

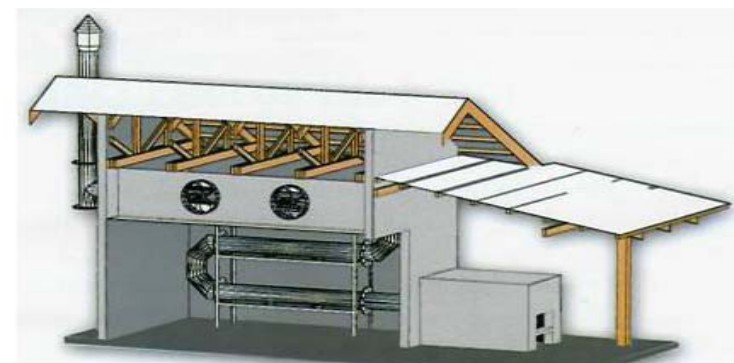


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**DEMONSTRATION AND APPLICATION OF PRODUCTION AND
UTILIZATION TECHNOLOGIES FOR RATTAN
SUSTAINABLE DEVELOPMENT IN THE
ASEAN MEMBER COUNTRIES
[ITTO-Philippines-ASEAN Rattan Project]**

Technology Guide No. 04

KILN DRYING OF RATTAN



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KILN DRYING of RATTAN

1.0 INTRODUCTION

The local furniture industry started in the 1970s with rattan and wicker products. These items made significant inroad into the export market and eventually led to the development of other product designs and utilization of other raw materials. To date, the Philippine furniture industry uses wide range of raw materials- rattan, wood, metal, bamboo, fossilized stones, buri, plastic, etc. These are used singly or in combination (mixed-media) in one product.

1.1 Profile of the Industry

Around 15,000 companies comprise the local furniture industry of which 2% are classified as large ventures and 98% are micro, small and medium enterprises. Said industry employs about 481,500 direct workers and 300,000 subcontractors. (Pearl 2 Proj. 2005). Other beneficiaries are the raw material gatherers, processors, suppliers and traders.

The 3 major furniture production areas in the Philippines are Cebu, Metro Manila and Pampanga.

Philippine furniture exports averaged to US\$312 million per year from 2000 to 2005.

The major product lines exported are wooden (48%) and rattan (31%) furniture.

Table 2. Estimated Cost of FPRDI-Designed Multi-Purpose Kiln Dryers

Type of Dryer	Loading Capacity		Estimated Direct Cost Material Cost/Labor Cost (PhP)	Total Cost (PhP)	Dimension of Chamber (m) (WxLxH)
	Lumber (bdft)	Rattan poles, Ave dia = 5cm (pcs)			
Flue-tube type	1,000	1,500 –1,600 ^{1/}	225,000/78,750	303,750	3.0x3.6x3.0
	1,500	2,000-2,200 ^{1/}	260,000/91,000	351,000	4.2x4.2x3.0
	3,000	2,500 –2,800 ^{1/} or 5,000—5,600 ^{2/}	300,000/105,000	405,000	4.8x4.2x3.0
	5,000	3,000—3,200 ^{1/} or 6,000—6,400 ^{3/}	470,000/164,500	634,500	4.8x6.0x3.6
	10,000	15,000 ^{4/}	680,000/238,000	918,000	5.4x10x4.2
Shell-tube type	1,000	1,500 –1,600 ^{1/}	200,000/70,000	270,000	3.0x3.6x3.0
Portable/ Demountable (Kerosene- heated)	1,500- 2,000	3,30-3,500 ^{3/}	227,000/98,000	315,000	2.4x6x2.5

Assumptions: ^{1/} Length of poles = 3.60 m (12ft)

^{2/} Length of poles = 2.44 m (8 ft)

^{3/} Length of poles = mixed 2.44 m (8ft) and 3.04 m (10t)

^{4/} Length of poles = 3.04m (10ft)

Note: Cost estimate of construction materials are based on high prices indicated on the Metro Manila Construction Materials Price and Indices as of First Quarter 2006. Labor cost is estimated at 35% of material cost.



21 a



21 b

Fig. 21. Bulk-piling of dried rattan poles over a rack without stickers (21a) or by bundles (21b) inside the warehouse.

5.0 COST OF KILN DRYERS INSTALLATION

Depending on the type of kiln dryers and loading capacity the cost of installation is summarized in Table 2. The total cost for each type of kiln dryer includes materials and labor.

During the said period, rattan furniture export averaged to US\$97.22 million per year. The top 5 export markets are US, Japan, UK, Australia and France.

The competitive strength of the industry in the global market is mainly associated to the Filipino skills in product design and development (Fig. 1). However, there are many issues and concerns which need to be addressed to improve the industry's performance. Among these include the sustainability of forest-based raw material supplies and modernization of processing equipment and facilities to improve productivity and product quality. At present manufacturing processes are still mainly manual with some mechanization. In general only the medium and large-scale enterprises have modern production facilities such as kiln dryers to facilitate drying of raw materials to required moisture content (MC).

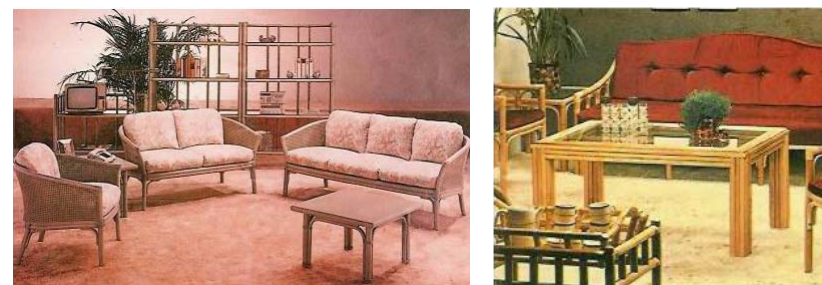


Fig. 1. Rattan furniture made in the Philippines

1.2 Importance of Drying Rattan Poles

Drying operation is an important integral part of processing system in a furniture plant. It provides the following benefits when the materials are dried to MC level required for the end-product or in service:

- renders the material dimensionally stable
- increases strength properties
- eliminates or reduces risk of fungal (<20% MC) and insects (<10% MC) attack
- facilitates absorption of preservatives (<30%MC)
- reduces transport costs
- facilitates machining, gluing and sanding
- facilitates application and adhesion of finishing materials (stains, varnishes, paints, etc).
- increases insulation value
- reduces risk of corrosion of metal fasteners/fittings in the product.

More often, the defects that occur in subsequent processing and even in finished products are associated to improper drying of raw materials.

Newly harvested rattan poles should be dried immediately to below 20% MC (if not applied with prophylactic treatment). These can be infected by staining fungi within 24-hr after harvesting (Fig. 2).

- Another way of knowing the termination of kiln drying operation involves calculation of the weights of the poles for MC monitoring at target MC level. Kiln drying is stopped once the weight of the pole samples reached the calculated weights at target MC level (i.e. 15%) which is computed by the formula:

$$\begin{aligned}
 W_c &= \left[1 + \frac{MC}{100} \right] \times \left[W_{co} \right] \\
 &= \left[1 + \frac{15}{100} \right] \times \left[1176.5 \right] \\
 &= 1.15 \times \left[1176.5 \right] \\
 &= 1352.97 \text{ or } 1353 \text{ g}
 \end{aligned}$$

Where: W_c = calculated weight at target MC
 MC (target) = 15%

4.5 Handling and Storage of Dried Poles

Following drying, dried poles are bundled and immediately delivered to the plant for further processing. If the dried poles are not processed immediately, these should be stored or bulk-piled in a well ventilated warehouse. The bundles should be piled horizontally in racks elevated at about 0.6m (2 ft) above the ground (Fig. 21)

- Firstly, determine the calculated oven-dry weight (W_{co}) of a particular pole sample (P1). Assuming its first recorded weight ($W_g 1$) is 2000 g at 70% MC as determined from the example under Section 4.2 the W_{co} is computed as follows:

$$W_{co} = \frac{W_{g1}}{1 + \frac{MC}{100}}$$

$$= \frac{2000}{1 + \frac{70}{100}} = \frac{2000}{1.7} = 1176.5 \text{ g.}$$

At the second weighing, the same pole sample (P1) for instance registered a weight of 1600 g or W_{g2} . The current MC or MC_2 is computed with the formula indicated in Section 4.2 but replace the W_o with W_{co} obtained above.

$$MC_2 = \frac{W_{g2} - W_{co}}{W_{co}} \times 100$$

$$= \frac{1600 - 1176.5}{1176.5} \times 100 = 36\%$$

- Repeat the computation for each pole samples after the next weighing period to monitor the progress of drying and current MC of the poles.
- Terminate the kiln drying operation after the poles for MC monitoring have attained the desired average MC level.



Fig. 2. Scraped rattan poles infected by staining fungi.

Stains and blemishes greatly reduce rattan pole quality. Their bending strength is reduced and as such they are prone to premature breakage during bending of curved furniture components. Fungal-stained poles require expensive bleaching chemicals to enhance the color. Others use artificial stains or coloring pigment during finishing to hide the fungal discoloration. Stained canes also fetch a lower price compared to unstained poles.

The moisture and starch content as well as the sizes of the pores of rattan can also affect susceptibility to insect infestation. Poles with 10 to 50% MC are liable to attack of powder-post beetles.

In finished products it has been observed that these are susceptible to attack of molds if the materials used are not dried below 20% MC. Blistering or premature peeling-off of finishes is commonly associated with improper drying.

2.0 METHODS OF DRYING RATTAN POLES

2.1 Air Drying

This is the most common and cheapest method of drying rattan poles (PCARRD 1985).

Air drying involves exposure of the rattan poles to the sun or under shade to dry. The common stacking pattern used in this drying system is to arrange the poles vertically or horizontally against a horizontal wooden frame or group them together in “wigwam” formation (Fig. 3 and 4).



Fig. 3 Air drying of rattan poles in near vertical (top) and horizontal position (lower photo)



Fig. 4. “Wigwam” form of drying rattan poles

- To facilitate drying open the exhaust and inlet vents for about 20-30 seconds at an interval of around one hour especially in the early stages of kiln drying. The purpose of this is to replace humid air with fresh air inside the kiln chamber. Kiln drying rate is quite slow if the air inside the kiln is fully saturated with water.
- In the final stage of drying, opening of the vents should be done at longer interval and shorter duration to avoid frequent fluctuation of DBT and WBT setting.
- Once final MC is attained, open all the vents. Refrain from feeding fuel to the furnace and close it to extinguish the fire and remaining lighted fuels.
- Allow the fans to operate until the load cools down before unloading poles from the kiln dryer.

Improper setting or use of KDS results to collapse or excessive checks on the surface of the poles. For small-diameter rattan species a lower setting of DBT and WBT may be used to prevent drying-related defects.

4.4. MC Monitoring

The randomly selected pole used for MC determination should be weighed and marked/coded individually and placed strategically within the pile for drying. As drying progress, these are taken out of the kiln and weighed from time to time (every 8-12 hr) to monitor the current MC which indicate the average MC of the poles. After weighing, these are placed back in their proper location inside the kiln. Current MC is computed by:

After piling or loading the poles to be dried inside the kiln, close the doors and vents then fire the furnace and turn-on the fans. Continue stoking the furnace until the required DBT and WBT are attained. The proper wet bulb depression (WBD) is attained by skillful manipulation of humidity through the spray line.

- Maintain the required DBT and WBT setting (Fig. 20) throughout the drying operation by regulating the fuel of the furnace and humidity inside the kiln.



Fig. 20. Wet bulb and dry bulb temperature gauges

- On the other hand, if the WBT setting is exceeded open both the exhaust and inlet vents to get the required setting.
- If the WBT drops to the required setting, open the spray line to increase humidity inside the kiln with the vents in closed position. Add fuel as the need arises to increase the DB and WB temperature.

This traditional drying method entails relatively long drying time to attain desired MC level. The duration of exposure depends upon the prevailing climatic condition of a locality, initial MC and diameter of the poles.

In general it takes 2-3 months to dry the poles below 20% MC. Air drying during the rainy season is longer than during the dry season and the possibility of fungal attack is greater. About 30-40% of the rattan poles get varying degrees of fungal stain with this drying method.

2.2 Kiln Drying

This is the fastest method of drying rattan poles (Natividad1995). However, depending on the type of the kiln the construction can be quite expensive.

Kiln drying involves the use of an enclosed chamber with controlled temperature, air circulation and humidity condition. The rattan poles are stacked horizontally and heated inside the kiln to facilitate drying to required MC.

Kiln drying or artificial heating of rattan poles results to lower MC and shorter drying time compared to air drying. Depending on the initial MC, diameter and species the duration of kiln drying to 15% MC ranges from 1.50 – 8.0 days.

The kiln dryer can be constructed as a permanent structure near or within the furniture factory. It can also be designed as a portable or demountable facility in rattan buying stations for immediate drying of poles brought down from the forest.

Heating of the kiln uses non-conventional sources of energy such as woodwastes, tree tops and branches.

3.0 FPRDI-DESIGNED KILN DRYERS

FPRDI has conducted several studies on the drying of rattan poles and design/development of kiln dryers (Gnanaharan and Mosteiro 1997).

Cortes (1939) investigated the air-drying of rattan poles and found that unscraped poles vertically stacked in the open took 26-wk to attain 22% average MC from an initial MC of 160%. The scraped poles, on the other hand, attained 13% MC in 5-wk from 120% initial MC. In a similar study where the rattan poles were stacked in near vertical position, Casin (1975) attained 20% and 23% average MC in 8-wk air-drying of scraped and unscraped poles, respectively. All the materials were heavily stained at the end of the drying period. Laxamana (1974) also studied the use of steam-heated kiln to dry 2.5 to 3.8 cm diameter Tumulim (*Calamus mindorenses* Becc.) poles. The drying time for scraped poles from 103-150% to 3-18% MC was

Fig. 19. Moisture meter.



4.3 Kiln Drying Operation

Kiln drying of rattan poles (or lumber) involves the use of kiln drying schedules (KDS) which specifies the appropriate combinations of temperature and RH inside the kiln to facilitate drying and avoid drying-related defects. Based on FPRDI studies, the following KDS are recommended for large-diameter rattan species (Table 1):

Table 1. Recommended KDS for Palasan and Limuran

Species	Dry Bulb Temp(°C)		Wet Bulb Temp (°C)	RH (%)	Remarks
Palasan & Limuran (Casin 1979)	(KDS1) 66		43	28	Green to final MC
Limuran (Laxamana 1974)	(KDS2) 83		53	23	Green to final MC
	(KDS3)	80	50	80.6	Green to 30% MC
		85	55	44	30% MC to final MC
	(KDS4)	75	62	52	Green-40%MC
		75	60	48.5	40-30% MC
		80	62	44	30-20%MC
		80	60	32	20-final MC

- Weight the disc samples and record the initial or green weights (Wg).
- Immediately dry the disc samples in an oven at $100 \pm 5^{\circ}\text{C}$ for 24 hours.
- Oven-dry the disc samples until a constant weight is attained (Wo). The initial MC is computed by the formula:

$$\text{MC}\% = \frac{\text{Wg} - \text{Wo}}{\text{Wo}} \times 100$$

Where: MC = moisture content
 Wg = initial or green weight
 Wo = oven-dry weight

Example:

$$\begin{aligned} \text{Wg} &= 107 \text{ g} \\ \text{Wo} &= 63 \text{ g} \end{aligned}$$

$$\text{MC} = \frac{107 - 63}{63} \times 100 = 69.84\% \text{ or } 70\%$$

- After computing the initial MC of each disc from the randomly selected moisture pieces or poles, compute the average MC of the poles to be dried.

The fastest way of determining MC is with the use of moisture meter (Fig. 19) which is commonly used for wood. The electrical-resistance type moisture meter can be used for the determination of final MC after kiln drying because the normal range of reading is 6-30% MC while the electrical-capacitance type moisture meter with 6-60% MC or higher effective reading range can be used for MC monitoring during kiln drying. However, the moisture meter should be properly calibrated for rattan to determine its correction factor and to get a reliable moisture reading.

from 1-5 days while the unscrapped poles with 85-145% initial MC were kiln dried to 5-15% MC in 2-10 days.

Mabesa E. and Mabesa C (1956) designed and installed a furnace-type kiln dryer for rattan poles. Kiln drying of Palasan (*Calamus merrillii*) and Limuran (*C. ornatus*) in this facility in scrapped and unscrapped forms resulted to less than 10% MC in 96-hr from more than 120% initial MC.

An experimental low-cost, furnace-type kiln dryer (Fig. 5) with a loading capacity of 500 poles was designed and developed by Casin (1979). Heat was generated by woodwaste-fired furnace and the hot air circulates naturally into the kiln through flue pipes. The smoke exits through a chimney. Humidification was through a spray line situated below the flue pipes. The dryer can reduce the MC of scrapped poles with 115 initial MC to 15% in 64 hours.

Another rattan pole dryer (Fig. 6) which is portable and demountable with 250-pole loading capacity was developed by FPRDI (Casin 1985). It has a frustum shape, 4m in diameter at the base, 0.8 m at the top, 3.8 m high and a total weight of 114 kg. The ribs are made of telescoping aluminum tubes and the structure is covered with tarpaulin. Heat which can reach a temperature of 45°C is provided by a charcoal drum kiln at the center of the structure. Scrapped Palasan poles can be dried from 80% MC to 15% in 72 hours.

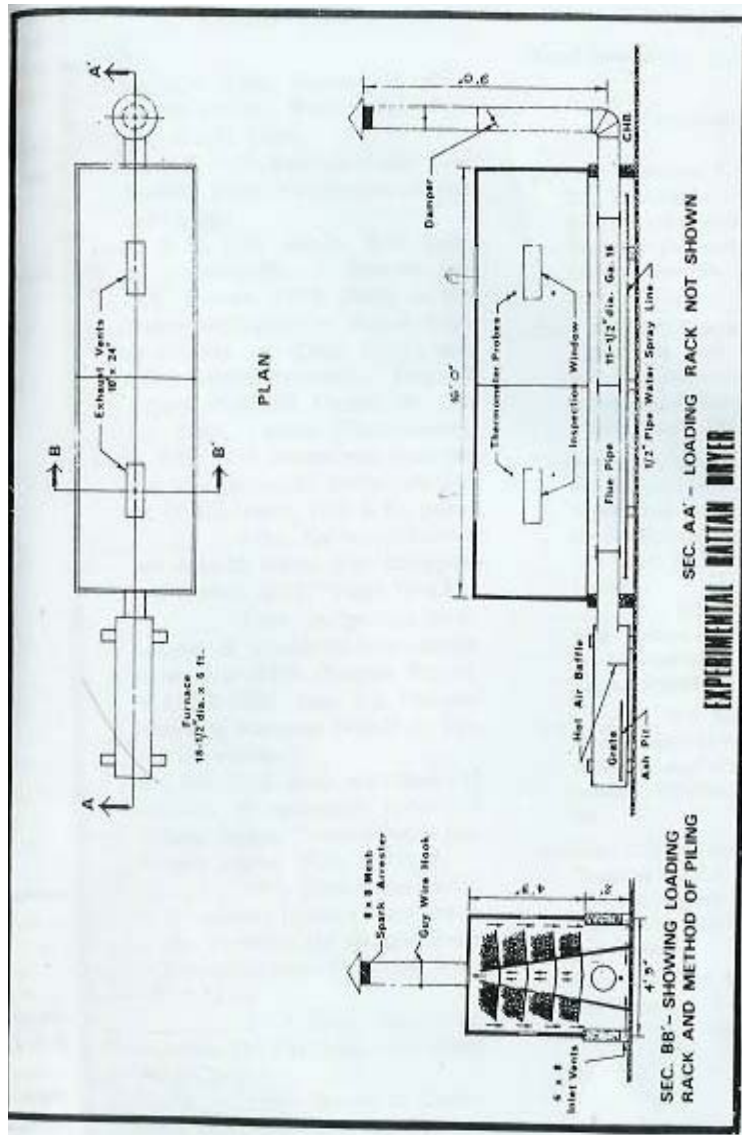


Fig. 5. Design of the Experimental Furnace-Type Dryer (Casin 1979)

- Once fully loaded, the rack or carriage is pushed or pulled by cable and pulley assembly inside the kiln. The orientation of the piled poles could be parallel or perpendicular to the direction of air circulation. Parallel orientation with respect to the air circulation dries relatively faster.
- For economic reasons, the load of the kiln dryer should be at full capacity during the drying operation

4.2 Determination of Initial MC

Prior to kiln drying operation the average initial MC of the batch of rattan poles to be dried should be determined by random sampling (5-10 pcs).

One accurate way of determining MC is by oven drying method. This involves the following steps:

- Cut 25 mm discs samples (3 pcs) at 0.6m (2 ft) away from the end of the randomly selected poles for initial MC determination.
- Properly mark or code each disc sample i.e. for Pole #1, 1A, 1B and 1C for disc sample # 1,2 and 3.

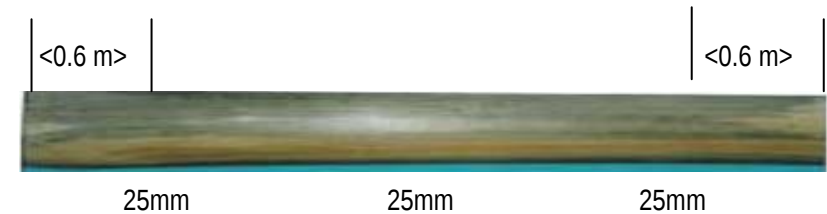


Fig. 18. Cutting diagram of disc samples

The poles may be piled in 2 ways:

- Bulk-pile the poles over a rack (Fig. 16) or loading carriage outside the kiln in horizontal position;

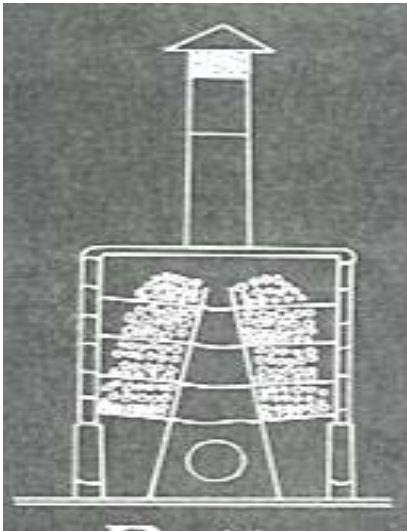


Fig. 16. Bulk piling of rattan poles over a rack.

- Tie the poles together in small bundles and pile the individual bundles horizontally by layer over a loading carriage (Fig. 17). Each layer is separated by rattan pole stickers with diameter of 25 mm or larger, length slightly longer than the width of the pile and about 0.6 (2ft) apart.

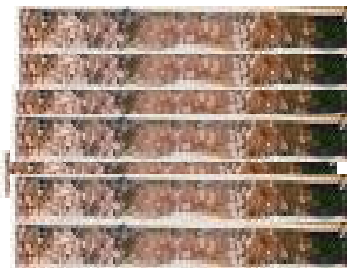


Fig. 17. Piling bundles of rattan poles with stickers in between layers



Fig. 6. A portable and demountable kiln dryer designed for drying rattan poles near or within the cutting site (Casin 1985)

The use of the foregoing rattan pole dryers presupposes the drying of the poles near the harvesting sites to control fungal infestation. However, said technologies have never gone beyond the experimental stage because the rattan gatherers and small-scale processors in the rural areas have limited capital to invest in the installation of drying facility.

Presently, the actual practice of rattan gatherers involves bulk delivery of the poles from the cutting site to the factory or depot where sun-drying or kiln drying is usually done by the processors. Here, the poles have already incipient to relatively advanced fungal attack. This problem is remedied by bleaching thus increasing the processing cost.

In view of the above and considering the mixed raw materials used in the furniture industry, the FPRDI designed and developed multi-purpose kiln dryers:

- 2 furnace-type with fixed structure; and
- One (1) diesel/kerosene-fired which is portable and demountable.

These can be installed near the cutting site for drying newly harvested poles and other raw materials to inhibit the growth of staining fungi. Another option is the installation at the factory or depot but the raw materials have to undergo prophylactic treatment after harvesting.

In large furniture plants, a sizing machine is used to scrape the poles of their outer skin and nodal bulges (Fig. 15). The machine produces cylindrical poles with uniform diameter. However, the poles to be processed in this machine must first be straightened.



Fig. 15. Sizing or rod-making machine

Piling. Proper piling of poles inside the kiln chamber allow hot air to circulate freely within the pile; thus heat is evenly distributed and results to faster drying and more or less uniform final MC.

To facilitate piling or loading of poles to be dried as well as unloading of dried poles, a rack or loading carriage made of angle bars with casters or rails is needed.

- A straightening machine can also be used if available (Fig. 14).



Fig. 14. A rattan pole straightening machine

Scraping of poles is usually done manually in green condition. This processing operation involves.

- Fabrication of an A-frame to support the poles to be scraped in near vertical position.
- Scraping of the nodal bulges and epidermal layer of the poles with bolo, knife
- spokes have metal scraper.

3.1 FURNACE-TYPE KILN DRYERS

FPRDI has developed and commercialized 2 kinds of furnace-type kiln dryers. These can be used for drying lumber and non-wood forest products (NWFP) such as rattan, bamboo, woody vines, buri, pandan etc (Cuaresma, 2002). The temperature and relative humidity inside the kiln are determined using dry and wet bulb sensors connected to temperature gauges. These operate within a temperature range 21°C to 82°C (70°F to 180°F).

Among the advantages of these drying facilities compared to other kinds of modern dryers (steam-heated, solar-heated, vacuum-type, etc.) are the following (Carmelo et.al 2005)::

- made of locally available materials;
- easy to operate;
- uses woodwastes as fuel;
- dries lumber and NWFP to MC level acceptable to the local/export markets; and
- size or loading capacity can be varied to suit the requirement of the end-user.

Said drying facilities have 5 major components: a) drying chamber; b) heating system; c) air circulation system; d) humidification system; and e) venting system.

3.1.1.1 Shell-Tube Type (Fig. 7)

Drying Chamber . The drying chamber measures 3.0m (10 ft.) wide by 4.2m (14ft.) long by 2.4 m (8 ft.) high. The total drying chamber area is 9.0 sq.m (100 sq. ft.). The structure is composed of square tube metal framing and double-walled 6mm thick fire resistance Hardiflex board. In between walls is a 50mm thick styrofoam as heat insulation. The inner walls, including exposed metal parts, are coated with “Weatherkote Type 3” for waterproofing and to minimize heat loss through the structure. The chamber is an air-leak proof structure with one main door for loading and unloading the material to be dried. It has 2 air inlet vents at the front wall and 2 exhaust vents at the back wall. In between the heat exchanger and the loading area is a firewall made up of fire resistant double walled hardiflex board with 50mm thick styro foam in between.

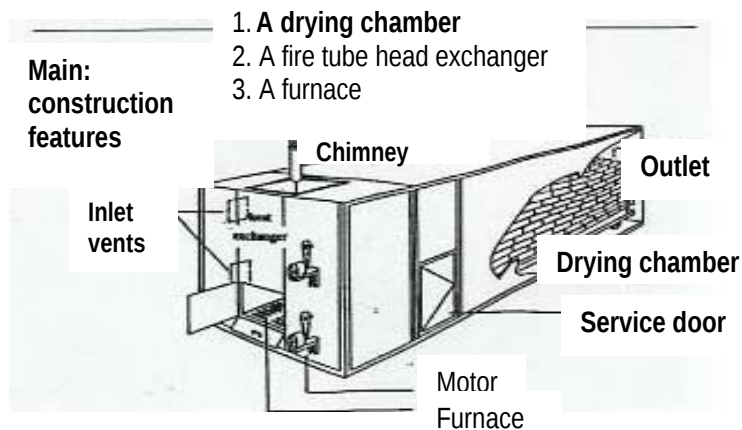


Fig. 7 Shell Tube –Type Furnace Dryer

Straightening involves the following operations:

- Heat the curvature in the pole to be straightened with a blow torch for 20-30 seconds.
- To minimize scorching or burn marks on the rind of the pole distribute the heat slowly and evenly by rotating the workpiece.
- Once sufficiently heated the pole may be straightened manually by applying a pressure at the curves or with the use of a straightening gadget (Fig. 13).



Fig. 13. A straightening gadget made of wood.



3a



3b

Fig. 12. Sorting of rattan poles (3a) and stack of sorted poles ready for drying (3b)

- Ideally a kiln charge should consist of one rattan species but these can be mixed provided the diameter and MC are more or less uniform.
- Freshly-cut and relatively air-dried poles must be kiln dried separately.

Straightening and Scraping. These are optional operations but, if done, these could facilitate handling and drying of poles. Straightened poles easier to handle and scrape by manual operation or by mechanized sizing machine. Scraped poles dry faster than unscraped ones. Scraping the epidermal layer of the poles also facilitates chemical absorption if the poles will be treated with fungicide or insecticide.

Heating System (Furnace to Chimney Assembly). The heating system is composed of 3 parts: the furnace, the heat exchanger and the hood to chimney assembly. These 3 components are placed one on top of the other where the furnace is at the bottom, the heat exchanger in the middle and the hood to chimney assembly at the topmost portion (Fig. 8). These components are connected by 10mm diameter bolt with garlock gasket in between components.

Close-up view of Shell Tube pipes (upper) and Furnace (lower illustration)

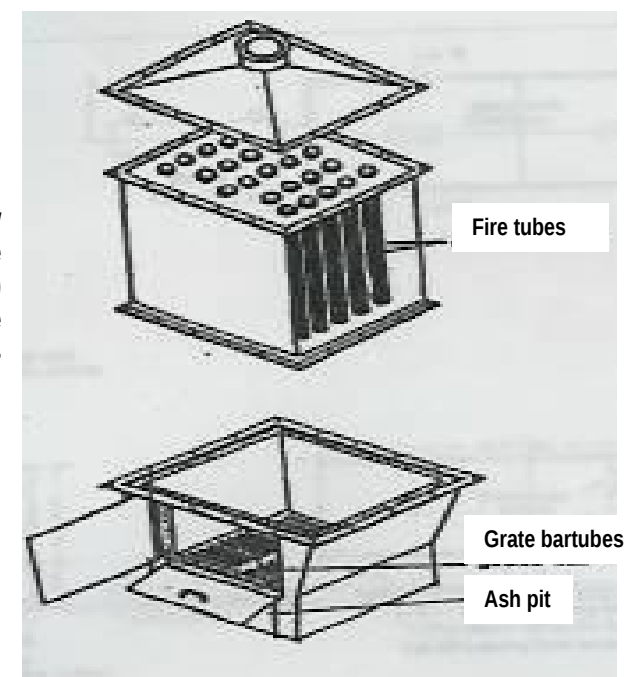


Fig. 8. Heating System (Furnace to Chimney Assembly) of the Shell-Tube-Type Furnace Dryer.

Furnace. The furnace is made of 6mm thick mild steel plate for outer casing with 100 mm thick refractory cement in the inner portion. The combustion area is 4,500 sq cm (720 sq. in) based on heat requirement of the chamber. The grate bars are fabricated cast iron with 12mm opening. The furnace has a main door and ash pit door.

Heat Exchanger. The heat exchanger is made of 10 mm thick mild steel plate casing and 19 pieces 75mm diameter by 0.9 m high B.I. pipes as heat exchanger. The pipes, which are vertically welded, are properly spaced in columns for a uniform heat distribution as per FPRDI's design and specification.

Hood to Chimney Assembly. The hood is made of 6mm thick mild steel plate designed to collect hot flue gas from the tubes before exhaustion to chimney. The chimney stack has a rain cap and mesh screen as spark arrester. A manually operated butterfly damper is installed below the base of the chimney to control the outflow of the hot flue gas and maintain the required temperature inside the chamber.

Air Circulation System. Air circulation is the internal movement of hot air inside the chamber from the heat radiating surfaces of the tubes to evaporate moisture, and replace heat loss through the kiln structure and the vents.

Temperature and Relative Humidity Control. For the control of the temperature and relative humidity during the drying operation, 2 dial gauges (analog type), 0-200°F graduation, 75mm diameter dial face with 1.82m (6 ft). capillary tube and provided with sensor at the end were used. One dial gauge will be for the dry bulb temperature and the other for the wet-bulb temperature. For the wet-bulb temperature, a water box made of steel plate material measuring 100mm width x 100 mm depth by 200mm length is installed.

Use of digital type temperature and relative humidity controllers makes the operation more simplified. These can be set to the desired requirements during the drying operation.

4.0 KILN DRYING PROCEDURE

4.1 Preparation of poles for kiln drying

Sorting of poles. Small-diameter poles dry faster than large-diameter poles. Likewise, freshly-cut poles have higher MC and requires longer duration of drying than partially dried poles. To facilitate drying and avoid wide variation of final MC the following should be done:

- Sort the poles to be kiln dried by diameter class, species and MC (Fig. 12).

cold rolled steel 1 ¼" diameter with keyways at both ends, (c) 4-electric motors, 1.0 hp, 220 volts, 60 cycles, (d) fan pulley, 200 mm diameter, 2 groove, B-type, (e) motor pulley, 100 mm. diameter, 2 groove, B-type and (f) Industrial type fan belts. The 4 fans are positioned strategically along the top panel with the 4 motors installed at the top. During the drying operation, the heat coming from the heat exchanger is sucked by the fans and then blown to the material being dried. The process continues until the desired MC of the material is attained.

Humidification and Venting System. The required humidification is supplied by a water spray line with 8 adjustable spray nozzles to give off fine mists. The water spray line, located below the second run of the flue pipe is manually controlled by a gate valve installed outside the chamber and within reach of the operator. As the fine mists impinge on the hot surface of the flue pipe, they vaporize and mix with the drying air inside the chamber.

There are 4 exhaust vents measuring 300 mm x 300 mm, provided with swinging cover attached to a round bar that is connected to the control lever for closing and opening. These are installed at the wall panel opposite the fans. Four inlet vents, are installed just below the fan pulley and are also attached to round bar and connected to the control lever.

A 2.4 cu m (1,000 bd ft) capacity dryer has 2 units of 60 cm diameter, 5-blade propeller fans installed. The 2 fans are driven by a 1hp, 220 v, single-phase electric motor. The fan system is a cross-shaft type located at the end wall in line with the heat exchanger. Another wall is placed between the heat exchanger and the load to prevent short-circuiting of air.

Humidification System. Humidification system involves a water spray line with 4 nozzles adjusted to give a fine mist. These are located at the right side of the heat exchanger. The nozzles are 45 cm apart. The spray line is manually operated and controlled by a control valve installed outside the chamber near the dial gauges. In the water spray line, humidification is supplied by opening the control valve from the main water line. The fine mist of water impinges on the heated surface of the flue pipe then vaporizes and mixes with the drying medium. This operation is done to build up the required relative humidity inside the chamber during the drying process to regulate evaporation of moisture.

Monitoring of humidity is done using the 2 dial-type thermometers, which are installed in the middle portion of the chamber opposite the flue pipe wall.

Venting System. The optimum vent opening for any particular kiln is difficult to determine. Fast drying at low temperature and low relative humidity requires high venting capacity. Opinions and experiences differ widely as to the proper size and number of vents. However, the amount of outgoing saturated air should be equal to the incoming dry or fresh air.

In the design, 2 inlet vents measuring 900 sq cm (144 sq. in) each are provided at the end wall of the kiln near the motor. Two (2) exhaust vents of the same size are located directly in level with the two fans at the opposite end. All vents are manually operated and controlled.

3.1.2 Flue-Tube Type (Fig. 9)

Drying Chamber. This is an enclosed chamber made of 15.24 cm (6") concrete hollow block wall and 10.1 cm (4") concrete slab flooring and ceiling. The kiln walls and ceiling can also be made from properly insulated wood boards. It may be single-ended or double-ended depending on the method of piling and movement of materials to be dried.

marine plywood is used for the exterior wall and 6mm thick Hardiflex boards are used for the interior walls. Fiberglass wool or 50mm thick Styrofoam is used as insulator for the walls. The structure parts or components are fabricated in panel form and are assembled on site by bolting each panel together. The flooring can either be made of concrete or panelized with metal frames and 18mm thick marine plywood as cladding.

Heating System. To meet the heating requirement, a 3-run hot-air flue pipe, 30 cm in diameter and of varying thickness was designed. The flue pipe is constructed in sections, provided with flange connectors at ends for ease of installation and maintenance. A 2.438 m length chimney completes the heating system. A manually operated butterfly damper at the base of the chimney controls the outflow of hot gases to maintain the required temperature inside the drying chamber. For the source of heat, a commercially available 2 ton capacity diesel/kerosene fueled igniter/blower was installed.

Fuel consumption of the igniter/blower is rated at 5 liters per one-hour operation.

Air Circulation System. The air circulation system consists of the following: (a) 4 units- 0.60 m. diameter , 6 blades aerodynamic fans, 4500 cfm, (b) Shafting made of

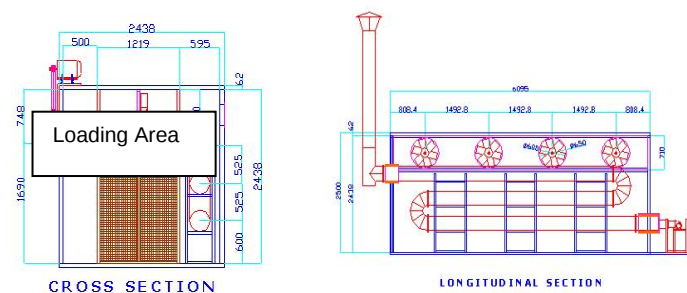


Fig. 11. Profile of the Kerosene-heated Portable/Demountable Dryer

It is suited especially in areas where burning of biomass fuel is restricted or scarcity of biomass fuel is experienced (Zamora 2004). It is demountable and portable and easy to operate and maintain. Diesel or kerosene can be used as fuel for the heating system.

Drying Chamber. The dryer measures 6.0 m. in length, 2.438 m. in width and 2.438 m. in height. The dimensions of the structure can be varied depending on the needs or requirement of the prospective end-user. (The drying chamber can be made of container van, with or without wheels, to reduce installation cost).

The structural frames are made of light metals such as 50 mm x 50 mm square tubes, 75 mm. C-purlin or 6mm x 50mm x 50mm angle bars. For claddings, 6mm thick ma-

A single-ended kiln has a set of doors in front for both loading and unloading of poles. On the other hand, a double-ended kiln has a set of doors in front for loading green poles and another set of doors at the other end for unloading kiln-dried poles. A double-ended kiln requires added cost for the railings and carriages.

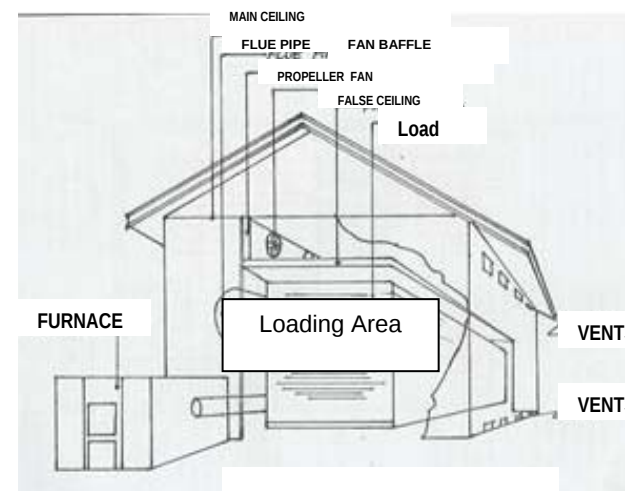


Fig. 9. Flue-Tube Type Furnace Dryer

The kiln structure anchors the essential features of the dryer: the heating, air circulation, and humidifying and venting systems. The flue pipe inlet is mounted on the front wall, while the chimney is mounted on the back wall. The ceiling anchors the fan and its housing, while the fan motor with pulley assembly is mounted on the left side wall

with pillow block supports. The inlet and exhaust vents are located on the right side wall.

Heating System. The heating system consists of the furnace and 3-run flue pipe (Fig. 10) with chimney. Wood or rattan waste fuel is burned in the furnace to produce hot gases. As the hot gases pass through the flue pipe by natural draft, heat then radiates from the flue pipe to the kiln chamber and the temperature inside the kiln increases. Heat comes out of the kiln through the chimney.

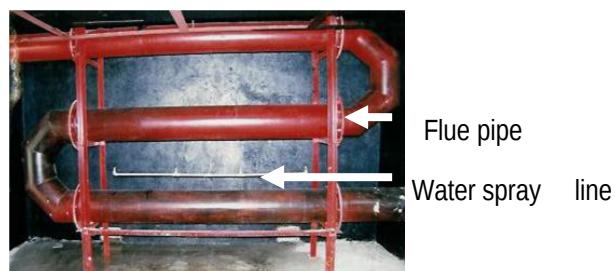


Fig. 10. Close-up view of the 3-run flue pipe inside the drying chamber

Air Circulation System. Air circulation in a kiln distributes heat from the flue pipe to the poles and enables moisture to evaporate from the poles.

The air circulation system consists of overhead cross shaft propeller fans evenly distributed along the length of the kiln

facing the right of the chamber. The number and size of fans depend on the dryer's loading capacity. Each fan is shafted to a motor with pulley assembly and is supported by pillow blocks and fan hangers. All fans, mounted in a housing, are anchored to the concrete ceiling. Air velocity must be between 1.8 to 3m per second.

To produce evenly dried poles, air must circulate uniformly in the kiln.

Humidifying and Venting System. Very high pressure on poles owing to increased temperature may cause drying-related defects such as collapse and surface checks. To avoid these drying defects humidity is increased by introducing water through the water spray line (Fig. 10). The water spray line has several nozzles that spray fine mists of water on the flue pipe. As water hits the hot surface of the flue pipe, it vaporizes and mixes with air, thus increasing the humidity inside the kiln. The kiln has an inlet to allow the entry of fresh air, while exhaust vents allow moist air to escape from the chamber.

3.2. PORTABLE/DEMOUNTABLE DRYER (Fig. 11)

This is another multipurpose dryer lately developed and commercialized by FPRDI as an alternative to the furnace-type dryer.