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SOLAR HEATED LUMBER DRYER FOR THE SMALL BUSINESS

Businesses that utilize small quantities of kiln dried lumber in their manufacturing process usually must purchase their lumber already kiln dried, rather than purchasing green (wet) lumber (which would cost much less than kiln dried lumber) and drying it themselves. A dry kiln is a major capital expense -- an all electric 2,000 board foot kiln, with a small electric boiler, would cost over $30,000. This fact, coupled with today's rising energy costs, makes small scale application of typical drying procedures impractical.

In recent years, electrically powered dehumidifier kilns have been developed for the small wood user, but even these kilns require a substantial capital investment, and energy costs are significant.

This article reports on a solar heated lumber dryer that requires only a minimal capital investment for the dryer and no energy, other than solar, except for the fans. This design is based on 18 years of research and development into solar drying of lumber within the U.S. Forest Service and various universities by this author. By the use of appropriate solar technology, therefore, it is now possible for the small wood using industry to purchase green lumber and dry it, in approximately 30 days, to 7 percent moisture content, at very little cost.

Design Fundamentals

The dryer described herein (Fig. 1 & 2) has been designed, constructed, and tested at Virginia Tech. This dryer can hold up to 1,500 board feet of 1-inch thick lumber per charge (or load) and has been designed to dry a charge in approximately one month of moderately sunny weather in the mid-latitudes of the United States.

The dryer incorporates a passive solar collector, similar to a greenhouse. There are four insulated walls and an insulated floor. The roof is clear plastic or fiberglass (two layers work better than one) sloped at a 45° angle to the South.[1/]

Solar energy enters the dryer through the clear roof and is incident on one of the black-painted interior surfaces. The energy is converted to heat and this heat is, in turn, circulated through the lumber pile where it is used to evaporate water. The evaporated water increases the relative humidity (RH) of the air; when the RH is too high, vents on the rear (north) wall can be opened manually to exhaust some of the humid air and bring in fresh, dry air.

At night, as the dryer cools, the RH will increase up to 100 percent. It appears that this high humidity is beneficial, in that it relieves drying stresses that have developed during the previous day. As a result, there are minimal residual stresses (or casehardening) at the end of drying.

To conserve energy, the fans are run only when the dryer has been heated above 65°F in the winter and 75°F in the summer.

One of the basic design features of this dryer is to have one square foot of collector (i.e., one square foot of sloped, clear roof) for each 10 board of 1-inch lumber in the dryer. This ratio works well for 1-inch oak, but may provide too much heat for 2-inch or thicker oak or too little for pine or other fast drying wood.[2/] The collector area can be increased (for easier drying woods than oak) by extending the roof southward, accompanied with a shorter south wall. On the other hand, the collector area could be reduced by covering part of the roof with plywood or other non-transparant material.

One may ask if the dryer would perform better if the south wall were clear. There is a trade-off in a solar dryer between the area of the collector and the area of insulated, solid walls. The more collector, the more solar energy collected, but in addition the greater the heat losses at night and in cold weather. The collector can use several clear covers and special covering materials to reduce losses, but this can be quite expensive. The Virginia Tech dryer is designed to control expenses and yet provide a functional, reliable design. The design is such as to dry a charge of lumber every month.

[1/] The optimum roof angle, above the horizontal, is equal to the latitude of the location, but can be increased by 10° to improve winter performance.

[2/] Oak is one of the more difficult drying woods because if dried too rapidly it will crack and check. Most other woods can tolerate more rapid drying. Thicker woods must be dried more slowly than thinner woods.

Construction Details (Figures 3 through 7)

The floor is framed with 2 x 6's, 16-inches on center, in order to be strong enough to carry the weight of the green lumber. Lumber should be preservative treated if in contact with the soil. Paper backed fiberglass batt insulation was installed between the framing members.[3/] The interior and exterior are covered with 3/8-inch plywood (exterior grade plywood suggested). The inside plywood is painted with two coats of freshly mixed aluminum paint,[4/] which, when dry, will act as an excellant vapor barrier. A third coat of flat-black paint is applied to the interior. The exterior is also painted, but a vapor barrier should not be used -- if any moisture does migrate into the walls, it must have an easy way to escape to the outside. For this same reason, paper-backed insulation rather than foil-backed insulation is suggested.

The roof is framed on fairly wide spacing. This spacing may have to be adjusted to accomodate the width of the covering material and any anticipated snow loads. The clear covering can be transparent polyethylene or other plastic sheets, but these coverings may deteriorate with heat, ultraviolet radiation, and continuous fluttering and flexing (from the fans). The most durable covering would be ordinary, almost transparent, corrugated fiberglass, available at most building supply firms. Two layers of covering, separated by a dead-air space, are suggested.

The dryer has two access doors at each end (east and west walls) to permit periodic examination of the lumber and measurement of moisture content. In addition, the Virginia Tech dryer has the roof hinged to the north wall and the south wall hinged to the floor. This permits the roof to be raised and south wall lowered to facilitate loading and unloading.

The vents on the north wall are framed openings with a small piece of plywood that acts as a door.

The fans are 3-speed window fans with thermostatic off-on control.[5/] The fans are fastened to the roof framing about 18-inches in front of the north wall with a plywood shroud or baffel around them extending downward 3 feet below the roof and running the full length of the dryer in order to force the air through the lumber pile.

[3/] If foil backed insulation is used, the foil must be perforated throughout to destroy the vapor barrier properties.

[4/] Aluminum paint can be made by mixing 18 grams of aluminum powder with 102 grams of spar varnish.

[5/] *Caution: Whenever the dryer will be left empty and fans will not be operating, the roof should be propped open slightly. If kept closed, temperatures at the peak can exceed 200°F.*

Drying Lumber in a Solar Dryer

Green lumber to be dried should be end coated with aluminum paint (described before) or other commercial end coating immediately after sawing to prevent large losses from end checks and splits. End coating is not too effective when applied after the lumber has begun to dry. Lumber should then be stacked in the kiln with a one foot clearance on either side of the stack (between the North and South walls and the stack) to permit adequate air circulation, and in neat layers, separated by stickers or spacers running perpendicular to the lumber's length. The lumber in each layer must be uniform in thickness. If the sawn lumber is quite variable in thickness, one or both faces of the boards should be planed or jointed before drying to obtain a uniform thickness to reduce warping during drying. Planing also reduces the risk of face or surface checking in oak. Green lumber will begin staining immediately if not stacked for drying.

Stickers also must be uniform in thickness. Stickers must be dry and often are 3/4-inch thick, 1-1/4 inches wide, and as long as the lumber pile is wide. (A complete guide to lumber stacking is in "Air Drying: A Guide to Industry Practice".) Stickers are placed perpendicular to the boards' length, every 12- to 18-inches along the lumber's length. The stickers are placed directly above the stickers in the lower layers.

If the lumber is of varying lengths, shorter boards are staggered by alternating them from one end to the other with the longest pieces always on the outside edges. The ends of every board should be supported with a sticker.

The stickers hold the lumber flat, preventing warp, while allowing air to circulate through the pile and dry the lumber.

While the lumber is being stacked, several boards must be cut (see next section) in order to provide sample pieces that can be periodically checked for moisture and can be observed for possible drying losses. After the lumber is stacked, another layer of stickers is laid down and a black-painted sheet of plywood is laid on top to act as a cover. The cover can be weighted with rocks or other material to help hold the top layers flat.

When drying lumber it is desirable to monitor its moisture content to avoid drying too rapidly and developing degrade. Moistures are measured from the sample boards and the daily rate of loss is compared with the "safe-rate" for that species. When drying is too fast, it may be necessary to block off part of the collector, or else turn the fans off and open the vents during the hottest part of the day. (If the fans are turned off, it is possible to develop temperatures around the fans that could melt the plastic components.)

Once the lumber is dry, it must be stored in a dry location (approximately 30 to 40 percent RH) to avoid regaining moisture. It may be stored in the dryer until more green lumber will be dried.

Cutting and Using Samples

The fundamental rule of drying lumber is that the quality of drying (freedom from degrade such as checks, splits, etc.) is controlled by the rate of drying (moisture loss per day). If quality were of no concern, wood could be dried in hours.

The maximum "safe-rate" for some hardwoods are presented below for 1-inch lumber. For 2-inch lumber, the 1-inch rate should be divided by 2.5.

SPECIES	MAXIMUM RATE OF MC LOSS PER DAY
Beech	4.5
Birch, Yellow	6.1
Cherry	5.8
Elm, American	10.4
Maple, Soft (Sap)	13.8
Maple, Hard	6.5
Oak, Red Upland	3.8
Oak, White Upland	2.5
Oak, Southern	Variable 1.0 to 3.0
Sweet Gum (Red Gum)	5.3
Tupelo (Black Gum)	10.9
Walnut	8.2

It is important to adhere to this rate when the lumber is first put in the kiln as the first half of the cycle is most critical in preventing degrade. As the lumber dries below 22 percent moisture, the risk of creating new degrade is nil.

In the solar dryer, the drying rate is slowed by covering up part of the collector, and on very hot, sunny days by shutting off the fans. This safe-rate refers to the loss in one day, not the average loss over several days. An 8 percent loss one day and 2 percent the next is not equivalent to a "5 percent per day" safe-rate.

In order to measure the moisture loss rate, it is impractical to weigh every board in the dryer and electric meters are not accurate enough. Therefore, we use the sample board method to represent the moisture of the lumber in the kiln. This method uses short, carefully chosen sample boards sawn from larger pieces of lumber and these sample boards are weighed periodically and estimated moistures are calculated. Generally, because the wettest lumber in the kiln has the highest risk of degrade development, the sample boards should represent the wettest lumber in the dryer; this means the lumber that is the most recently cut, is the widest and thickest, contains the heartwood, and is quartersawn.

The precise procedures in preparing sample boards are:

1. Select lumber to be used.

2. Cut a 30-inch sample board and then two 1-inch sections from the sample board, avoiding areas near knots and areas closer than 12-inches to the ends of the lumber. (Figure 8)

3. Number the sections and sample board.

4. Immediately weigh the sections (accuracy of about 1 gram required). It is important that they not lose weight after cutting and before weighing. Record weight on the section with a marker pen.

5. Weigh the sample board and record weight on sample (accuracy of 0.1 pounds).

6. End coat the sample board.

7. Place sample board in the lumber stack in a location where it will dry at the same rate as the rest of the lumber in the dryer.

8. Place sections in an oven 215-218°F (102-103°C).

9. After the samples are dry -- usually 18-36 hours depending on the oven -- reweigh and obtain the oven dry weight.

10. Calculate the mositure content of each section and average the MC of two sections to obtain the MC of the sample board.

$$\%MC = \left(\frac{\text{wet weight}}{\text{oven dry weight}} - 1\right) \times 100$$

11. Estimate oven dry weight of sample board using average MC above and weight from step 5.

$$\text{Est. O.D. weight} = \frac{\text{wet weight, step 5}}{(100 + \%MC)} \times 100$$

12. Write the Est. O.D. weight on sample board when it is next weighed so that it is readily available.

13. Periodically reweigh the sample board to obtain a new, current moisture content.

$$\text{Current \%MC} = \left(\frac{\text{(current weight)}}{\text{(Est. O.D. weight)}} - 1\right) \times 100$$

14. Occasionally it is necessary to cut new sample boards when the lumber is at 20% MC to obtain more accurate values. To do this, cut one new moisture section 6-inches from the end of a sample board. Then follow steps 3 through 11, except that only one section is used. The "wet weights" in steps 10 and 11 are the weights determined after the sample and new section are sawn.

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SCHOOL OF FORESTRY
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Some Useful Publications

A. Log Treatments

Lane, P. H., and Scheffer, T. C.
1960. Water sprays protect hardwood logs from stain and decay. Forest Prod. J. 10(6):277-282. (Forest Products Lab., P.O. Box 5130, Madison, WI 53705)

B. Sawing

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1965. A simplified procedure for developing grade lumber from hardwood logs. U.S.D.A. Forest Serv. Res. Note FPL-098. (Forest Products Lab., P.O. Box 5130, Madison, WI 53705)

C. Polyethylene Glycol

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1978. Drying eastern hardwoods. U.S.D.A. Agr. Handbk. No. 528. 102 pp. (Supt. of Doc., U.S. Gov't. Printing Office, Washington, D.C. 20402)

Peck, E. C.
1962. Drying 4/4 red oak by solar heat. Forest Prod. J. 12(30):103-107. (Forest Products Lab., P.O. Box 5130, Madison, WI 53705)

Rasmussen, E. F.
1965. Seasoning small quantities of lumber. U.S.D.A. Forest Serv. Res. Note FPL-089. (Forest Products Lab., P.O. Box 5130, Madison, WI 53705)

Rietz, R. C.
1971. Air drying : A guide to industry Practice. U.S.D.A. Agr. Handbk. No. 402. 110 pp. (Supt. of Doc., U.S. Gov't. Printing Office, Washington, D.C. 20402)

Wengert, E. M.
1971. Improvements in solar dry kiln design. U.S.D.A. Forest Serv. Res. Note FPL-0212. (Forest Products Lab., P.O. Box 5130, Madison, WI 53705)

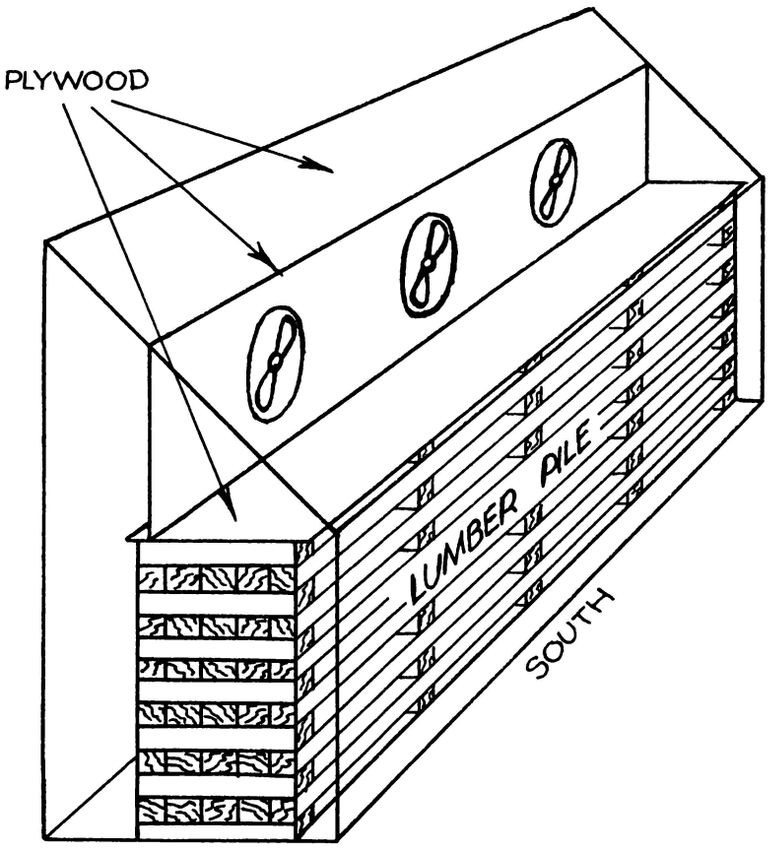

FIGURE 1 -- A sketch of the solar dryer shows its simplicity. The roof is clear plastic or fiberglass; the walls are framed with 2 x 4's with insulation and plywood covering; and the floor is 2 x 6's with insulation and plywood covering. The interior plywood walls, baffels, and fan housings are painted black to absorb maximum solar energy.

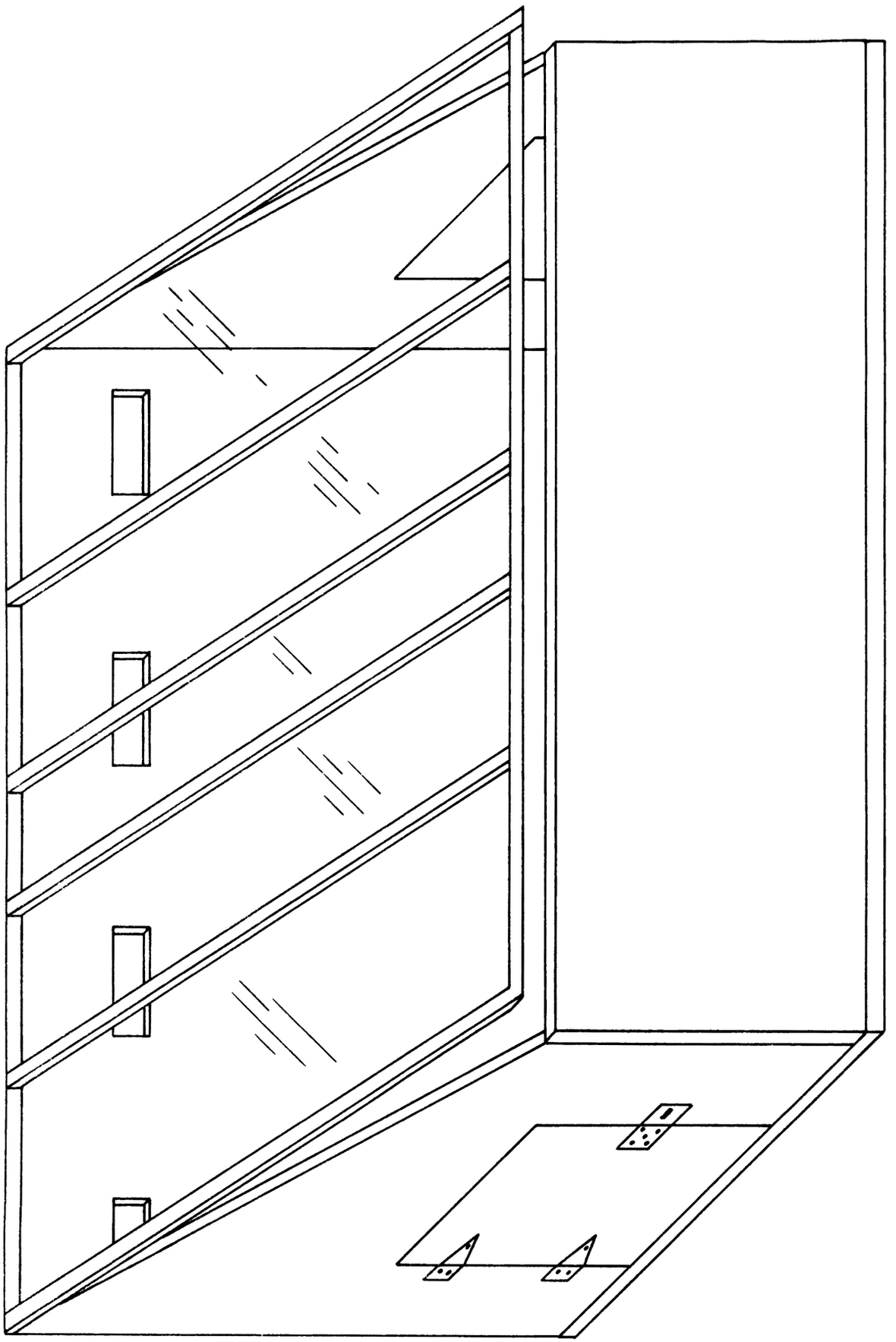

FIGURE 2 -- Sketch of dryer assembly, with roof opened slightly, shows overall assembly. The roof is hinged at the top to the north wall and the south wall is hinged at the bottom to the floor so that the dryer can be opened for loading. Doors in the east and west walls permit daily inspection.

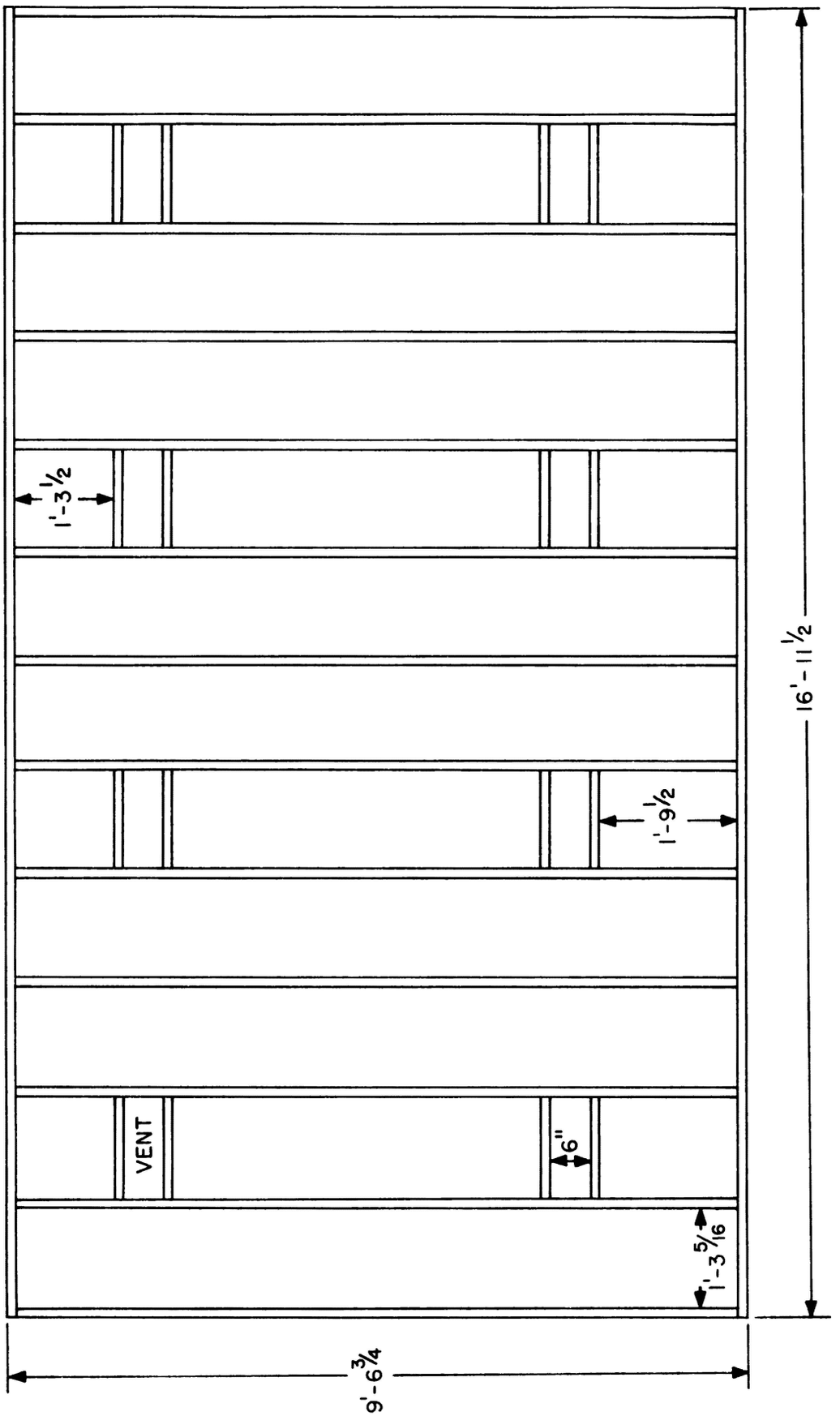

FIGURE 3 -- Framing of north wall. All lumber is nominal 2 x 4. (Scale 1/2" = 1')

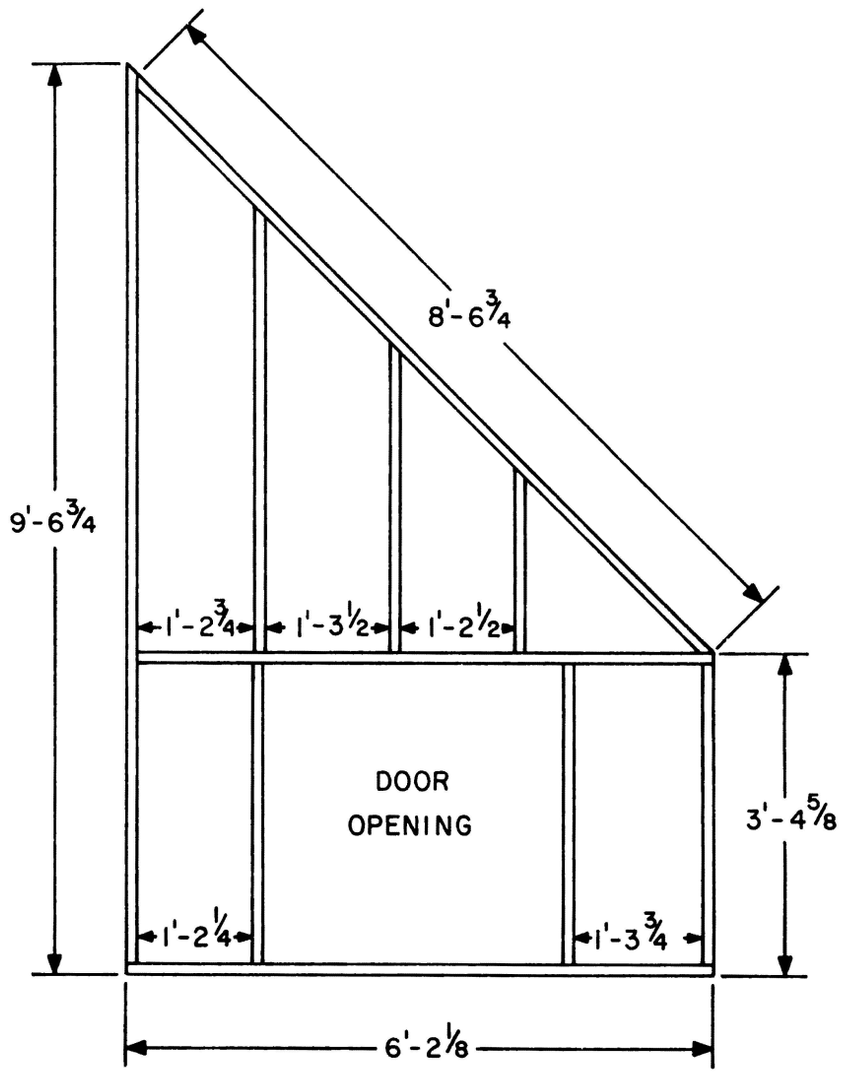

FIGURE 4 -- Framing of east and west walls. All lumber is nominal 2 x 4. (Scale 1/2" = 1')

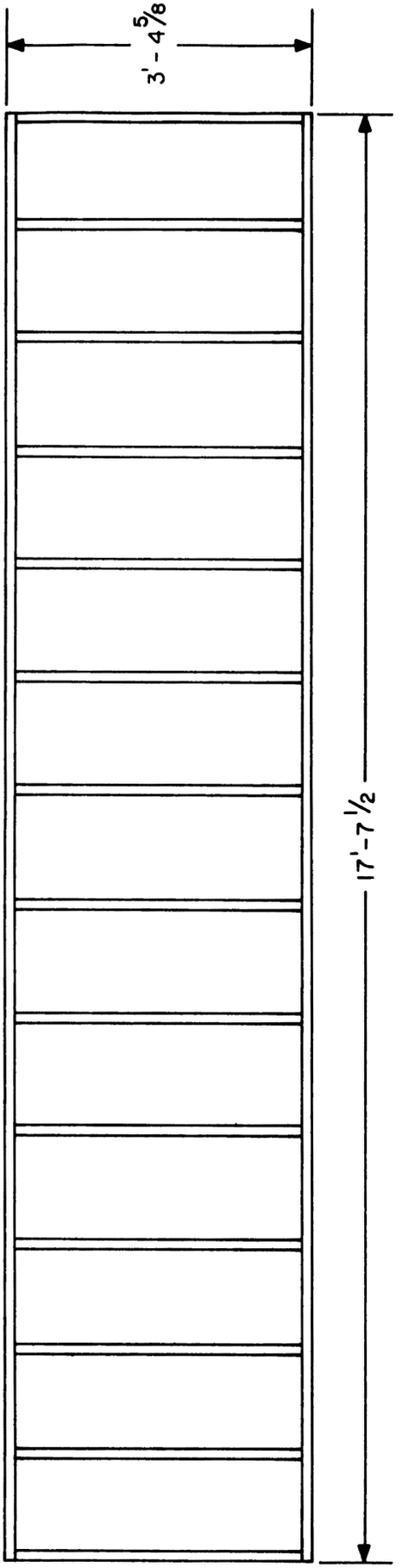

FIGURE 5 -- Framing of south wall. All lumber is nominal 2 x 4. (Scale 1/2" = 1')

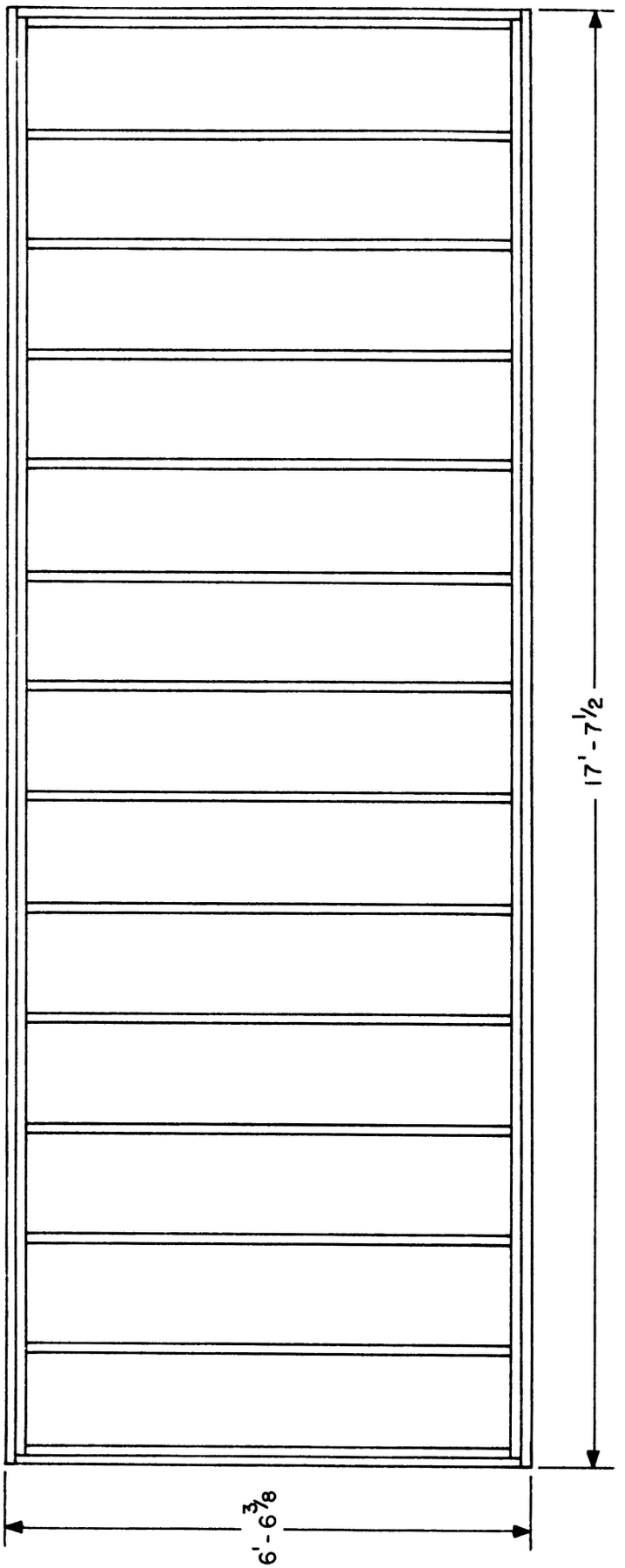

FIGURE 6 -- Framing of floor. All lumber is nominal 2 x 6. (This may have to be increased to 2 x 8 for heavier loads or long spans. Scale 1/2" = 1'.)

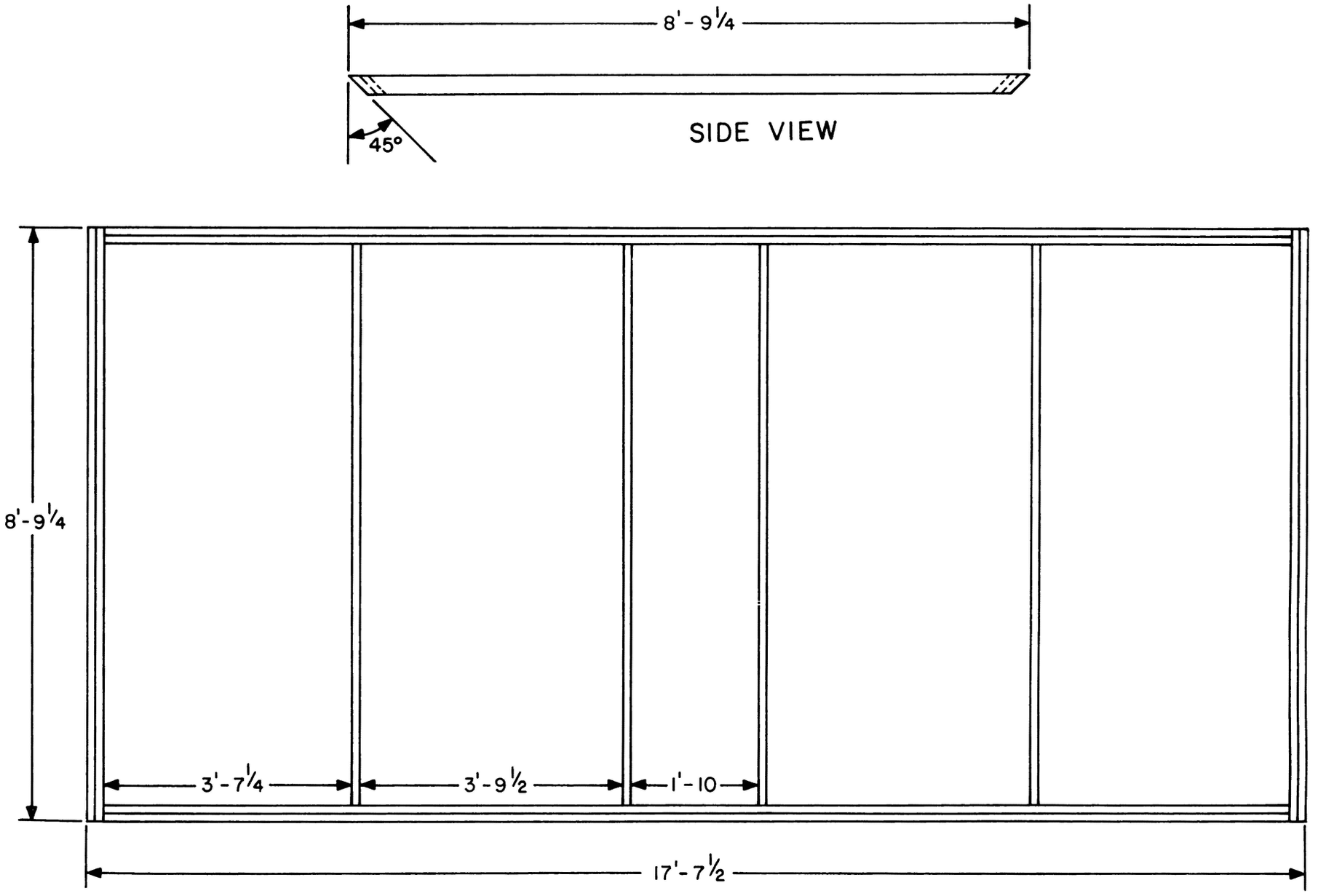

FIGURE 7 -- Framing of roof. Spacing may be altered to accomodate width of covering material or heavy snow loads. All lumber is nominal 2 x 4. (Scale 1/2" = 1')

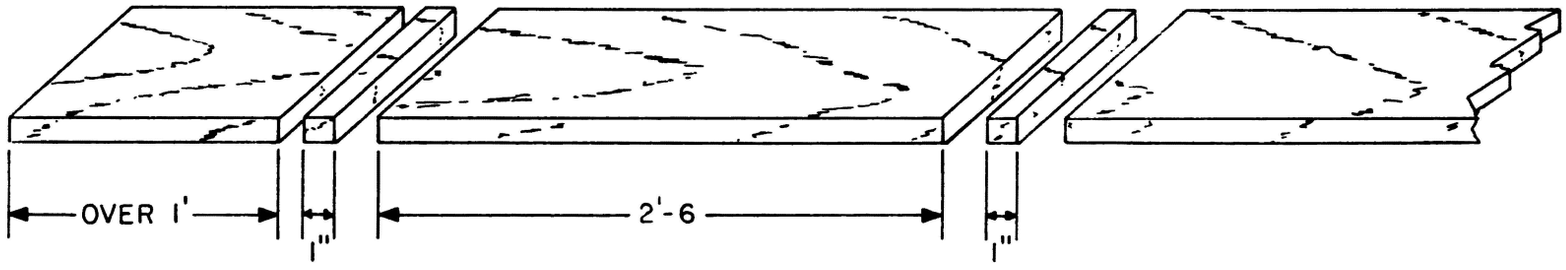

FIGURE 8 -- A 30-inch sample board cut from a large piece of lumber is used to estimate the moisture content during drying. The 1-inch wafers are used to estimate the initial moisture content of the sample.