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14694

DP/ID/SER.A/588
17 May 1985
English

CONSTRUCTION OF A PROTOTYPE SOLAR TIMBER DRYING KILN

SI/GUY/84/802

GUYANA

Technical report: Study of timber drying in Guyana and requirements for drying kilns *

Prepared for the Government of Guyana
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of R.A. Plumptre **
Consultant on timber drying and
solar kiln design

United Nations Industrial Development Organization
Vienna

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** Research Officer, Commonwealth Forestry Institute, Oxford, U.K.

Explanatory Notes

The following abbreviations have been used in the text of the report:

square metres	- m^2	feet	- ft
cubic metres	- m^3	inches	- in
hectares	- ha	board feet	- b.f.
centimetres	- cm	cubic feet	- ft^3
moisture content	- m.c.	equilibrium moisture content	- e.m.c.
Guyana dollars	- G$	fibre saturation point	- f.s.p.
United States dollars	- US$	United Nations Development Programme	- UNDP

Abstract

Timber drying for joinery, furniture and prefabricated housing manufacture was examined. Kiln drying is essential, because in the conditions of temperature and humidity in Guyana timber, air dried, will only reach an e.m.c. of 17-19% m.c. For use inside a house in the Caribbean area 12% m.c. is required and for export to temperate countries 8-9% is necessary to avoid defects caused by shrinkage after manufacture in furniture and joinery. For the larger sawmills and woodworking concerns conventional kilns, either steam heated or dehumidifier kilns are recommended, but for the small and medium sized operations solar kilns are suitable. A "Jakrap" model of a simple solar kiln of 7 m^3 capacity was erected at the Forestry Commission's Kingston yard in Georgetown and recommendations are made that an aluminium frame and melinex glazed kiln of 7 m^3 capacity be erected and used for experimental purposes and commercial timber drying at the Kingston yard.

A further recommendation is made that a new design of kiln of 22 m^3 capacity, for which drawings are given, be constructed in co-operation with the Forestry Commission at the Kingston yard using a maximum of local materials and a minimum of imported materials. The different solar kiln types should then be compared with each other and conventional kiln drying for quality, time and cost.

Acknowledgements

The author is indebted to Messrs. J. Douglas and C. Hall of the Guyana Forestry Commission for generous assistance, transport and hospitality. It was due to the hard work and the efficiency of their staff that the Jakrap kiln was constructed in time without more than limited assistance by the author and it was possible to see all kiln drying facilities in the country. The assistance of Mr. R. Field-Ridley, an architect working with Walvis Ltd., is also gratefully acknowledged for helping in the construction of the 'Jakrap' kiln. The author is also grateful for assistance from Ms. C. Davis the UNDP resident representative who showed considerable interest in the project and joined the visit to Demerara Woods Ltd. Dr. N. Trotz, Head of the Institute of Applied Science and Technology, showed the author round the Institute, accompanied the party visiting Demerara Woods Ltd., and showed considerable interest in the project. Mr. R. Hastings kindly provided transport for two of the three long trips out of Georgetown and showed the author his charcoal operations and timber drying related to them.

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INTRODUCTION

This report covers a two week consultancy on timber drying in Guyana. A copy of the job description is contained in Appendix I. A slight modification to the brief was made on the recommendation of Mr. D. Cody, who was at the time carrying out a survey of the furniture and joinery industries, to include all kiln drying as well as solar kilns.

The Guyana forests cover some 18 million hectares; with a population of 800,000 in the country, the domestic consumption of locally grown wood products is only about 180,000 m^3 in log form and 90,000 m^3 sawn per annum, while some 5 million m^3 are sold as logs (Douglas, 1984). Even at the present low rate of yield of some 5 m^3/hectare obtained during harvesting of the forest it is not in any danger of being overcut. The potential for export of manufactured wood is therefore great. At the present time exports are very largely (70%) Greenheart (Ocotea rodiaei) because of its exceptional properties of high strength, great durability and relative stability. Some four other species have been exported in any quantity but the local furniture and joinery industry uses between 15 and 20 different species.

Although only a relatively small percentage of the forest has so far been harvested the area covered has been quite extensive because of the search for Greenheart and the price it commands. This has resulted in long transport distances for logs both by road and by river and there is now growing pressure on sawmillers to market and purchasers to buy more species.

The majority of species used are naturally durable and a large proportion of them are dense, slow to dry, hard to machine and heavy in use. Many, however, are highly decorative and very strong. More species from the forest could almost certainly be utilised, given protection from log borers in the forest and during transport to industries and adequate preservation treatment after sawing. The present project is, however, concerned with the drying of the species currently used as solid timber in the furniture, joinery and prefabricated housing and building industries.

I. WOOD DRYING IN THE TIMBER INDUSTRIES

Wood drying is carried out by the sawmill industry and by wood users in the form of furniture, joinery and prefab. housing manufacturers and builders. A list of industries visited by the writer is given in Appendix 2 together with the product manufactured and the seasoning facilities available. It was clearly not possible to visit all industries but five days were spent visiting industries and a further day seeing the facilities of the Forestry Commission Forest Industries Development Unit. All industries with drying kilns were seen.

In general the quality of timber handling and drying in Guyana is low; in almost every industry visited untidy piles of valuable timber were to be seen, often lying in the sun, with many pieces showing severe distortion. Timber piled into sheds or stores often had little chance of drying evenly or even drying at all in any reasonable length of time. Timber stick stacked was often of different lengths with the longer lengths unsupported and consequently bowing under their own weight and distorting severely. Stickers were too far apart (often 4-6 feet) and timber was distorting between them. No timber was seen protected or end coated to prevent end split or distortion except at the Forestry Commission's yard.

A. Timber Drying at Sawmills

Air Drying

All sawmills visited except those in the Corentyne area had some air drying sheds. The quality of air drying varied but in general the quality of stacking was poor and not all timber was stacked to dry, much of it was machined green. Some of the Corentyne mills were moulding wet timber straight off the saws, but two showed an interest in solar drying trials.

Kiln Drying

The larger sawmills have steam heated drying kilns but at the two largest mills the kilns are not yet in operation although at one mill they had been installed for three years and at a third the kilns were old and the vent controls and temperature and humidity recording charts were out of action. The large mills aim to produce mouldings and prefab. housing for export, and one was in production making prefab. housing with timber that was at a moisture content of over 30%.

B. Timber Drying at Furniture and Joinery Workshops

Air Drying

The quality of air drying was on the whole better in these industries, most had drying sheds and several had closed timber stores for the drier timber and one had a room equipped with fans to give a forced air circulation but timber inside it was not properly stacked.

Kiln Drying

One furniture manufacturer has a small dehumidifier kiln which he is not currently using allegedly because of the cost of electricity to operate it.

It would, however, suit his requirements ideally if put into operation although the cost of electricity would be in the region of G$0.34 per b.f. (G$ 141 or US$ 33 per m^3) to dry a charge of average dimensions and wood density (assuming G$ 0.84 per unit, 2 KW/hr, 24 hour operation and 20 day drying period from green to 12% m.c.). This assumes that the dryer runs at one third the maximum KW rating of 6.

Other manufacturers rely on air drying and limited storage inside workshops or closed stores.

The furniture and joinery manufacturers almost all stated that they had had complaints of movement and splitting of furniture made by them both from local customers and from customers elsewhere in the Caribbean. As indicated by Cody (1985) the potential for exports to the Caribbean and possibly beyond are good provided the quality of drying and design and manufacture are good enough.

C. Building Contractors

Only two building contractors were visited and they relied entirely on rather poor air drying sheds.

D. Equipment for Measurement of Moisture Content of Wood

There did not appear to be adequate equipment at any of the joinery and furniture workshops visited to measure the moisture content of the wood being used. None had a moisture meter and none had oven drying and weighing facilities necessary to measure moisture content. The result is that they have no way of testing their timber before they use it.

The only organisation that has and uses moisture meters and oven drying and weighing to determine moisture content is the Forestry Commission's Forest Industries Development Unit. They have at least two operational moisture meters and an oven and scales. They also have some 48 moisture meters which at present are not functioning, but could probably be put back into working order, given a competent electrician. They are relatively new.

II. WOOD DRYING IN THE GUYANA CLIMATE

Figure 1 gives histograms of humidity at Timehri Airport and figure 2 shows equilibrium moisture content of wood for given conditions of temperature and humidity. It can be seen that the equilibrium moisture content of timber in the Coastal Climate in Guyana is around 17-18% moisture content. Whatever length of time timber is stacked in open sheds or covered stacks it will never go much below this moisture content.

Inside closed buildings moisture content will vary but will probably be around 12% moisture content because of higher temperature or lower humidities (air conditioners lower humidities). Timber to be used in furniture or joinery for the Caribbean area needs to be dried to 10-12% m.c. to ensure its performance will be adequate. Timber to be used in temperate climates with centrally heated buildings needs to be dried to 8-9% m.c. This can only be done in some form of kiln, whether conventional or solar.

III. DRYING CHARACTERISTICS OF TIMBERS CURRENTLY USED FOR JOINERY, FURNITURE AND PREFAB. HOUSING

Appendix 3 gives a list of timbers stated to be used in the survey of the furniture industry giving their density, recommended kiln drying schedules and notes on drying characteristics. They vary in density from 0.48 g/cm^3 to 1.06 g/cm^3. The schedules recommended are also given in the same appendix. It can be seen that schedules B & C are slow schedules for slow drying woods while E, F & G are moderate schedules and J is a fast schedule. Of the species used six require B & C and of the untested species one probably requires these schedules. Six, plus probably three untested species, require E, F or G and one requires J. Seven, therefore, have to be dried very slowly, nine at a medium speed and one can be dried fast. The latter is only used in very small quantities.

IV. QUANTITIES OF TIMBER REQUIRING KILN DRYING

Appendix 4 gives the quantities of timber used annually by the thirteen firms replying to Cody's questionnaire (Cody, 1985). It is estimated (Hall, 1985) that there are some forty more small joinery and furniture workshops using woodworking machinery in the neighbourhood of Georgetown, and many small carpenters. The major manufacturers of timber frame housing are not included in the total but most are equipped with their own kiln drying facilities except possibly some of the building contractors who are relatively small producers of prefab. timber housing.

It can be seen from the appendix that four firms use over 500 m^3, two 200-500 m^3, four 100-200 m^3 and three less than 100 m^3 per year. The four largest consumers either manufacture considerable quantities of joinery items as well as furniture or make prefab. housing.

V. CHARACTERISTICS OF CONVENTIONAL AND SOLAR KILN DRYING

The conventional kiln controls both humidity and temperature according to schedules prescribed for different timbers, the severity of drying possible, in terms of height of temperature and lowness of humidity, varies according to the timber being dried. Two processes are taking place; the first being the removal of water or water vapour from the surface of the wood and the second the movement of water or vapour from the interior of the wood to the surface. In all slow-drying woods the latter is limiting and rate of drying depends on rate of movement through the wood. Given an adequate moisture gradient this is very largely temperature-dependent provided case hardening and collapse do not occur. Kiln schedules are designed to keep these defects to a minimum and final steam treatments are designed to relieve stresses at the end of drying.

With solar drying it is not possible to control temperature other than by raising it above ambient by 10-20^o in the middle of the day. Humidity can be very considerably controlled by opening or closing vents to remove or retain humid air produced by evaporation of water from the wood. Typically, the simple greenhouse-type solar kiln in the tropics reaches a temperature of about 40^{o}C, in the middle of the day, in the early stages of drying dropping to about 3-4 ^{o}C above ambient at night. Midday humidities are around 80-90% provided vents are not opened too far and rise to nearly 100% at night if fans are shut off at night. As drying proceeds midday temperatures rise to as much as 50-55 ^{o}C on clear days with humidities as low as 40-50% in the later stages of drying while night temperatures drop to 2-3 ^{o}C above ambient and humidities rise to 60-80%. Day temperatures, therefore, follow fairly closely the slower conventional kiln schedules while night temperature gradients in the timber may help to speed vapour diffusion from the centre to the surface of the wood. Solar kilns, therefore, become more competitive compared with conventional kilns when drying slow-drying, hard, heavy timbers. All kiln drying is best done after a preliminary period of air drying except for very fast drying woods where fast schedules can be used or for timbers which deteriorate if not kiln dried from green.

Very refractory woods may require careful air drying with end sealing and shading to prevent too rapid air drying and checking and splitting. The higher humidities in a solar kiln may often be less severe on the timber than air drying.

A. Different Designs of Solar Kilns

Solar kilns can be divided into the following three main design types:

- Greenhouse kilns
- Kilns with integral box collectors
- Kilns with external collectors

Greenhouse Kilns

This is the simplest and cheapest type of kiln, where the kiln is a single structure containing the timber stack and heat absorbing surfaces in the same chamber. It can be single or double glazed. It has a size limit and unless very "stretched" beyond the dimensions of the stack alone it is probably not efficient over a 12-15 m^3 capacity.

Kilns with integral box collectors

Box collectors, normally of prismatic shape with one side glazed, are more efficient than flat plate collectors if painted black on internal surfaces. A kiln built up of a series of boxes of this type could be built to dry efficiently 20-25 m^3 of timber at a time for a stack of 8-10 metres long. For longer stacks a greater volume is possible. The cost of this type of kiln is greater, but not very much greater, than for the greenhouse kiln.

External Collector Kilns

These kilns are less limited in size since efficient, well insulated external air or water filled collectors can be manufactured of any size and the hot air or water pumped into the kiln chamber which is also efficiently insulated. These kilns are very much more costly, they are more difficult to control and operate and, in the writers opinion, are not worth considering for Guyana.

B. The "Jakrap" Solar Kiln at the Forestry Commission yard at Kingston

The kit for the kiln had not been built up when the writer arrived in Guyana, and so part of the time was spent in building it. It had been completed by the end of two weeks, with the assistance of the staff at the yard, and was in operation. This kiln and its successor, an aluminium frame and "Melinex" glazed kiln of the same shape and size, are designed to hold 7 m^3 of timber and are demountable so that they can be moved from stack to stack. In this way a stack of timber can be partially air dried and then drying is completed in the kiln by placing it around the stack without having to move the timber. This saves time and labour particularly where fork lift trucks are not available. If stacks are provided with good covers overlapping the ends of the stacks by several feet and are correctly oriented with relation to the sun, air drying under stack covers can be as quick, and gives as high a quality of drying, as air drying in sheds. End coating of the timber may be necessary for refactory woods. This type of solar kiln can be used in batteries in large timber yards if necessary.

C. Advantages and Disadvantages of Solar Kilns

The advantages of solar kilns over conventional kilns are as follows:

- lower capital cost (by a factor of 5-10 for greenhouse types)
- lower running cost for power and labour
- less skill required to operate them adequately
- ease of construction and maintenance
- continuous supervision not needed (no boiler man)
- high quality of drying because it is slow
- little maintenance required other than replacement of glazing material.

The disadvantages are:

- small capacity
- slower drying (by a factor of 1½-3 times depending on timber species and thickness)
- glazing materials have relatively short life (1 year in tropics for horticultural polythene and 5 years for Melinex)
- glazing materials are fragile but can be repaired.

D. Costs of operation of a Solar Kiln in Guyana

Appendix 5 gives an estimate of costs for the Aluminium framed, Melinex-glazed Kiln manufactured by Cambridge Glasshouse Co. Ltd. operating in Guyana. Assumptions on rate of drying are based on experience with woods of similar density dried elsewhere in the kiln in the tropics. Labour is charged at G$ 15 per day rather than the current Government rate of G$ 11 per day. Electricity was costed at 1984 rates; a new price is due shortly but the new rates are not known. Costs of drying per b.f. are estimated at G$ 0.18 for 16 kiln loads (charges per year) G$ 0.22 for 12 loads a year and G$ 0.30 for 8 loads per year. Equivalent costs per m^3 are G$ 77, 94 and 128 respectively.

The figures for 16 loads a year assume that the timber is 1 inch (25 mm) thick and is partly air-dried first (for 3 weeks). If kilning is done from green the time taken is likely to be 5-6 weeks per load and the 8 loads per year would be the more likely production. A similar time would be taken for 2 inch thick timber partly air-dried first while 3 and 4 inch thicknesses would be slower still. If 2 inch timber is cut into narrow widths of 2 x 2, 3 x 2 or 4 x 2 it will dry at a rate somewhere between the rate for 1 inch and 2 inch thicknesses. Much furniture and joinery timber is in these dimensions and the majority is one inch or less so that 16 or 12 loads per year should normally be achievable. As mentioned in paragraph IB the cost of electricity for the dehumidifier kiln was estimated at about G$ 0.34 per b.f. for 1 inch timber drier from green to 12% m.c. and probably about G$ 0.17-0.20 for timber air-dried first.

Comparable costs estimated by Mr. C. Hall for the 95 m³ conventional kiln, drying timber from green to 12-14% m.c. at Kingston, were:

	G$
Labour for stacking and loading	0.0480
Labour for drying (boiler operator etc.)	0.0885
Electricity	0.2220
Total running costs	0.3585
Overheads	0.0615
Total	0.420

Both sets of costings for the conventional kilns are incomplete but assuming air drying as a preliminary to kiln drying, this G$ 0.42 could probably be reduced to G$ 0.25, not including depreciation (capital cost) or land rental and interest on timber stocks. The solar kiln cost of electricity is G$ 0.0225 per b.f. considerably less than the G$ 0.17-0.20 for the dehumidifier and G$ 0.13 for the large steam heated kiln of 95 m³ capacity.

VI. KILN DRYING REQUIREMENTS FOR THE GUYANA TIMBER INDUSTRY

A. Existing kiln capacity and drying practice

The large sawmills at Demerara Woods Ltd., Interior Forest Industries Ltd. and Guyana Timbers already have adequate kiln seasoning capacity of their own provided it is put into working order. At Kingston, the Forestry Commission's Forest Industries Development Unit has one 17 m³ capacity kiln operating, spares for a 95 m³ kiln have been ordered to put it back into working order and a 30 m³ kiln and boiler have been purchased and are due to be erected. Assuming the three kilns at Kingston are put in working order and kiln drying of timber for the trade is done from green to 12% m.c. it is likely that 20 days will be required in the kilns per load. 17 charges of 142 m³ could be put through the kilns per year, once they are operating or a total of 2414 m³.

The requirement for the thirteen largest firms in Georgetown are 5835 m³ (see Appendix 4) so the Commission at full production could meet about 40% of the requirements of these firms. There is, however, a sizeable sawmill industry in the Corentyne area making little if any attempt to dry timber at all and several millers were moulding profiles for timber housing straight off the saw with water running out of the wood. The resulting surface finish was extremely poor and purchasers, even if they then dried out the timber, would encounter great difficulties in putting it together and obtaining a reasonable surface finish.

At present the only kiln in the country which is being properly operated is the 17 m^3 kiln being operated at Kingston by the Forestry Commission. Elsewhere drying practice varies from being non-existent to being seriously attempted but very imprecise. In spite of this Guyana has a heritage of beautiful wooden buildings, both public and private, which is surpassed by very few. This is a tribute either to better seasoning practice in former times or the very forgiving nature of the country's timbers.

There is little hope, however, of successful and trouble free entry into Caribbean furniture or joinery markets and even less into North American or European markets without competent kiln drying to 12% for the Caribbean and 8-10% for temperate regions. Prefabricated housing components for the Caribbean area should be dried preferably to 12% m.c., but drying to 20% for most components except windows and doors and flooring is probably acceptable because equilibrium moisture content for the external parts of a house is 17 to 18%.

B. Advantages and Disadvantages of a Central Kiln Drying Facility at Kingston

The Kingston yard provides the only reliable kiln drying in the country at present and it is also recognised as a centre where training can be obtained; it is gaining a reputation for good quality drying. This reputation suggests that joinery and furniture manufacturers would be keen to use this facility to have their own timber drier or would be willing to buy dried timber from the Commission. This is becoming the case and growing numbers are requesting this service, although, with only the 17 m^3 kiln operating at present, the quantity of timber which can be dried is very limited: as the full 142 m^3 capacity becomes available the ability to dry timber for the trade will increase. There are, however, several factors to be taken into account in the provision of a central drying facility to custom dry timber for the trade as follows:

1. The trade becomes very dependent upon the efficient functioning and operation of a small number of kilns.

2. Some 18 species in some 5 different thicknesses are currently used which would require sorting and drying on different schedules or drying on the schedule suitable for the slowest drying timber in the charge. This could become very wasteful of energy and time with a large kiln containing different species and sizes.

3. Customer's timber will have to be carefully labelled and sorted after drying and customers with fast drying species and sizes will not want to wait for the slower timbers owned by others to dry.

4. There will be a tendency for some timber to be over-dried and there will be temptation to under-dry the slowest drying woods.

Similarly, the following factors need to be taken into account in building up stocks of dried timber at the Kingston yard from which the trade can purchase ready-dried timber:

1. The different members of the trade tend to specialise on particular timbers and these are different for different firms.

2. The trade reacts to its customer's preferences for timber for furniture ordered by them. There are therefore, likely to be changes in patterns of demand.

3. It is unlikely that the Forestry Commission will be able to hold stocks of all the species and sizes required. If they do, they will find some are very slow moving and this leads to problems of storage and tying up capital for too long a time.

4. One aim of the Commission is to get more species on the market and undoubtedly more species than are currently used for furniture, joinery or flooring could be used. Promotion of the use of more species is very important to the rational and economic use of the forest, since 5 m^3/ha is a very low volume to be taking out of the forest and leads to uneconomic logging and sawmilling. Promotion of more species would, however, complicate further the problem of kiln drying and stock holding.

C. Balance Between Forestry Commission and Private Drying

The Commission is providing a very valuable service which should be expanded as planned, but it cannot dry timber for the whole trade as indicated above nor can it cope with the complexities of large numbers of species and sizes.

Similarly, the provision of a small number of large kilns is almost certainly not what is needed by the trade except for prefab. housing, where large quantities of a small number of sizes of, at present, a limited number of species are required. Preservation to treat non-durable woods for housing is urgently required and would increase the range of species which could be used for this purpose.

The aim, therefore, should be to equip as many private firms as possible which are attempting to produce high quality furniture and joinery, with kilns which are suitable to their size of operation and to train them to use them efficiently. This requires the right size of kiln with the right capital and running costs for the size of operation concerned.

Several small kilns are probably more suitable than one large one provided economies of scale are not too great. The dehumidifier type kiln is economic on labour and energy used but is expensive on electricity while steam heated kilns are cheap on electricity but high on capital and labour costs.

D. The Suitability of Solar Kilns for Guyana Industries

The size of operation of several of the joinery and furniture manufacturers given in Appendix 4 suggest that they are not large enough to require a conventional kiln even of a dehumidifier type.

If it is assumed that one 7 m^3 solar kiln dries 112 m^3 a year a single solar kiln would keep each of the four smallest companies going and since these are selected from the largest firms in the business there will be many more smaller concerns which could use one. From the approximate costings in Chapter V, it appears that they would prove competitive in cost, particularly if combined with a preliminary period of air drying.

Their simplicity of construction, maintenance and operation make it possible for them to be operated by a small concern with staff who have only limited skills and training. It should be emphasised, however, that some skills and training are required for any form of kiln drying. The wood industries in Guyana, appreciate, to some extent the need for drying but have very little knowledge of kiln operation, schedules and methods of moisture content determination.

It is considered, therefore, that the 7 m^3 demountable kilns are suitable, in combination with air drying, and are worth introducing to Guyana. The polythene covered timber "Jakrap" kiln is now erected and operating and it is suggested that an Aluminium framed, Melinex covered kiln should also be introduced to operate at the Kingston yard in drying timber for the industry. Comparisons of performance and costs should be carried out between:

- the "Jakrap" kiln at the Forestry Commission's Kingston yard
- the Aluminium/Melinex kiln at the Kingston yard
- the dehumidifier kiln at Walvis Ltd.
- the 17 m^3 steam heated kiln at the Kingston yard
- the 95 m^3 steam heated kiln at the Kingston yard.

In order to introduce a greater amount of local materials and manufacture into solar kilns it is also recommended that a large solar kiln capable of taking 22 m^3 of timber and having integral box-type collectors should be built using timber supplied by the Forestry Commission, fans of the same model as those used in the "Jakrap" and Aluminium Kilns and Melinex of the same gauge and width as that used for the Aluminium kiln.

Figure 3 gives a drawing of the proposed design. It would require approximately 200 m^2 of Melinex as compared with about 90 m^2 for Aluminium/Melinex kiln and seven fans instead of two.

Appendix 6 lists the equipment recommended to be supplied.

It is proposed that the box collector kiln should be used as a dehumidifier as far as possible and water condensing on the outer skin during the night should be drained away and vents kept nearly closed during the day.

VII. TRAINING

The level of knowledge about wood properties and wood drying in Guyana is such that training is needed; it is needed not only for kiln operators but also the management of furniture and joinery firms in order that wood drying may be given the priority that it deserves in raising the quality of their products.

For management a number of one day seminars should be sufficient to give them the basic principles of wood drying including:

- Theory of radial, tangential and longitudinal shrinkage and movement of wood
- Calculation of percentage shrinkage and movement
- Calculation of percent moisture content
- The effects of atmospheric humidity and temperature on moisture content of wood and the concept of equilibrium moisture content

- Methods of measuring moisture content:
  - electric moisture meters
  - oven drying and weighing
- Rates of drying of different species and timber thicknesses
- Moisture contents required for different end uses and locations
- Theory of kiln drying and different types of kiln
- Kiln schedules and how they operate
- Air drying and building and orientation of stacks.

For kiln operators a weeks course is suggested which would include the above, but would also include the building of stacks, the loading and unloading of kilns, the setting and monitoring of kiln controls, the placing of sample boards and measurement of moisture content from them and simple kiln maintenance.

It is suggested that one seminar and one training course for kiln operators, if there is demand for one, is held during the second stage of the consultancy.

A. The Second Stage of the Project

If the equipment is ordered and dispatched to Guyana in advance of the consultant's second visit and the main materials for the structures of both kilns are prepared before his arrival it should not be necessary for him to be in the country for more then three to four weeks. The competence of the Forestry Commission's staff is such that they are quite capable of building the kilns themselves, given the necessary drawings and construction details, but for the main construction of the new design it would be desirable for the consultant to be there.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

The following are the main conclusions:

1. The climate of Guyana is such that air drying in most places will not dry timber below 17-19% m.c., no matter how good the drying techniques.

2. Kilns are, therefore, essential to dry timber for joinery and furniture which should be dried to 12% m.c. for the Caribbean area and 8-9% for temperate climates where central heating is used. For prefab. housing 12% is necessary for internal joinery and 18-20% for framing and external cladding.

3. Only one kiln is operating efficiently in the whole country - at the Forestry Commission's Timber Research Division at Kingston.

4. Air drying practice is poor almost everywhere, but the better joinery and furniture makers have all had complaints of drying defects in furniture supplied by them. They are aware of the need for better drying and appear willing to install kilns and learn how to use them.

5. Many firms are small and use too little timber to keep a conventional kiln operating. Solar kilns, therefore, appear to be a possible alternative for the smaller operators.

6. The Kingston Kiln drying facility is being built up to 142 m^3 but there are drawbacks to its drying more than a proportion of the timber required by the trade. These are listed in the main report.

7. The "Jakrap" Solar Kiln has just been erected and will be a useful tool for comparing solar kiln and conventional kiln costs and speed of operation.

8. The general knowledge of drying and wood properties in the timber trade is poor and training in general wood drying and kiln operation are required.

B. Recommendations

The following recommendations are made:

1. The "Jakrap" Kiln should be compared with conventional kilns for speed, quality and cost of drying.

2. An Aluminium framed, Melinex glazed kiln of the same size and shape as the "Jakrap" kiln should be supplied to and installed by the Forestry Commission's Kingston depot.

3. A large Melinex and Timber Solar Kiln as shown in Figure 3, capable of taking 22 m^3 at a time should also be erected at the Kingston depot for trial with the aid of staff there.

4. The list of equipment for wood drying research given in Appendix 6 should be purchased to enable the laboratory at Kingston to do adequate wood drying research.

5. Training for managers of furniture and joinery workshops in the form of a series of one day courses should be run at the Kingston yard.

6. Training courses of 1 week each should be run for kiln operators as and when kilns or solar kilns are acquired by the trade.

7. The consultant should return for a period of 3-4 weeks to complete erection of the Aluminium and Melinex kiln after a start has been made by the Forestry Commission Staff and he should help build the new design of Timber and Melinex Kiln. He should also run one or possibly two one day courses/seminars for managers and a kiln operators course if there is demand for one.

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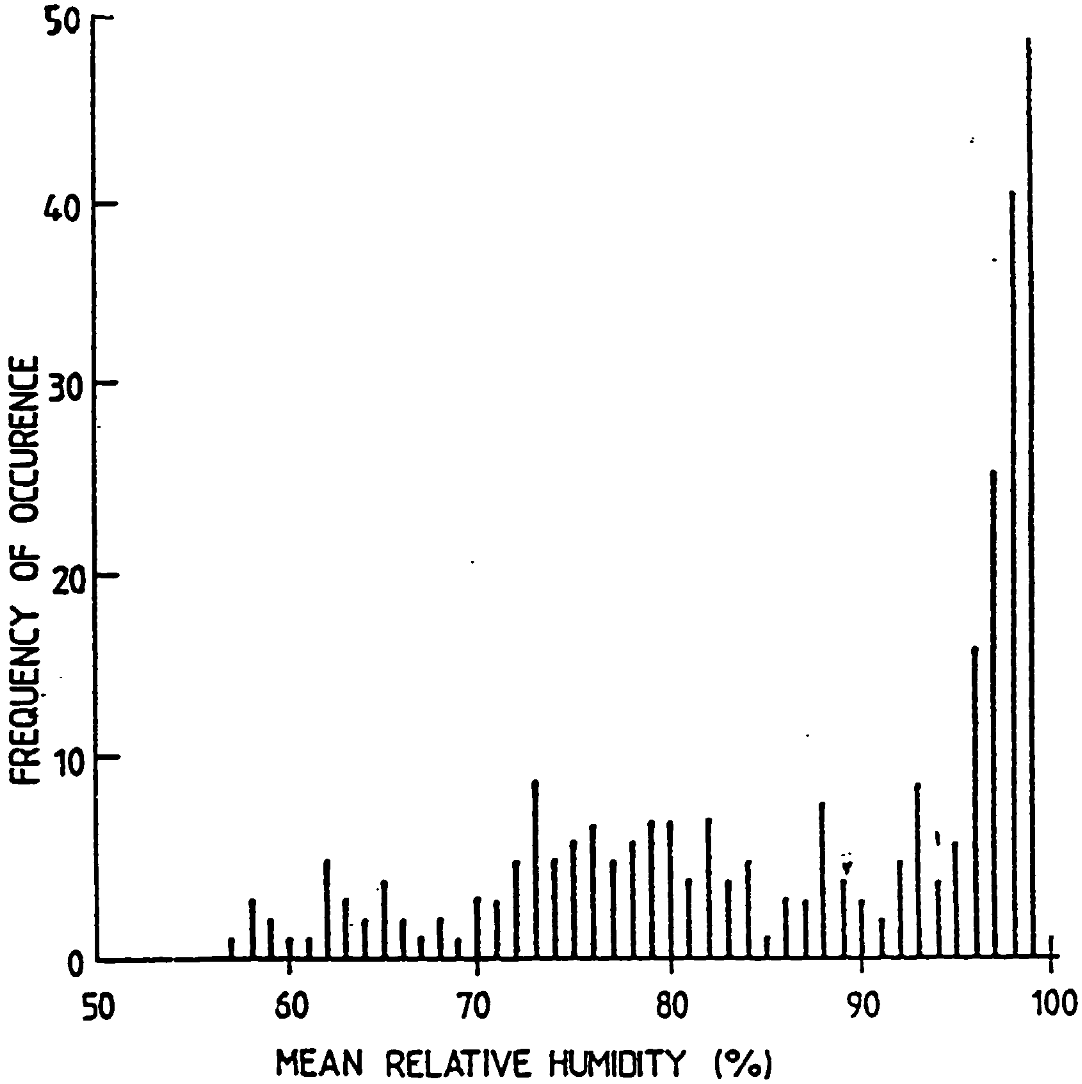

Figure 1 Relative humidity at Timehri airport in 1973, after Bonar [2]

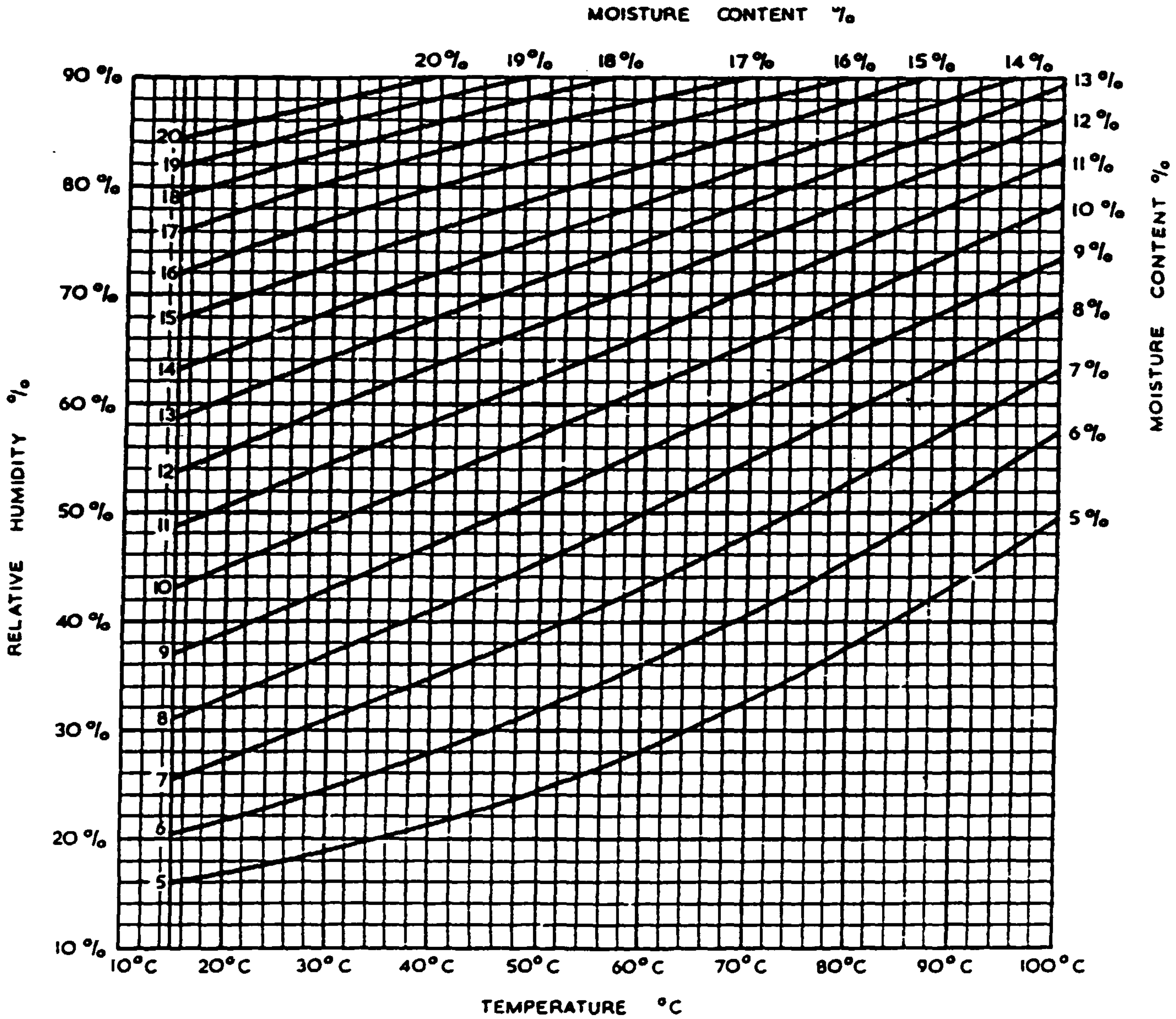

Figure 2. Relationships between humidity temperature and equilibrium moisture content of timber.

APPENDIX I

JOB DESCRIPTION

Post title: Consultant in solar drying of timber and solar kiln construction.

Duration: Two months (split mission).

Date required: As soon as possible.

Duty station: Georgetown.

Purpose of project: To determine the economic and technical parameters of timber drying in Guyana using solar kilns and develop a prototype (greenhouse type) solar timber drying kiln.

Duties: During the two phases of his split mission, the consultant will, in collaboration with the counterpart agency (Institute of Applied Science and Technology) undertake the following activities:

First phase - exploratory mission:

1. Survey of the needs of small entrepreneurs for kiln-dried timber.
2. Finalization, based on the above, of the technical specifications of the kiln to be developed (size, type and detailed design).
3. Drawing up of the list o equipment and materials to be provided by the project and that of those items which could be purchased locally (the local versus imported components will be clearly shown).
4. Selection of the species to be test-dried in the kiln.
5. Prepare an interim report outlining in detail the tasks to be completed by the counterpart agency prior to his return.

Second phase - implementation:

1. Erection cf the kiln.
2. Starting of its operation.
3. Testing of the kiln by operating it with the selected species.

The consultant will present the results of his mission in a final report, which will contain detailed information on the design of the kiln, its operation procedures, its actual costs, etc.

Qualifications: Wood technologist specialized in wood drying and experienced in solar kiln construction and operation.

APPENDIX 2

Wood Processing Plants Visited and their Drying Facilities

Name of Firm	People Consulted	Operation Performed	Wood Drying Facilities	Current State of Wood Drying
Forestry Commission Forest Industries Development Unit, Kingston.	J. Douglas C. Hall	Joinery & Furniture manufacture, wood products research.	Three kilns (conventional) - one small experimental - one 17 m^3 (7000 bf) kiln - one 95 m^3 (4000 bf) kiln All steam heated. One solar kiln kit. Air drying in open sheds and some stacks outside sheds.	The 7 m^3 kiln is in operation drying timber for the Unit's own use and a limited quantity for customers. Spare parts for the 95 m^3 kiln have been ordered. Have own drying facilities and 2-3 operational electrical moisture meters.
Guyana Timbers Ltd.	C. Peters C. Anderson	Large sawmill with Prefab. housing operation.	One battery of high temperature 85°C (max.). Kilns of 24 m^3 (10,000 bf) capacity. One battery of low temperature (75°C), 155 m^3 (65,000 bf) capacity. Air drying in sheds and some stacks in open.	Boiler operating and the 155 m^3 kilns contained a half charge of timber. Temperature low and vents and control for humidity and temperature were not operating. Not much control of drying or control of final moisture content.
Walvis & Sons Woodworking Establishment	W. Davis R. Field-Ridley	Joinery & Furniture manufacture	One Dehumidifier kiln 5.3 m^3 (2400 bh). Air drying in racks in a shed.	Kiln has been used but is not currently being used. Cost of electricity given as a reason for not using it.
Guyana Wood Products Ltd.	B. Gittens F. Gittens B. Harper	Joinery, Furniture, toys and prefab. housing.	Currently only air drying sheds. Proposal for a 50 m^3 (21000 bf) drying kiln.	Air dried timber currently used and no facilities for testing moisture content.
G. Singh & Sons	G. Singh	Furniture Manufacture	Limited air drying facilities in shed.	Air dried timber used. Is considering purchase of dehumidifier.
Precision Woodworking Ltd.	H. Bulkhan	Furniture	Air drying only.	Air dried wood used.
Fries Furniture	Wong	Furniture	Open yard and closed shed for air drying.	Air drying only.
Persaud's Furniture	B. Persaud	Furniture, much of it upholstered.	Air drying in sheds.	Air drying but considering installation of kilns.
TWIGA Construction Company Ltd.	-	Joinery and prefab. housing, broom handles.	Air drying sheds.	Air drying only with limited shed capacity.
Interior Forest Industries Ltd.	T. Persaud	Large Sawmill.	Batteries of three large kilns 380 m^3 (160000 bf) capacity. Air drying sheds.	Installation of kilns not yet complete.
Amarali Sawmill	M. Amarali	Medium Sawmill	Air drying shed. No kilns.	Very little drying. Timber sold green.
Haroon Fazal Sawmill	H. Fazal	Medium Sawmill	No drying facilities.	No drying carried out.
Baijnauth & Sons	C.B. Baijnauth	Medium Sawmill	No drying facilities.	No drying carried out.
J & Z Sawh	J. Sawh	Large/medium sawmill.	No drying facilities.	No drying carried out.

APPENDIX 3

Timbers used by Joinery and Furniture Manufacturers and their Drying Properties and Guyana kiln schedules

Common Name	Botanical Name	Density 12% m.c. g/cm³	Recommended kiln schedule	Drying Characteristics
Red Cedar	Cedrela odorata	0.48	J	Dries rapidly without marked distortion.
Crabwood	Carapa guianensis	0.64	C	Dries slowly with tendency to split in early stages.
Determa	Ocotea ruba	0.66	E	Slow diffusion of moisture in wood: difficult to dry.
Dukali	Parahancorinia amapa	0.61	-	Air dried easily with little degrade.
Greenheart	Ocotea rodiaei	0.99	B	Dries slowly with minor degrade: checking and splitting may occur but distortion not severe.
Hububalli	Loxopterygium sagotii	0.66	-	Low movement, dries readily with little degrade.
Kabukalli	Goupia glabra	0.87	F	Kiln dries easily without degrade if dried slowly.
Kirikau	Iryanthera lancifolia	0.56	-	Air dries easily with little degrade.
Locust	Hymenaea courbaril	0.87	C	Dries readily without distorting or splitting.
Mora	Mora excelsa	0.99	B	Slow drying required to prevent checking and distortion.
Purpleheart	Peltogyne pubescens	0.95	F	Dries well and fairly rapidly with little degrade.

APPENDIX 3 (Continued)

Common Name	Botanical Name	Density 12% m.c. g/cm^3	Recommended kiln schedule	Drying Characteristics
Shibadan	*Aspidosperma album*	0.91	E	Dries without difficulty.
Silverballi (brown)	*Licaria canella* (part of group of species)	0.80	G	Dries well with little degrade.
Silverballi (kereti)	*Ocotea* spp. (part of group of species)	0.75	G	Dries well, slight surface checking may occur.
Tatabu	*Diplotropis purpurea*	0.92	C	Dries slowly but without distortion or splitting.
Tauroniro	*Himiria balsamifera*	0.80	-	Dries fairly well without degrade.
Wamara	*Swartzia leiocalycina*	1.06	B	Dries slowly with considerable surface checking & end splitting but distortion not serious.

GUYANA

KILN SCHEDULE A

Suitable for timbers which must not darken in drying and for those which have a pronounced tendency to warp but are not particularly liable to check.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	95	35	87	30.5	70
60	95	35	83	28.5	60
40	100	38	84	29	50
30	110	43.5	88	31.5	40
20	120	48.5	92	34	35
15	140	60	105	40.5	30

KILN SCHEDULE B

Suitable for timbers that are very prone to check.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	105	40.5	101	38	85
40	105	40.5	99	37	80
30	110	43.5	102	39	75
25	115	46	105	40.5	70
20	130	54.5	115	46	60
15	140	60	118	47.5	50

KILN SCHEDULE C

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	105	40.5	101	38	85
60	105	40.5	99	37	80
40	110	43.5	102	39	75
35	110	43.5	100	38	70
30	115	46	103	39.5	65
25	125	51.5	109	43	60
20	140	60	118	47.5	50
15	150	65.5	121	49	40

KILN SCHEDULE D

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	105	40.5	101	38	85
60	105	40.5	99	37	80
40	105	40.5	96	35.5	70
35	110	43.5	97	36	60
30	115	46	97	36	50
25	125	51.5	101	38	40
20	140	60	105	40.5	30
15	150	65.5	112	44.5	30

KILN SCHEDULE E

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	120	48.5	115	46	85
60	120	48.5	113	45	80
40	125	51.5	116	46.5	75
30	130	54.5	117	47	65
25	140	60	120	49	55
20	155	68	127	53	45
15	170	76.5	136	58	40

KILN SCHEDULE F

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	120	48.5	111	44	75
60	120	48.5	109	43	70
40	125	51.5	109	43	60
30	130	54.5	109	43	50
25	140	60	115	46	45
20	155	68	124	51	40
15	170	76.5	136	58	40

KILN SCHEDULE G

Suitable for timbers which dry very slowly, but which are not particularly prone to warp.

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	120	48.5	115	46	85
60	120	48.5	113	45	80
40	130	54.5	123	50.5	80
30	140	60	131	55	75
25	160	71	146	63.5	70
20	170	76.5	147	64	55
15	180	82	144	62.5	40

KILN SCHEDULE H

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	135	57	127	53	80
50	135	57	126	52	75
40	140	60	126	52	65
30	150	65.5	129	54	55
20	170	76.5	136	58	40

KILN SCHEDULE J

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb) °F	Temperature (Dry bulb) °C	Temperature (Wet bulb) °F	Temperature (Wet bulb) °C	Relative humidity % (Approx.)
Green	135	57	123	50.5	70
50	135	57	119	48	60
40	140	60	118	47.5	50
30	150	65.5	121	49	40
20	170	76.5	127	53	30

KILN SCHEDULE K

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb) °F	Temperature (Dry bulb) °C	Temperature (Wet bulb) °F	Temperature (Wet bulb) °C	Relative humidity % (Approx.)
Green	160	71	151	66	80
50	170	76.5	156	68.5	70
30	180	82	159	70.5	60
20	190	88	153	67.5	40

KILN SCHEDULE L

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb) °F	Temperature (Dry bulb) °C	Temperature (Wet bulb) °F	Temperature (Wet bulb) °C	Relative humidity % (Approx.)
Green	180	82	165	74	70
40	200	93.5	162	72	40

KILN SCHEDULE M

Moisture content (%) of the wettest timber on the air-inlet side at which changes are to be made	Temperature (Dry bulb)		Temperature (Wet bulb)		Relative humidity % (Approx.)
	°F	°C	°F	°C	
Green	200	93.5	184	84.5	70
50	210	98	179	81.5	50

[From Stevens, M.R. and Pratt, G.H. (1961). Kiln Operators Handbook, HMSO, U.K.]

APPENDIX 4

Quantities of Timber used per Annum by Joinery and Furniture Manufacturers.

Company's Number	Timber used b.f	Timber used m^3
1	42,500	101
2	40,000	95
3	124,000	295
4	25,000	60
5	364,000	867
6	400,000	952
7	832,000	1981
8	30,000	71
9	64,000	152
10	260,000	619
11	53,000	126
12	156,000	371
13	61,000	145
Total	2,451,500	5,835

APPENDIX 5

Solar Kiln Cost Estimate for Aluminium and Melinex 7 m^3 kiln

	US$
Capital Cost:	
Building Kiln : kit cost in Guyana	3,500
Erection - 6 men for 10 days @ G$ 15/day	209
Extras (paint, CGI etc.)	100
	3,809
Operating Costs:	
Land Rental: 300 m^2 (3 weeks air drying and 3 weeks in kiln giving 16 loads per annum allowing for holidays, enough for two (2) stacks @ US$ 1/m^2/year)	300
Labour: 2 man days per load for monitoring and 1 load per 3 weeks 4 man days stacking per 3 weeks 2 man days to move kiln (16 charges/year) @ $ 15/man day	447
Power: 10 hrs x 7 days x 3 weeks x 16 charges x 0.375 kw/hrs x 0.84 G$ per kw	246
Maintenance 5% capital cost/year	190
Annual capital charge: 20% of capital cost	762
OPERATING COST TOTAL	1,945
Working Capital:	
Assuming three loads of 250 ft @ G$ 24/ft^3	4,186
6 weeks rent labour and power	188
TOTAL WORKING CAPITAL	4,374
TOTAL ANNUAL COST 20% annual interest for 6 weeks	101
TOTAL COST OVERALL	2,046

Unit Cost

Cost/m^3 = US$ 18.27
Cost/ft^3 = US$ 0.522
Cost/b.f. = US$ 0.044
G$ 0.187

APPENDIX 5 (Continued)

Costs at Different Production Rates

Kiln Loads/Annum

		Kiln Loads/Annum 16	12	8
Throughput ft^3		4,000	3,000	2,000
Land rent	US$	300	300	300
Labour	US$	447	335	224
Power	US$	246	185	123
Maintenance	US$	190	190	190
Annual capital charge	US$	762	762	762
Total costs	US$	1,945	1,772	1,599
Working capital	US$	101	101	101
		2,046	1,873	1,700
Cost/ft^3 + capital	US$	0.513	0.624	0.85
or	G$	2.24	2.68	3.66
Cost/b.f.	G$	0.19	0.22	0.30
Cost/m^3	G$	79	94	128

Revenue

The mark up per b.f. for kiln seasoning is normally between G$ 0.5 and 1.0. Assuming a figure of $ 0.5. Revenues would be G$ 24000 (US$ 5581) for 16 loads, 18000 (US$ 4186) for 12 loads and 12000 (US$ 2791) for 8 loads.

Net profits would, therefore, be US$ 3535, US$ 2313 and US$ 1091 respectively per kiln per annum.

APPENDIX 6

List of Equipment Required

Item	Cost US$ Overseas purchase	Local purchase
Aluminium frame/Melinex covered Solar kiln complete with frame, motors, switchgear and glazing landed Guyana	4000.00	
Mettler top loading electronic balance 6100- 0.1 g Model TE 6000	1100.00	
Avery Scale No. 1306 BFP/S 77 - 01842	600.00	
"Tromatic" Cubbage/Bolmann moisture meter measuring moisture content from green to dry	400.00	
3 x 100 pack charts for Moore Dry Kilns No. 6237	20.00	
Small electric power saw for trimming stack ends	100.00	
4 x pocket steel tapes metric/imperial	30.00	
2 scientific and two simple, solar operated calculators	60.00	
30 inch (76 cm) bowsaw & 10 blades	25.00	
Dial gauge comparator for measuring timber shrinkage and movement (Mercers)	300.00	
Reichart wedge-type microtome knife with 15°-20° blade angle for OmE sledge microtome	30.00	
Books on timber technology and timber drying	100.00	
Four simple wet and dry bulb thermometers for monitoring kiln performance	60.00	
Spare ½ hp electric motor for experimental drying kiln	120.00	
Set of tools including AF & Metric open ended spanners and one large and one small star and slot screwdrivers	30.00	
7 x fans and motors for box collector kiln @ $ 250 each	1750.00	
200 m^2 Melinex	400.00	
Bolts to join structure	45.00	
Timber (1100 b.f. of 4" x 2" & 300 b.f. of 2" x 1")		500.00
Plywood		160.00
Black polythene/wire mesh		120.00
Black paint		30.00
TOTALS	9170.00	810.00

APPENDIX 7

Consultant's Itinerary

Date	Activity
Wednesday 30/1	To Vienna.
Thursday 31/1	Briefing UNIDO, Bassili, Hallet, Emery, Mennel and Ivanov.
Friday 1/2	To London and Port of Spain, Trinidad. Night POS.
Saturday 2/2	To Georgetown, Guyana, saw J. Douglas and C. Hall.
Sunday 3/2	Discussions Douglas, Hall and D. Cody.
Monday 4/2	Meeting at UNDP with Mr. C. Davis, Cody, Douglas - visit to Forestry Commission's Kingston Yard and equipment.
Tuesday 5/2	Visits to furniture and joinery manufacturers and start building of "Jakrap" solar kiln with R. Field-Ridley.
Wednesday 6/2	Visits to furniture and joinery and furniture manufacturers and Guyana timbers. Work on "Jakrap" kiln.
Thursday 7/2	Full day visit to Interior Forest Industries sawmill and kilns.
Friday 8/2	Visit to IAST Meeting Dr. Trotz and work on "Jakrap" kiln.
Saturday 9/2	Work on "Jakrap" kiln, report writing.
Sunday 10/2	Free, report writing.
Monday 11/2	All day visit to Corentyne to visit sawmills and woodworking establishments with Douglas and R. Hastings.
Tuesday 12/2	Work on "Jakrap" kiln and report writing.
Wednesday 13/2	All day visit to Demerara Woods Ltd. sawmill, gasification plant and kilns with Douglas, Trotz and Davis.
Thursday 14/2	Completion of "Jakrap" kiln and commissioning, meeting with furniture and joinery manufacturers.
Friday 15/2	Meeting with Davis and Douglas at UNDP. Completion of draft report. Leave midday for Trinidad and London.
Saturday 16/2	Arrive London.

APPENDIX 8

Drawings of Proposed New Kiln Design

Figure 3. End view.

Figure 4. Side view.

FIGURE 3. END VIEW OF PROPOSED NEW KILN

Scale 1cm = 30·48cm (1ft)

EAST – WEST Orientation

1300mm wide, 125 mil thick 'Melinex' glazing in seven single strips covering whole structure and clipped into position by moulded timber battens in grooves in rafters.
End walls either glazed or plywood cladded.

Fans with integral high-temperature wound motors accessible through trap doors in ceiling operated by light switch or time clock

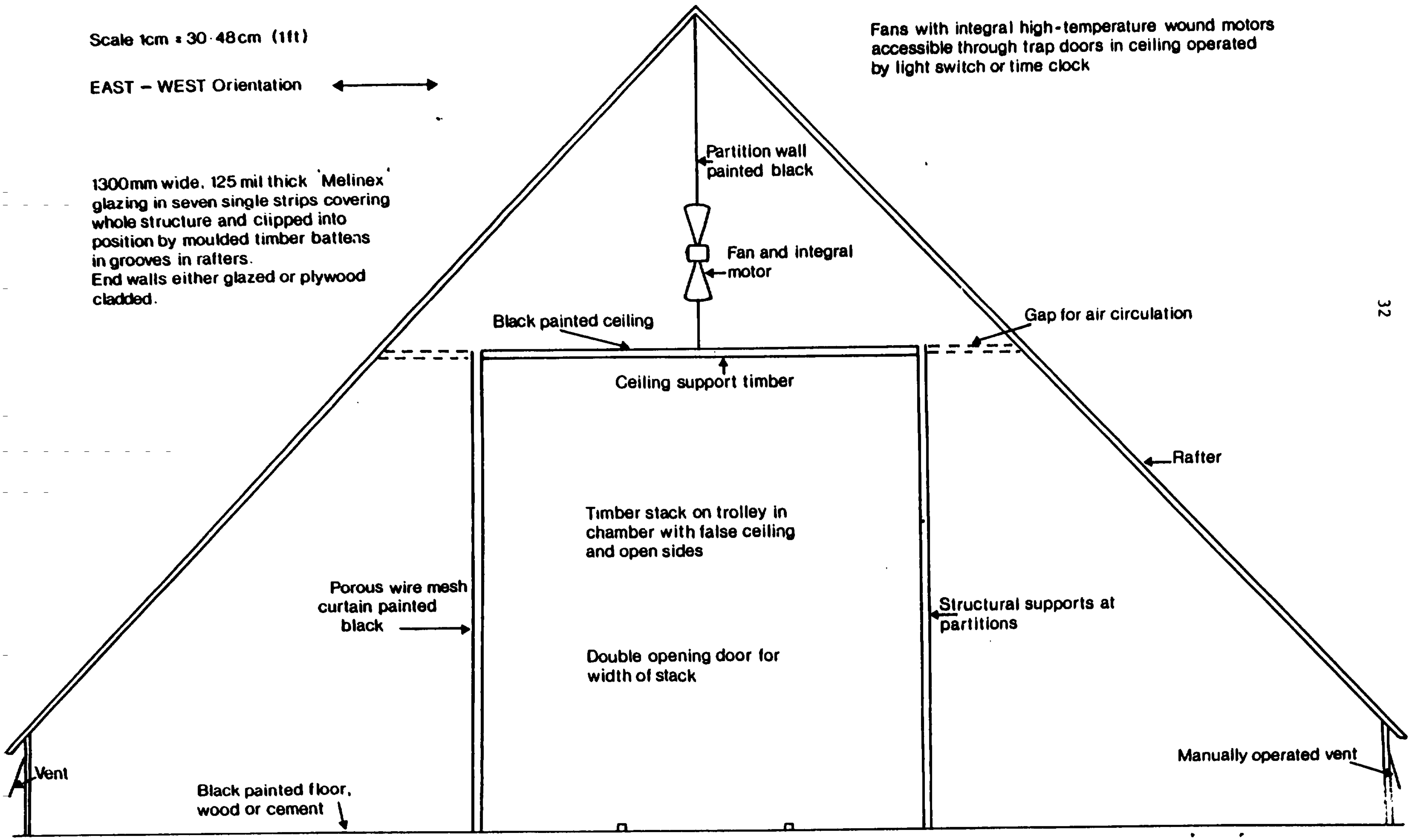

FIGURE 4. SIDE VIEW OF PROPOSED NEW KILN

Scale 1cm = 30·48cm (1ft)