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SOLAR LUMBER KILNS

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**DESIGN
IDEAS**

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Front cover top to bottom: San Juan Kiln, New Mexico, Project Director—John Vincent. Eureka Springs Kiln, Arkansas, Project Director—Thomas Bangert. Ozone Kiln, Arkansas, Project Director—John Alexander. Copies of final reports pertaining to these kilns may be obtained from the U.S. Department of Energy Region VI Appropriate Technology Small Grants Program, P.O. Box 35228, Dallas, Texas 75235.

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SOLAR LUMBER KILNS

Design Ideas

Angela M. Robbins

New Mexico Energy Research and Development Institute
Information Center at The University of New Mexico
Albuquerque, New Mexico 87131

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WHAT IS A SOLAR KILN?

A solar kiln has two main parts—a kiln drying *chamber* and a *solar collector* area. The chamber looks much like a shoe box, and the sloping collector is located on the long southern side of the chamber.

Green or partially air-dried lumber is stacked inside the kiln chamber. Heat from the sun is collected and vented into the chamber. This *thermal energy* removes moisture from the lumber until the lumber is dry enough for woodworking.

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WHY BUILD ONE?

Lumber can be air-dried, solar kiln-dried, or dried by heat produced from burning wood waste or natural gas. Traditionally the first two drying methods have been selected when small quantities of dried lumber are needed. Large commercial kilns often cannot afford the time it takes to air-dry or solar kiln-dry lumber. These commercial groups choose the latter method.

When lumber is air-dried, it is subjected to thermal conditions which are uncontrollable. Commercial kilns attempt to produce large volumes of lumber dried at the fastest controlled rate possible. Air and commercial drying are suitable methods for removing moisture content, but frequently these methods do not dry lumber to the moisture content preferred by furniture makers.

Air drying is the least costly of the three methods and takes the longest. Traditional commercial drying is capital intensive; this drying process is the most expensive, but large *charges* (90,000 board feet or more) are dried in as little as 4 days in the summer.

Small quantities (1500 board feet) can be dried in a solar lumber kiln in 4 to 28 weeks. A solar kiln requires moderate capital costs but the first charge recovers these costs. Successive charges cost as little as 11% of the cost of traditionally dried lumber. A solar kiln is not ideal in all business instances. But if time and volume are not factors, if you would like a kiln close to your woodworking site, and if you require high-quality lumber—a solar lumber kiln fulfills these needs. The costs of commercially dried lumber are often prohibitive to staying in the woodworking business. A solar kiln may well be able to provide the economic margin necessary to stay in business.

It is possible that the solar collector components of the kiln may qualify for state or federal tax credits. A copy of your design should be sent to your local taxation office for analysis of its compliance for business credits, direct or indirect solar gain tax credits.

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DRYING FUNDAMENTALS

The objective of drying lumber is to reduce the moisture content of green fresh cut wood to 6 to 8% with a minimum of *drying defects*. Thermal energy is necessary for evaporating this moisture. However, wood drying is

complicated by the molecular structure of the wood itself. The cells of wood contain *free water* which can be evaporated easily and quickly. The remaining 30% of the moisture is *bound water* and requires more thermal energy and time to remove it from within the cell walls. Shrinkage occurs when the content falls below 30%. When wood is dried too quickly, the moisture content of the exterior surface and the core of the wood differs greatly and also causes shrinkage. Unrelieved *stress* results in drying defects. Drying defects include checking, splitting, twisting, honeycombing (internal collapse), case hardening, etc.

You might ask why lumber is not just put out in the sunlight to dry. Direct sun causes the surface of the wood to dry at a faster rate than the interior of the wood. This uneven drying causes stress which causes defects in the lumber. Proper air-drying or stacking wood inside a kiln away from direct sunlight, separate from the collector area, reduces uneven drying effects.

FIGURE 1 DEFECTS

SPECIES	HEARTWOOD	SAPWOOD
<u>Softwoods</u>		
PONDEROSA PINE	40%	148%
DOUGLAS FIR (Rocky Mountain)	30%	112%
WHITE FIR	98%	160%
REDWOOD	86%	210%
<u>Hardwoods</u>		
OAK-RED (Southern)	83%	75%
OAK-WHITE	64%	78%
BLACK CHERRY	58%	—
WALNUT	90%	73%

FIGURE 2 MOISTURE CONTENT

The drying period varies according to time of year, type, and thickness of the lumber and local climatic conditions. In kilns that have been operating over a 10-year period, it has been established that about 400 hours of direct sunlight on the collector area are needed to dry a full 1000-board-foot charge of wood. About 800 hours are typically received over the summer period with about 140 days of sun. At this drying rate, two charges can be dried each summer. Winter drying takes significantly longer.

The average initial moisture content differs for each type of green wood. Sawyers cut both heartwood and sapwood, softwood and hardwood. Drying time is about the same for all types. The higher the moisture content, the faster the rate at which it evaporates. As the content drops below 30% the moisture evaporates with greater difficulty and shrinkage occurs.

Air circulation in a passive solar kiln is generally around 25 cubic feet per minute. Temperatures rarely exceed 150°F. A commercial fossil-fired or wood-fired kiln is capable of producing temperatures of 200°F and evap-

oration air-flow velocities of 400 cubic feet per minute. For this reason, solar lumber drying has been referred to as gentle. Solar drying is dependent on the weather, and therefore drying time is not predictable; however, the operator can dry to meet individual moisture content needs. The volume of lumber dried can be increased by air-drying lumber to 15-20% and then putting it into the kiln to reduce the remaining moisture to the 7-8% range. If green lumber cannot be kiln-dried immediately, for economic, climatic or quality reasons, air-drying should be done with great care. Green wood must be end-treated and stacked properly. The stack should be under a protective awning. Green lumber that is to be kiln-dried immediately should also be end-sealed as soon after cutting as possible. Air-dried and green lumber, or varying thicknesses of lumber, should not be kiln-dried together because drying times vary.

A charge of wood must be properly stacked inside the kiln chamber to allow maximum benefit from air circulation. The lumber is stacked with uniformly-sized stickers between each course of lumber. Stickers or spacers are dry wood strips cut long enough to go across the entire course of a kiln charge. The stickers are generally

FIGURE 3 PROPER STACKING

FIGURE 4 DRYING RATE CURVE FOR CHERRY (○)
LOADED IN NOVEMBER AND ANOTHER
CHERRY (▲) CHARGE LOADED IN JULY

FIGURE 5 DRYING CURVES FOR 1 3/4" (▲) AND 8/4" (○)
THICK PONDEROSA PINE

$\frac{3}{4}$ " thick by $1\frac{1}{4}$ " wide. The stickers must all be the same size so that the drying lumber will be evenly supported. The stickers should be set about 24" apart on each course. Stacks should be at least 18" from the kiln walls, and for every 2-3' stack width there should be a 10-15" vertical space. The lumber should be 6-12" off the floor. Do not stack any lumber against the kiln walls.

Moisture content of wood varies according to location and species of wood. Generally, the moisture content of soft woods is greater than hardwoods. For these reasons, woods are dried differently in different regions. For example, in Arkansas where the humidity often approaches 70%, it is standard practice to air-dry lumber for a couple of months until the moisture content is reduced to 20%.

FIGURE 6 COMPLETED SKY MAP FOR 36°N LATITUDE

FIGURE 7 MERCATOR SKY MAP: WINTER SUN/SUMMER SUN

At that point, it is kiln-dried. New Mexico humidity is generally around 30% and green lumber is immediately kiln-dried to reduce defects. Furthermore, it is not uncommon to provide a *conditioning* cycle at the end of the drying process which returns moisture to the dried lumber. At this point steam is piped into the kiln chamber to provide additional *stress relief*. These drying methods are discussed further in the kiln design sections.

The wood industry measures moisture content with commercial meters and with oven-dried samples. Either or both of these procedures should be used throughout the drying process to determine individual kiln-drying requirements.

DESIGN FACTORS

The solar kiln design works well as a total passive system, but it is sometimes enhanced by adding appropriate mechanical aids. There are three design factors, each of which is essential for operating a successful solar kiln. Siting, Kiln Collectors, and Kiln Chambers.

SITING

Selection of the site on which to build a kiln is based on proximity to tree-cutting area, drying area, and wood-working area. In addition, a site must be chosen that offers maximum exposure to the sun's warming radiation. By plotting the *altitude* and *azimuth* of the horizon on a sky map you can locate areas that will be shaded or sunny. Keep in mind that the sun's *altitude* changes with the latitude and season, and both the altitude and the *azimuth* change throughout each day as the sun moves across the sky. For example, the sun's highest altitude is at 12:00 noon. At the New Mexico and Arkansas sites it is close to 78° in the summer and 30° in the winter. In southeast Texas the altitude is 82° in summer and 35° in winter. The sun's azimuth at 9 a.m. at a given site might be 40° east of south and, at 3 p.m., 40° west of south.

FIGURE 8 CONVECTIVE LOOP

You can plot objects on a sky map to help determine the altitude (or angle of the sun from the horizon) at any time of day or year. Stand on the prospective kiln site, face south, and follow the instructions with the handlevel beginning on page 15.

SOLAR KILN COLLECTORS

Solar kilns are dependent on heat collected from the sun's radiation. Two types of radiation provide this heat—shortwave visible light and longwave infrared rays. It is the infrared rays which provide most of the thermal energy used in solar heating. The infrared rays strike a collector surface and are conducted through the glazing material. The longwave nature of the infrared rays inhibits the escape of the rays back through the glazing. This creates what is referred to as a *greenhouse effect*. The heat is trapped and available in the collectors or a storage area for use in the kiln chamber.

Solar energy is used in either a direct or indirect manner. Air-drying lumber is a direct use of solar energy. Extensive direct gain should be avoided to circumvent lumber defects. Lumber is dried indirectly in a kiln. The kiln chamber may serve as a collector, but generally collectors are installed separate from the drying chamber. The heated air from the collector is dependent on the law of *convection* for transfer to the kiln chamber through vents.

Convection is a natural flow of air whereby cooler air sinks and warmer air rises. Solar collectors on the south side of the kiln absorb the sun's radiation. As the radiation heats air in the collectors, the air expands and rises. Cooler air from the kiln chamber replaces the heated air leaving the collector. This *thermosiphon* process continues as long as the collectors are exposed to the solar radiation.

A solar kiln design can be simply passive, or it can use active mechanical boosts to improve passive performance. A passive design is solely dependent on the local weather and may have wide temperature variations requiring careful venting. An active system can force heat into a storage area and/or deliver it to the kiln chamber when chamber temperatures drop significantly. Theoretically, an active system with storage can maintain a higher average temperature than a passive system without storage. The active system is more sophisticated but has a greater potential for failure to heat—particularly if the active components cannot be bypassed for total passive operation.

SOLAR KILN CHAMBERS

The kiln chamber should be designed to minimize heat losses. An ideal chamber is framed in wood, fully insulated and caulked. Although some kilns have been built on concrete slabs, this is not recommended. Even well insulated slabs have significant heat losses. Concrete mass also absorbs the solar heat intended for drying

FIGURE 9 OZONE KILN -- COLLECTOR AND ROCKBED STORAGE SECTION

the lumber and does not release it at a rate suitable for kiln drying.

Floor framing should be able to support a full lumber charge. Maximum collector area is 1 square foot for each 10 board feet to be dried. If this formula provides too much heat for given conditions, a portion of the collector area can be shaded.

Overheating can melt plastic fans or other mechanical parts. An empty solar kiln should always be left open and vented. Temperatures in an empty kiln can reach a potentially dangerous 200°F. A charged solar kiln tends to stay in the range of 80-140°F.

Each of the three kilns to be reviewed meets individual preferences. The objective of each is to provide a gradually changing environment to reduce the moisture content of green lumber to a 6-8% range and produce high quality lumber.

OZONE KILN -- NORTH VIEW OF LOADING DOORS

FIGURE 10 PROTOTYPE FOR THE EUREKA SPRINGS KILN
 -- HEATED AIR FROM BOX COLLECTOR IS FORCED INTO THE CHAMBER

SOLAR KILN DESIGNS

THE OZONE KILN

The Ozone Kiln is an active solar dryer. The rectangular structure is of wood siding on stud framing. The collector area covers almost the entire southern facade of the kiln area. The *flat plate* collector surface is double-glazed and vented into a rock-bed storage area. The collector area is supported by plywood behind which additional vents and fans are located.

As a general rule, a solar kiln collector inclination is equal to the latitude of the site plus 10°. In this case the kiln was over-designed at 51° to provide higher temperatures in winter months. Ozone's latitude is 36°. The kiln has a 1500-board-foot capacity and is loaded through four large doors on the north side of the kiln chamber. As this manual goes to press, the first charge is in the kiln and when dried will be used in cabinet work and furniture-making at the same site.

The kiln is 12' x 20' x 6' and sits atop a rock mass of 6' x 20' x 5'. The 1¼" rocks are contained in an insulated concrete masonry bed which also serves as the foundation for the kiln. Thermal heat is accumulated through the collector area. The heat is drawn off the top of the collector and forced through three vents (two with blowers) into the rock bed for storage. Blowers are activated when the collector air is 10°F above the storage

FIGURE 11 BOX-TYPE COLLECTOR

area. Four 12" x 16" vents dump heated air into the drying chamber from the storage area. Each vent has a 1/5 hp blower which has a capacity for moving 1000 cubic feet of air per minute. Each blower is controlled by a thermostat and will begin operating when the storage area is 80°F or above.

The kiln design temperature range is 80-140°F. The collector surface area is 20' x 8' and was over-designed in order to maintain drying temperatures at the top of this range. In the winter months, with poor climatic conditions, the rock bed storage area has been maintaining an average temperature of 80°. It is assumed that summer temperatures will be significantly greater, thus drying time for summer charges will be much shorter.

The advantage of the storage capabilities is reflected in this 80°F temperature. Without storage, given the same conditions, the temperature of the air in the kiln could drop significantly lower than 80°F and the drying time would be greater. It is assumed, although the first charge is still in the Ozone Kiln, that the active system will shorten the drying time compared to that required in a totally passive kiln.

The designer of this kiln dries hardwood which has an initial moisture content much lower than soft woods. The lumber is air-dried to a 20% moisture content at which point it is put into the solar kiln. Since it has been air-dried, all vents are left wide open as soon as the kiln is charged. As the moisture content of the lumber approaches the desired 6-8% content, the vents are gradually closed. This prevents outside moisture, often 50% or more, from entering the kiln and reversing the drying process. Closing vents also produces higher temperatures necessary in the final drying stage.

THE EUREKA SPRINGS KILN

The Eureka Springs Kiln is a design aided only by circulation fans. After much reading, and some experimental design and construction work, the final design decisions were made. The kiln is up on posts and was designed with portability in mind. It would be possible to remove the collector from the kiln chamber and transport each piece on a flatbed truck.

The 8' x 12' kiln looks very much like the Ozone Kiln and also operates on the convection theory. The box-type collector has a 45° angle for optimum radiation in winter as well as summer.

The box-type collector looks like a box cut diagonally. The collector has three wood-paneled wall surfaces (painted black) that absorb the sun's heat when situated toward the south. The fourth surface or floor of the col-

lector is tin, painted black. The designer suggests that all the collector surfaces should be metal for a higher heat absorption rate. The four surfaces of the collector reflect heat to one another that might otherwise be lost off a single collector surface. The result is more heat for drying. The collector area is 100 square feet glazed with fiberglass sheeting, set on a stud framework and sealed with a silicone caulk.

EUREKA SPRINGS KILN
-- VIEW OF INTERIOR

Vents are cut into the south floor and upper north wall of the collector. Solar heated air circulates through top vents into the kiln, releases heat in the drying chamber, and returns to the collector for reheating. Each vent is 15-20" long and enables uniform air distribution along the length of the kiln chamber. The convection is aided by three 12" 1/40 hp fans which require minimal electricity. The fans aid air circulation which is essential for carrying off moisture and providing an even drying environment. The kiln chamber is fully insulated to reduce loss of the heated air coming from the collector.

The Eureka Springs Kiln chamber has two 4" x 10" floor vents to the outside. When green lumber is dried, the vents are kept closed during the first week or so. High humidity created by this closed system reduces checking of the green wood. After this initial high humidity period the vents are opened to decrease humidity and increase drying rates. The vents are located between two stacks of wood and, once they are opened, cause a draft from the collector. This draft speeds up the drying process. The designer recommends a screen for the vents to keep out rodents.

FIGURE 12 SAN JUAN KILN -- CROSS-SECTION
SHOWING LUMBER CHARGE, COLLECTORS,
HEADERS, VENTS AND STEAMPIPE

This kiln successfully dries 2000 board feet of 1¼" white and red oak to 7% moisture content in 6 weeks. The drying time will vary—longer in winter and shorter in summer. The drying time can range from 30 days to close to 5 months depending on climatic conditions. On an 80°F day the Eureka Springs collector temperature rises to around 130°F.

THE SAN JUAN KILN

The San Juan Kiln is a passive design in the purest sense. The kiln has no mechanical equipment and operates totally by natural convection. To provide stress relief a wood-fired steam generator is stoked up.

The San Juan Kiln produces a more desirable dried lumber than that available from commercial sources and produces it at a fraction of commercial costs. The kiln is at the same site as the designer's woodworking business. The lumber is used for furniture and cabinet manufacture.

The kiln chamber is 8' × 16'. It has a capacity of over 1000 board feet and is loaded through a large door on either the east or west end. The black corrugated metal roof slopes sharply to the south. The walls and floor are 5/8" exterior grade plywood with the exception of the south wall which is black corrugated metal. All except the south wall are insulated with 3" rigid foam.

The four collector boxes are each 3' × 6' and are situated at the lower south side of the kiln chamber. The total collector area is 72 square feet. Each box is made of exterior grade plywood and has two compartments. The lower compartment is for cool air flowing from the kiln. The air *loops* around into the upper compartment where it is heated by the collector. The collector is a series of aluminum beverage cans cut in half and mounted on a thin aluminum sheet made from used offset printing plates. Both are painted black.

The natural thermal loop continues into the drying chamber. A sheet metal header duct channels heated air into the top southern area of the kiln. This header creates a down-draft into the drying area. The air circulates through the lumber and returns to the collector area at the lower south end of the chamber. The header could be modified if the collectors were located at a higher position on the southern chamber wall.

Four wall vents were constructed at the upper portion of the north wall opposite each collector on the lower, south wall. These vents are larger than the collector inlets and encourage rapid release of excess humidity and heated air.

New Mexico woodworkers often use soft wood, such as ponderosa pine, which is kiln-dried slowly to a 30%

moisture content for about 5 days. During this period all vents and doors are sealed shut. This period causes the greatest degree of stress in the lumber and care must be taken to gradually reduce the moisture content. The vents are then opened slightly to allow exhaustion of some of the humid, warm air. This level of venting is maintained until a 20% moisture content is reached. At 20% the vents are gradually opened wider and the process is allowed to accelerate. Natural stress reversal occurs during the 20-15% period so very gradual adjustments should be made in venting and humidity change during this period.

SAN JUAN KILN -- THE STEAM GENERATOR

The stress that occurs during drying may cause warping or splitting during resawing, ripping, or non-uniform machining operations. The San Juan kiln has a wood-fired steam generator made of adobe bricks, mud mortar, a 50-gallon barrel, and ½" rigid copper tubing. This steam generator is used during a final phase of the drying process if the lumber charge is to be machined. The lumber to be conditioned is allowed to dry to 4-5% moisture content. Steam piped from the drum to the drying chamber allows the moisture content of the lumber to return to the desired 6-8%. The surface cells of the lumber swell, relieving stress in about 6 to 8 hours.

The intent of the San Juan Kiln designers was to construct a natural convection kiln at the least possible expense. In this instance, fancy materials did not mean a better quality end product. A natural convection system made with some materials at hand made the construction project financially feasible. The most rewarding outcome of the kiln project, however, has been the continual high quality of the lumber that is dried. *Regardless of the energy and monetary savings, the designers feel that this high quality lumber alone justifies use of a solar kiln.*

ECONOMICS

The potential for self-sufficiency and control of economic factors is great for the woodworker or sawyer

drying lumber in a solar kiln. Thomas Bangert, who makes quilting frames, equated savings in real terms which are shared here:

IN ONE QUILTING FRAME THERE ARE 30 BOARD FEET OF WOOD.	
I BUILD THEM OUT OF OAK:	
\$.20 a board foot (green)	
x 30 board feet	
\$6.00 in wood bought locally at Sept. 1980 prices	
\$1.75 a board foot (commercially dried)	
x 30 board feet	\$52.50
\$52.50 in board bought from retail lumber dealers at Sept. 1980 prices	- 6.00
	\$46.50 is the savings per frame

Payback of the cost for solar kiln materials will vary, of course, according to the capital outlay. In Bangert's case the capital expense was \$700 which included an old A-frame which was torn down and recycled. The A-frame provided much more material than was needed. His kiln will dry 1500 board feet per drying charge. Bangert recovered his \$700 total investment with the first 450 board feet he dried. Thereafter, each time a load of oak is dried he will save \$2325 at September 1980 prices. This is a significant incentive for constructing a solar lumber kiln and one way to increase profit margins.

In one of the kiln projects, 300 board feet of solar kiln-dried wood was given to local woodworkers to be used in traditional projects. The woodworkers each stated that the wood was the best quality they had ever worked with. Each filled out a rating sheet marking drying defects found in the lumber. Out of a possible 425 points only 26 defect points, or 6% of the lumber, had experienced flawing. This 6% was within an acceptable defect range and did not reduce the value of the lumber.

By adding collector area and proper venting to any of the three kilns described in this manual it is assumed that board foot capacity could double. Climatic conditions and lumber dimensions would still be variables in the drying time period. With a little experimentation the on-site kiln could be designed to be productive for a small commercial business facility.

The U.S. Department of Energy funded a 50,000-board-foot capacity kiln in Canton, Mississippi which has 2500 square feet of collector area, a 5000-gallon water heat storage tank and finned pipe exchanger. Solar provides 40% of the heating requirements for drying the wood. This is significant in that, for each 1000 board feet, a commercial fossil-fueled kiln requires 200 kWh of electricity and 6 million Btu of gas heat.

Another 25,000-board-foot commercial kiln is located in Louisiana and has 2 box-type collectors. This kiln dries wood in only twice the commercial time at a considerably lower cost.

The proportion of collector area to board feet is 1 square foot of collector to each 10 board feet to be dried. This proportion provides for maximum collector ability during winter months and maximum thermal gain necessary for drying hardwoods. In commercial use, the ability to dry lumber throughout the winter is critical, so this proportion should not be compromised. Total commercial solar drying might not be as practical as in a small-scale drying operation. When drying commercially, solar could be a partial heat source. The solar could be used as a primary or secondary source with a backup in either instance of wood waste, gas, or other fuel.

THERE ARE MANY ADVANTAGES TO SOLAR LUMBER DRYING

- Solar energy can be used in remote areas where traditional fuel sources are not available.
- Desirable quality of the final product.
- Savings in fossil fuels and expenses for purchasing these fuels.
- Pollution reduction.
- Increased profit margins for businesses.
- Continued operation during power outages or shortages.

COMPARISON OF KILNS

KILN/COST	USE	ACTIVE/ PASSIVE	CHAMBER CAPACITY	COLLECTOR SQ FT
OZONE, AR \$5000	HARDWOOD FOR FURNITURE AND CABINET WORK	ACTIVE: 1/5 Hp BLOWERS WITH ROCKBED STORAGE	1500 bd ft DRYING TIME NOT YET AVAILABLE	160 SQ FT FLAT PLATE COLLECTOR
EUREKA SPRINGS, AR \$700 WITH RECYCLING	HARDWOOD FOR BUILDING FRAMES	ACTIVE: 1/40 Hp FANS ASSIST CONVEC- TION	1000 bd ft DRIED IN AS LITTLE AS 1 MONTH	100 SQ FT BOX COLLECTOR
SAN JUAN, NM COST NOT AVAILABLE	SOFT WOOD FOR FURNITURE AND CABINET WORK	PASSIVE: STEAM GENERA- TOR AND NATURAL CONVEC- TION	1500 bd ft DRIED IN AS LITTLE AS 50 DAYS	72 SQ FT FLAT PLATE COLLECTOR

* COSTS ARE APPROXIMATE AND VARY GREATLY
ACCORDING TO DESIGN

There is no one correct kiln design. Each project has its unique design specifications and designers are encouraged to create and improvise.

REFERENCES

For more information about solar lumber kilns and solar energy in general, here are some suggested materials:

Air Drying of Lumber, A Guide to Industry Practices, Agriculture Handbook No. 402, USDA, Forest Service, Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

Constructing and Operating a Small Solar-Heated Lumber Dryer, Forest Products Utilization Technical Report No. 7, Paul J. Bois, USDA, Forest Service, Madison, Wisconsin, 1977.

The Do-It-Yourself Solar Handbook, A Step-By-Step Guide to Solar Water Heater Construction and Installation for Hawaii, State of Hawaii, Department of Planning and Economic Development, January 1981.

Dry Kiln Operator's Manual, U.S. Department of Agriculture, Forest Service, Agriculture Handbook #188.

Removal of Water from Wood, Jay A. Johnson, Forest Products Research Society, 2801 Marshall Court, Madison, WI 53705.

Solar Remodeling in Northern New Mexico, New Mexico Solar Energy Association, 1372½ Cerrillos Road, Santa Fe, NM 87501.

Additional Information:

Alexander, John; Walnut Fork Design, Builders, and Woodworking Company, Inc., Walnut Route, Ozone, Arkansas 72854. Telephone (501) 428-5822.

Bangert, Thomas; Prairie Woodworks, P.O. Box 464, Eureka Springs, Arkansas 72632.

Vincent, John R.; P.O. Box 32, San Juan Pueblo, New Mexico 87566. Telephone (505) 852-2506.

U.S. Forest Products Laboratory; P.O. Box 5130, Madison, WI 53705.

Arkansas Forestry Commission, P.O. Box 4523, Little Rock, Arkansas 72214. Telephone (501) 664-2531.

New Mexico Forestry Division, P.O. Box 2167, Santa Fe, New Mexico 87503. Telephone (505) 827-2312.

Oklahoma Forestry Division, 122 State Capitol, Oklahoma City, Oklahoma 73105. Telephone (405) 521-3886.

Texas Forest Products Laboratory, P.O. Box 310, Lufkin, Texas, 75901. Telephone (713) 632-6666.

NOTES

PLOT A SKY MAP

1. A solar kiln can be located at an azimuth up to 30° east or west of true south with true southern orientation being the most ideal. To find true south you must first locate magnetic south with a compass. True south will vary according to site. At the New Mexico site true south is about 13° east of magnetic south. At the Arkansas site it is 7° east of south and in southeastern Texas true south is $7\frac{1}{2}^\circ$ east of magnetic south. Variations occur at each locality and change with time. Aviation maps can be a resource for this information.
2. Attach a plumb bob at the designated spot on the handlevel.
3. The horizon consists of the tallest objects you see as you face true south. Plot the angle of these objects. Look over the handlevel to the highest point true south. The plumb bob will designate the angle of the object. Plot this angle on the sky map at the correct azimuth.
4. Plot the horizon at azimuths of 15° increments both east and west of true south.
5. Connect the points you plotted with a dotted line. The prospective kiln site will be sunny at the time indicated above the solid line or dotted line, whichever is highest. Keep in mind that trees grow, deciduous trees lose leaves in winter and the angle or altitude of the sun from the horizon changes seasonally.

SKY MAP TO BE USED FOR SITES IN ARKANSAS
AND NEW MEXICO AT 36° N LATITUDE

WORKSHEET

SKY MAP TO BE USED FOR SITES AT 32° N LATITUDE

HANDLEVEL

ATTACH A WEIGHT
AT THIS POINT

SIGHT ALONG THIS TOP EDGE

DIRECTION THE
COMPASS POINTS

TRUE
SOUTH

DO NOT MICROFILM
COVER

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