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CONSULTANT IN SOLAR ENERGY WOOD DRYING

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URUGUAY

Technical report: Evaluation of a demonstration solar wood drying kiln, the potential for solar wood drying and proposals for wood processing research and extension in Uruguay*

Prepared for the Government of the Republic of Uruguay
by the United Nations Industrial Development Organization

Based on the work of D. K. Gough,
consultant in timber drying

Backstopping Officer: R. M. Hallett
Agro-based Industries Branch

* This document has not been edited.

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INTRODUCTION

Mr D K Gough, Consultant in wood drying, undertook the mission from 14 to 29 August 1991.

The terms of reference dated 7 August, 1990 proposed that the Consultant would design an appropriate solar wood drying kiln to be built at the Cerro Colorado Timber Enterprise. He would specify the materials required for construction and the laboratory equipment required for moisture content testing.

The consultant would then depart the country while the kiln was being built, leaving a workplan and details for initial trials. He would return for a second period to evaluate the kiln operation and present a seminar on timber drying, possibly in conjunction with a promotional event to show products made from solar dried wood.

Due to delays in finalising the appointment of a Consultant, the National Counterpart for the project, Mr Carlos Meyer, in the intervening period, made a study tour of forest products laboratories in France, England and the USA. He returned with a design for a small solar kiln from the Virginia Polytechnic Institute, which he built at the Rubina Agricultural Research Station, on the outskirts of Montevideo. This kiln was completed in May 1991 and the second charge of timber was nearing the end of its drying period when the Consultant arrived on 18 August, 1991.

At that stage, a revised program of work was developed as follows :

1. Evaluate the kiln construction and its operation, taking temperature readings and air speed measurements.

2. Propose a schedule of drying trials.

3. Visit some of the sawmills and timber seasoning operations in Uruguay to determine the potential for solar wood drying.

4. Propose kiln designs for industry use.

5. Present a short seminar on timber seasoning with particular reference to solar wood drying.

6. Propose the institution of a Wood Processing Research and Extension Service in Uruguay.

ACKNOWLEDGMENTS

The duration of this consultancy was relatively short. Nine days were spent in Uruguay and apart from time spent in evaluating the demonstration solar kiln, valuable discussions concerning forestry, sawmilling, the wood using industries, timber seasoning, the potential for solar wood drying kilns and the need for a wood processing research facility were held with the following :

Mr Antonio Santin	Santin Carpinteria
Mr Alberto Voulminot	Industrias Forestales
Mr Enrique Voulminot	Industrias Forestales
Mr Carlos Scarcela Prego	Caja Bankarias
Mr Gustavo Guillamon	Alameda Wismar
Mr Gustavo Perez Ariztia	Raices SRL
Mr Michael Brown	Forestal Orientale
Mr Benoit Wyaux	Wyaux Carpinteria
Ms Rosario Pou Ferrari	National Forestry Development Project
Mr Jaime Latorre Alonso	National Forestry Development Project
Ms Carolina Sans Dobe	Dept of Forestry, Agriculture Faculty

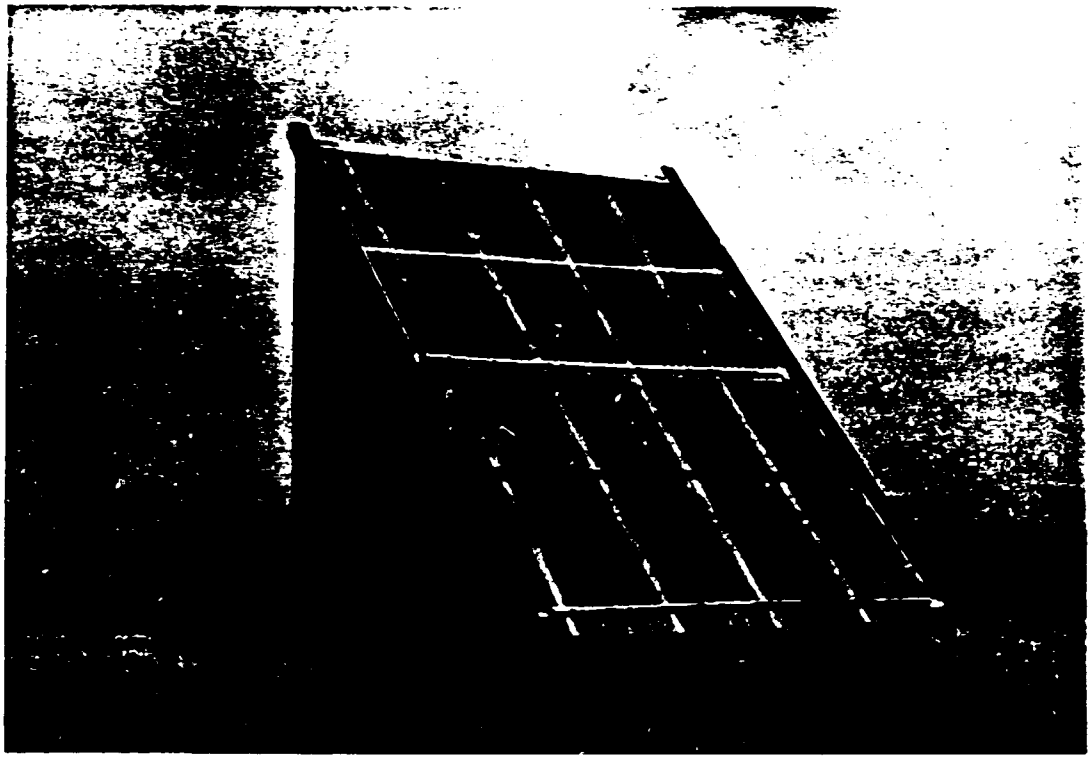
Input to the project by the National Counterpart, Mr Carlos Meyer, has been considerable, both prior to the Consultant's arrival and throughout the period of the consultancy.

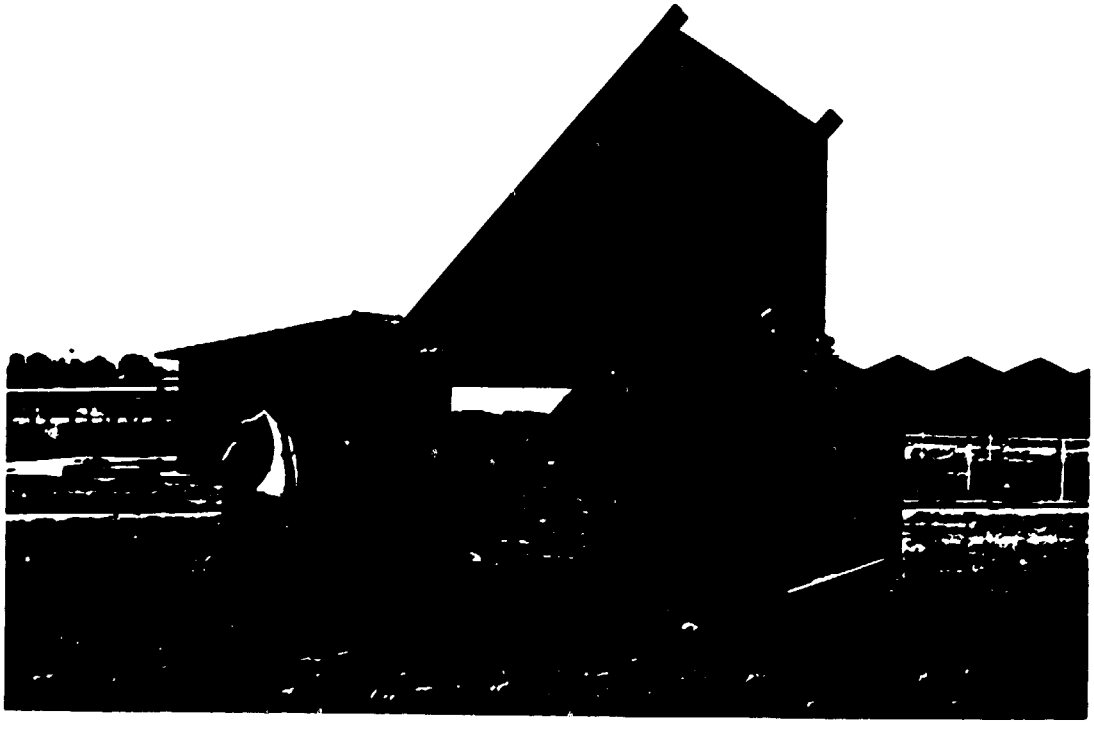
Finally the guidance and help given by the UNDP Resident Representative, M Paul van Hanswyck de Jonge, Program Officer, Mr Georgio Vicarelli and the UNIDO Representative in Buenos Aires, Mr Luis Soto-Krebs in gratefully acknowledged.

1. Demonstration solar kiln

1.1 Description

The photographs below show the demonstration kiln built at Rubina Agricultural Station by the National Counterpart for the project, Mr C Meyer.





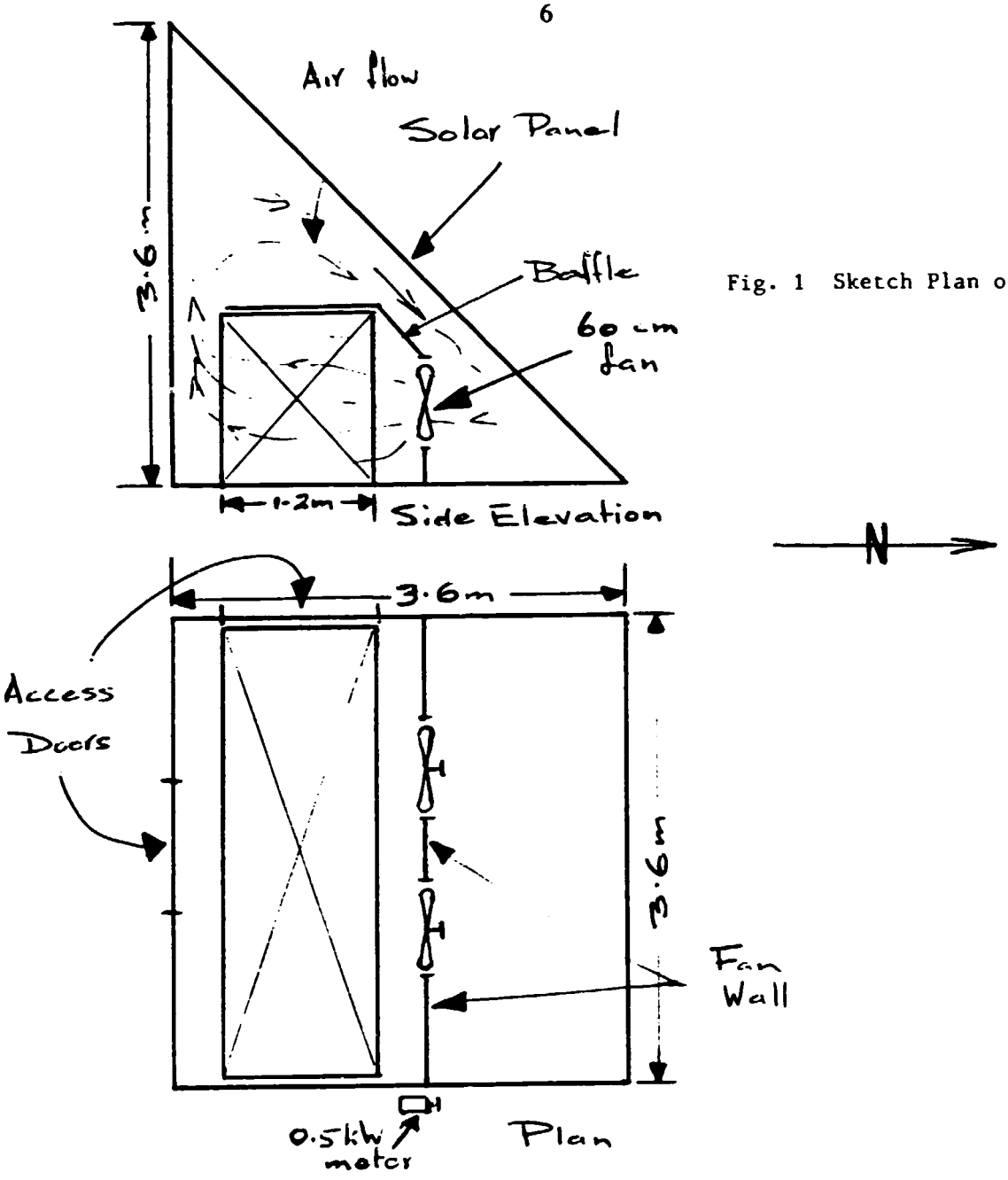


Fig. 1 Sketch Plan of Rubina Kiln

The solar panel is of corrugated, fibreglass reinforced polyester and the floor, east, south and west walls are of plywood sheet and timber frame construction, with polystyrene foam insulation in the cavity. The two, 60 cm, non-reversing fans are driven by a single 1.5 kW motor.

A charge of 50mm thick Pinus species from the Arazati plantation was in the kiln at the time. It had been in the kiln about 3 weeks and the moisture content was about 18%.

1.2 Temperature measurements

Temperature and relative humidity measured inside and outside the kiln on a cloudy day were :

	Inside	Outside
Temp	24^0	21^0
R H	63%	70%

It was noted that gaps under the corrugations, at the top and bottom of the kiln, were allowing the hot air in the kiln to escape. These gaps were plugged with foam rubber and subsequent temperature measurements taken on a cold, cloudy day were 21^0 inside and 17^0 outside. This difference would improve greatly on a sunny day. Differences of 24^0 (54^0 inside and 30^0 outside) have been recorded by Gough(1). It is important to maintain as high a temperature as possible in the kiln and to achieve this, all air leaks should be closed off. This can not be done when drying very green timber because the vents need to be open when the rate of moisture release is high, as it is with green timber.

As mentioned by Gough(1) the most economical system for operating solar kilns is to air dry from green to about 25-30% moisture content, and then place the timber in the kiln, keeping the vents closed. The rate of moisture release at this stage (bound moisture after fibre saturation point) is so slow that the relative humidity does not get too high. There will always be minor leaks around the door, and opening the door once a day to weigh the sample boards is sufficient to give an exchange of air.

1.3 Air flow

The air speed was measured on the air exit side of the stack using a hot-wire anemometer. Measurements were taken at every second sticker space down the stack, at four positions along the stack.

The results (in m/sec) tabulated below, show a high degree of variability and a quite high average figure.

(1) See Appendix I

	Row 1	Row 2	Row 3	Row 4	
West Side	1.5	2.4	4.7	4.5	East Side
	3.4	3.7	4.5	3.7	
	4.2	4.7	3.6	3.7	
	4.5	4.4	2.8	4.5	
		1.9	0.9	2.5	
	1.3	1.4	0.6	-	
	1.5	1.6	1.1	1.7	
Average	2.7	2.9	2.6	3.4	

As air flow through the stack of 1m/sec is adequate for solar kiln drying, the fan speed was reduced from 1400 rpm to 700 rpm by exchanging the 200 mm diameter drive pulley with one of 100 mm diameter. Subsequent air flow readings were :

	Row 1	Row 2	Row 3	Row 4	
West Side	1.6	1.1	1.0	1.8	East Side
	1.9	1.9	1.7	1.6	
	1.7	2.5	1.8	2.0	
	2.1	2.0	1.6	1.9	
	1.6	1.3	-	1.0	
	1.0	0.8	1.0	0.6	
	0.8	1.0	0.5	0.7	
Average	1.5	1.5	1.2	1.4	

This situation is very good. The uniformity is better, and as it is still above 1.0 m/sec, it is proposed that the same fan size and speed would be sufficient for a wider stack (see section 4.1).

A fan motor rated at 0.5 kW should be adequate for this task.

1.4 Moisture content monitoring

Two sample boards were being used to monitor the drying rate of the charge. Two is probably enough for routine drying in a kiln of this capacity, but it is

recommended that more are used in larger kilns and when experimental work is being undertaken. The sample boards were located on the air-exit side of the stack, which is good, however care should be taken that knots and other defects are not included in sample boards. Also the ends should be sealed with paint to prevent rapid drying from the ends. Two coats of water based acrylic paint should be sufficient. (Water-based paints are also easier to use than oil based)

An example of a convenient form for recording sample board data is attached (APPENDIX II).

Also, it is recommended that for research work in particular, a new calculated oven dry weight be obtained at the end of drying from additional oven dry sections cut from each sample board after the final weight has been taken. The original calculated oven dry weight is likely to be less accurate than the final one, particularly when there is variation in moisture content along the length of the sample board. The new and more accurate calculated oven dry weight can then be used to recalculate the moisture content values.

2. Schedule of drying trials

Only 50 mm thick *Pinus* has been dried in the Rubina kiln so far. These trials were quite successful but they were undertaken before the air leaks were plugged and they were also undertaken during the cold winter months.

It is proposed that trials be undertaken on :

(i) 25 mm thick *Eucalyptus grandis*

(ii) 38 or 40 mm thick *Eucalyptus grandis*

(iii) 25 mm thick *Pinus*

(iv) 38 or 40 mm thick *Pinus*

Each trial should be organised to include an air dried stack so that air drying can be compared with solar kiln drying. Then, when the kiln dried stack is finished, the air dried stack can be moved into the kiln to finish it off.

It is recommended that good quality timber be selected for drying. Boards containing pith and excessive knots should be excluded. They would never be suitable for use in high quality products and may give a poor impression during this demonstration phase.

Eucalyptus grandis in 50mm thickness could be considered after it had been air dried. The efficiency of solar kilns is best when 25 mm thick timber is being dried and timber users should be encouraged to purchase in the thickness they will be using, rather than pursuing the traditional approach often adopted, of ordering thick material (40 and 50 mm) and resawing it to thinner dimensions for eventual use. Thick material can be dried, but it takes much longer, the costs are higher and the chance of loss from drying degrade is often higher also.

3. Visits to sawmills/seasoning operations and joinery plants

3.1 Industrias Forestales, Puerto Arazati

Forest owners, sawmillers and manufacturers of wood products. *Pinus elliottii, P. taeda* and some *P.radiata* were being sawn in a relatively modern mill. The timber was being air dried and kiln dried in a Chilean designed kiln operating at about 80^0.

This is a highly integrated operation in which glue laminated beams and edge glued panels of various stock sizes are produced and fuel briquettes are made from the mill waste. The quality of these products appeared to be very good and the cleanliness and air of efficiency in the firm's retail yard in Montevideo was most impressive.

3.2 Alameda Wismar, Paysandu

Sawmillers, timber producers, for both export and local markets.

This was a labour intensive but apparently busy operation cutting *Pinus, Eucalyptus* and *Populus*. At the time, *E.grandis* was being cut for export to Italy for making pallets.

Two old steam heated kilns were in operation and a large chamber had been constructed to install a deliumidifier kiln.

3.3 Caja Bancarias, Piedras Coloradas

Forest owners, sawmillers and manufactures of wood products from *P.elliottii, P.taeda, E. globulus, E.grandis.*

A modern mill had just been completed and two steam heated drying kilns were near completion. The kilns will be operating up to about 80°. They have a capacity of about 50 m^3 each and use the longitudinal shaft fan system.

This mill was still gearing up to full capacity but should be able to process around 40000 m^3 of logs per year.

3.4 Raices SRL, Orgoroso

Sawmillers and manufacturers of wood products.

P.elliotii, P.taeda, E.globulus, E.grandis and *Populus* were all being sawn in an

interesting and well integrated operation which produced a wide variety of products including tooth picks from poplar and clothes pegs from *Pinus*. Other products were glue laminated beams and edge glued panels and table tops. A large, hot water heated drying kiln, designed by the owner was in the course of construction.

3.5 Wyaux Carpinteria, Paysandu

Main product was bee hive boxes and frames produced mainly from low grade *E.grandis*. This was an efficient operation which was value-adding to low grade timber. A timber drying kiln had been built but was no longer in operation.

3.6 Forestal Orientale, Paysandu

Forest owners. 60/40 partnership between Shell and a Finnish paper company to produce the raw material for short fibred pulp. No local equity. An above ground high shade nursery, 1.25 ha in extent, was nearing completion. The current program is to plant 200 ha of forest per year rising to 2000 ha per year. This appeared to be a very efficient operation. *E.grandis* was the main species and there is no intention to produce saw logs; only chips for export. It is understood that most other large forest plantation projects have the same policy.

3.7 Carpinteria Santin, Montevideo

A wide range of joinery, kitchen and bathroom cupboards, office furniture, etc. was being produced, mostly from timber from Paraguay and Brazil. Parquet flooring was also made by this company at its sawmill at Cerro Colorado, from locally grown Eucalypts. This is where it was proposed that a solar kiln be built, but unfortunately the current demand for this product was only about 30% of plant capacity and the proposal is on hold for the time being.

3.8 Technomadera, Montevideo

This company produces a large range of modular furniture for offices and homes, mainly from wood panel products - particle board, plywood and medium density fibreboard. Very little solid wood is used except for doors and windows.

4. Solar kiln designs for industry use

4.1 Small scale solar kilns for furniture and joinery manufacturers

The kiln at Rubina has a capacity of about 2.5m^3 of 25mm boards or 3m^3 of 50 mm thickness. A kiln of this design, with drying time averaging about 15 days (depending on species and thickness), after air drying to 25 to 30% moisture content, is expected to be of considerable value to furniture and joinery manufacturers :

- their inventory of air dried timber could be reduced
- the degrade often suffered when stacks of timber are left to air dry for long periods would be reduced
- moisture content lower than the outside equilibrium moisture content can be achieved

As mentioned in section 1.3, the air flow measured in this kiln was extremely good and it is proposed that using the same fans and electric motor, the kiln capacity could be increased. Stack volume of about 3.7m^3 of 25 mm boards or 4.5 m of 50 mm thickness could be achieved as shown in fig.2, by an increase in stack width from 1.2 m to 1.8 m.

Also shown in fig.3 is a system of rails and low profile trolleys which could be fabricated so that air dried stacks constructed on the trolleys can be pushed into the kiln. Two stacks could be air drying as shown (under temporary stack covers) while one stack is being kiln dried. The 2:1 ratio of air drying time to kiln drying time would be expected to provide convenient and efficient operation.

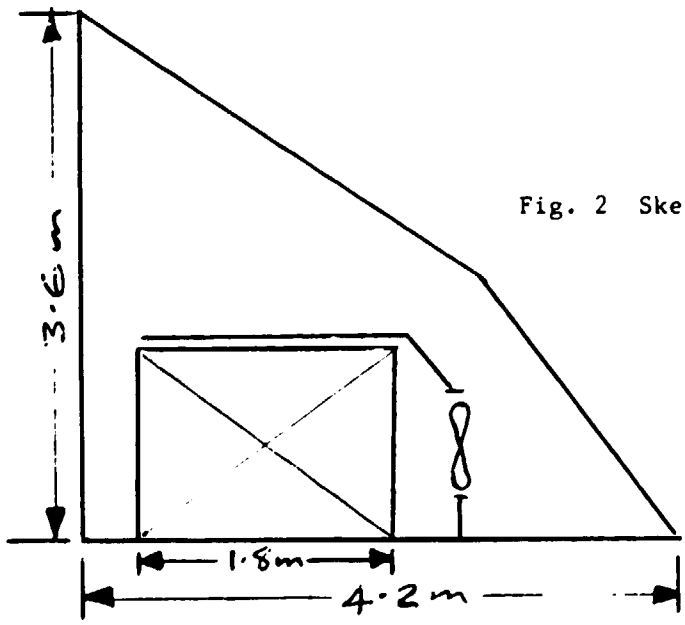
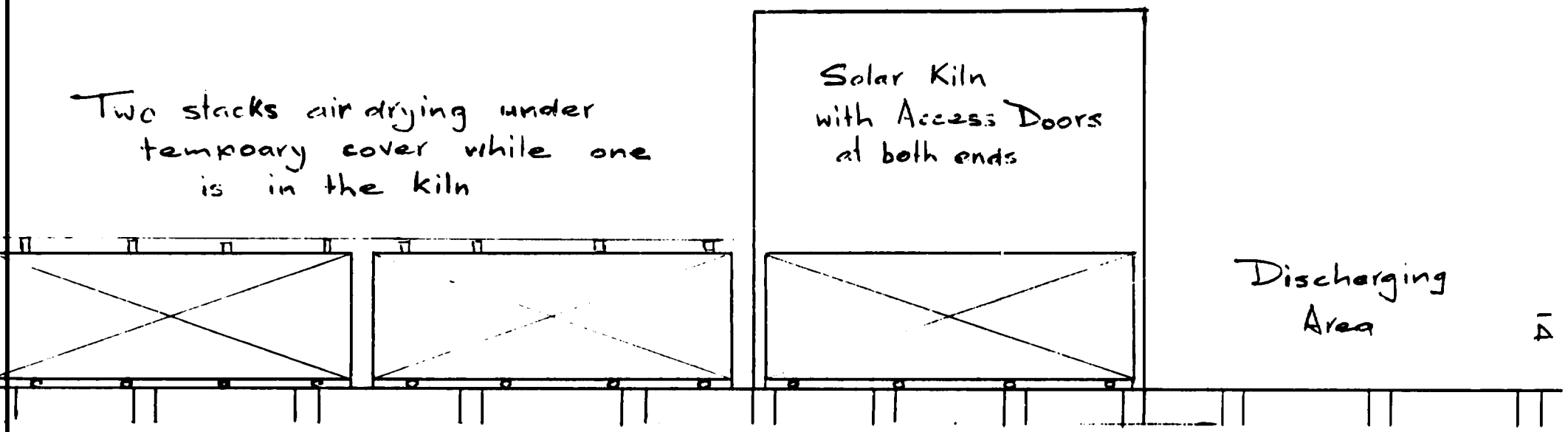


Fig. 2 Sketch Plan of Enlarged Rubina Kiln



Low-profile trolleys running on angle-iron rails

Fig. 3 Operating system for air drying and solar kiln combination

4.2 Sawmill scale solar kiln

The design and photographs for a solar kiln to hold 15m^3 of 25mm boards or 22 m^3 of 50 mm material was presented at the seminar and a complete set of specifications including a materials list, comprehensive building notes and working drawings was left with the National Counterpart, Mr C Meyer. This design, which was developed by the Consultant, has been used to construct about 20 units in various parts of Australia and the Pacific Islands. This set of specifications is intended for use in Uruguay only, and further sets are available on application to the Queensland Forest Service (see Appendix III) for US$250.00.

4.3 Important aspects of solar kiln construction & operation

The solar sheet cladding used on the Rubina kiln is of corrugated, fibreglass reinforced polyester. It is effective but is not of very high quality, being relatively opaque and easily damaged.

A much better product is clear corrugated polycarbonate sheets. Unfortunately it may have to be imported to Uruguay but it is extremely tough and unlike the fibreglass reinforced polyester, does not deteriorate with exposure.

Quality of materials and quality of construction is considered to be most important. A kiln that is poorly constructed will soon fall into disrepair and before long will not be used. But with care in construction, solar kilns which will give years of use, can be built quite cheaply by the average sawmilling enterprise. The most expensive item is the air circulation unit (fans, motor and electrical installation) followed by the solar sheet cladding.

For most efficient operation, all air leaks must be plugged, the sheeting must be well fixed in the first place, and the stacks must be built to occupy all of the stack chamber. If the stack does not fill the chamber, the space left at the ends or on top must be baffled so that the air flow is directed through the stack and is unable to by-pass it. If baffles are not used the drying will be non-uniform and will be longer than it need be.

5. Seminar on wood seasoning

A short seminar was held on 27 August to which sawmillers, furniture makers, forestry students and government officers were invited.

The presentation by Mr Gough covered the following aspects:

- the reasons for seasoning wood
- the costs involved and the need to run an efficient operation
- definition of important terms
- good stacking and appropriate kiln operations - the two important factors for success
- solar kiln drying and its potential in Uruguay

Mr Meyer spoke about the UNIDO solar wood drying project and described the kiln at Rubina, mentioning how it could be enlarged by 50 percent.

Mr Gough described his design for a solar kiln of 15 m^3 capacity, showing photographs and construction drawings.

The above seminar material was based on a comprehensive text prepared by Mr Gough for a Kiln Operators' Course. A copy of this text, including overhead transparencies has been left with Mr Meyer for use by manufacturers and kiln operators, or for presenting further courses.

6. Proposals for a wood research and extension service in Uruguay

There has been a limited amount of sawmilling activity in Uruguay for some time, but as the existing plantations mature and others are established, the availability of sawlogs will increase enormously. While it is acknowledged that most of the current planting of eucalypts is intended for pulp, it is expected that a significant sawmilling industry will develop in parallel with the pulp industry.

The sawmilling industry and the use of locally produced timber, both hardwood and softwood, for furniture, joinery, house construction, transmission poles, etc, has the ability to make a substantial contribution to employment and to the economic development of the country. For this to occur however, improved consumer confidence must be generated in locally produced timber.

It is most important at this early stage, that all timber products are of a high quality and provide reliable service.

It is recommended that a graduate forestry engineer or wood technology specialist be employed to provide a research and extension service in timber processing and the use of timber. Such a position should be within the infrastructure of Government, with funding and the development of a work program being the joint responsibility of Government and the industry.

The specialist would ensure that quality was maintained in :

. preservative treatment of timber -
  CCA treatment of transmission poles
  Treatment of susceptible sapwood (*E. rostrata*) against Lyctids.
. seasoning of timber -
  Pinus, poplars and eucalypts in conventional kilns, solar kilns and high temperature kilns.
. timber grading -
  Introduction of grading rules.

The specialist would undertake projects within industry plants, but access to some laboratory facilities and an area for various trials such as at Rubina, or the Agriculture Faculty of the University, would be necessary.

The specialist would maintain a library of technical information and would keep up to date with world wide developments in seasoning, preservation, processing, etc, relevant to the local industry.

The specialist would provide an independent investigation service for industry, applying scientific methods and statistical evaluation to all research projects.

It was not possible during the limited period of this consultancy to develop firm recommendations on the proposal, however, the following comments and options are presented as a starting point for a comprehensive study.

- All of the sawmills visited, appeared to be faced with similar technical problems, particularly with timber seasoning, yet all were attempting to solve these problems independently, with varying degrees of success. A trained specialist would be able to apply scientific methods to such problems and could draw on his study of up-to-date world wide literature, to provide cost effective solutions.

- From discussions held with Ms Carolina Sans, Coordinator, Dept of Forestry at the Faculty of Agriculture, it appears that wood science forms a significant part of the forestry degree course. It is proposed that the specialist should liaise with the Department and involve students in the running of research projects, to undertake measurements and analyse data. This would foster an interest in timber technology within the students and would provide for industry, a small pool of graduates, having specialist expertise in the processing and use of wood.

- Discussions were held with Ms Rosario Pou and Mr Jaime Lattore, National Coordinator and Executive Director respectively, of the UNDP/FAO Forest Development Project, concerning the merit of this proposal and the possible location of the "Timber Research and Extension Service" within a Government Agency.

Agencies discussed as suitable options were :

(i) Laboratoria Technological Uruguay (LATU) which incorporates the National Committee for Quality.

(ii) Instituto Nacionale de Investigationes Agropecuaria (INIA).

(iii) The Ministry of Agriculture.

Industry input should be via Industry Associations. There is a range of Industry Associations which should be considered but not all may be appropriate :

(i) Forest Association (within the Rural Association).
(ii) Association of Exporters of Sawn Timber.
(iii) Wood Industrials Centre.
(iv) Wood Industrials Association.
(v) Chamber of Furniture Makers.

It would not be realistic to expect that these private sector associations would take the initiative in forming a "Wood Research and Extension Service" and, as it has the potential to be of long term benefit to the country as a whole, it is most necessary that Government takes the lead. Joint involvement however, in management, program development and funding, remain an essential key to the success of the proposal.

An issue raised during discussion was the impending introduction of "Mercosur", the common market for Brazil, Argentina, Paraguay and Uruguay. It is possible that this may temper any rapid expansion of sawmilling in Uruguay, but even the current wood processing and wood using industries still have an urgent need for a technically competent and well administered Wood Research and Extension Service.

7. Recommendations

(i) Moisture Content monitoring during timber seasoning:

- use defect-free sample boards
- seal the ends with water based acrylic paint (2 coats)
- use the recording form in Appendix II
- use four sample boards per stack
- determine a new calculated oven dry weight at the end of drying by cutting two new MC sections from the sample boards.

(ii) Further drying trials :

- see p.10 for proposed trials
- select good quality timber for the trials
- monitor an air dried stack for comparative purposes
- involve students from the University, Department of Forestry in the operation of these trials and the analysis of results

(iii) General points on construction and operation of solar kilns:

- ensure all air leaks are plugged
- use good quality materials in kiln construction
- baffle the gaps around a stack if it does not fill the chamber
- air dry the timber under cover to about 25-30% MC before kiln drying
- encourage customers to order timber in the thickness they are going to use - this saves drying time and reduces drying degrade
- splitting of eucalyptus boards can be controlled to some extent by sealing the ends with a micro-crystalline wax and placing the end rows of stickers (fillets) right over the ends of the boards, in an attempt to reduce the rate of end drying.

(iv) Wood research and extension service :

- undertake a feasibility study for setting up a wood research and extension service which would be managed and funded on a joint government/private sector (Industry Associations) basis
- determine which Government agency should be responsible for the administration of the Service.

(v) The future of the project depends upon :

- undertaking further trials in the Rubina kiln, as per section 2, using University students to assist
- the commitment of either a sawmiller or joinery/furniture maker to construct a solar kiln for his own use
- the forest industries seminar being held as proposed in March/April 1992.

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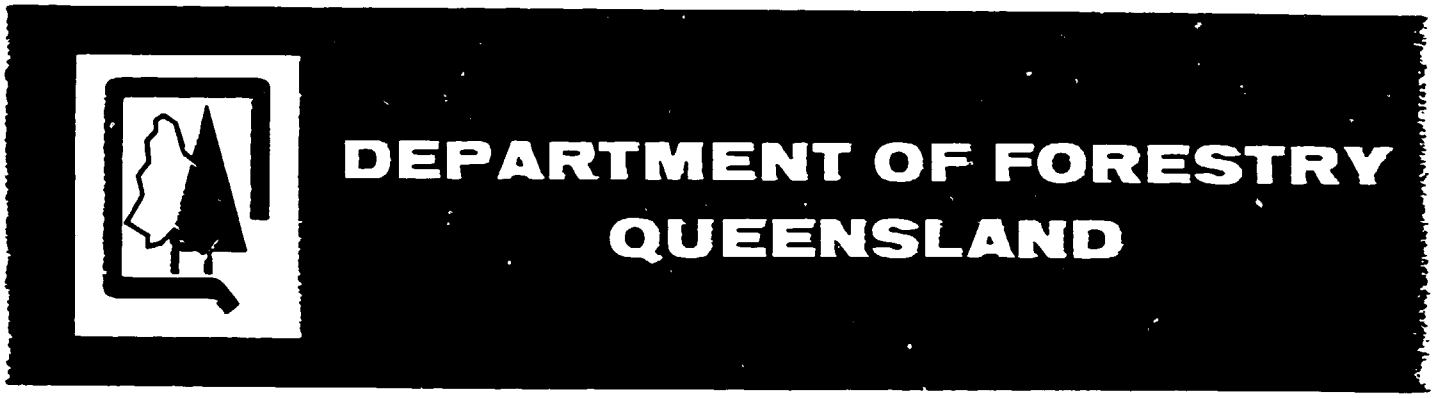

TIMBER SEASONING IN A SOLAR KILN

BY

D. K. GOUGH

ABSTRACT

A solar kiln of 15 cu m capacity has been built for demonstration and research purposes in Brisbane, Queensland. Details of design and construction, capital and operating costs are given together with drying rates for a range of species dried in the solar kiln and for matching air dried stacks. On a fine day the maximum temperature in the kiln is about 18° C to 24° C above the maximum outside temperature. The kiln is effective and can dry timber to below equilibrium moisture content in a relatively short time. The most effective system of operation is to air-dry the timber to about 20 to 25 per cent moisture content before moving it into the kiln.

SAMPLE BOARD MOISTURE CONTENT RECORD

STACK NO.: ..... TIMBER: ..... STRIPPING FINISHED: ...../...../.....

Sample Board No.									
Size									
M/C Sections	A	B	A	B	A	B	A	B	
Orig. Wt.									
O.D. Wt.									
M.C.									
Sample Board M/C									
Orig. Wt.									
Wt. at 12%									
Calc. O.D. Wt.									
Date and Time	Wt.	M/C	Wt.	M/C	Wt.	M/C	Wt.	M/C	AVERAGE M/C

PLANS AND BUILDING NOTES FOR THE QUEENSLAND FOREST SERVICE SOLAR KILN

by G. Palmer

obtainable from
Queensland Forest Service
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Indooroopilly Qld 4068
Australia Fax (07) 371 2217

Complete set for US $250

Queensland Forest Service
DEPARTMENT OF PRIMARY INDUSTRIES

APPENDIX IV

Backstopping Officer's Comments

The report presents a straightforward account of a short mission to evaluate the work of counterparts and to advise on follow-up activities aimed specifically at introducing solar kiln drying and generally at developing the wood industry sector.

The recommendations are all sound an data should continue to be collected on drying trials using the kiln built by the counterpart - after certain minor modifications and repairs.

Owing to the current high priority given to developing the wood sector, the Government should seriously consider providing further technical assistance as recommended. Also, following the Seminar on the Use of Wood in Construction in the Latin American and Caribbean Region (4 - 8 November 1991, Quito) attended by two participants from Uruguay, attempts should be made to look into developing a national timber structural design code, in concert with other countries of the region, especially those of Mercosur, and to demonstrate successful, cost-effective timber structures (such as bridges by the Ministry of Public Works) in an integrated programme.