SIMPLE SOLAR HEATED TIMBER DRYERS: DESIGN, PERFORMANCE AND COMMERCIAL VIABILITY

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ABSTRACT

The general performance of solar heated timber drying kilns is discussed and their advantages and disadvantages compared with air drying and conventional kiln drying, in particular their ability to dry timber down to moisture contents suitable for immediate use for furniture and joinery manufacture and the high quality of drying with difficult woods. Different kiln designs are discussed and volume capacity and absorber area/ timber volume ratios are given for a number of kilns described in the literature. The design and operation of a small low cost kiln built at Oxford† which can be made up from a kit is described in more detail. Simple costings are included for the kiln.

Introduction

Wood shrinks as it dries below about 30 per cent m.c. (fibre saturation point). Above f.s.p. water is removed from the cell cavities but the walls are saturated; below f.s.p. the cell lumens are empty and water is removed from the walls causing the wood to shrink; because of the arrangement of matter in the walls and the arrangement of the cells in the wood the shrinkage is different in the radial, tangential and longitudinal directions in the tree. This differential shrinkage may cause distortion of the wood and if joinery or furniture is made from wet wood which later dries out, gaps will develop and distortion may occur. These facts have been well known by those who worked in wood for many centuries; the heat from the sun has been used for thousands of years to dry timber and until relatively recently the only method of drying timber was air-drying. What is not so widely appreciated is that air-drying by itself is seldom, if ever, sufficient to dry timber to a moisture content where it can safely be used for good joinery or furniture work within a building. The equilibrium moisture content of wood dried in an open shed or under stack covers in a yard is normally 5-8 per cent above the e.m.c. of wood in a closed building in the same climate. Air drying in Britain, for instance, dries timber to 17-18 per cent m.c. but the e.m.c. inside a non-centrally heated building is about 12 per cent and in a centrally heated building 8-10 per cent. In a country such as Uganda, on the equator, the higher humidity and temperate change the situation very little and the equivalent figures are 17-20 per cent in the shed, according to season, and 12 per cent inside a closed building. The same is true for most highly populated areas of the world where the climate is not arid. For timber to be used for many structural purposes, as in a roof truss, this difference in moisture content is not critical but the 5-8 per cent difference is extremely important for joinery and decorative uses such as furniture, since it represents about a third of the total shrinkage from 30-12 per cent m.c. Before the days of kiln drying the good carpenter kept his timber for a long period after normal air drying, within his workshop often in a loft, which was warmer and drier than the main shop, and which completed the drying process. In the last hundred years or so the drying of timber has been speeded up by the development of drying kilns which are merely chambers containing the wood in which temperature,

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† Three elm doors were recently fitted in an extension to a cottage; we learn that the timber for these was dried to 14 per cent in the above kiln and that after four months all was well. [Ed.]

humidity and air circulation are controlled to give the fastest possible drying consistent with an acceptable quality of dried timber. The rate at which the wood can safely be dried is dependent on how fast it is possible to get water to move from the middle of a piece of wood to its surface without damaging the wood in the process. The rate of drying varies with the dimensions of the timber, the structure and nature of the wood and its permeability to water movement. Oak, for instance, takes five to ten times as long to dry as pine and many tropical woods are heavy, hard and difficult to dry although the high quality furniture and joinery woods, such as the Mahoganies, Teak, the Merantis and Iroko are relatively quick and easy to dry. In the cases of Teak and Iroko their very low percentage shrinkage on drying has contributed to their stability and popularity.

Solar kilns

Solar timber drying kilns merely apply the principles used in a greenhouse to the drying of timber where heat is trapped inside a structure glazed with a material which is transparent to short wave radiation (light) and non-transparent to longer wave radiation (heat) and which at the same time reduces heat loss by conduction and convection. The differences between a greenhouse and a solar kiln are, however, important and are as follows:-

1. A solar kiln needs to trap as much heat as possible whereas a greenhouse does not.
2. Air circulation is essential in a solar kiln to remove water from the wood surface whereas convection gives sufficient air circulation in a greenhouse.
3. Temperatures increase and humidity decreases in a solar kiln as the timber dries whereas, in a greenhouse, the more constant they remain the better. Low night or high day temperatures are less critical in solar kilns provided humidity is right.

Solar kilns have been built and tested in a number of countries. Probably the most recent and comprehensive literature review on the subject is contained in Tschernitz and Simpson (1977).

The kilns built have varied considerably in size and design but most have been modifications of a simple greenhouse-type structure while one Australian kiln has used separate solar collectors to heat a conventional seasoning kiln thus replacing artificial heat with heat from the collectors.

With few exceptions the kilns have been research kilns: many have worked quite satisfactorily on a research scale but few, if any, have found their way into commercial use. The reasons for this may be many but the following are some of them:-

1. Most kilns have been built in countries where the demand for properly seasoned timber is small and the supply tends to be met by the largest suppliers who often operate conventional kilns with a relatively large throughput.
2. In developed countries the climate is often unsuitable for about half the year and most large concerns require high and continuous throughput.
3. The structures which have been built, while being relatively cheap and easy to construct compared with conventional kilns, are nonetheless rather too complicated to build, particularly in developing countries, for the small sawmiller, or joinery or furniture workshop.
4. Both conventional kilns and greenhouses have been available in kit or prefab form with instructions on how to build them. Solar kilns have not.
5. There have been fears that solar kilns, as well as being slower than conventional kilns, are also less controllable, and therefore, produce an inferior product.
6. There has been a lack of appreciation of the major difference between air drying and solar drying which is not that solar drying is quicker, which it is, but that with it it is possible to dry timber to an equilibrium moisture content of 8-10 per cent, even in Britain in summer, whereas, as mentioned above, the e.m.c. achieved in air drying is almost always above the moisture content required inside a closed building. It can, therefore, do the whole job of a conventional kiln, whereas air drying cannot.

7. Suitable durable materials for glazing the kilns have been difficult to obtain. The plastics have problems of strength, durability and optical properties and glass is heavy, expensive and requires a complicated supporting framework. All are, to some extent, fragile but glass is rather more easily broken than the plastics.

Characteristics of solar kilns

The characteristics of solar kilns, as reported in the literature when used in the tropics, or in summer in temperate climates, are quite surprisingly similar if the very small ones (with a capacity of under 1½m^3 (50ft^3) of sawn timber) are ignored as being atypical and not attractive commercially.

They are as follows:-

1. Drying from green to 12 per cent m.c. takes 2-3 times as long as in a conventional kiln (operating at temperatures below boiling point).
2. Drying is normally about twice as fast as air drying down to 20-25 per cent m.c. but thereafter is much faster and e.m.c.s obtained vary between 6 and 12 per cent.
3. Quality of drying in solar kilns is high for the following reasons:-
   (a) General rate of drying is slow compared with conventional kilns.
   (b) Daily variations in temperature are larger than with air drying but variations in humidity are much lower; humidities are relatively high during the critical drying period at moisture contents just below f.s.p.
   (c) Humidities in the solar kilns are around 90-100 per cent overnight, until moisture content of the charge is below 18-20 per cent, and the timber has a mild 'reconditioning' treatment every night. This is much more pronounced in a plastic covered kiln than in a stack of timber which is air drying, and the kiln conditions are thus very different from the conditions for air drying although this is not immediately apparent. The smaller solar kilns which contain small volumes of timber in relation to their total volume and their surface area, tend to produce more severe drying conditions in the middle of the day than do the larger kilns. This results in case-hardening and other defects but the larger kilns do not appear to suffer from these defects if correctly vented.

Table 1 lists some of the main solar kilns which have been built. Publications describing them are listed in the bibliography.

Wengert (1971) studied the performance of the Troxell and Mueller kiln (see Table 1) and assessed heat losses from different surfaces of the kiln.

Design of the Oxford kiln

The writer operated two solar kilns in Uganda for 7 years; after an initial period of research they were used to dry Iroko timber for furniture manufacture by the Ministry of Works. The operation of the kilns was satisfactory and the quality of timber dried was good but the structures were double glazed with 'Mylar' weatherable film (a clear polyester material) which was expensive and difficult to get. It lasted for about 6 years, at an altitude of 1100 metres on the equator. The structures were also fixed and trolleys and rails were necessary to load timber into and remove timber from them. They were, therefore, quite expensive and double glazing has been found to be of very limited benefit. Double glazing gives some benefit overnight but during the day the reduction of radiation entering the kiln due to the second layer is often greater than the heat retained by the double layer.

The Oxford kiln has been designed to use a single glazing of horticultural grade polythene placed as simply as possible over a stack of timber. Two 24 inch fans driven by two 0.25 hp electric motors are used to circulate air over a black painted corrugated metal absorber and through the timber stack. The capacity of the kiln is 200-250 ft^3 (5.7-7.1 m^3) of sawn timber.

TABLE 1

SOLAR KILNS CAPACITY AND ABSORBER AREA/TIMBER VOLUME RATIO

Kiln	Capacity		Absorber area/volume ratio	
	m^3	ft^3	m^2/m^3	ft^2/ft^3
Johnson (USA)	0.93	33	3.64	1.11
Peck (USA, Wisconsin)	1.00	35	8.86 (roof + walls)	2.7 (r+w)
Peck and Maldonado (Puerto Rico)	4.8	170	2.89	0.88
Chudnoff (Puerto Rico)	7.14	252	2.62	0.8
Terazawa (Taiwan) Tchernitz and Simpson	5.00	177	no collector	no collector
Plumptre (Uganda 1)	3.3	117	1.67	0.51
Plumptre (Uganda 2)	13.0	459	2.62	0.8
Troxell and Mueller (Colorado, USA)	2.8	99	?	?
Casin (Philippines)	1.1	39	3.15 (roof only) 10.8 (roof and walls)	0.96(r) or 3.3 (r+w)
Sharma (India, Dehra Dun)	4.3	152	2.76	0.84
Read and Choda (Australia)	6.4	226	8.86 (separate collector units)	2.7
Gough (Fiji design to be built)	12.0	424	5.91 (roof and walls)	1.8 (r+w)
Plumptre (Oxford 1)	7.1	250	3.77	1.15
Aleon (France)	5.0	175	3.31	1.01
Tchernitz and Simpson (Madison, USA)				
1. Prototype	2.4	83	8.07 (separate collector units)	2.46
2. Design for Philippines	9.5	333	8.07 (separate collector units)	2.46

The general principles of the kiln operation are shown in Drawing 1. The kiln consists of a 'lean-to' structure containing the fans in a 16 × 4 ft plywood baffle which is roofed with black corrugated metal and connected by five rafters pinned with bolts to a 'truss' sitting on top of the stack; the stack is also covered by a layer of black corrugated metal sheet but separated from it by a layer of insulating material. The structure thus formed has a polythene cover in which doors and vents are made using 'Velchro' stapled to the polythene: the roof can be guyed down to tension it and the sides and floor of polythene are folded into each other and buried in a shallow trench dug around the kiln. The cover and truss can be simply removed for unloading and reloading, the cover can be easily and quickly renewed. The kiln parts are portable, using four people, to a new stack and can be reused there, provided there is an electrical supply at the new site. It is probable that the kiln would be most effectively used in drying stacks which had first been partially air dried although it has not as yet been used in this way.

The whole intention of the design has been to produce a kiln which is cheap and easy to build rather than one which is sophisticated and costly.

Photographs of the experimental kiln now in operation are shown in Plate 1.

Performance of the Oxford kiln

The kiln has been developed over the last 3-4 years and has been used largely for drying 2 and 3 inch oak for reconstruction work in Magdalen College, Oxford. The timber is cut from the College's own woodland. During 1976 summer two inch (5 cm) thick oak dried from over

40 per cent m.c. to 10-12 per cent in four months and during 1977 a fresh charge of oak dried from 60-100 m.c. in June to 12-14 per cent in October (5 months). This compares with normal drying practice of 6 months air drying and 1½ months kiln drying for two inch oak.

The quality of drying was, on the whole, very good, with little or no surface checking and only slight distortion. The 1977 charge which was started at the hottest time of the year was slightly case-hardened probably due to the fact that vents were opened too much too early but end split and collapse were slight. The college however, used the 1977 timber, expressed itself as satisfied with the quality of it and paid for a new kiln to be built in 1978. A student has been working during 1978 on kiln performance and heat gains and losses in the two Oxford kilns but no attempt is made here to summarise his work.

The 1978 kiln has been built from a kit designed to send out to purchasers in as compact a form as possible. The purchaser is left to buy his own timber for the frame of the structure and corrugated metal roofing sheet for the black painted absorbing surface. This kiln has performed well throughout both summer and winter drying oak timber for Magdalen College and a second has been built and used by a nearby estate to dry elm timber successfully during the summer. The kilns in Britain have withstood the gales and snow of the 1978/79 winter without any deterioration of the main structure and very little other than slight stretching of the polythene. In May 1979 a kiln was erected in Dominica for tropical trials and is being used to dry Gommier (*Dacryodes excelsa*) and a further two are being built in Tanzania.

The main problems in the tropics will be to determine the length of life of the polythene and the ability of the motors to stand up to the higher temperatures. The motors are, however, high-temperature wound and there should not be any problem with overheating but this needs to be proved. The cost of the kits is approximately one tenth of the cost of a prefabricated conventional kiln of the same capacity. Costs of construction and operation depend very much in Britain on labour costs; the costs given in Appendix 1 give very rough estimates for tropical countries based on experience with previous kiln designs in the tropics. The estimates for this country are based on rather more reliable figures but little work has been done with softwood. Very little supervision of the kiln is required; two man hours per week for checking kiln operation and moisture content testing is normally all that is required. This is an advantage in Britain where labour wages are high while the simplicity of operation and supervision is an advantage in the tropics.

The length of period during which drying to 12-14 per cent is possible is restricted in Britain to the period from April to October. During the rest of the year the kiln is moderately efficient in removing water from green timber, but probably not very much more efficient than normal air drying, and during that period of the year the e.m.c. in the kiln would be higher than 12-14 per cent m.c. During summer, maximum day temperatures in the kiln are about 15°C above ambient shade temperatures and at night minimum temperatures 3-8 per cent above ambient temperatures. Both night and day temperatures in the kiln depend on the moisture content of the wood and the humidity in the kiln as would be expected.

In Britain the main application for these kilns would seem to be for the small timber user or producer who wants to dry small quantities of timber himself rather than send it away to be dried at considerable cost in transport and drying charges. In tropical countries the application could be more widespread since the conditions are more favourable and the size of operations often smaller than in this country. The quality of drying compares very well with the best commercial kiln drying and solar kilns can, even in Britain, prove to be a commercially viable operation where quantities of timber to be dried are small and particularly where slow drying or 'difficult' woods need to be dried. Clearly larger quantities of timber can be dried in batteries of solar kilns but the area of land required would be greater than for commercial kilns. Kits of the Oxford kiln are now being offered for sale commercially or alternatively drawings and building instructions alone are being offered which assume that the purchaser can supply tools and materials himself. The kilns are, however, still experimental and unproved as far as the tropics are concerned. Meanwhile further research is being carried out to improve the performance and durability of the present model, without appreciably increasing its cost, and to try out new designs.

General considerations in solar kiln design

The advantages of solar kilns are therefore, high quality drying particularly for woods that are slow and difficult to dry, low initial cost, low running cost, low cost of supervision and low level of skill required to operate them. They are simple to erect and are energy-saving. Their disadvantages are that they are slow compared with conventional kilns and dependent on the weather. They also take up a larger area of ground than conventional kilns. There is, of course, no reason why batteries of solar kilns should not be used just as is the case with conventional kilns provided there is a sufficient area of land to accommodate them. They cannot, in Britain, give a steady supply of dried timber but in the tropics should do so except where wet seasons have long periods of dull, cloudy weather.

Clearly they can be made more efficient but if they are to be used in developing countries in the tropics low cost, simplicity of construction and reliability are probably more critical than efficiency and speed of operation. They also need to be available, if possible, in different sizes to suit different needs.

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APPENDIX 1

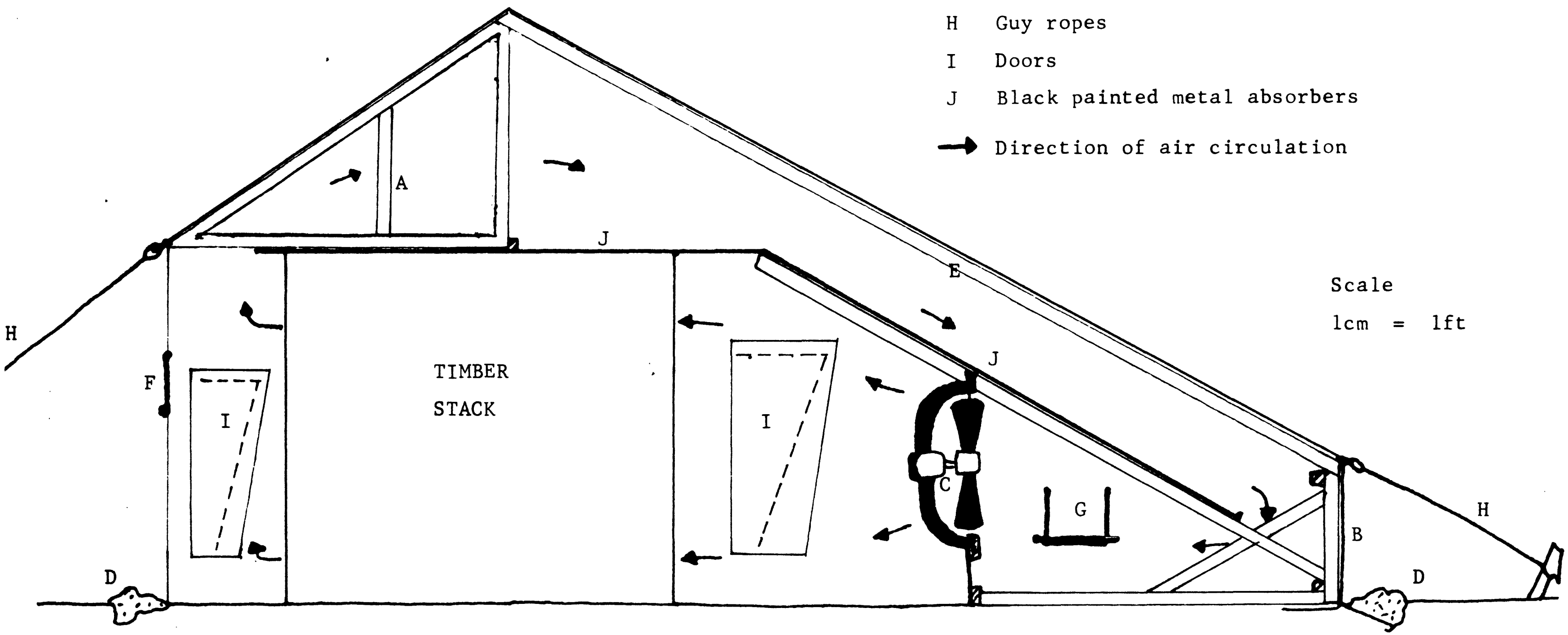
Oxford Solar Kiln Costs at 1/1/79

		£
A.	Costs in Britain (assumes a 5 month drying period only)	
	Capital Costs including kit plus parts and spare cover; 16 man days at £15 per day for building	1100
	Depreciation per annum (main structure over 5 years and polythene over one)	260
	Kiln capacity 7.14m^3 (250 ft^3)	
	Operating costs for 2 inch oak; assuming drying takes 5 months, including electricity, erecting and renewing polythene cover (8 man days), supervision and maintenance and depreciation	428
	Unit Costs for 2 inch oak per cubic metre £59.9 per cubic foot £1.71	
	Operating Costs for 1 inch Pine in U.K. assuming drying takes 3 weeks	97
	Unit Costs for 1 inch pine per cubic metre £13.60 per cubic foor £0.39	
B.	Costs in Tropical Developing Country (assumes 12 month operation)	£
	Capital Cost allowing 25% extra for transport and £6 per day wages	1231
	Depreciation per annum (polythene over 1 year and main structure over 5)	286
	Operating Costs 2 inch mahogany (2 months drying) Labour (£4 per day), depreciation, electricity, supervision and maintenance	104
	Unit Costs per cubic metre £14.06 per cubic foot £0.42	
	Operating costs for 1 inch softwood (2 weeks drying)	37.5
	Unit Costs per cubic metre £5.25 per cubic foot £0.15	

Drawing 1 SOLAR KILN

Side View

A Main roof support truss
B Front of kiln
C Fan assembly and support for absorber
D Trench for anchoring polythene sides of kiln
E Rafters pinned to A and B
F Rear vent
G Side vent
H Guy ropes
I Doors
J Black painted metal absorbers
→ Direction of air circulation



Scale
1cm = 1ft