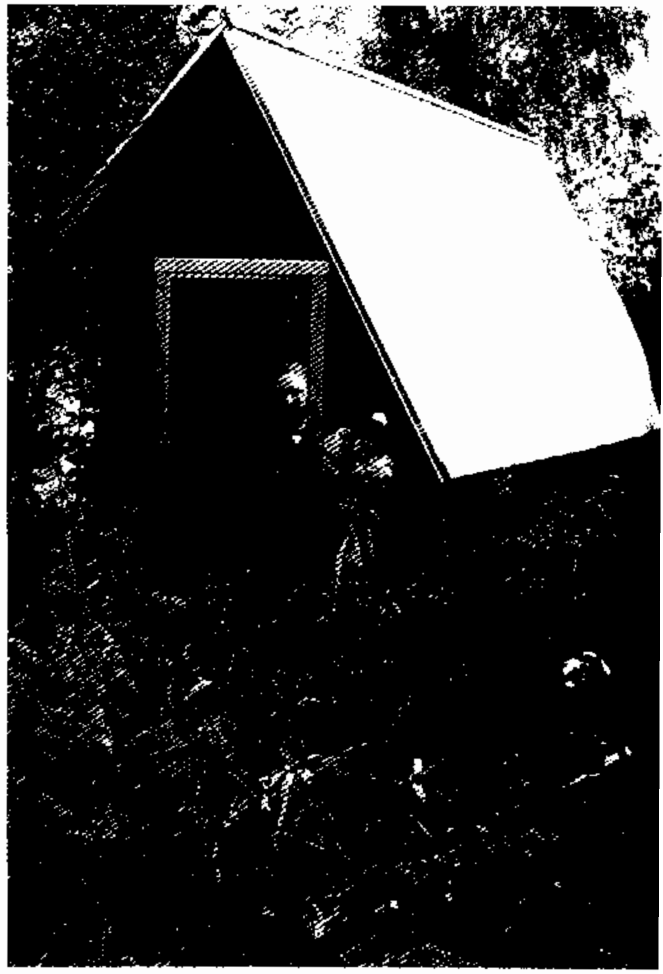
SOLAR KILNS TO DRY WOOD

the projects of Bruce Forster and Charles Simmons



Charles Simmons' solar kiln near Fairbanks.

In his proposal to the Alaska Council on Science and Technology, Bruce Forster stated the problem behind his plan: "Many woodworkers with whom I am in contact lament the quality of commercially available 'dried' lumber here in Alaska." Not only is imported lumber of uneven quality and high price, but the Alaskan woodworkers are surrounded by "a renewable resource of such potentially high quality that it seems wasteful not to take advantage of it . . . our local timber, spruce, birch and cottonwood, when properly dried is not easily matched in workability and beauty.

"However, for a small woodshop to invest in a dry kiln represents a major capital expense out of reach of the average Alaskan craftsman." Not only is a standard kiln expensive, so is any typical heated space. Yet it takes an extremely long time to air-dry wood outside of a heated building, and even outside, space is usually at a premium. So for northern woodworkers, the catch to using northern woods seems to lie in that phrase, 'properly dried.'

HOW WOOD DRIES

As background for his project report, Charles Simmons provided an article by William W. Rice, a teacher of wood science and technology at the University of Massachusetts, that explains the processes by which wood dries.[1] Trees, logs and freshly sawn boards hold free water contained in the wood's cell cavities, and bound water held in the cell walls by molecular attraction. As the wood dries, the free water proceeds from cell to cell by capillary action, while the bound water moves by diffusion. Since it is like emptying liquid from a cup, the loss of the free water does not change the cell dimensions; however, as the bound water is released from the cell walls during drying, the cellular spaces contract and the wood shrinks. In very small pieces of wood, all the free water leaves first, followed by the bound water. Larger pieces of wood dry from the surface towards the center, so bound water is evaporating at the surface while free water is still traveling from the interior. This creates moisture gradients and hence drying stresses in the wood, producing cracks, splits and warp collectively known as 'degrade' to wood experts.

Temperature, humidity and air movement through a stack of lumber all affect the drying process. A wood-drying kiln permits its operator greater control of all three factors than nature affords, and thus makes degrade less likely. Basically, a dry kiln is a well-insulated box equipped with devices to provide heat, move air, and adjust humidity. Constructing a kiln of any size can be expensive, as Forster's quote above indicates, but for northern craftsmen, heating one could be prohibitive. It is not surprising that two woodworkers in

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Bruce R. Forster *earned a B.A. degree from Glassboro State College in New Jersey, holds Industrial Arts and Elementary Education certificates, and taught school for six years before becoming a self-employed furniture maker near Homer, Alaska.* **Charles Simmons** *is a part-time cabinet maker near Fairbanks; one of his hand-crafted rocking horses was featured in a toy exhibit at the University of Alaska-Fairbanks museum this winter.*

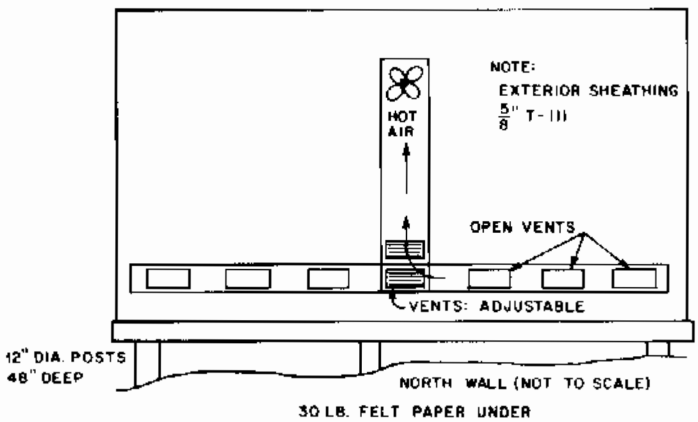
different parts of the state pounced on the idea of using the sun to heat their kilns.

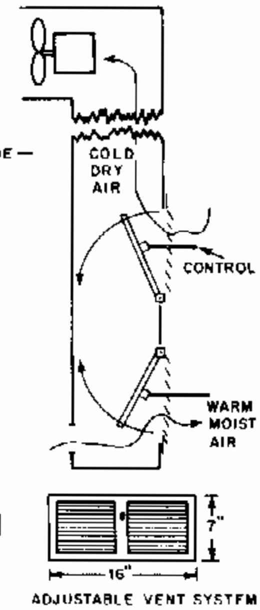
A SOLAR KILN

Though they were working completely independently, both grant recipients were inspired by the pioneering work of Eugene Wengert, Extension Specialist in Wood Technology at Virginia Polytechnic Institute. Wengert's design[2] looks like a rectangular box with one corner sliced off at a 45° angle along the south-facing long dimension. The sliced-off portion is covered with glass or other transparent material, producing a structure looking like an insufficiently glazed greenhouse. The unglazed walls and floors are fully insulated and are painted black on the inside to absorb heat. Sunlight entering through the glazed roof strikes the dark walls and baffles, generating heat which is circulated by thermostatically controlled fans. Excess heat and humidity are released through manually operated vents on the rear (north) wall. That excess heat can be generated is underlined by Wengert's warning that the structure must be left open when it is empty, because temperatures can reach 200°F at the peak when there is no mitigating effect from evaporation. The kiln may also be covered with canvas when not in use.

The plan is based on Wengert's 18 years of research and development in solar lumber-drying for the U.S. Forest Service and various universities, so Forster and Simmons could be confident that the idea was sound. The challenge lay in adapting the design to Alaska conditions and to the needs of each woodworker.

The vents on Bruce Forster's kiln are standard items. However, he modified the upper vent so it hinges properly, yet still sheds rain from the outside.

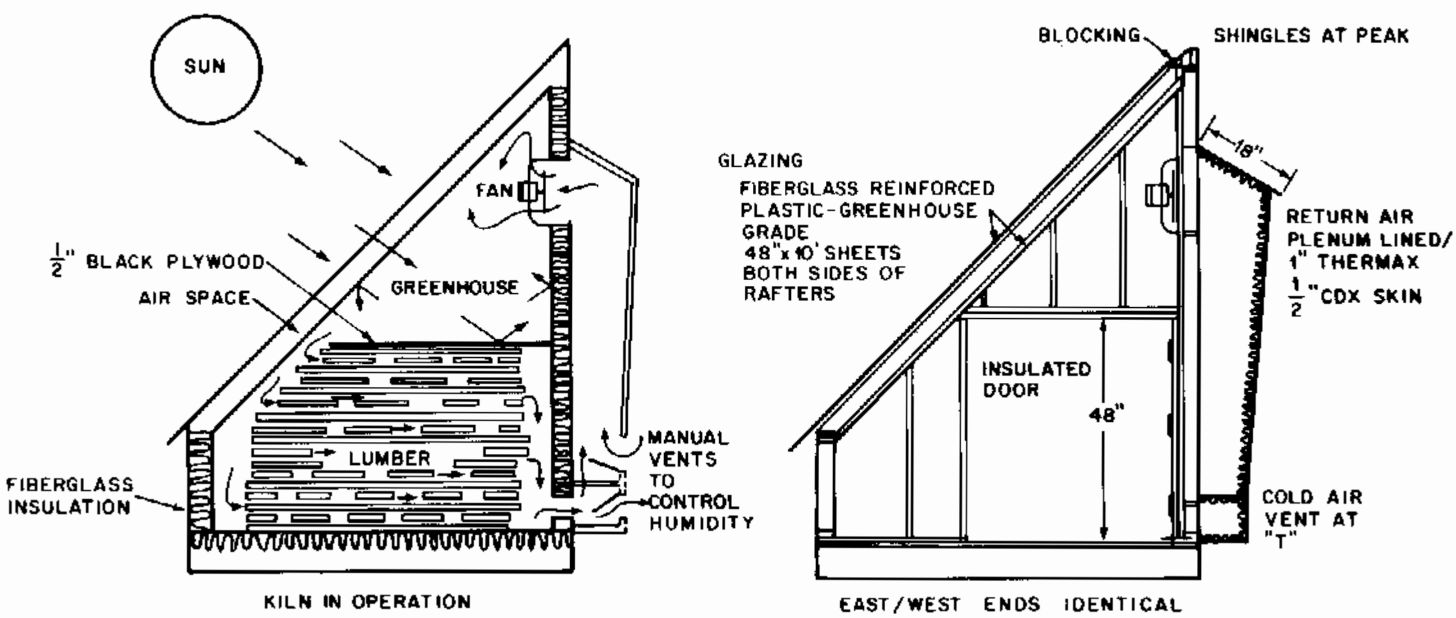




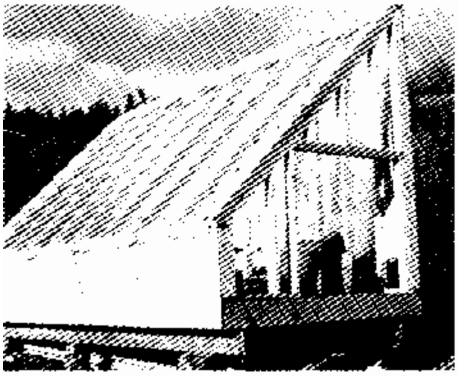
THE ALASKA KILNS

Bruce Forster's Project

Forster lives near Homer. The area is sometimes called 'the banana belt of Alaska' by envious residents elsewhere in the state, since it receives neither the intense cold of the Interior nor the heavy precipitation that falls on other communities along the northernmost Pacific coast. Forster judged that the Wengert design needed little modification to function well at his location, and the size seemed appropriate for his needs as a self-employed cabinetmaker. He did double-glaze the transparent portion of the roof to cut down on heat loss, and used a kind of fiberglass designed for greenhouses (Sun-Lite™ fiber-reinforced plastic) that — unlike the less expensive clear plastic

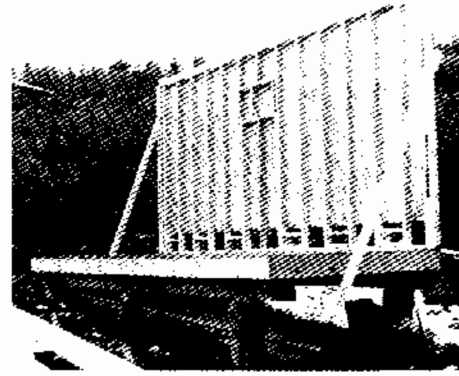


Forster's kiln: the lumber charge (left) must be covered with black-painted plywood placed snugly against the north wall to force circulating air through the lumber.



East wall framing of Bruce Forster's kiln. South-facing roof is covered with fiber-reinforced plastic.

North wall, raised as one piece, shows framing for fan opening and lower vents.



materials Wengert suggested — does not turn cloudy or opaque after continued exposure to the ultraviolet in sunlight. He also decided that one fan, rather than the three in the original design, would move enough air for his purpose. A thermostatic control starts the fan when the temperature in the kiln reaches 70°F.

His building stands on a foundation of six pressure-treated posts 12 inches in diameter, set in two rows four feet apart and driven four feet into the ground. The foundation and floor have to be unusually sturdy for a building measuring only about 7 x 17 feet, since wet lumber is heavy; Forster used 4 x 8 beams and 2 x 8 joists topped with ¾-inch CDX plywood for the floor deck. All materials purchased for the kiln's construction, listed on Table 1, cost about $2000 total in 1980. The illustrations give a fair idea of the structural details.

What is harder to show is the effort that had to be made to control moisture migration. Conventional building practice calls for a vapor barrier between the inside surfacing material and the insulation, and for typical home or office conditions of temperatures less than 70°F and relative humidities less than 30% that method is fine. However, in a solar dry kiln the temperature can exceed 100°F with relative humidities near 100%, which puts the interior surfaces in conditions like those of an equatorial swamp — and building materials do not last long unprotected in an equatorial swamp. Therefore Wengert recommended sealing the interior surfaces very carefully so that moisture remains inside where it can be controlled. Although Forster followed the suggested method, which was to cover the interior surfaces with two coats of waterproofing aluminum paint before applying the final coats of flat black paint, he would recommend using a 6-mil poly vapor barrier.

TABLE 1
MATERIALS FOR THE FORSTER KILN

Quantity	*Size*	*Item*
2	2x8x18	Joists
16	2x8x8	Joists
75	2x4x10	Frame
8	2x4x18	Frame
2	4x8x18	Beams
5	3/4x4x8	CDX floor
12	5/8x4x8	T-11 8 OC
3	10' Z	Metal Edge
10	3/8x4x8	CDX walls
4	1/2x4x8	CDX
9	4x10	Greenhouse F.R.P./NLS
5	3-5/8x15	Fiberglass insulation
3	Pr 3 1/2	Butt hinges
x	12-2	UF wire
2		Single device boxes
1		Switch
1		Cover plate
6		Wire nuts (Y)
20 lb	16d galvanized	Nails
10 lb	7d galvanized	Nails
6 lb	5d galvanized	Nails
300	1x2x10	# 3 Pine stickers
2 Bundles		Undercourse shingles
x	30 lb	Felt paper
4 tubes		Silicone
2 cans		"Great Stuff" (urethane foam)
2		Door weatherstripping
4		Door deadbolts
2		Door handles
2	1x4x18	Thermax for plenum
x		Romex staples
1	3'	Heat/cool thermostat/115 VAC ½ flex conduit
1	115 Vac - 2100 C.F.M. 1/15 HP - 1.6 A 1550 RPM	Fan - direct drive exhaust - Emerson Electric
2 gal		Aluminum paint
2 gal		Flat black paint

Charles Simmons' Project

Simmons is a part-time cabinetmaker who lives near Fairbanks, an area with a demanding climate that few people envy. For years he had wanted to construct a solar kiln but was not satisfied with any design until he saw Wengert's. He reports that when he saw the Wengert design, "I was immediately impressed with its elegance, simplicity and low cost. Other designs have employed separate solar collectors, whereas here the building itself is the collector."

He too followed the original plan quite closely, but as the accompanying photos show, he decided that a slightly smaller structure would meet his needs for cabinet quality wood adequately. He also made the collector angle steeper, to gather solar energy more efficiently at his near-65°N location (in comparison, Homer is close to 59°N latitude). Since he did not intend to attempt using the kiln during winter, the structure is not superinsulated; he used 3½" insulation and 6-mil polyethylene sheeting as a vapor barrier. The Fairbanks area receives too few hours of winter sunshine to generate much heat, and temperatures below about 70°F do not promote drying.[1] Like the Forster kiln, his has two layers of glazing.

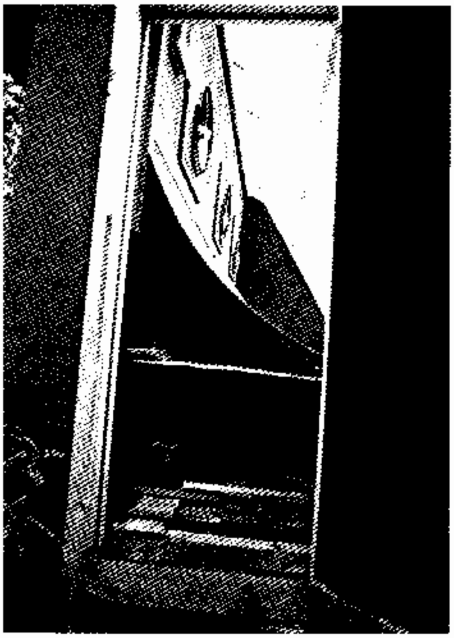
Simmons' kiln, 6' wide by 16' long, is built on a foundation of 6 x 6 posts. The 2 x 8 floor joists are spaced 16" on center and support 5/8" plywood flooring. The approximately 128 square feet of collector is glazed with Filon;™ he covers the kiln with canvas when it is not in use.

Though his kiln was smaller than the Wengert prototype, Simmons decided that keeping the air moving through the lumber was vital, and so followed the suggestion of using three fans. His are 16-inch diameter, two speed, mounted on an interior baffle (see photo) and regulated by two thermostats. He indicates that he would have preferred three-speed high temperature fans but was unable to find any. (For the benefit of anyone contemplating building a solar kiln, he notes that interior-mounted fans should have a minimum of Class B rated insulation.)

If he were building it today, Simmons estimates that his kiln would cost about $2500.

OPERATION

How well any wood-drying kiln operates depends in large part on the capacity of its operator to pay attention to details. The green planks first must be end-coated with waterproofing (latex paint works well), so the ends do not desiccate and crack or split. Lumber must be stacked carefully in the kiln, with at least a foot of air space on all sides of the stack. So air can circulate through the stack, single layers of planks are separated with spacers, called 'stickers', placed perpendicular to the boards' length every 16 to 18 inches. The ends of each board must



Simmons used three two-speed fans to move air through his solar kiln.

be supported with a sticker as well. During drying, the operator has to monitor the wood's moisture content with an electric moisture meter or by periodically weighing sample boards. As his experience increases, an operator can determine moisture content fairly accurately just by feeling the wood.

A solar wood dryer is as demanding as any other variety of dry kiln when it comes to stacking requirements, but — because of its natural heat source — is more forgiving for managing moisture content. As the sun angle changes in the evening so that light is no longer striking the kiln's interior, the building begins to cool down. Cooler air can hold less moisture, so the relative humidity (RH) will increase to as much as 100%. This cooling and rise in the RH is important, because it slows down evaporation from the wood surface, giving the moisture moving outward from within the planks' interior time to catch up with the overall drying process. The stress associated with steep moisture gradients (discussed above) is prevented, and the solar process produces wood with very little degrade. The potential for drying stress is greatest early in the drying process, so during the first days the vents are kept closed, and may be closed again whenever conditions warrant. (Typical commercial-scale kilns try to achieve the same effect by adding steam to the air when their monitoring devices show that drying is proceeding too quickly; determined backyard operators may spray plank surfaces with a garden hose when their sample boards weigh too little too soon.)

RESULTS

Simmons' kiln can dry about 1100 feet per charge, but he chose to start small: "On May 15, 1982, I put in 500 board feet of 24% moisture content birch. After finally loading the kiln it was very satisfying to look into one of the vents and have my glasses fog up immediately from the exhausted humidity, proof that the kiln was doing its job. In about two weeks of ideal drying weather, the birch dried to 6—9% moisture content."

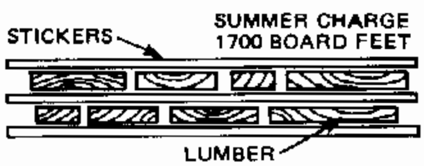
Forster has run several loads, including one of green oak hauled in by a friend from Oregon. With succeeding loads, he has adjusted the kiln and his procedures to improve the results. He had estimated that the kiln would hold a 2000 board foot charge; an early discovery was that though it can hold that much, there was no way for the person loading it to get out when it was full. (The Wengert design had the roof and bottom of the south wall hinged, so the entire front of the building could open for loading — a complexity, and probable source of heat loss, that both grant recipients chose to avoid.) The actual full charge is about 1700 board feet: that much rough green spruce will dry to an ideal moisture content after 200 hours of sunny summer weather.

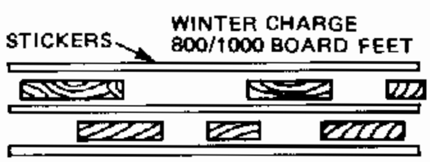
Ideal moisture content (MC) depends on relative humidity: for spruce, 7½% MC is ideal at 38% relative humidity (RH). Equilibrium moisture content (EMC) is the relationship between bound water and relative humidity, according to species of wood. At the EMC, wood neither gains moisture (swells) nor loses moisture (shrinks).[3] For spruce:

at 75% RH, 14% MC is ideal;
at 50% RH, 9% MC is ideal;
at 25% RH, 5% MC is ideal.

In summer Forster dries spruce to 7–8% MC in Homer's average RH of 50%; in winter spruce is dried to 5–7% MC in average RH of 20%.

Though commercial kilns use stickers half an inch thick, both Forster and Simmons believe that ¾" is the minimum that should be considered for kilns like theirs; Forster uses 1 x 2s as stickers. He adjusts stickering seasonally; more space is needed for air to circulate through the stack by September, when "the sun just doesn't have enough oomph."





Forster did make one change to the kiln itself. Despite sealing, the ends of the boards were becoming dryer than the centers by 5 to 6%. Plugging the east and west vents with insulation solved that imbalance, and the stacks now dry uniformly.

ALTERATIONS?

Simmons' only complaint with his kiln is that he has not been able to use it more. He is looking forward to trying it out during the 'marginal months', and believes he can use it effectively for six months out of the year. He has received inquiries from other woodworkers about trading or selling lumber dried in his kiln.

Bruce Forster has had more time to consider changes. He located the kiln so it would receive good sunlight and was convenient to his woodworking shop; however, that location was also close to a dirt road. The road dust settles on the collectors, blocking the light, so from time to time during the summer he has to take a dust mop and clean the plastic glazing. He thinks glass would be superior to plastic for the glazing, and that an additional fan might "change the whole picture" for the better – but "Really, it works like cheap oil in the 50s. There's just no need to do it any better." Glass would have cost far more and would have been more difficult to work with, and another fan would "just be more machinery taking more power." He believes the diurnal cycle of the solar kiln helps produce wood of a quality superior to any other available in his locality. The economics of his kiln help bear out that opinion: he pays for each new load of green lumber by selling half of his previous kiln-dried load, and his lumber sells immediately.

He would advise anyone contemplating building a solar dry kiln to put a great deal of effort into moistureproofing during construction; Thermax or some similar insulating material that is unaffected by water might be preferable to fiberglass, though again there would be a cost tradeoff for the improved performance. He considers that a 6-mil plastic vapor barrier would be more effective than the two layers of aluminum paint that Wengert recommends. Simmons, who did use 6-mil plastic, thinks that vents on the exterior wall at the top and bottom of each stud cavity could also be used to vent moisture that got into the insulation.

Forster also stresses that good stacking procedure is important. If the lumber stacks are not equal and level, air circulation will be poor: "You should be able to check it with a framing square."

POSSIBILITIES

Charles Simmons notes, "The amount of heat collected is impressive. I think similar collectors could be used to provide solar capabilities to sites where it is not convenient to have the collector on the house itself. The heat could be moved in insulated underground ducts." He sees solar wood-drying kilns as a valuable asset for any serious woodworker or small lumberyard anywhere in the state. Ideally wood should be at an equilibrium with the humidity at its location before it is installed. Homes in interior Alaska, especially wood-heated houses, have unusually low humidity levels. Wood becomes super dry, below 6% MC, inside such homes. Anyone installing cabinets, trim or flooring should have properly dried lumber. Also, since half the weight of green wood is water, drying lumber reduces both the shipping costs and the general difficulty of moving the wood.

Bruce Forster agrees that solar kilns can lessen Alaska's dependence on imported lumber and make it easier to use Alaskan trees for something other than firewood or export; he would like to see the kilns used more widely everywhere, since two-thirds of the energy used in manufacturing lumber is consumed in drying it. Though well-satisfied with his kiln's performance, he doubts that such solar dryers would be commercially successful on a large scale in Alaska. The problem is time: The lumber that goes from green to 7% moisture content over 200 sunny hours in his kiln can be dried during only about four days in a conventional, intensively managed kiln.

For larger lumberyards trying to use local wood, an ideal approach might be to use a solar kiln to bring the wood down to 15–20% moisture, then finish the process with a commercial dehumidifier. This two-stage process would speed up the drying considerably. For smaller-scale operations, where volume and thus time are not so crucial, the chief problem confronting managers could be providing good storage space for the dried lumber. Wood is hygroscopic and will reabsorb moisture freely unless it is protected. However, once green wood is dried, most of the drying stresses will not recur even if the lumber reabsorbs moisture, and the wood will be quite useable. In Fairbanks 12% MC seems average for unheated storage.

To whatever extent solar kilns eventually find use in Alaska, there is no question that the two presently in operation are successful, and satisfying to their owners.

REFERENCES

[1] Rice, W. W. 1977. Dry kiln. *Fine Woodworking*, Spring. p. 39-43.

[2] Wengert, E. M. 1980. Solar Heated Lumber Dryer for the Small Business. Virginia Cooperative Extension Service Report MT # 20C (Utilization and Marketing), Blacksburg, VA. 16 p.

[3] Headley, R.B. 1980. Understanding Wood. The Taunton Press, Newton, CT. ♦