 ft 5 in. wide x 6 ft 8 in high x 18 ft 8 in. long. Deducting 2 feet in height for the over head fans and 1-1/2 ft on each side for the required plenum this leaves space for a maximum lumber package of 4 ft wide x 4 ft high. Two units of 8 ft- 3 in. long lumber will fit in with about 2 feet of extra space that will need to be closed off (baffled) to prevent air from short circuiting around the lumber rather than passing through the units. Taking all of this into consideration the maximum lumber capacity for this kiln is about 2000 BF (two units, end-to-end, each 28 layers of stickered, 1-in. thick lumber, 4 ft wide x 8 ft - 3 in. long). The recommended dehumidifier for this capacity of lumber is one with a 2 horsepower compressor. Larger compressors are over powered and make it difficult to control the rate of drying. Figure 6 illustrates such a 2000 BF capacity dehumidification dry kiln converted from a 20 ft container. All dimensions are approximate, inside measure. The kiln is show with a dehumidifier unit measuring 20-1/2 in. deep x 32-1/2 in. wide x 40 in. high. To accommodate the placement of the unit inside the chamber the plenum on the side with the dehumidifier must be at least 26-in. wide, leaving 16-in. of plenum on the other side when 4-ft wide units of lumber are loaded into the kiln, negatively influencing air flow uniformity.

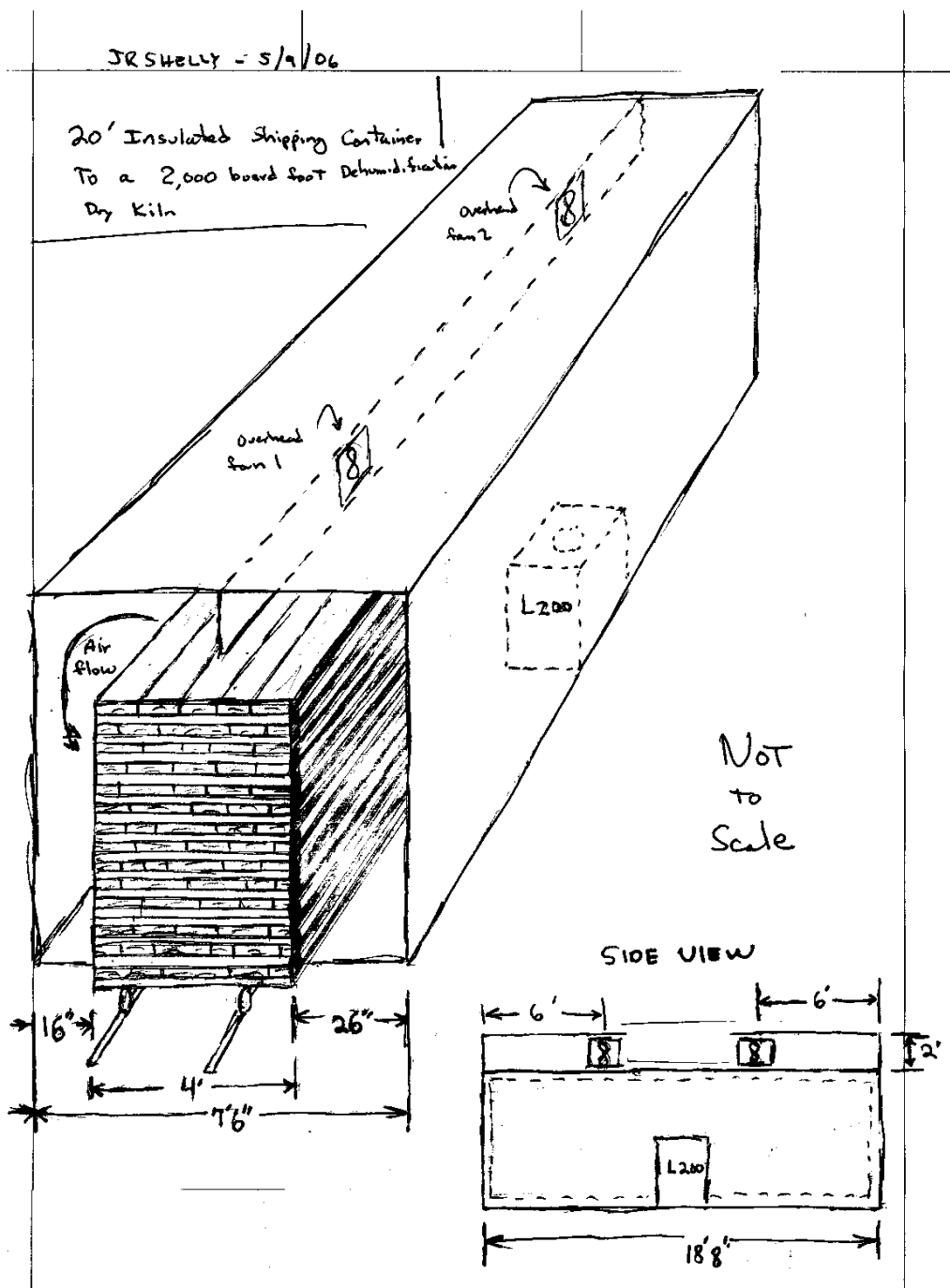


Figure 5. Track-loaded, 2000 BF capacity Dehumidification Dry Kiln converted from a 20 ft, insulated shipping container

A major draw back to the 2000 BF kiln design illustrated above is the need to have the drying chamber fully loaded to get uniform air flow and quality drying. If smaller amounts of lumber are expected to be dried on a regular basis than a smaller drying chamber would be a better choice. A variation to the 2000 BF, track loaded kiln illustrated above is shown in Figure 7. This drying chamber is designed to dry 1000 BF and to be forklift loaded from the end. This design will work well if only short lengths of lumber will be dried. The 7 ft - 5 in. width of the container limits the length of lumber to about 7 ft.

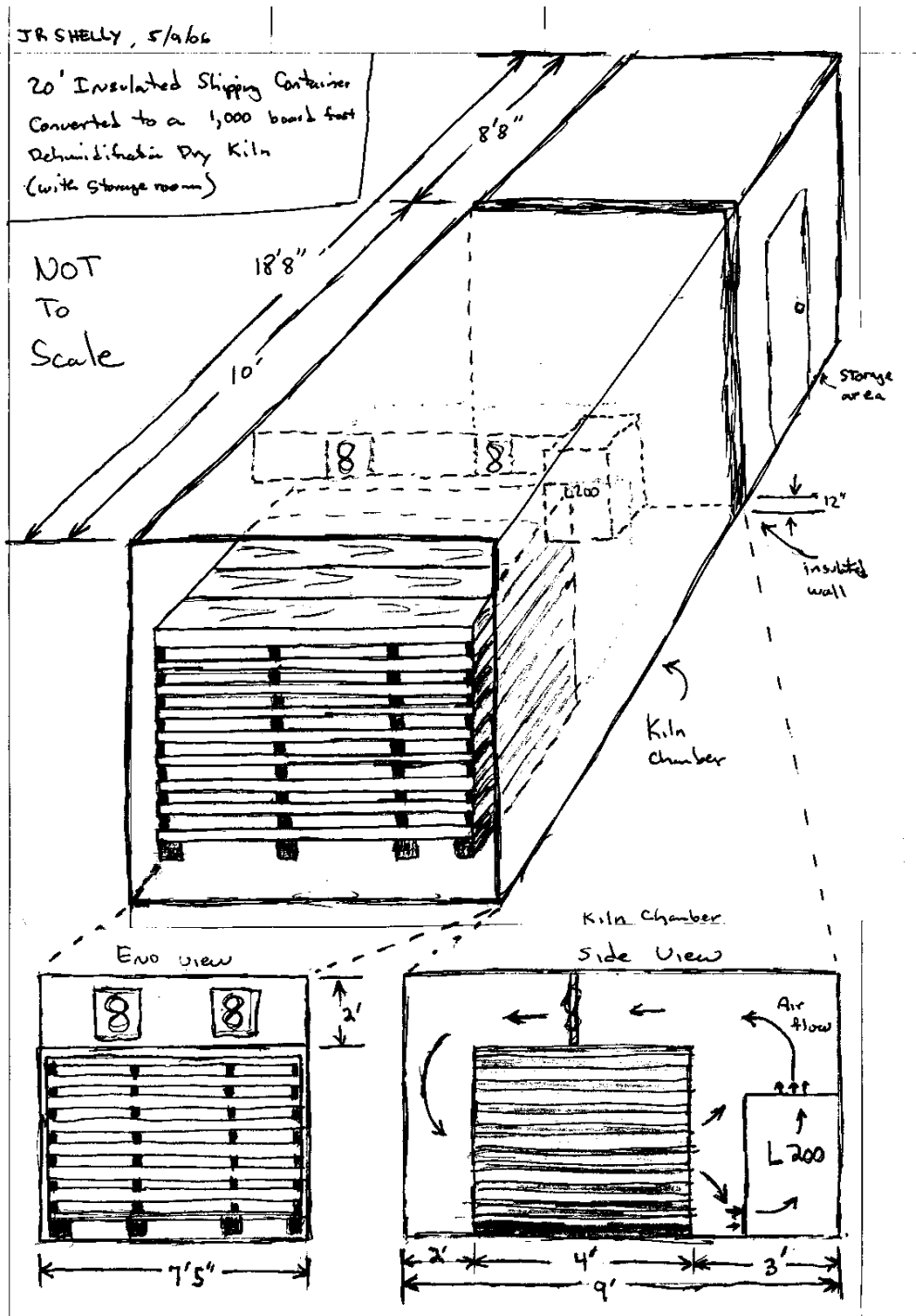


Figure 6. Forklift loaded, 1000 BF kiln converted from a 20 ft shipping container

A modification of the kiln shown in Figure 7 is shown in Figure 8. It designed for small quantities of 8 ft to 10 ft lumber. The dehumidifier was moved into the storage area and ducting was added to direct the outflow of air from the dehumidifier into the kiln chamber. A major disadvantage is that the lumber cannot be loaded by forklift, it must be hand stacked.

Not to Scale

All dimensions are approximate inside measure

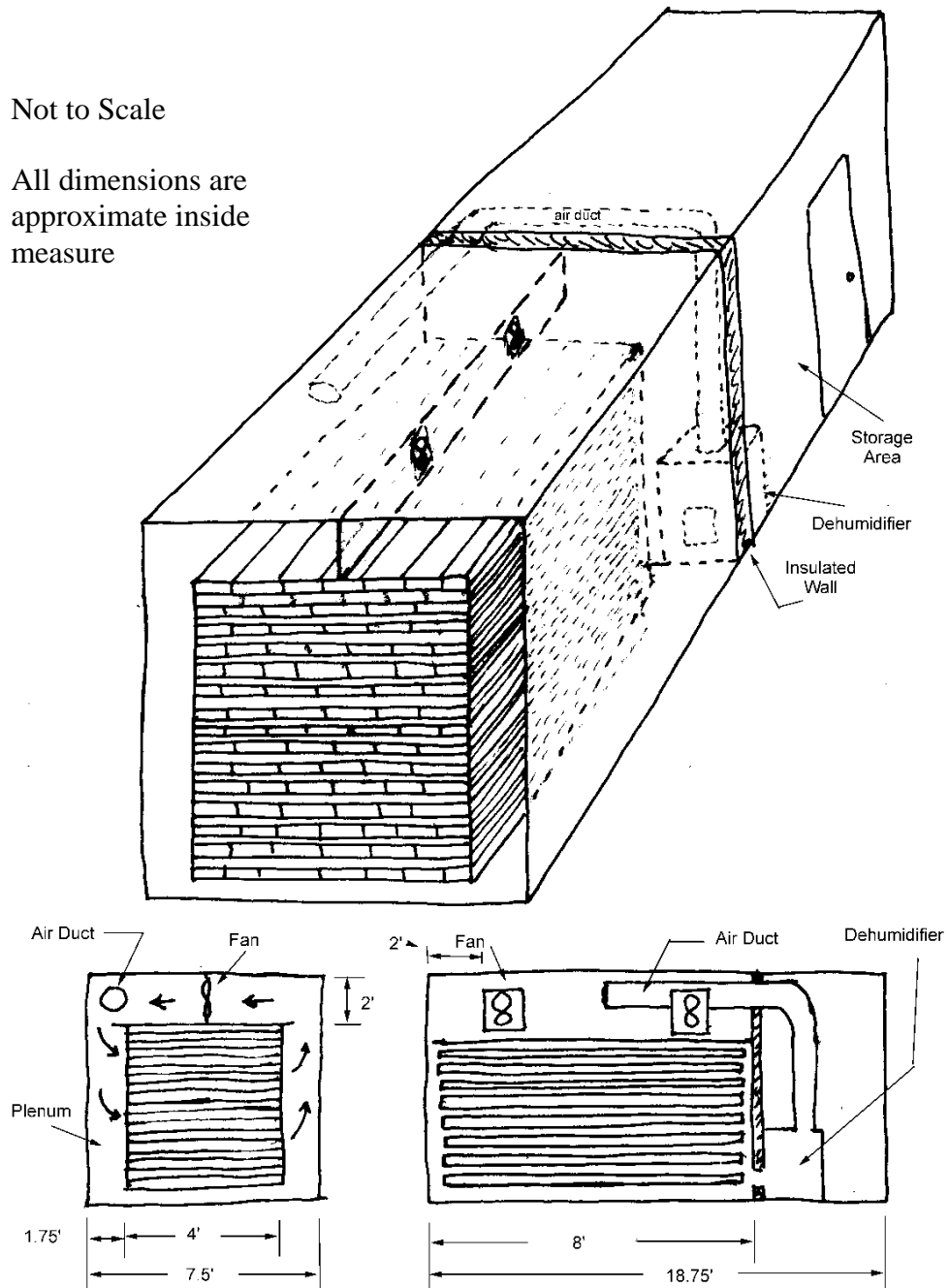


Figure 7. Hand-loaded, 1000 BF kiln for 8 ft long lumber, converted from a 20 ft shipping container

The 2000 BF capacity kiln illustrated in Figure 6 was built as a demonstration kiln by the California Department of Forestry. The kiln was designed for two units of lumber, each 4 ft x 4 ft x 8 ft long, that could be loaded onto kiln carts and pushed into the kiln. The series of photographs in the attached appendix shows the various components of the kiln and documents the proper technique to load the kiln and prepare it for drying. The approximate costs of the materials for the conversion of this 20-ft shipping container were as follows.

Category	Description of Item(s)	Approximate Cost
20' Insulated Shipping Container	Reconditioned with refrigeration equipment removed	\$2,700
Kiln cart wheels	Caster, V-groove, each rated for 2500 lbs	\$650
Steel to build kiln carts	Angle-iron and I-beam	\$1200
Steel rails	V-shaped to match kiln cart wheels, 100 lineal feet	\$500
Miscellaneous	Fan mounts, baffles, wiring, hardware, etc.	\$800
TOTAL		\$5,850

Adding the costs of fabrication and labor the total kiln cost could easily approach \$10,000. It is not a clear cut decision as to whether or not the container kiln conversion is a wise decision. Remember that this kiln has the inherent shortcomings described earlier, such as difficulty in loading the kiln properly, not having adequate restraint for keeping warp-prone lumber flat, and difficulty in obtaining uniform air flow in the kiln. If the lumber that is expected to be dried in the kiln is not prone to excessive warp it may be a valid choice but one needs to compare the costs carefully to the cost of building a kiln from the ground up that is designed specifically to dry lumber according in accordance with all the recommended best practices.

Appendix

The following photographs depict the 1000 BF dry kiln built by the California Department of Forestry from a reconditioned, insulated, 20- ft shipping container.



Figure 1. Completed Kiln



Figure 2. Insulated Shipping Container before Kiln Conversion, with Refrigeration Unit Removed.



Figure 3. Inside of Completed Kiln Chamber with Charge of Lumber in Place



Figure 4. Control Unit Accessible from Outside of Kiln



Figure 5. Unloaded Kiln Carts in Empty Kiln



Figure 6. Kiln Cart Tracks



Figure 7. Placement of Kiln Track Extensions



Figure 8. Close-up of Track Extension Connection to the In-kiln Tracks



Figure 9. Empty Kiln Cart on Track Extensions



Figure 10. Loading a Unit of Lumber (4ftx5ftx8ft) onto the Kiln Cart



Figure 11. Placement of the Unit of Lumber on the Kiln Cart Supports



Figure 12. Pushing the Unit of Lumber into the Kiln



Figure 13. Lowering the Fan Baffles



Figure 14. Placement of the End Baffle



Figure 15. Loaded Kiln Ready to Close the Doors