## OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

## DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

## FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

## CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

20182

Distr.
RESTRICTED

IO/R.269
22 April 1993

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

ORIGINAL: ENGLISH

# GLOBAL DEVELOPMENT OF THE RUBBERWOOD INDUSTRY

DU/INT/92/012

**Technical report: The current status of the rubberwood processing industries in selected tropical countries of Aisa***

Prepared for member countries
by the United Nations Industrial Development Organization,
associated agency of the International Trade Center,
which acted as executing agency for the
United Nations Development Programme

Based on the work of Horatio P. Brion,
consultant in production of sawn rubberwood

Backstopping officer: Antoine V. Bassili
Agro-based Industries Branch

---

* This document has not been edited.

V.93 84387

# EXPLANATORY NOTES

The monetary units of the countries visited under this mission corresponding current official exchange rates were:

| | | |
|---|---|---|
| Indian Rupee: | IR | 28.10 = US$1.00 |
| Indonesian Rupiah: | IRp | 2,040 = US$1.00 |
| Malaysian Ringgit: | M$ | 2.55 = US$1.00 |
| Philippine Peso: | PhP | 25.00 = US$1.00 |
| Sri Lankan Rupee: | SLR | 43.02 = US$1.00 |
| Thai Baht: | ThB | 25.06 = US$1.00 |
| Viet Namese Dhong: | VND | 10,750 = US$1.00 |

The following acronyms are used in this Report:

| | |
|---|---|
| CIRAD-Forêt | New Name of Centre Technique Forestier Tropical (CTFT), Nogent-sur-Marne, France |
| ESCAP | Economic and Social Commission for Asia and the Pacific |
| FRIM | Forest Research Institute Malaysia, Kepong, Selangor, Malaysia |
| GAT | General Agreement on Tariffs and Trade |
| MIDA | Malaysian Industrial Development Authority Kuala Lumpur, Malaysia |
| MTIB | Malaysian Timber Industry Board, Kuala Lumpur, Malaysia |
| RRII | Rubber Research Institute of India, Kottayam, Kerala, India |
| RRIM | Rubber Research Institute of Malaysia, Kuala Lumpur, Malaysia |
| ITC | International Trade Centre UNCTAD/GATT |
| UNCTAD | United Nations Conference on Trade and Development |
| UNIDO | United Nations Industrial Development Organization |

A hyphen between numbers (e.g., 1-5) indicates the full range involved, including the beginning and end points.

A full stop (.) is used to indicate decimals.

A comma (,) is used to indicate thousands, millions, billions.

The following symbols, and/or abbreviations as used in this report:

| | |
|---|---|
| IR | Indian Rupee, currency unit of India |
| IRp | Indonesian Rupiah, currency unit of the Republic of Indonesia |
| M$ | Malaysian Dollar, Ringgit, currency unit of the Federated States of Malaysia |
| PhP | Philippine Peso, currency unit of the Republic of the Philippines |
| SLR | Sri Lankan Rupee, currency unit of Sri Lanka |
| ThB | Thai Baht, currency unit of the Kingdom of Thailand |

| | |
|---|---|
| US$ | U.S. Dollar, currency unit of the United States of America |
| VND | Viet Namese Dhong, currency unit of Viet Nam |
| bd. ft. | Board Foot or Board Feet |
| CCA | Copper-chrome arsenate, an insecticide and fungicide used in the rubberwood processing industry |
| $cm^2$ | square centimeter |
| dia. or D | diameter |
| etc. | "et cetera", and so forth |
| ft. or ' | foot; feet; 12 inches |
| ha. | hectare (10.000 $m^2$) |
| Hg | height of mercury, used in connection with pressure measurement |
| HP | horse power |
| hrs. | hours |
| hrs./day | hours per day |
| in. or " | inch; inches |
| K. D. | kiln-dried; kiln-drying |
| KW | kilowatt; 1000 watts |
| $m^3$ | cubic meter |
| mc or MC | Moisture Content |
| mm | millimeter; 1/1000th of a meter |
| $mm^2$ | square millimeter |
| m/min | meters per minute |
| $m^3$/yr. | cubic meters per year |
| N/$mm^2$ | Newtons per square millimeter, unit of pressure or force |
| NaF | sodium fluoride, anti-fungus chemical |
| PCP | pentachlorophenol, an insecticide |
| % | per cent |
| S4S | surfaced (planed smooth) on all 4 faces of the lumber board |
| TCT | Tungsten-carbide-tipped |
| vs. | "versus"; compared with; against |

# TABLE OF CONTENTS

## FIGURES

## TABLES



## ANNEXES

## EXECUTIVE SUMMARY

This paper studies the respective rubberwood processing industries of six rubber producing countries of Asia. It further evaluates and rates them compared to that of Malaysia, with a view to drawing an up-to-date picture of the status of this industry in Asia. Upon consultation with top executives from the International Rubber Research and Development Board (Brickendonbury, U.K.), the International Rubber Study Group (London, U.K.), the Centre Technique Forestier Tropical (Nogent sur Marne, France), and the Institut de Recherches sur le Caoutchouc (Paris, France), India, Indonesia, the Philippines, Sri Lanka, Thailand and Viet Nam were chosen as the subjects of this study. The state of development of the rubberwood processing industries in the selected countries was studied for the period 1980-1989, supplemented with the more recent developments from 1990 to the present.

The component phases of the industry were studied, noting the existing differences in the level of the industry's development, and looking into relevant contributory factors prevailing in the countries visited, so that an assessment of the potentials for the development of the industry based on the country's existing industrial resources could be drawn. The study was further augmented by visits to various types of rubberwood processing plants, which included fixed-type sawmills, plywood and particle board manufacturing plants, pallet fabrication shops, furniture and joinery factories, and a shop which produced components for the building and construction industry. Typical logging operations were also observed during the field visits: from a simple manual type in Sri lanka to a highly mechanized logging system observed in Malacca, Malaysia. A third type of logging operations, geared to supply the material input for a particle board plant, was also observed in Thailand.

The common industry practice is to deliver the rubberwood logs to the sawmill or plywood plant within a maximum of 60 hours during the dry season or much sooner during the rainy part of the year in order to avoid biodegradation of the logs at the cutting site. Preservative treatment of the rubberwood logs in the logyard is done mostly in big factories which handle a large volume of rubberwood inventory in the logyard; whereas small and medium rubberwood sawmills do not treat their log inventories with preservative chemicals for they do not keep more than two days' supply of logs in the log yard. A majority of the Asian countries visited use borate compounds for protecting their rubberwood. However, Copper-Chrome-Arsenate (CCA) is still used in India.

Mechanized rubberwood log loading techniques and handling facilities were observed mostly in Thailand and Malaysia. The system used such modern equipment as self-loading cargo trucks equipped with one to two-ton hydraulic operated cranes. On the other hand it appears that many rubberwood logging contractors are not financially capable of investing such modern transport and handling facilities.

The bandsaw, of either vertical or horizontal design, is the most commonly used principal log breakdown machinery in rubberwood sawmilling operations. Mobile types of sawmill have lately become popular in small-scale sawmilling operations. Circular saws are commonly used both for cutting boards to desired length and for ripping operations. Most of the small and medium size sawmills visited have purely manual sawblade maintenance facilities. Thus, the cutting precision, efficiency and quality in the rubberwood sawmills in Asia are generally lower than the corresponding performance of hardwood sawmills. Cupping, warping and twisting problems that occur when rubberwood boards are air-dried can be traced to the "flat sawing" cutting pattern generally used in rubberwood sawmilling operations. This may be overcome by using the "peeling" sawing pattern, similar to the technique developed for sawing coconut wood. Lumber yield rates in rubberwood sawmills were found to average at about 30%, much lower than those attained in hardwood sawmills.

Lately, those borate/boric acid rubberwood preservatives have gained a wider use over pentachlorophenol (PCP) and Copper-Chrome-Arsenate (CCA) compounds caused by market resistance to the toxic and carcinogenic effects of PCP and CCA. However, there is still need for lower cost preservative treatment systems and methods of applying them on rubberwood boards.

Preservative treated rubberwood can be dried using the seasoning techniques and facilities (kiln-driers, dehumidifiers, vacuum driers etc.) which are currently available in the market. In spite of its high initial cost, vacuum driers have lately become acceptable in the industry due to the good performance and shorter drying periods as compared to conventional types of drying equipment.

The state of development of the rubberwood secondary processing industries in the Asian countries visited indicate that of Malaysia and Thailand as the most developed, followed by India, Indonesia, Sri Lanka, Viet Nam and the infant rubberwood processing industry of the Philippines being the least developed.

For the same type of end product, the manufacture of rubberwood secondary processed products follows the same sequence of operations as that for hardwood. However, a small additional cost, however, is incurred in the production of items which use laminated (edge-glued) boards or finger-jointed components.

Recent studies on the availability of rubberwood indicate the possibility of establishing additional manufacturing capacities to the existing rubberwood processing facilities. A full development of the rubberwood processing industries in 1991 could have supported additional processing capacity 1.75 times that of the existing installed capacity in Asia and more than double the existing capacity at world level.

Recent studies indicate that at least 75 percent of the total rubber tree plantations of the world is owned and operated by smallholders who do not have the financial capability to observe and implement desirable cutting cycles, nor the silvicultural practices required by proper maintenance and care of the rubber plantation, particularly during the first seven years of the rubber tree's life. Government assistance is needed to help the rubber industry produce more latex, as well as high volumes of better grade rubberwood logs. Furthermore, adoption of standard grading rules for rubberwood logs and boards, at both the national and international levels, will provide a tremendous boost to the development of the rubberwood processing industries.

# I. INTRODUCTION

## A. Scope of the study

The over-all objective of this study is to describe the state of development of the rubber processing industries of key rubber producing countries in Asia, other than Malaysia. Rubber trees are reported to be grown on commercial scale in the following Asian countries: Bangladesh, Cambodia, India, Indonesia, Malaysia, Myanmar, Papua New Guinea, People's Republic of China, Philippines, Sri Lanka, Thailand, and Vietnam. Rubber trees are also grown in other countries, but both the areas planted to rubber trees and the corresponding production of latex are negligible compared to the countries listed above. Hence, it was assumed that their rubberwood processing industry would be too small vis-a-vis the major rubber-producing countries to be relevant to this study. There may also be no rubberwood processing industries in those other countries.

Thus, it was decided to choose five or six major rubber-producing countries; study, evaluate and rate (compared to Malaysia) their respective rubber processing industries with the expectation that a representative image of the industry for Asia (other than Malaysia) can be depicted.

### 1. Basis of selection and countries selected

With guidance from Dr. Peter Allen of the International Rubber Research and Development Board, (United Kingdom), Dr. F. Sekhar of the International Rubber Study Group (United Kingdom), Bernard Parant of the Centre Technnique Forestier Tropical (France) and Hubert Omont of the Institut de Recherches sur le Caoutchouc (France), the following parameters were established and used for the selection: rubber production since 1991; area planted to rubber trees vis-a-vis natural forest cover; and, known levels of industrialization and development of the wood processing industries in the country being evaluated.

The rankings given below are relative and are based on the knowledge and experience of the above-named rubber industry experts who have been involved the monitoring, development and support of the rubber industry on an international basis during the last 20 years or more.

a) Rubber Production:
- i. Thailand
- ii. Indonesia and Malaysia[1]
- iv. India
- v. China, Sri Lanka and the Philippines
- viii. Viet Nam and Papua New Guinea

---

[1] Not covered in this study

b) Degree of Industrialization - Wood Processing:
   i. Thailand and Malaysia[1]
   iii. India
   iv. Philippines, Indonesia, China and Sri Lanka
   viii. Viet Nam and Papua New Guinea

c) Area Planted with Rubber Trees:
   i. Indonesia
   ii. Thailand and Malaysia[1]
   iv. India and China
   vi. Sri Lanka and the Philippines
   viii. Viet Nam and Papua New Guinea

Based on the above ratings, the following countries were selected:

China
India
Indonesia
Philippines
Sri Lanka
Thailand

Viet Nam and Papua New Guinea were kept as alternate target countries for this study. Unfortunately, the visit to China could not be fitted in within the tight time and budgetary constraints. Thus, Viet Nam was chosen as the sixth country to be included in this study.

2. **Time periods studied**

The status of the rubberwood processing industries of the countries selected was studied for the ten-year period 1980-1989 and then the more recent developments, if any, from 1990 to the present. There was a significant development of the rubberwood processing industries among the leading rubberwood processing countries in the south and southeast Asian region during the period of 1980-1989; and it would be of great importance to the overall objectives of the project to know how much of this technology was assimilated and/or adapted to local conditions by other countries since 1990.

B. <u>Methodology of the study</u>

A comparative description of the status of the rubberwood processing industries of the target countries is presented in the following chapters of this paper based on the parameters selected. Wherever possible, major differences in the attained level of development of the industry are indicated, and contributory factors prevailing in the country are discussed, leading to an assessment of the potentials for the development of the industry based on the country's existing industrial resources.

The agricultural aspects of the rubber industry were studied as part of the efforts to determine the availability of rubberwood logs during the periods studied. Among others, the volume of rubberwood logs expected to be obtained through the rubber tree replacement activities were compared to actual log yields, wherever available data allowed such comparison. The more common diameters and lengths of the stems of rubber trees in the area visited were also noted, in relation to the volume of rubberwood logs harvested.

Logging activities were also looked into, both in terms of degree of mechanization and duration of activities during the year. Log bucking techniques were observed, with particular interest in log sizes obtained, and number of logs cut from each stem.

An idea on the amount of rubberwood stems and branches used for fuelwood in the latex processing activities, as household fuel, and how much was burned in the fields to "help fertilize the land for the ensuing rubber tree replanting activities" were also obtained, wherever possible.

Pre-processing preservative treatment of rubberwood logs was also noted, together with the number of days the logs remain in the plantation before they are transported to the processing plants, as reported by logging contractors/operators.

Log handling techniques (both at cutting site and factory log yard), together with the method of transporting logs from cutting site to the factory, were also observed and noted.

Visits to rubberwood processing plants gave indications as to the level of development of the industry in each country visited. Visits to various types of rubberwood processing plant included:

a) In the primary processing activities:
- a number of sawmills (only fixed type of sawmills, using bandsaws or circular saws for the primary log breakdown, were visited, as mobile sawmilling operations were not accessible during the time of the visit);
- one plywood manufacturing plant, producing 19mm (3/4 in.) x 900mm (3 ft.) x 900mm (3 ft.) plywood panels; and
- one particle board manufacturing plant producing 19mm (3/4 in.) x 1200mm (4 ft.) x 2400mm (8ft.) panels.
- there was no MDF fibreboard plant in the countries visited, other than Malaysia and Thailand[2];

b) In the secondary wood processing industry:
- a number of pallet fabrication shops;
- two mouldings production plants;

---

[2] for Thailand, information provided by Mr. Simula

- a number of furniture and joinery manufacturing plants, some of them with their own sawmilling, preservative treating and kiln-drying facilities; and
- only one plant engaged in the production of components for the building and construction industry (in India) was visited; and

c) In the tertiary wood processing industry:
- two factories producing finger-jointed and/or laminated (edge-glued) components as part of their over-all woodworking operations;
- one shop fabricating toys, novelty items and other hand-crafted products; and
- one rubberwood charcoal-making facility and briquette production shop, using woodwastes from the sawmill and pallet fabrication shop (included in the tertiary wood proecessing industries because it uses the wastes of secondary industries as raw material).

## II. CURRENT STATUS OF THE INDUSTRY

### A. Principal characteristics and needs of Rubberwood logging operations in selected Asian countries

#### 1. General sequence of logging operations

Rubberwood logging operations, before and during the early 1980's, were normally carried out by contractors who were paid to clear the land to permit the replanting of rubber trees. This type of logging operation was found to be still practiced in areas of some Asian countries (the Philippines, Viet Nam and Sri Lanka) where the rubberwood processing industries have not yet developed appreciably so that the main value of rubberwood is a fuel for smoking latex sheets and as a household fuel for cooking purposes. However, the advent of more developed rubberwood processing activities during the mid 1980's to the present, has resulted in rubberwood logs being processed into marketable products, the concept and practice of logging in the rubber plantations have become mechanized to meet the demands of the rubberwood processing industry for bigger volume, better quality logs and a more dependable supply of the material. Thus, it is now a practice for the rubber tree farmers (or plantation owners) in most of the major rubber producing countries in Asia to sell the mature rubber trees, with the condition, of course, that the land be cleared, leveled and ready for replanting. Final clearing is done by burning all stumps, twigs and small branches that are left behind after the rubber trees are felled and the logs are extracted and transported to the sawmills or wood-based panel factories. Three typical rubberwood logging systems are presented in the following paragraphs, together with their respective estimated (or reported) costs.

a) <u>The simple manual type of Rubberwood logging</u>

The first system is the most primitive, the least mechanized and was observed in Sri Lanka. The system is purely manual, using hand tools (hand-operated winch, pulley and cables, axes, hoes, handsaws, etc). A team of ten men: three winch operators and seven diggers and helpers, is normally required when using this logging system. A hand-operated mechanical winch is anchored to the base of one rubber tree (see Figure 1) with 25mm (1 in.) cable. A loop of 19mm (3/4 in.) cable is passed through the output end of the winch (see Figure 2) to the sheave of a 250mm (10 in.) diameter pulley (see Figure 3), and acts as the tension link between the tree and the winch. Another loop of 19mm (3/4 in.) cable (see Figure 4) is passed through the fixed end of the pulley and anchored [about 2000mm (6 ft. 5 in.) above the ground] on the stem of the rubber tree to be felled (see Figure 5). The winch is then operated (see Figure 6) to take up the cable slack and set up the initial tension. Once this has been done, the diggers and hoers start chopping and cutting off the roots around the base of the tree (see Figures 7 and 8). Further tension is gradually applied on the cable while more and deeper roots around the base of the tree are cut. When the tree is rid of its root anchors down to the depth of about 300mm (1 ft.), the diggers/hoers move away from the tree and greater tension is applied on the pulling cable until the tree starts to fall down (see Figure 9). Once felled, the tree stem is then cut to the desired log lengths, allowing one saw length for the stump (see Figures 10 and 11). The stem portion with less than 100mm (4 in.) diameter, together with the branches and twigs are then cut to short lengths (600-750mm) for fuelwood purposes. The long logs are then manually loaded lengthwise on the truck's bed (see Figure 12). Short logs (1800mm or 6 ft. long or shorter) are loaded across the width of the truck's bed. One team of 10 workers can fell 20-25 rubber trees per day. The contractor pays the team SLR 50 (US$1.16) per tree. All tools and implements are owned by the contractor. On the basis of an average 0.75 m3 of wood obtained from each rubber tree, the felling and yarding cost (to the contractor) would be a minimum of SLR 62.50 (US1.45) per cu. meter. The total log cost is thus:

| | |
|---|---|
| Felling and yarding labour | US$ 1.45 per $m^3$ |
| Additional labour cost, clearing and burning stumps, branches and twigs | 1.45 |
| Log handling and transport (to within 50kms. of logging site) | 4.75 |
| Stumpage price (Horana area) | 8.75 |
| T o t a l | US$ 16.40 per m3 |

Figure 1
Manually-operated winch is anchored
to the base of a Rubber tree

Figure 2
Cable is passed through the output end of the winch

Figure 3
Cable pulley assembly which acts as tension link between tree to be felled and the winch

Figure 4
19 mm cable attached to fixed end of pulley (note hook at the end of the cable)

Figure 5
Hooked cable end is wrapped around stem of tree to be felled

Figure 6
Winch is operated by moving lever handle forward and backward

Figure 7
Roots anchoring Rubber tree to the soil surface on side facing winch are cut

Figure 8
Roots on the other side of the Rubber tree are also cut

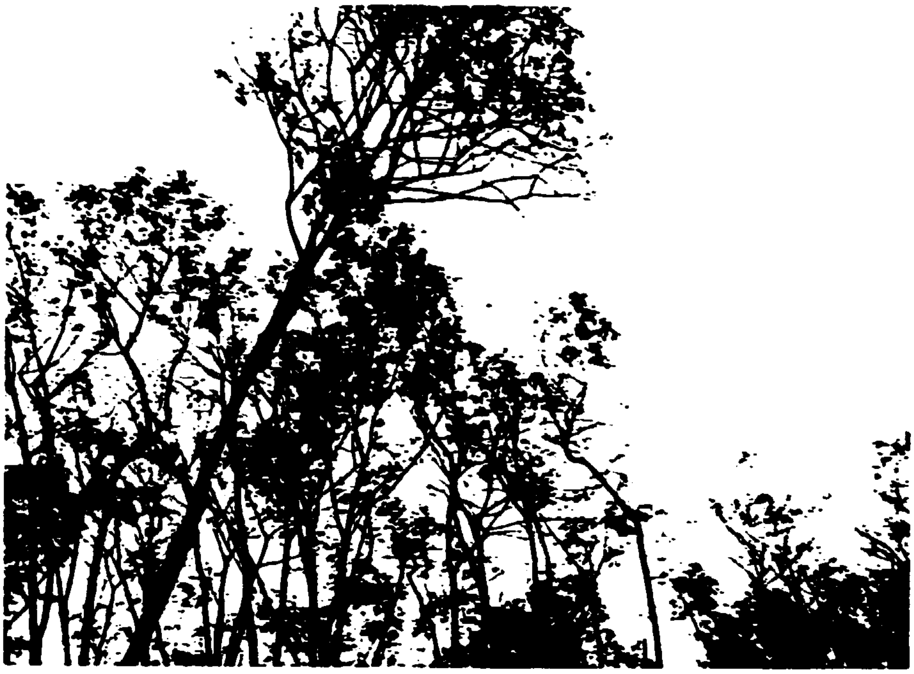


Figure 9
Rubber tree starts to fall as tension
on cable is increased

Figure 10
Location of first log length is
measured by handsaw length

Figure 11
First cut is done as close as possible to the top roots of the tree

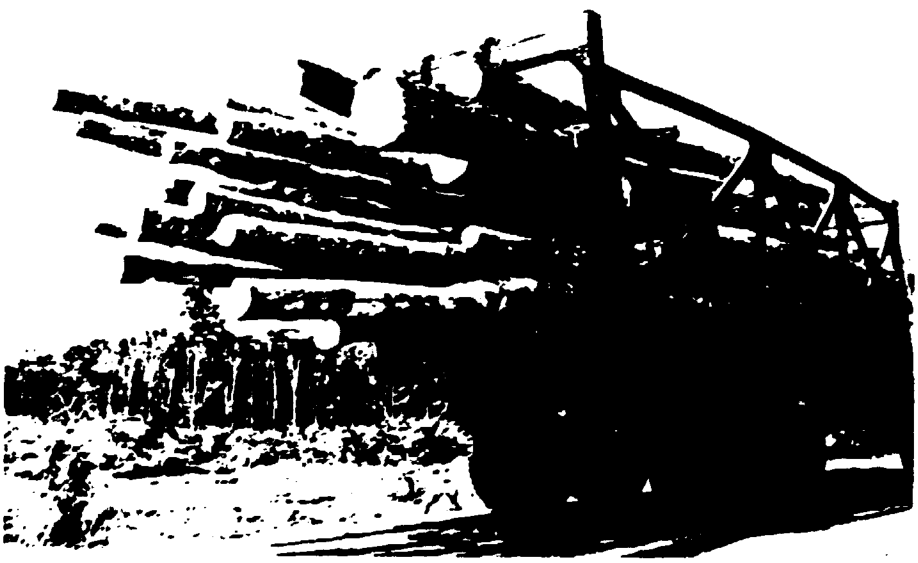


Figure 12
Large diameter logs are loaded lengthwise along bed of the truck

Currently, rubberwood logs sell at an average of SLR 30 per cu. ft. (US$ 24.63 per m3) for small logs (600mm girth, 1200-2400mm long) and SLR 34 per cu. ft. (US$27.91 per cu. m.) for big logs (750mm and larger girth, 1800-2440mm or longer), delivered to factory site in the Horana area of Sri Lanka. Thus, it appears that the gross margin to the contractor (of US$8-11 per m3) is attractive enough, considering the low capital investment.

The estimated per capita logging productivity of the system is about 1.69 m3 per worker per day.

b) <u>The Highly Mechanized Logging System</u>

The most highly mechanized rubberwood logging system, among the logging systems observed under this project, is composed only of 4 men, 2 units of heavy equipment (a front-loader/payloader/traxcavator with pneumatic tires and a backhoe/ditch-digger on caterpillar threads) and a chainsaw. This system was observed in Tebong, Malacca, Malaysia, and the 4-man team is the standard logging operations unit of the Rubber Industry Association of Malaysia (composed of 30 rubberwood logger/sawmiller members). The team can clear-cut, yard logs and clean one hectare of rubber tree plantation (ready for replanting) in one day.

The sequence of operations is as follows:

i. The front-loader/payloader/traxcavator, loosens the roots of the tree to be cut by pushing on them with the bucket blade at the base of the tree (see Figure 13). Then it topples the rubber tree by pushing the stem at about 2.5-3.0 meters above the ground (see Figure 14);

ii. The chainsaw operator, with the aid of the helper, bucks the stem into the desired log lengths, cuts the branches and twigs into shorter lengths that can be handled by the front-loader/payloader/traxcavator;

iii. After felling all the rubber trees in the one-hectare plot, the frontloader picks up the bucked logs and piles them in pre-determined locations for truck-loading activities. The same machine is used to load the rubberwood logs onto the cargo trucks, guided by the team helper and, sometimes, the chainsaw operator;

iv. Meanwhile, the back-hoe (see Figure 15) is used to pull the tree stumps out of the ground and pile them in pre-designated locations to be burned later or transported to other users' shops;

Figure 13
Front-loader
loosens base roots
of Rubber tree

Figure 14
Front-loader topples tree
by pushing at stem 2.5-3.0 meters
above ground

Figure 15
Back-hoe used to pull tree stump off the ground

v. After each truck is loaded, the front-loader/traxcavator is used to clear and prepare the one-hectare plot for replanting (see Figure 16).

Figure 16
1-hectare plot of rubber tree farm cleared during logging operatioons the previous day

Using the prevailing labour pay rates, transport charges (to within 50 kms. of the cutting site) in the area, and stumpage price, the following putative cost is derived:

| | |
|---|---|
| Labour cost | US$ 0.33 per $m^3$ |
| Equipment depreciation cost | 0.36 |
| Fuel and lubricants | 0.35 |
| Other overhead costs | 0.22 |
| Transport costs | 30.50 |
| Stumpage price | 17.50 |
| T o t a l | US$ 49.26 per $m^3$ |

Rubberwood logs sell for about US$ 61.00 per $m^3$ (based on M$220 per tonne, delivered to factory site), in the area. Thus, a gross margin of roughly US$ 11.70 per $m^3$ may be expected by the rubberwood logging contractor. On the basis of an average availability of 180 $m^3$ of rubberwood logs per hectare, the team's per capita logging productivity is 45 $m^3$ per worker per day, which is almost 27 times that of the purely manual system of rubberwood logging observed in Sri Lanka.

c) Rubberwood logging for particle board plant input

Normally, the rubberwood particle board plant input consists of stems and branches less than 150mm in diameter. These parts of the felled rubber tree become readily available after the larger portions of the stem (bigger than 150mm in diameter) are bucked into lengths good for either the woodworking (furniture/joinery) or plywood plant. Thus, this logging system is highly labour intensive. The following paragraphs describe this type of logging operations as done in southern Thailand.

The working unit is composed of 20 workers, divided into 5 teams of 4 men per team. Each team is equipped with one chainsaw with a 450mm or 500mm long blade. All log handling is done by hand. Logging activities continue daily throughout the year; each worker being given one-day rest each week on a rotation basis. The basic operations sequence is as follows:

i. Cut available stems and branches into log bolts 1800mm, or shorter, which can be carried by a worker (see Figure 17);
ii. Segregate logs with diameters less than 150mm (see Figure 18);
iii. Pile logs of each group length separately at pre-selected locations, accessible to the cargo trucks (see Figure 19); and
iv. Load the logs on the truck for transport to the particle board plant (see Figure 20).
(Note: Each 4-man team stops cutting and piling work when a truck comes to be loaded.)

Figure 17
Cutting and piling small-diameter stems and branches

Figure 18
Rubberwood logs with less than 150mm diameters are segregated

Figure 19
Logs are piled separately according to length

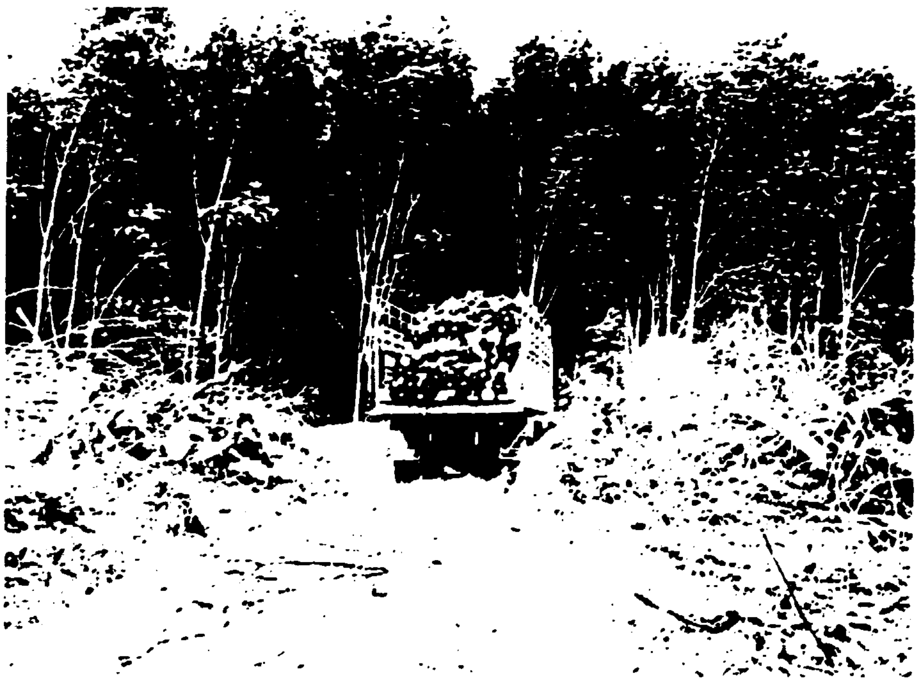


Figure 20
Rubberwood logs, loaded along length of truck bed is transported to particle board plant

The workers are paid according to the following pay rates:

| | |
|---|---|
| Chainsaw Operator | ThB 10,000 (US$400)/month |
| Ordinary Worker | 7,000 (US$280)/month |

The 20-man crew can log about 0.5 hectare a day. Each 4-man team can load 2 trucks per day.

Transport costs are about ThB 480 per trip, and each truck can make 2 trips per day to the factory which is about 15 kilometers from the logging site.

The logging cost is estimated as follows:

| | | |
|---|---|---|
| Labour | ThB 67.55 | (US$ 2.70) per $m^3$ |
| Transport/Handling | 338.98 | (US$13.56) per $m^3$ |
| Total | ThB 406.53 | (US$16.26) per $m^3$ |

Note: No stumpage charges are included because they were already collected at the regular sawlog harvesting activities. The Rubberwood materials involved in this logging operation were materials left over after the extraction of sawlogs from the area.

Based on the average rubberwood log yield of 180 $m^3$ per hectare, of which 15 per cent have diameters of 150mm and larger (i.e. 85 per cent of the log yield has diameters less than 150mm, suitable for particle board production), the productivity of the logging system described above is about 3.8 $m^3$ per man per day.

There are variations on the level of mechanization of logging operations, most of which are based on the use of the chainsaw as the principal cutting equipment. However, yarding and truck loading operations still remain highly labour intensive. The logging systems described in the preceding paragraphs represent approximately the extremes in the level of mechanization, as practiced today in south and southeast Asia. No information is yet available on fully mechanized logging for the particle board plant's log input. This is an aspect of the rubberwood industry which merits further development activities in order to improve both outputs and costs of logging activities for small diameter stems, branches and twigs, noting the fact that the manufacture of the particle board is a high input volume activity.

Studies in Malaysia indicated that only about 15 per cent (based on volume) of the total cut of rubber trees preparatory to replanting activities are good for industrial processing into sawn timber. The rest are stems and branches with diameters less than 10 centimeters, which could be used in particle board and medium density fibreboard production. Furthermore, studies on sawmilling operations of rubberwood logs (FRIM, Malaysia) indicated an average sawn timber recovery of about 30 per cent.

The resulting sawn timber volume is further reduced during the drying (roughly 4 per cent shrinkage) and secondary processing (about 30 per cent loss in furniture and joinery production) operations. Annex II shows the waste wood generated during the harvesting and conversion of rubberwood into secondary industrial processed products.

## 2. Preservative treatment of Rubberwood logs

None of the rubberwood logging enterprises (with daily outputs ranging from 15-150 $m^3$), which were observed in the six Asian countries, treat rubberwood logs for protection against fungi and wood borers. It appears that the common practice is to deliver the rubberwood logs to the sawmill or plywood plant within the shortest possible time after cutting, usually within 60 hours of felling during the dry season and much sooner during the rainy part of the year. The newly arrived rubberwood logs in the log yard are immediately given a prophylactic treatment against wood borers. This consists of spraying or dipping with an anti-fungus chemical solutions (3 per cent boric acid solution); and insecticides (2-3 NaPCP or CCA in water) against wood borers. This is done mostly in big factories requiring a bigger volume of rubberwood inventory in the log yard. However, observations made during visits to small and medium rubberwood sawmills, showed that they do not protect their rubberwood logs with any type of chemical treatment for they do not keep more than two days' log inventories and, thus, see no justification in protecting their rubberwood logs with any type of chemical treatment, at all, for they do not keep more than two days' supply of logs at their logyards. In India, the most popular insecticide is the copper-chrome-arsenate (CCA) compound; although, due to the discoloring effect of CCA, the borate/boric acid system is recently gaining popularity among the rubberwood processors in that country, in spite of the fact that the latter is only a fungicide and not an insecticide. All the other Asian countries visited use the borate/boric acid system (either by the spraying or dipping). The general belief is that application of anti-fungus and insecticide coatings on log ends prevents further or rapid biodegradation of the log bolts. None of the rubberwood processing plants visited under this project gather data or keep figures on the penetration of the preservative into the rubberwood logs, nor do they have any studies on how effective this kind of treatment is in protecting the rubberwood logs against fungus and insects. No cost figures are available on this particular aspect of the rubberwood processing operations, as the labour and materials costs are absorbed by the sawmilling operations.

The protective effects of sealing rubberwood log ends with sealants such as "shellkote" mixed with ANTIBLU products (3 per cent 3737 and 1.5 per cent 3739) were demonstrated by Hong *et. al.* and Tan *et. al.* in separate experiments conducted in 1980. Log end sealing is not practiced in all the sawmills visited under this project.

3. **Log transport and handling techniques and facilities**

Aside from Malaysia mechanized rubberwood log loading techniques and facilities were observed only in Thailand (among the countries covered in this study). Self-loading cargo trucks, equipped with 1-2 ton hydraulic-operated cranes, help increase loading efficiency, thus reducing truck turn-around time to almost one-third that needed for manual loading. These, however, were observed only in logging operations wholly owned by medium or large scale rubberwood processing firms. It appears that almost all of the contractors interwiewed in conjunction with this study) are not capable of setting up this type of log handling facilities since it is capital intensive. However, rough calculations based on figures furnished by one logging supervisor in southern Thailand indicate a potential reduction of log handling cost by as much as 30 per cent of the corresponding cost of the conventional manual type of log handling.

4. **Major factors affecting Rubberwood logging operations**

There are a number of factors, peculiar to the site of the rubber plantations, that affect the efficiency and costs of logging operations. The following paragraphs discuss the effects of some of the more apparent major local factors.

a) Terrain and Soil Characteristics

The ideal logging site is one which allows maximum daily extraction and transport of rubberwood logs to the processing plant. This situation is possible if the terrain and soil characteristics provide firm road conditions which allow easy access by men, equipment and trucks into and out of the logging site, even during the rainy season. The problem is compounded in locations with clayey soil, which has high water absorption properties. Adequate drainage and strengthening of the foundations of principal access roads to and within the rubber plantation are indicated so as to prevent the loss of logging, yarding and transport operations output by as much as 50 per cent, (or almost 100 per cent at worst), during the rainy periods of the year. It should also be noted, in this respect, that good drainage helps a sustained healthy growth of the rubber trees, which leads to higher latex production and bigger rubberwood yields.

b) Size of the Rubber tree farm

The size of the rubber tree farm directly affects the rational disposition of the rubberwood residues during tree felling and yarding operations, which in turn affects the maneuverability and turn-around time of logging trucks. Furthermore, the smaller the farms, the less adaptable they are to higher mechanized logging, yarding and log transport activities. According to the managers of both the Malaysian and

Thai logging outfits observed during the country visits, a minimum of 30 has. provide rubberwood supply for planning and execution of highly or fully mechanized logging and transport operations. In this case, fewer log pick-up points are required, so that log piling, truck loading and transport turn-around time are all reduced, contributing to lower log costs. Rough estimates, based on data supplied by the Thai logging outfit, indicate that rubberwood log yarding and transport cost reduction of as much as 12 per cent may be achieved for every 25 per cent decrease in the number of pick-up points.

c) Clone or Seedling Type Planted in the Area

For one reason or another, certain clone and/or seedling types have been found to grow better and produce more latex in certain areas. The same genetic reasons determine the length and diameter of the rubber tree stem and branches. Similarly, genetic considerations dictate at what height above the ground the first branches grow, thus helping determine the maximum log lengths into which the stems can be cut. Mechanization of logging and yarding activities is better applied to logging yields with longer and bigger diameter logs, since fewer pick-up points are required. Thus, rubber clone or seedling types that grow intc rubber trees with long stems and large diameters help reduce logging and transport costs in rubberwood logging operations. Furthermore, longer boles and larger diameters help increase the recovery in sawing (for the greater diameter) and in the conversion to furniture components (for the longer lengths).

d) Availability of trained labour

It is indicated in previous paragraphs that mechanized logging and transport operations help assure the rubberwood processing plants a continuous and reliable supply of large volumes of logs. Mechanization of rubberwood logging and transport operations, as illustrated above, is possible when trained labour, among others, is available in the locality. Otherwise, the highly skilled labour component of the basic mechanized logging and transport crews will have to brought in from other places, thus increasing the labour cost, and eventually, the logging and transport cost. This situation was observed in southern Thailand, the Horana area in Sri Lanka and southern Philippines, where tractor operators, truck drivers and mechanics have to be recruited from other provinces or districts of the country, and an "expatriation" cost paid.

## B. Sawing Rubberwood

### 1. Sawmilling machinery and equipment

Rubberwood sawmilling facilities in the six Asian countries (other than Malaysia) visited under this project are principally equipped with bandsaws (either vertical or horizontal) as the primary log breakdown machinery. None of the sawmills visited used frame saws for primary log breakdown operations, most probably because of higher investment costs and capacities higher than those needed for sawing rubberwood logs. Further processing processing (edging and cut-off operations) on the rubberwood boards are mainly done on circular saws (table type). However, in some sawmills, a pendulum type or manually operated "push-pull" type of saw is used for cutting boards to length.

#### a) Fixed Type vertical and horizontal bandsaws

The most commonly used primary log break-down saw and resaw is the vertical bandsaw model with 75mm-125mm sawblade width, mounted on 900mm-1050mm (36"-42") diameter bandwheels, and a 600mm x 900mm table with appropriately designed fence (see Figure 21). This type of bandsaw (without a log carriage) is used in Thailand, India, Indonesia, and the Philippines. Some bandsaws of the same type are equipped with manually pushed carriage. There are found in Indonesia (see Figure 22) and the Philippines (Figure 23). These bandsaws can cut logs with diameters of up to 500mm . The Philippine type of carriage, however, helps produce straighter cuts and more precise milled surfaces, i.e., variations in dimensions from one end of the board to the other is almost nil, or if there is any, it is insignificant. Furthermore, lumber recovery is increased because each of the carriage pedestals can be positioned independently to align the taper of the log bolt being cut parallel to the face of the bandsaw blade, so that the cut is made along the taper of the log. Bigger diameter and longer log bolts give a higher lumber yield than the smaller diameter and shorter log bolts. This type of bandsaw can process 10-15 $m^3$ of rubberwood logs per 8-hour shift, with a normal labour complement of two workers (one bandsaw operator, who is also the sawyer and a helper) when milling logs with diameters 100mm-200mm; or three workers (one bandsaw operator and two helpers) when milling logs with diameters larger than 200mm. The horizontal bandsaw with a manually pushed log carriage (see Figure 24), is widely used in Sri Lanka and Viet Nam.

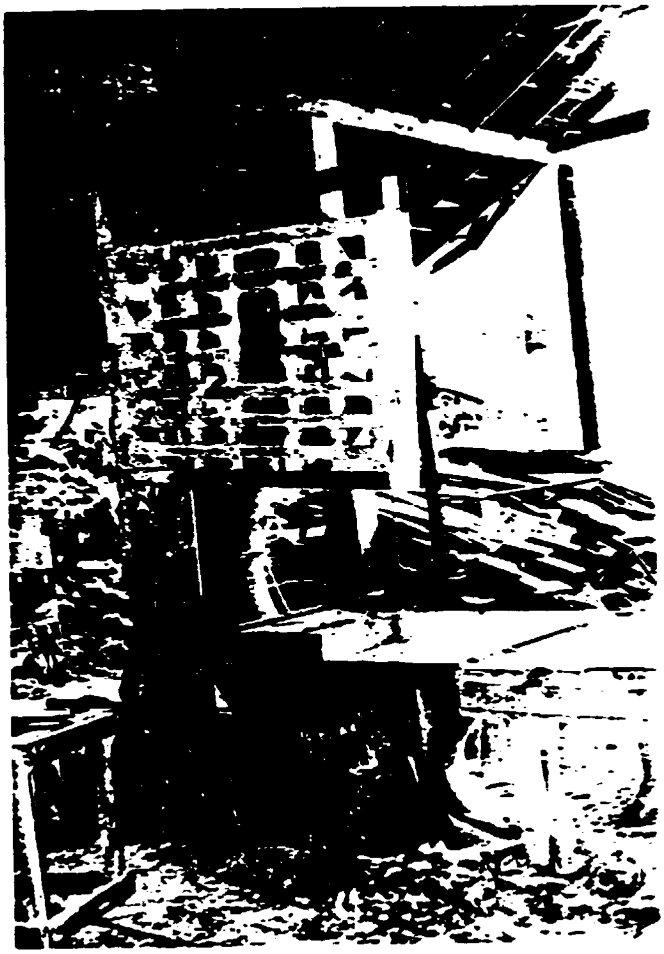


Figure 21
Typical bandsaw used in
Rubberwood sawmills in Asia

Figure 22
Vertical bandsaw
with manually
pushed carriage

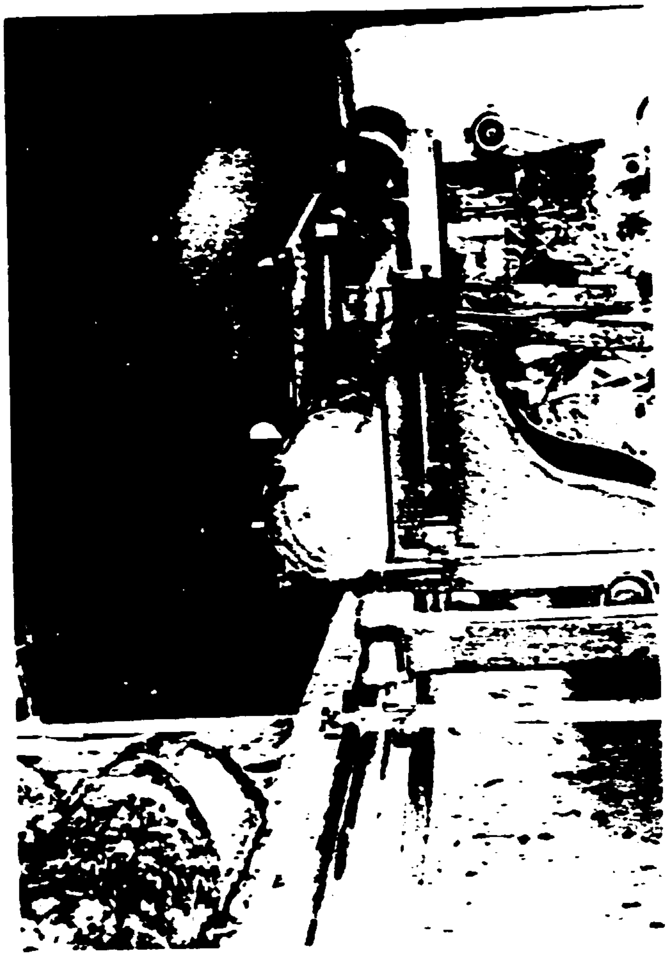


Figure 23
Vertical bandsaw with improved design of log carriage

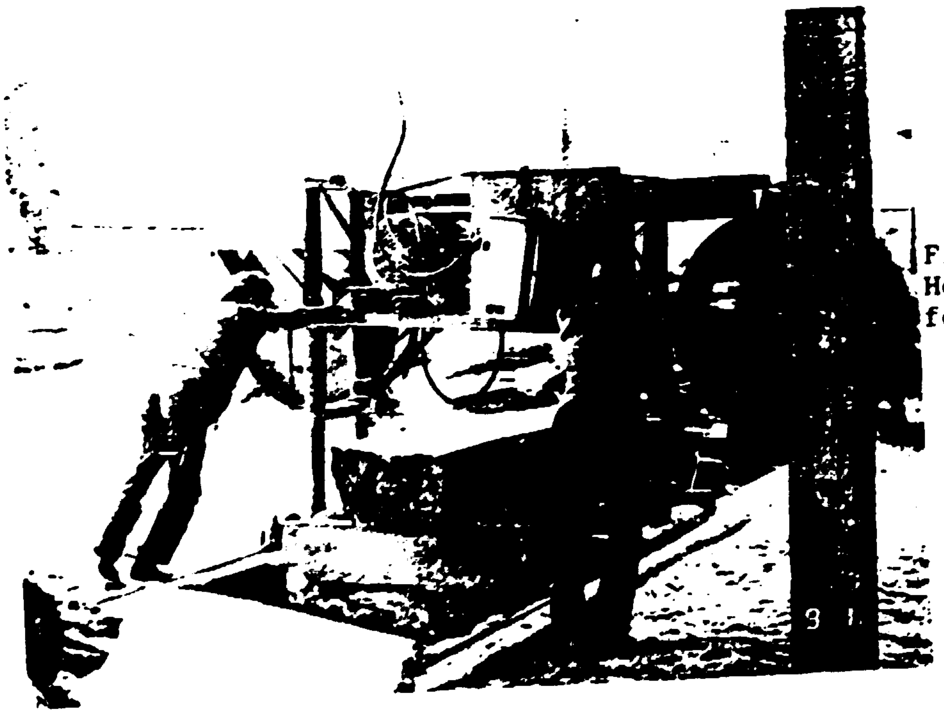


Figure 24
Horizontal bandsaw for sawing Rubberwood

b) Mobile type sawmills

The better known mobile sawmilling equipment for the rubberwood processing industry are the circular saw and the horizontal bandmill types.

The mobile circular saw specially developed by CIRAD-Forêt for rubberwood processing (see Figure 25) can saw logs with diameters of 80mm to 400mm and from 1000mm to 4000mm long at daily capacities ranging from 5 to 8 $m^3$. As currently designed, thicknesses are pre-set at 21/41/54/60/80mm and all widths are possible. The saw is powered by a 42 HP engine. The saw assembly, including log feeding and lumber output platforms, is mounted on a carriage with special size pneumatic tires. The entire equipment weighs only 1200 kgs. and can be pulled by a small or medium size vehicle on unpaved trails or paths.

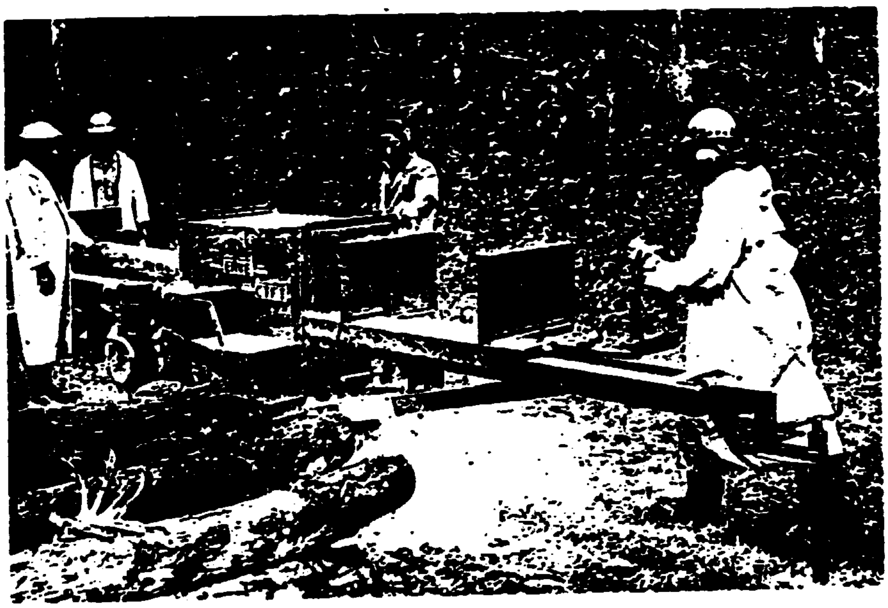


Figure 25
Mobile circular sawmill designed by CIRAD-Forêt

The mobile horizontal bandmill developed by FORESTOR of England for hardwood logs (see Figure 26) can also be used for milling rubberwood logs. This saw uses 100mm (4") wide thin kerf sawblades, mounted on 900mmm (36") diameter bandwheels, powered by a 25KW (34 HP) diesel engine. The log is pushed through the sawblade by a hydraulic log handling mechanism. The complete saw assembly is mounted on a specially designed trailer using traditional size pneumatic tires. A minimum daily output of 10 $m^3$ is expected when milling rubberwood.

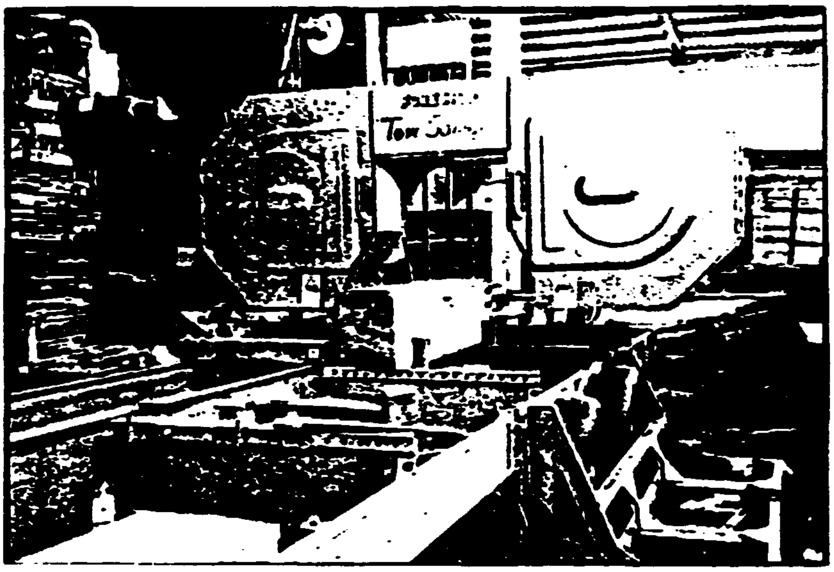


Figure 26
Mobile horizontal bandmill designed by FORESTOR

It can be seen from the design of the trailers on which the saw assemblies are mounted that the CIRAD-Forêt model, aside from requiring less floor space, can be pulled on roads or trails less developed than that required by the FORESTOR model. Thus, it appears that the CIRAD-Forêt model would be more applicable to sawmilling operations in smallholders' rubber plantations, while the FORESTOR model would be do well in sawmilling operations in medium and large size rubber estates.

Vietnamese and Laotian sawmillers are reported to be using locally-made copies of the CD4 mobile sawmill. The CD4 is actually the forerunner of the present FORESTOR. Another mobile circular sawmill is the KARA series, made in Finland, and especially designed for sawing small-diameter logs, such as pine and rubberwood logs.

c) <u>Secondary sawmill saws for lumber processing</u>

The most common edger used in the Asian rubberwood sawmilling industry is usually of simple design and locally built. Sawblade diameters vary from 250mm to 350mm, with 3mm-5mm kerf and are usually made of conventional cutting tool steel. Only the medium and large sawmills use tungsten-carbide-tipped (TCT) circular saw teeth. In some shops, the legs and frame are made of welded flat and angle-iron steel bars, the saw table and fence are usually made of hardwood species available in the locality. However in most cases, the machine table, frame and legs are all made of wood (see Figure 27).

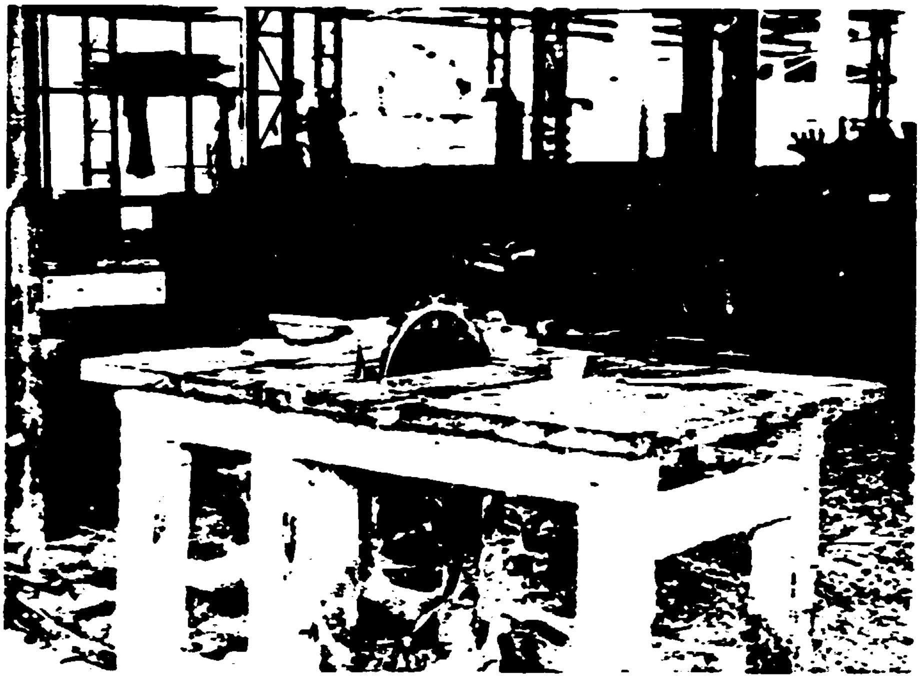


Figure 27
Locally made edger saw with all-wood table, frame and legs

Thus, the overall machine weight is lighter than the corresponding all-steel models supplied by internationally known machinery manufacturers. The workpiece is pushed manually against the sawblade, guided by the wooden fence. Consequently, cutting precision is not high enough for fine joinery work, and so much material has to be removed during the planing/jointing operations to obtain the desired final dimensions of the workpiece. The cutting precision and output, therefore, depends almost entirely on the worker. Data furnished by users of this type of saw indicate that a crew of three workers (a feeder, and two helpers) can cut 5-7 $m^3$ of lumber per eight hour shift.

Cutting-to-length operations may also be done on the edger saw described above by using a sawing fixture that will firmly hold two or more workpieces while the fixture is being pushed through the sawblade. The normal output for this type of operation is estimated at 6 to 8 $m^3$ per day.

Other types of circular saws are also used when cutting lumber to the desired length. Figure 28 shows a pendulum type of cut-off saw observed in sawmilling operations in Mindanao, southern Philippines; while Figure 29 is a radial arm saw observed in sawmilling operations in Sumatra, Indonesia. Both saws are powered by a 0.75 KW (1 HP) electric motor and require a minimum working crew of two men and give outputs of 8 to 10 $m^3$ per eight hour shift.

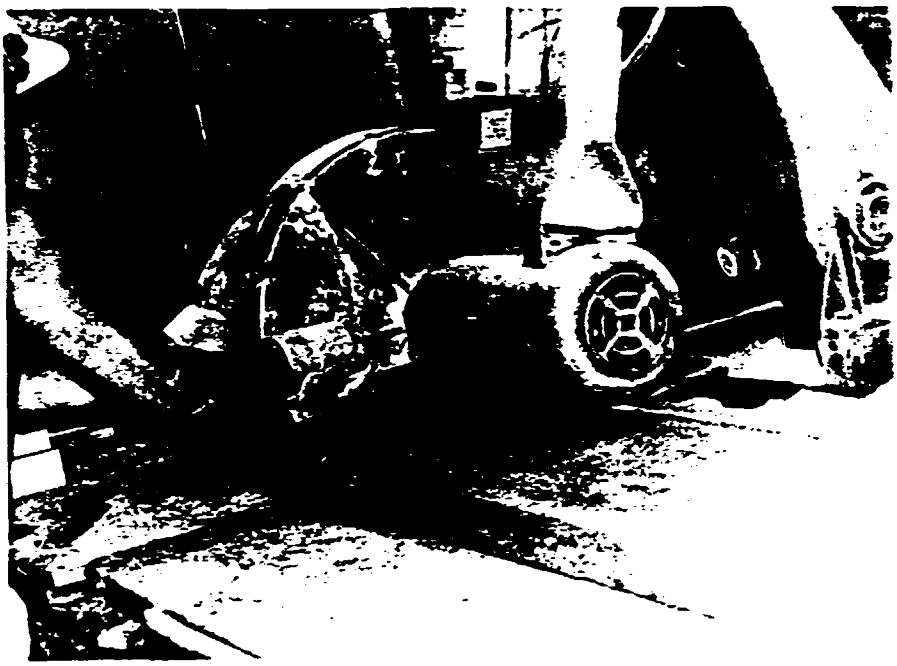


Figure 28
Pendulum type cut-off saw

A more sophisticated vertical bandsaw (see Figure 30) was observed doing re-sawing operations in the sawmilling section of a furniture/joinery factory in Sri Lanka. The principal log break-down equipment was a 600mm (24") diameter circular saw. Slabs and squared logs were cut on the circular saw and re-sawn on this bandsaw. The bandresaw had a 100mm (4") wide blade, and was equipped with a spring-loaded feed roll. A handwheel device allowed infinitesimal movement of the metal fence nearer to or away from the bandsaw blade, thus giving better precision than the bandsaws described in the preceding paragraphs. This bandsaw may be powered by a 5.2 KW (7 HP) to 7.46 KW (10 HP) electric motor for the main bandwheel drive and a 0.75 KW (1 HP) electric motor for the feed drive. The standard operating crew was composed of a feeder (bandsaw operator), a helper and a lumber-piler, to attain outputs of 12 to 15 $m^3$ per eight hour shift. This type of bandsaw gives the best cutting precision among the bandsaws discussed in this section.

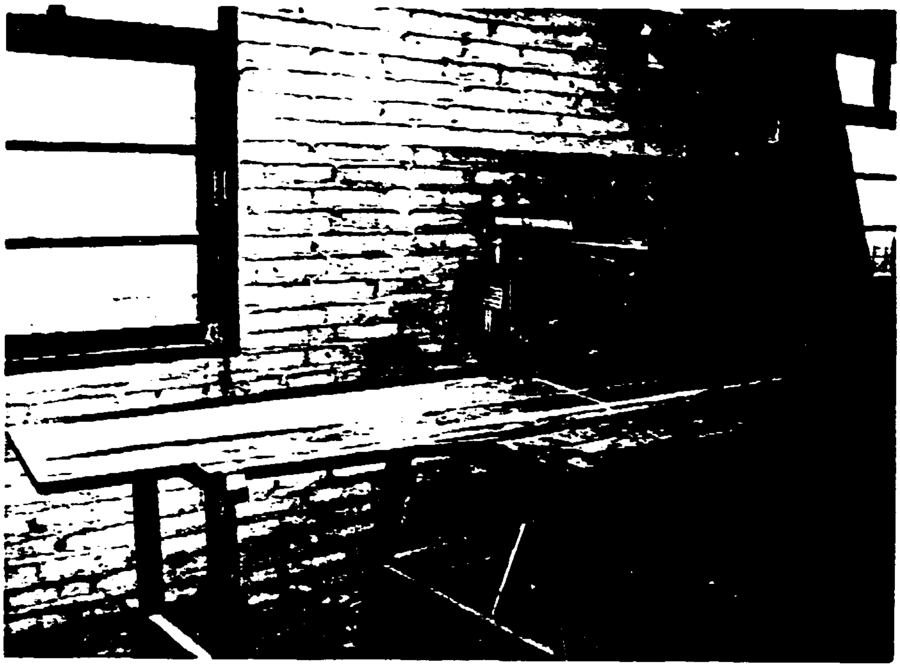


Figure 29
Radial arm saw with locally fabricated wooden table

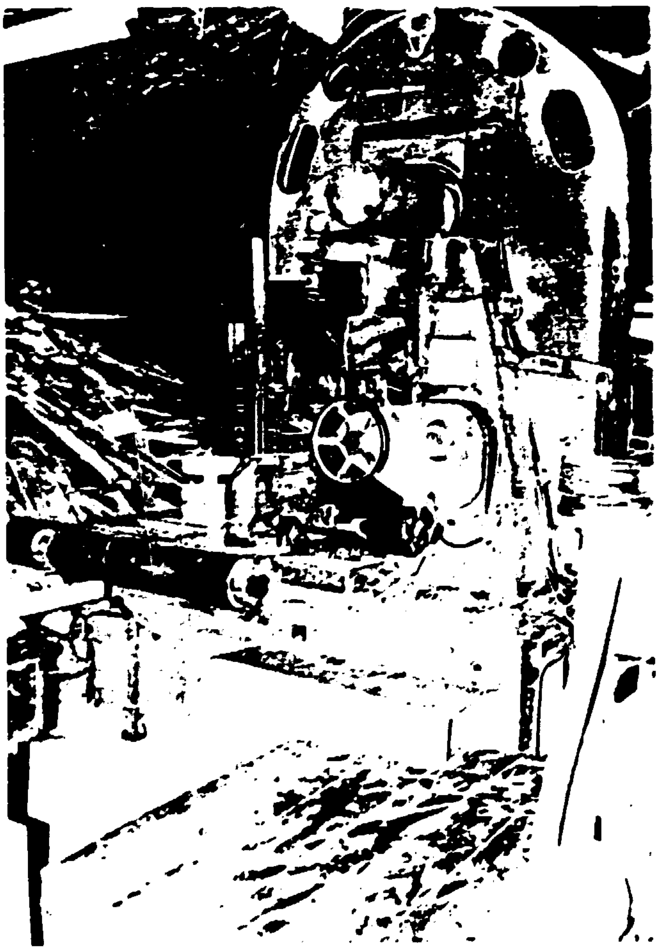


Figure 30
Vertical bandsaw
with powered feed roll

d) <u>Sawblade servicing equipment</u>

Sawmilling machinery and equipment cannot cut rubberwood efficiently without adequate tools and equipment for sharpening and maintaining the sawblades. The sawblade servicing equipment observed in the rubberwood processing industries of the six Asian countries visited under this project range from the purely manual facilities in a sawmill in Viet Nam (see Figure 31) to the complete and highly mechanized saw-doctoring shop established under a UNIDO technical assistance project in a woodworking factory in Sri Lanka (see Figure 32). Cutting efficiency and quality in the latter factory was, of course, much higher than that in the other sawmilling plants.

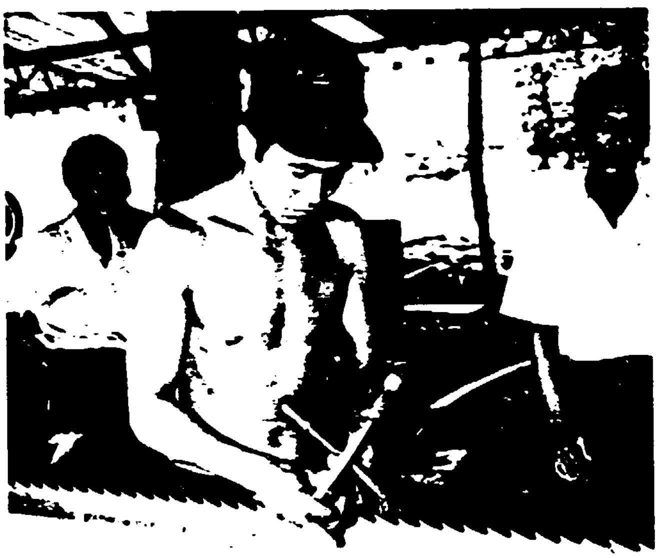


Figure 31
Manual swaging bandsaw blade teeth

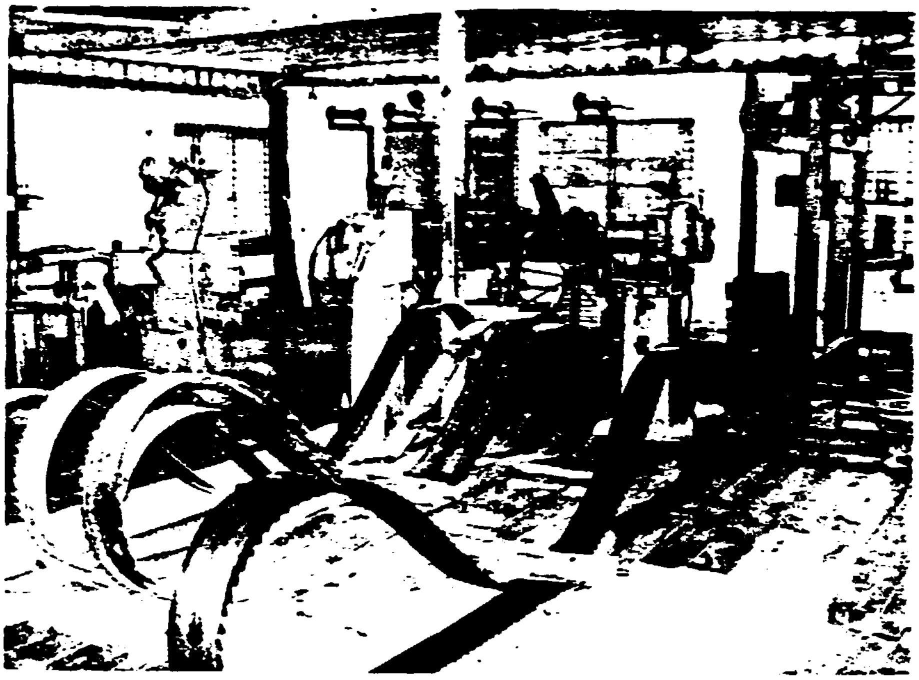


Figure 32
Mechanized facilities for saw-doctoring

## 2. Sawing patterns and yields

The sequence of rubberwood sawmilling operations, in general, as practiced in all the sawmills visited, is about the same. Rubberwood logs are squared or cut into slabs, which are subsequently edged or re-sawn into boards with the desired thicknesses and dimensions. (None of the rubberwood sawmilling plants visited under this project debarked the rubberwood logs before sawmilling. The reason is that the sawmilling pattern allows the bark to be automatically taken off during the edging operations, if not possible during the main log breakdown operations at the main bandsaws). Cutting boards to desired length is done mostly by sawmills which are part of an integrated woodworking complex. It is a common practice in ordinary rubberwood sawmills to cut the rubberwood log bolts to pre-determined rough lengths and surface and cut the kiln-dried boards to final lengths in the furniture or joinery plant.

The principal difference in sawmilling techniqu[illegible] [illegible]ises from the sawing pattern used, which eventually l[illegible] to significant differences in lumber yield rates. The most co[illegible]mmonly used sawing pattern in the rubberwood industry is an adaptation of the "flat sawing" technique used in the hardwood sawmilling industry (see Figure 33).

In Pattern "A", the log bolt is halved on the first pass of the bandsaw blade. Then, turning the sawn face of each half flat on the bandsaw table, boards of the desired thicknesses are cut according to the conventional "flat sawn" sawmilling pattern for hardwood logs.

In Pattern "B", a slab is cut on the first sawblade pass to make an edge on one side of the log bolt. The log bolt is then turned 90° to put the flat face on top of the bandsaw table. Then, boards of the desired thicknesses are cut according to the conventional "flat sawn" sawmilling pattern for hardwood logs.

It is very apparent from Figure 33 that cutting through the log centre is unavoidable, particularly if there is a taper on the rubberwood log bolt. It will be noted that the boards which are cut through the center of the rubberwood log bolt contain the less dense core. It is estimated that at least 20 per cent of the boards produced using sawmilling Patterns "A" or "B" contain the less dense core section of the log bolt. These boards with mixed density sections present warping and twisting problems during kiln-drying (or seasoning) operations, leading to degrades. It is claimed that this sawing pattern produces sawn timber yield rates of 34 to 47 per cent and, after cutting off defects, a net lumber yield rate of about 31.6 per cent.

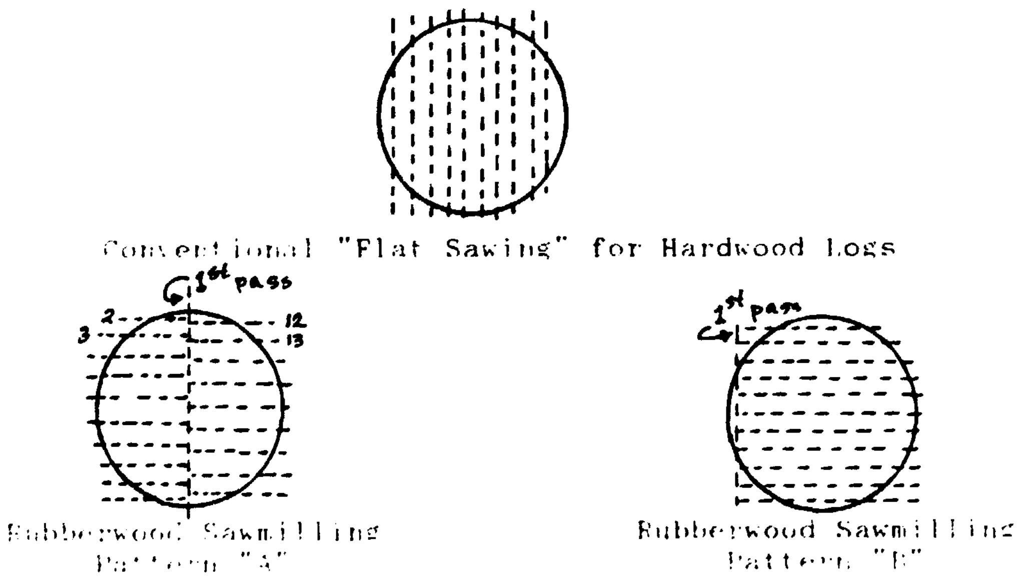



Figure 33
Rubberwood Sawing Patterns

The same problems were experienced during the development of an appropriate sawing pattern for coconut wood, where the density difference between the core and the periphery is significantly larger. This problem was completely eliminated by the use of the "peeling" type of sawmilling pattern, shown in Figure 34.

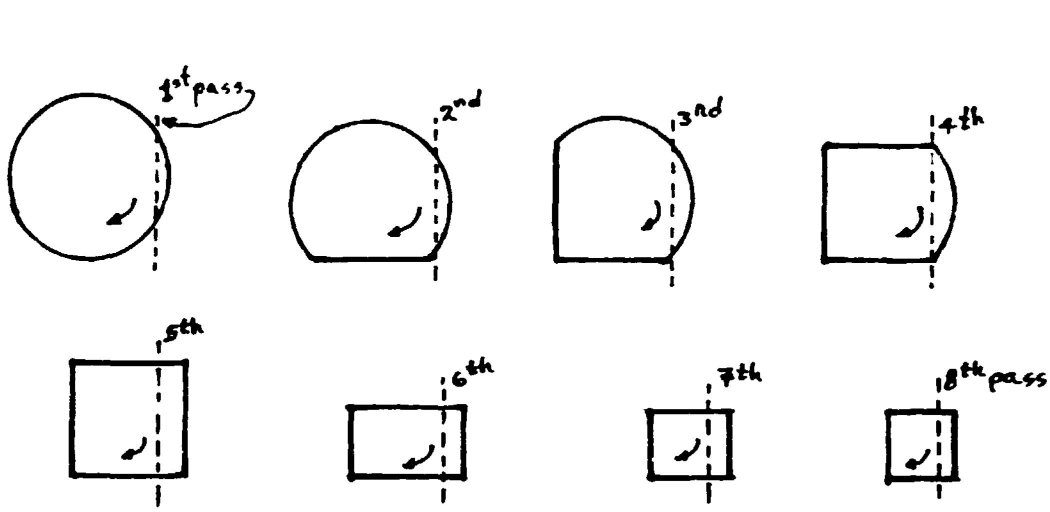



Figure 34
Suggested "Peeling" type of sawmilling pattern

The "peeling" type of sawing pattern is best done on a bandsaw with an appropriately designed log carriage, where the pedestals can be moved independently of one another, thus allowing the taper of the log bolt to be set parallel to the bandsaw blade side. The first sawblade pass cuts a reference face such that the resulting slab maximum thickness is about 25mm (1"). The log bolt is then turned 90° and another 25mm slab is cut on the second pass. (Note: These 25mm slabs are later re-processed into narrow, 12-15mm thick, strips.) The process is repeated until the log bolt is squared on the 4th sawblade pass. Boards of desired thickness are then cut on each face of the squared log as it is turned over 90° at each sawblade pass. The lumber boards thus produced do not contain mixed density sections. Sawing coconut wood log bolts, using the "peeling" cutting pattern, gave net lumber yield rates of 44 per cent to 54 per cent, or an average of about 49 per cent. Although this sawing pattern was mentioned in some studies on lumber yield rates done in Malaysia, this sawing pattern was not observed in any of the countries visited in Asia (not even Malaysia). The diameters of rubberwood log bolts are in the same range as the diameters of coconut wood log bolts. The diameter of the rubberwood core section, related to the log bolt's total diameter, is significantly smaller than that of the coconut wood log bolt. Thus, in order to reduce, if not totally eliminate, kiln-drying (seasoning) degrades due to differential moisture evaporation rates over the total surface of rubberwood boards, the "peeling" type of sawing pattern might be the solution. This type of sawing pattern requires a small additional investment on the appropriately-designed log carriage; and results to a small loss in sawing output during the training period of the sawyer and the sawing crews. The "minus" features, however, are insignificant compared to the potential benefits presented by the "peeling" type of sawing pattern, and will be more than paid for in the long run. More studies involving actual sawing runs on the use of this pattern on rubberwood logs are suggested.

3. **Estimated sawing costs**

The following assumptions and basic considerations were used in the calculation of sawing costs presented in the following paragraphs.

i. The cost of logs, delivered to the sawmill, is US$ 33.00 per $m^3$, which is about the average among the rubberwood log costs in the Asian countries covered in this study;

ii. The labour pay rate, based on the Thai Rubberwood industry pay scale, which is about mid-way between the lowest wage rates (in Viet Nam) and the highest (in Malaysia) among the countries visited, is as follows:

| | |
|---|---|
| Technician | US$ 26.50 per day |
| Highly Skilled | 20.00 per day |
| Skilled | 16.00 per day |
| Semi-Skill | 12.50 per day |
| Unskilled | 11.20 per day |

iii. The equipment complement is composed of the basic operating module for a fixed sawmilling plant:
1 unit, Vertical Bandsaw, 100mm saw blade width, with a carriage for 2400mm long logs, (rated capacity of 8-10 $m^3$ per 8-hour shift);
1 unit, edger circular saw, with a sliding table, 300mm-350mm sawblade diameter, (rated capacity of 10-12 $m^3$ per 8-hour shift); and
1 unit, circular cross-cut saw, 300-350 sawblade diameter, (rated capacity of 10-15 $m^3$ per 8-hour shift).

The equipment cost and depreciation charges are given in Annex I.

iv. All material handling activities are manual; and

v. The personnel complement is also given in Annex I for a daily rubberwood log input of 10 $m^3$ (or lumber output of 3 $m^3$ per day).

The unit cost structure in terms of sawn timber output (based on a lumber yield rate of 30 per cent) is shown in Table I.

Table I
Putative sawmilling costs

| Cost item | Cost per $m^3$ output | | |
|---|---|---|---|
| Raw Material Cost* | US$ | 33.50 | per $m^3$ |
| Direct Labour | | 29.83 | |
| Indirect Labour | | 18.67 | |
| Machinery Depreciation | | 1.02 | |
| Administrative and other overhead expenses** | | 19.00 | |
| Total Sawn Timber Unit Cost | US$ | 102.02 | per $m^3$ |

Note: * Includes cost of prophylactic log preservative treatment (by spraying), estimated at 1.5 per cent of log cost
** Estimated at an average of 30 per cent of Direct Cost (i.e., Raw Material + Direct Labour Cost)

## C. Preservative treatment operations

### 1. Preservative treatment

Industry experience indicate the urgent need for treating the newly sawn rubberwood timber with chemical solutions to combat fungal infestation and wood borers, before seasoning (or kiln-drying). The current rubberwood processing industry in Asia uses three generic types of preservatives, namely: pentachlorophenol (PCP) compounds; copper-chrome arsenate (CCA); and the borate/boric acid solutions. The use of PCP has greatly diminished lately due to regulations against the use of the chemical in foreign countries which buy rubberwood products. The toxic effects of CCA has discouraged Asian countries from using the chemical, except India where the chemical is still being used in many rubberwood processing plants. It should be noted that PCP and CCA are both insecticides, while boron compounds are principally fungicide solutions. Thus, there are two general schools of thought in the choice of preservative chemicals.

One group maintains that until a non-toxic, non-discolouring insecticide is developed, CCA or PCP should be mixed with the fungicide solution to protect the rubberwood sawn timber during the period before seasoning or kiln-drying. This is still the belief of many rubberwood processors in India, and some in Sri Lanka. It is held that using the system will not limit to a few days' supply the volume of sawn rubberwood timber inventory before seasoning.

On the other hand, rubberwood products of the group led by the Thais and Malaysians, mindful of the foreign market restrictions on wood products using toxic and/or carcinogenic chemicals, have received a remarkable degree of acceptability in the American, European and Japanese markets by treating the newly sawn rubberwood timber only with boron compounds and keeping as low as possible the inventory of sawn rubberwood timber before kiln-drying operations. It appears that the other Asian countries (Indonesia, Viet Nam, the Philippines, etc.) have followed the Thai and Malaysian technique of preservative treatment for sawn rubberwood timber. More recently, the use of boron compounds in treating rubberwood has gained ground in India and Sri Lanka.

a) Methods of application

Dipping sawn rubberwood in borate/boric acid solutions (see Figure 35) is still practiced in Sri Lanka, Viet Nam and the Philippines. The efficacy of this method of preservative application is very doubtful since the penetration of the chemical into the wood is only a few millimeters.

Figure 35
Rubberwood preservative dipping tank

Spraying fresh-cut rubberwood timber with boron compounds was observed in Sri Lanka. The boards are stacked ceiling-high with 19mm spacers between layers (see Figure 36). Then the chemical solution (30 per cent borax/boric acid solution in water) is sprayed, using the same type of sprayer used to spray insecticides in agricultural farms. The chemical penetration of wood in this type of application, just like dipping, is limited to a few millimeters, and is not enough to give ample protection to the sawn rubberwood timber. It appears that this technique of applying chemical preservatives on rubberwood needs sufficient time to allow the chemical to be diffused into the wood, just as is done in the regular dip-diffusion technique where the boards are close piled, covered with tarpaulin (to prevent evaporation of moisture from the boards) for two to three weeks before the pile is uncovered and re-stacked with stickers for air-drying.

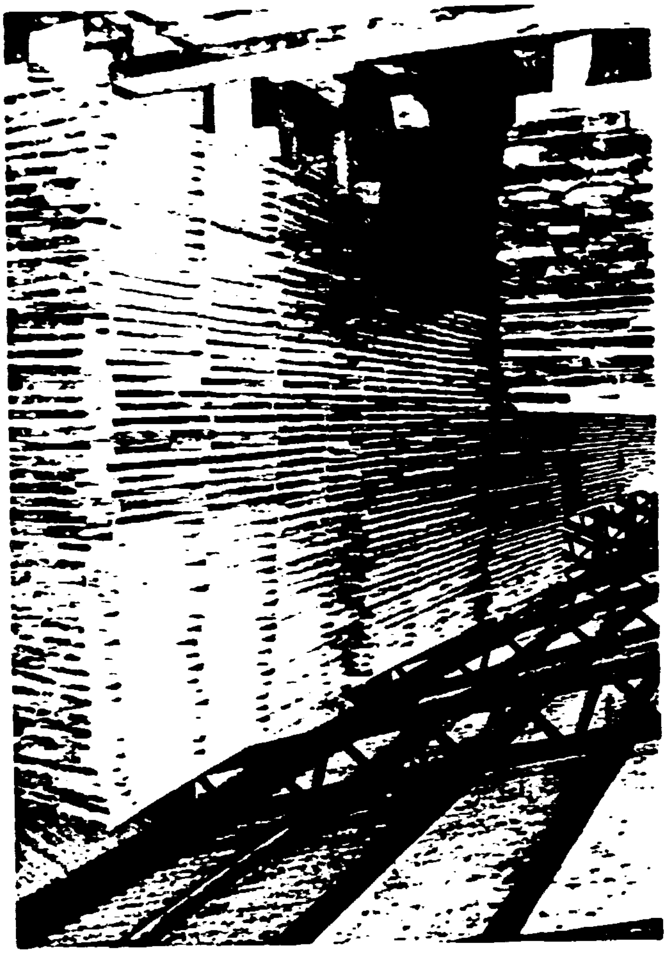


Figure 36
Rubberwood boards stacked for spraying preservative

The technique of impregnating wood boards with chemical preservatives using pressurized tanks was recently also applied to rubberwood. This is more commonly known as the vacuum/pressure type of wood impregnation.

One type of vacuum/pressure impregnation uses a single (or mono-) cycle, composed of first subjecting the charge to 635mm Hg (25" Hg) vacuum for a minimum of 2.5 hours, thus sucking the moisture out of the boards. Then preservative solution is pumped into the tank at a pressure of 12.65 kg/cm$^2$, which pressure is maintained for at least 3 hours. Most of the mobile impregnation plants, are designed for mono-cycle impregnation, e.g., the French model developed by CIRAD-Forêt (see Figure 37) and the Indian model developed by ASCU-India (see Figure 38).

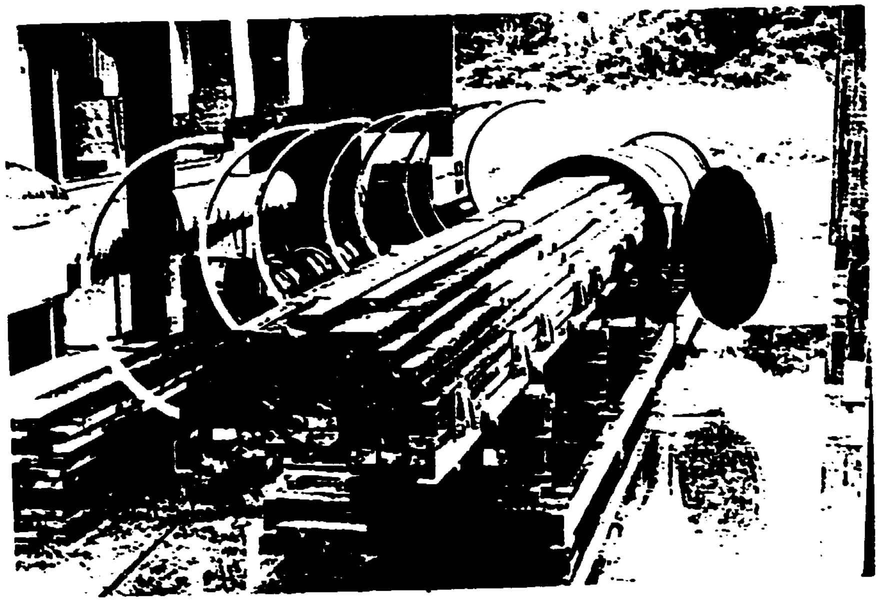


Figure 37
Mobile vacuum/pressure treatment plant (CIRAD-Forêt)

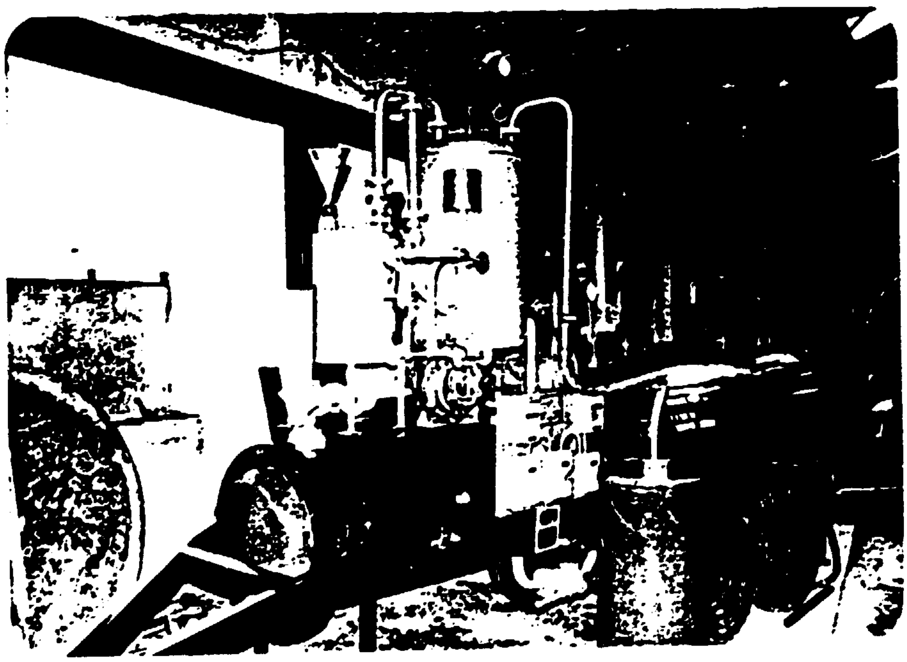


Figure 38
Mobile vacuum/pressure treatment plant (ASCU India)

Another design developed in Denmark of the fixed type, (see Figure 39), uses the multi-cycle impregnation technique. During the first stage, the charge of rubberwood boards is subjected to an oscillating pressure cycle (a succession of vacuum, then pressure) according to a pre-designed time sequence. The idea is to attain 100 per cent penetration by the preservative material into the wooden boards within the shortest possible time. A second phase follows, with a less frequent oscillation of vacuum and pressure, to lay a coat of anti-stain chemicals on the fully impregnated rubberwood boards. It is emphasized by the designers of this vacuum/pressure treatment plant that the oscillating pressure heats up the wooden charge, thus preparing them for a more effective and faster drying operation. One hundred per cent chemical penetration of 125 mm thick rubberwood boards was attained with the use of the equipment. This equipment was designed and developed by the Danish Wood Treatment Co., Ltd., and, together with the vacuum dryer developed by Moldrup (also a Danish firm), form the most advanced timber impregnation and drying system now available in the market.

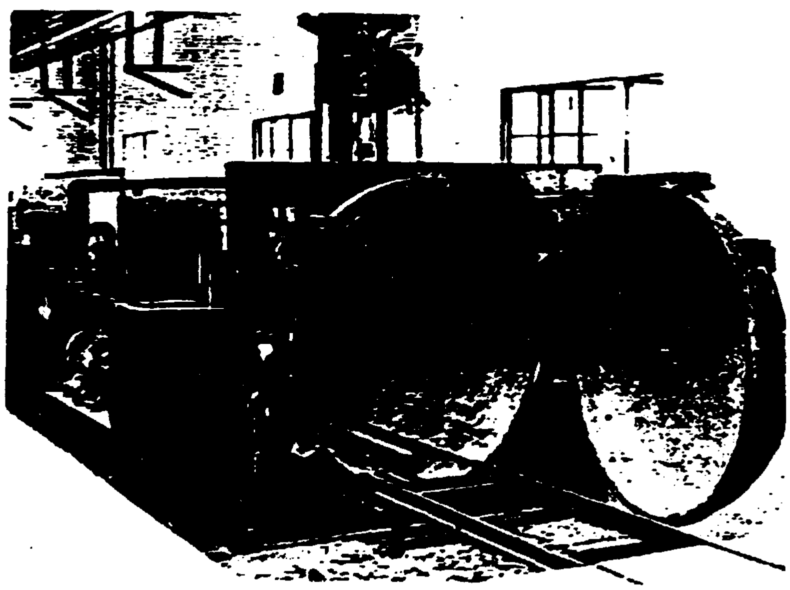


Figure 39
DWT impregnation plant fixed, multi-cycle type

A fixed type impregnation plant was developed by the South Indian Timber Industries (SITI), in Kottayam, Kerala, which operates on the mono-cycle principle (see Figures 40 and 41). Samples of 50 mm thick rubberwood boards treated in this type of impregnation plant showed 100 per cent penetration. No data on chemical retention was available.

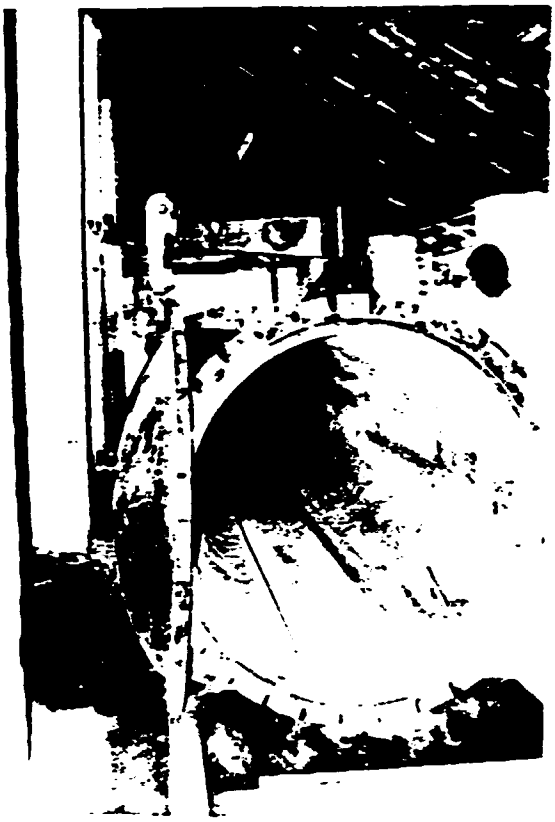


Figure 40
SITI impregnation plant
fixed, mono-cycle type

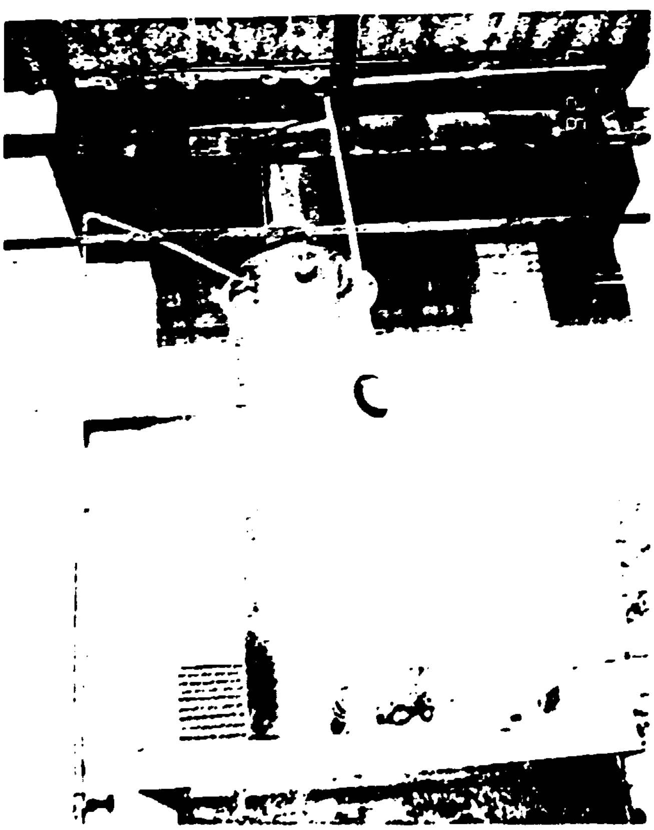


Figure 41
Preservative storage tank
for SITI impregnation plant

Both models of the fixed type of preservative treatment plants are designed to impregnate two charges (loads) of rubberwood boards per day.

There are other models of pressurized impregnating equipment, developed by other European and Asian manufacturers which are available in the market. However, most of these models operate on the mono-cycle system.

b) Formulations of preservative chemicals

The industry practice is to use formulations recommended by the supplier of the chemicals. Thus, a number of commercial brands of wood preservative based on PCP are now available in the market (DOWSITE, SOLIGNUM, for example, which are both popular among the hardwood sawmillers of southeast Asia). Some are water borne; while others require petroleum derivatives as solvents. Among the CCA based preservatives now available are ASCU/TANALITH (which is well-known in India and Sri Lanka); BOLIDEN (which is widely used in southeast Asia); CELCURE (which is well-known in southeast Asia),etc. Both PCP- and CCA- based preservatives impart their respective colour to the treated wood.

There are a number of boron-based preservative chemicals formulation which have been suggested for particular uses and application techniques.

A sawmill in Viet Nam fabricating rubberwood pallets were observed dipping the pallet components in troughs containing the following chemicals dissolved in water:

| Chemical | Amount Used/m³ of Rubberwood |
|---|---|
| Sodium Flouride (NaF)-- | 2.0 kg |
| Boric Acid ------------ | 0.4 kg |
| Borax Powder ---------- | 0.8 kg |
| Benzoate -------------- | 0.6 kg |
| Javel Powder ---------- | 0.9 kg |
| PCP ------------------- | 0.5 kg |

It will be noted that the above formulation contains a bleaching agent (Javel Powder) and an insecticide (PCP). The discolouring effect of PCP is very slight. The chemical penetration and retention are not known to the user. However, an inspection of the completely assembled pallets (in stock for about two weeks) showed mild fungigrowths and no insect infestation, indicating that chemical penetration and retention have not reached the minimal level for long-term protection of the rubberwood components of the pallets. The cost of this formulation is about US$6.00 per m³ of rubberwood treated.

Other boron-based preservatives are sold in the market today under commercial brand names (e.g.,INJECTA H of the DWT Hevea wood treatment system and Formula 7, distributed in Malaysia by Inagro-Sendirian Berhad, Kuala Lumpur), and as part of a package deal with the manufacturer or supplier of preservative impregnation plants.

Thai users of boron-based preservatives applied with the use vacuum/pressure equipment attained 100 per cent penetration of rubberwood boards at an approximate preservative chemicals cost of ThB 95.00 (US$3.80) per cubic meter of treated rubberwood.

c) Cost of preservative treatment

The assumptions and basic considerations used in the calculation of preservative treatment costs are presented as follows:

i. The cost of sawn rubberwood timber is US$ 102.02 per $m^3$. as calculated in the preceding section;
ii. The labour pay rates are as determined in Section 3(iii), above;
iii. The boron-based preservative chemicals will be applied by the use of multi-cycle vacuum/pressure impregnating equipment, the equipment cost and depreciation charges are as given in Annex III;
iv. The preservative chemicals usage cost is US$3.80 per $m^3$ of treated rubberwood;
v. Material handling activities are semi-mechanized (with the use of a 2-ton forklift), the equipment cost and depreciation charges being given in Annex III; and
vi. The personnel complement required by a daily output equivalent to the total volume of 2 charges of the vacuum/pressure tank is also given in Annex III.

The unit cost structure in terms of treated sawn timber output is shown in Table II.

Table II
Putative costs of preservative treatment

| Cost Item | | Cost per $m^3$ Output |
|---|---|---|
| Sawn Timber Cost | US$ | 102.02 per $m^3$ |
| Preservative Chemicals Cost | | 3.80 |
| Direct Labour | | 2.93 |
| Indirect Labour | | 2.80 |
| Machinery Depreciation | | 5.57 |
| Administrative & other overhead costs (30 per cent Direct Cost) | | 32.63 |
| Total Treated Lumber Unit Cost | US$ | 149.75 per $m^3$ |

D. Drying sawn Rubberwood

Preservative-treated rubberwood, particularly dip-treated and sprayed boards, is still subject to biodegradation. Moulds and other types of Fungi may grow on the surfaces of the dip-treated or sprayed boards, specially during very humid or rainy days. Seasoning the preservative-treated rubberwood help strengthen the wood's resistance to biodegradation.

Rubberwood boards can be dried by currently available seasoning (drying) techniques and facilities, such as kiln-driers, dehumidifiers, vacuum driers, etc. There is, however, one great difference, among others, between drying hardwood (or softwood) and rubberwood boards. The current normal practice when seasoning hardwood (or softwood) is to air-dry the boards from green to an average MC of 25 to 30 per cent, before kiln-drying or dehumidifying them. The objective of this practice is to shorten the kiln-drying (or dehumidifying) period, thus increasing the utilization rate of the drying equipment and consequently decreasing the unit drying cost. This practice takes at least two weeks (for 25mm board) during the dry season and much longer for thicker boards and during the rainy period of the year. Preservative-treated rubberwood boards cannot be stacked too long before kiln-drying (or dehumidifying), for this practice encourages biodegradation of the boards as the preservative coating on the board surfaces leaches out with exposure to the elements. It is highly desirable to keep the waiting period between preservative treatment and kiln-drying (or dehumidifying) as short as possible, to avoid biodegradation problems. Thus, the current industry practice is start the kiln-drying (or dehumidifying) process on boards which have 60 per cent MC or higher. This unique characteristic of preservative-treated rubberwood favors the use of vacuum driers. The industry trend is to use large capacity vacuum driers.

**1. Mobile drying Equipment**

The CIRAD-Forêt, in France, has developed a "mobile" dehumidifier for rubberwood, equipped with a solar heat energy accumulator (see Figure 42) so that it can operate partly on solar energy. The dehumidifier is composed of a heat pump, heating resistance and fans arranged inside the plywood box. The moisture present in the air is condensed by the dehumidifier and is progressively evacuated as water is formed. A regulator fitted outside the plywood box controls the dehumifiying operations inside the box. The equipment is deemed mobile, for the equipment itself, together with the plywood box housing (knocked down), can be loaded on a 5-ton truck, transported to the rubber tree plantation, and erected in less than 24 hours. The installed dehumidifier ahs a drying capacity of 0.5 to 3 cubic meters per charge, according to the desired model. The equipment fans require about 0.7 KW (1 HP) of electric power. The dehumidifier equipment (excluding the plywood box housing) weighs only 37 kg; and can evacuate 8 liters of water from the rubberwood boards per day for models up to 3 $m^3$ capacity.

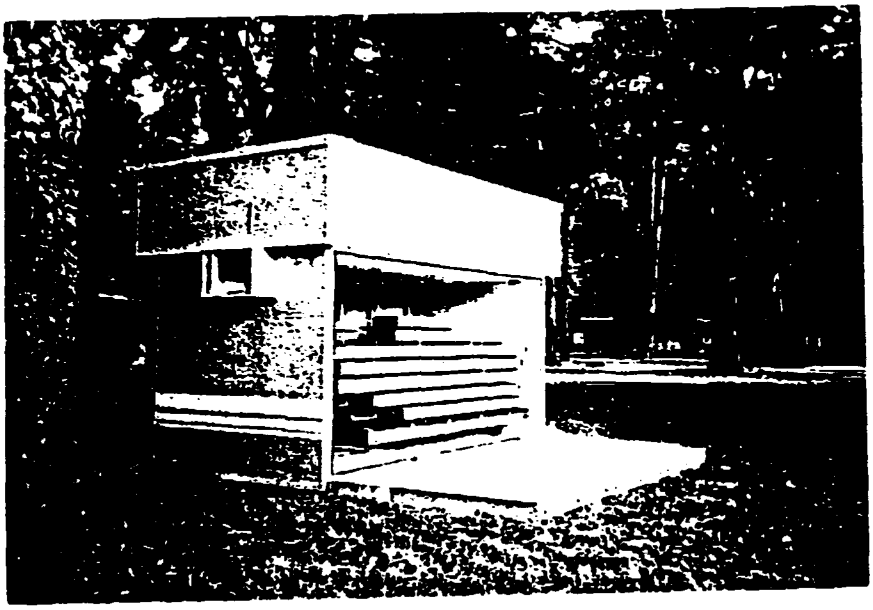


Figure 42
Portable dehumidifier made by CIRAD-Forêt

2. **Fixed type Rubberwood drying equipment**

Southern India Timber Industries, in Kottayam, India, is offering a number of kiln-drying facilities of various capacities and of the conventional hot-air/steam heated design, on a package deal which includes the operation of the driers and training of the personnel during the first year of operations. The package deal also includes the supply of a steam generator designed to match the kiln-drying capacity, using rubberwood waste material generated by the sawmilling and woodworking operations as fuel for the boiler furnace.

The unique feature of a kiln-drying plant (of the conventional hot-air type) observed in Sri Lanka is the use of solar power to provide additional heat to the kiln-drying chambers (see Figure 43). Solar heat is collected by charcoal material laid at the bottom of trenches, where water pipes are embedded. The heated water is then channeled to specially designed heat exchanger inside the kiln chambers.

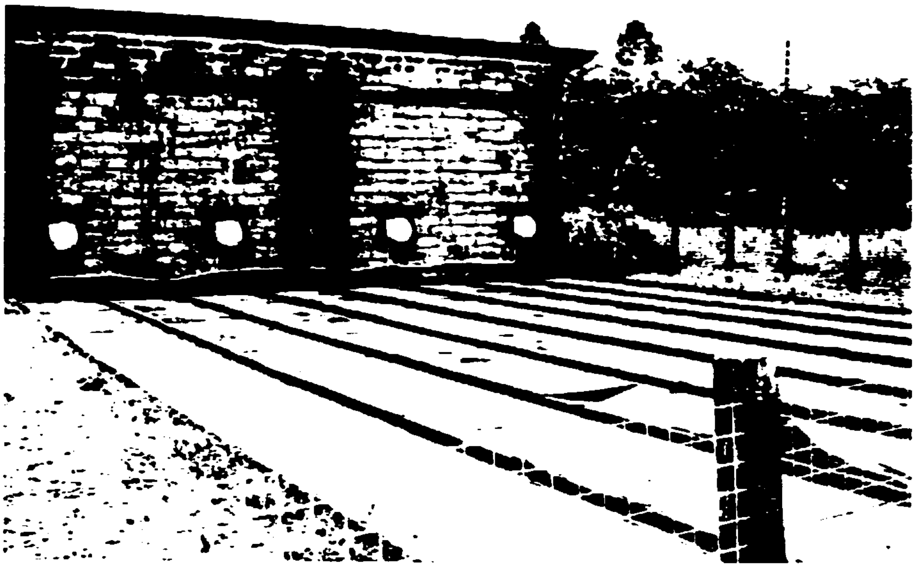


Figure 43
Solar energy accumulator (Sri Lanka)

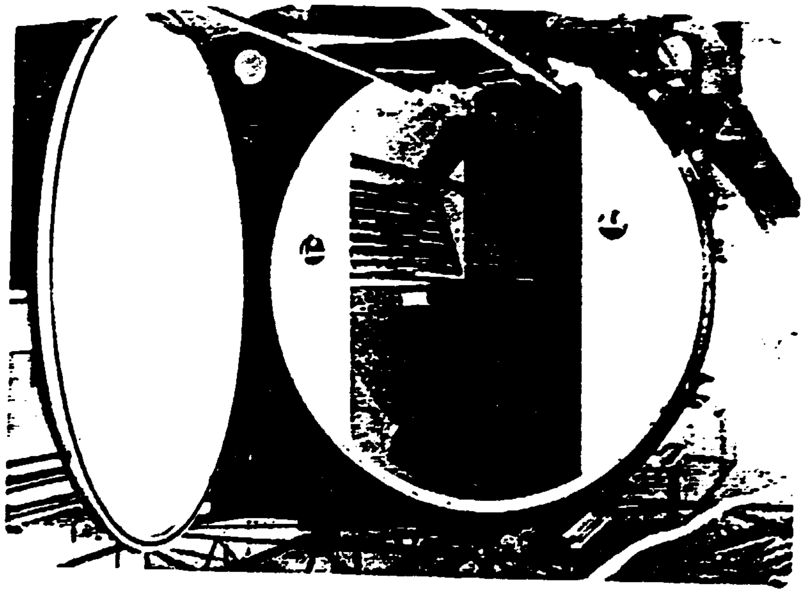


Figure 44
MOLDRUP vacuum type drying plant

A more recent development in rubberwood drying is the vacuum drying plant designed by the Moldrup group of Denmark (see Figure 44) . More than 50 units of this type of drier, of varying capacities, have been erected in the Asian rubberwoood processing areas. The system has electronically controlled (and programmable) vacuum pumps. Users in Indonesia and Thailand are satisfied with the simple guidelines for the operation of the drier. The most popular model (according to two Indonesian users of the equipment, and confirmed by three Thai rubberwood furniture factory managers) is the DWT-AP which can dry wet rubberwood (down to 10 to 12 per cent MC) in less than 8 hours. Models with capacities above 10 $m^3$ per charge are now in operation in Indonesia and both southern and eastern Thailand. Vacuum driers are increasingly being used in the furniture industry in Europe, and other models are now manufactured by other European firms.

Another type of drying process, still in the laboratory development stage (at FRIM, Kepong) is the radio frequency/ vacuum method. This method makes use of radio waves to effect heat energy transfer to the wood within a vacuum container. The drying process is conducted at lowerer temperatures than conventional methods and thus offers less degradation incidence. Application of this drying technique on an industrial scale should provide cost-savings in terms less drying degrades.

## 3. Drying schedules and programmes for Rubberwood

Drying programmes for vacuum type driers are usually developed by the equipment supplier during the trial run period to meet the buyer's specific operating requirements. Thus, drying programmes for different installations of vacuum driers, even though manufactured by the same firm, are not interchangeable. It is best to consult the equipment supplier before any significant adjustment is made of the supplier-recommended drying programme.

Similarly, drying schedules developed for conventional kiln-driers or dehumidifiers are not normally interchangeable, because the kiln characteristics are not necessary identical, even though they are of the same capacity, model, and supplied by the same manufacturer. However, the following kiln-drying schedule developed by the Forest Research Institute Malaysia is presented below as a take-off point for developing kiln schedules (see Table III) for drying rubberwood in newly-installed kiln-driers.

Table III

Kiln-drying schedule for drying Rubberwood

| Moisture content (%) | Dry bulb temperature (°C) | Wet bulb temperature (°C) | Approximate Relative Humidity (%) |
|---|---|---|---|
| Green | 48.5 | 46 | 85 |
| 60 | 48.5 | 45 | 80 |
| 40 | 51.5 | 46.5 | 75 |
| 30 | 54.4 | 47 | 65 |
| 25 | 60 | 49 | 55 |
| *10 | 68 | 53 | 45 |
| *15 | 76.5 | 58 | 40 |

Note: * The last two steps in the drying schedule may be repeated at smaller wet bulb depressions, as equalizing and case-hardening prevention steps, until the desired final moisture content is attained.

The kiln-dying period for 25mm thick lumber was 5 to 6 days for a final MC of 8 per cent to 12 per cent at a cost of M$40 (US$15.70) per $m^3$; while 50mm thick boards were dried for 10 to 12 days to a final MC of 8 per cent to 12 per cent at a cost of M$60 (US$23.50) per $m^3$.

4. **Drying costs for Rubberwood**

In anticipation of wider use of vacuum driers in the rubberwood processing industry in the near future, the cost calculations presented below apply to vacuum drying of rubberwood, under the assumptions and basic considerations listed as follows:

i. The cost of treated/kiln-dried sawn rubberwood timber is US$149.75 per $m^3$;

ii. The labour pay rates is as listed in Section 3(iii), above;

iii. The drying equipment is of the vacuum type, 10 $m^3$ capacity per charge, 2 charges per day;

iv. Material handling activities are semi-mechanized (with the use of a 2-ton forklift), shared with the preservative treatment section, the equipment cost and depreciation charges given in Annex IV; and

v. The personnel complement required by a daily output equivalent to the total volume of 2 charges of the vacuum cylinder, as listed in Annex IV, the material handling crew being shared with the preservative treatment section.

The unit cost structure in terms of dried-timber (10 per cent-12 per cent MC) output is shown in Table IV.

Table IV

Putative Drying Costs for Rubberwoods

| Cost Item | Cost per $m^3$ Output |
|---|---|
| Cost of treated timber | US$ 149.75 per $m^3$ |
| Direct labour | 3.73 |
| Indirect labour | 2.80 |
| Depreciation of equipment | 18.88 |
| Administrative & other overhead costs (30% Direct Cost) | 46.04 |
| Total Dried Lumber Unit Cost | US$ 221.20 per $m^3$ |

E. Secondary Processing of Rubberwood Sawn Timber

**1. Secondary processing of Rubberwood in Asian countries**

The secondary processing industries using rubberwood in the six Asian countries under consideration in this study presented the whole range of stages in the industry's development: from the infant rubberwood sawmilling and pallet-making activities in the Philippines, to the most advanced woodworking technologies being used today in the export-oriented manufacture of rubberwood furniture and joinery products in Malaysia and Thailand. Correspondingly, the stage of development of the industry in a country is reflected by the availability and reliability of the industry's statistics and operational data: the lower the stage of development of the rubberwood processing industry in a country, the harder it is to get up-to-date and reliable industry data. Peculiarly, government officials and industry leaders, who are involved in one way or another in the rubber and/or rubberwood processing industries of their countries, would always refer to Malaysia as the source of more up-to-date data about the industry. India and Thailand are the only exceptions to this observation. It could only be surmised that this is an after-effect of visits to the Malaysian rubberwood processing industries by participants from other Asian countries who attended workshops, seminars, trade and/or industry conferences in Malaysia and elsewhere, sponsored by the Malaysian government and international agencies such as UNIDO, the International Rubber Research and Development Board, etc. The following paragraphs describe the rubberwood processing industries as best as could be done within the data made available by the respective government officials and industry leaders in the countries visited.

a) The Indian Rubberwood processing industry

India's rubberwood processing industry is backed-up by approximately 466,000 hectares of rubber plantation, of which about 5,000 hectares are cut annually for replanting purposes. Thus, at least 900,000 $m^3$ of rubberwood logs are available annually for the processing industry. Ninety-eight percent of the rubber plantations are located in the southwestern state of Kerala. This explains the concentration of the rubberwood processing plants in Kerala.

The current use of rubberwood, as reported by the United Planters Association of Southern India (UPASI), is given in Table V.

Table V

Industrial use of Rubberwood and end products

| End product | Annual consumption ($m^3$) | Percentage of total |
|---|---|---|
| Packing cases | 440,000 | 66.0 |
| Plywood | 84,940 | 12.7 |
| Safety Matches | 110,000 | 17.0 |
| Treated Rubberwood | 30,000 | 4.3 |
| Total | 664,940 | 100.0 |

The total output of treated rubberwood is produced by 13 firms, which in turn convert these into secondary processed products such as mouldings, doors, furniture, toys and novelty items. The total output of the rubberwood processing industry is sold in the domestic market. V. Haridasan, in a study in 1987, reported 273 rubberwood processing units in 1985, of which 111 produced plywood, 146 are veneers and match splints producers and the rest manufactured other types of products. Recent reports from UPASI indicate that not all of the firms are still operational in 1992.

Noting that India is a "timber deficit" country, it stands to reason that any available wood specie is converted to "highly essential" products such as packing cases and safety matches, before it is considered for conversion to other products. This explains why the rubberwood secondary processing industry in India has grown at a much slower pace than those of Thailand and Malaysia, although the rubber industry was introduced to the country a only few years later than Malaysia and almost about the same time as it was brought to Thailand.

Moreover, the state of development of the rubberwood secondary processing industry is still behind that of its hardwood counterpart. The principal reasons are:

i. The whole industry is geared to serve the needs of the domestic market where product quality is definitely lower than those accepted in the foreign market; thus the industry has not found the need for more sophisticated machinery and equipment which give the high quality and volume demanded by foreign buyers;
ii. More than 80 per cent of the rubberwood processing industries is owned and operated by small- and medium-scale entrepreneurs who do not have the financial capability to establish and operate large-scale production activities; and
iii. Existing financial resources are geared to latex production and there are hardly any funds availabe for industrial processing of rubberwood.

b) Rubberwood processing in Indonesia

Indonesia has the largest rubberwood resources among the Asian countries covered in this report. These attained, in 1991, approximately 3,040,000 hectares of rubber tree plantations. In spite of this advantage, the Indonesian rubberwood secondary processing industry is still a long way from effective rationalization. As of June 1992, the Indonesian rubberwood secondary processing industry was composed of 34 plants registered with the Department of Industry, with end products and installed capacities as listed in Table VI.

Table VI

Secondary processing plants in the Indonesian Rubberwood industry

| End Product | Number of Plants |
|---|---|
| Kiln-Dried/Treated Lumber | 4 |
| Mouldings | 9 |
| Furniture and Components | 7 |
| General Woodworks Products | 3 |
| Floor Tiles | 3 |
| Laminated Panels & Blockboards | 3 |
| Finger-Jointed Products | 1 |
| Others | 4 |
| Total | 34 |

Source: Directorate General, Multifarious Industries, Ministry of Industry, Jakarta, Indonesia

However, caution was expressed by officers of the Directorate General that they have no information as to which of the registered firms were still operational. Furthermore, the lost refers only to registered firms and it is possible that there may be a number of unregistered firms.

Although government policies indicate support for the development of the rubberwood processing industry, it appears that implementing guidelines have still to be formulated and implemented so that the advancement of the industry can materialize. This is the major reason why the country's rubberwood secondary processing industry is very much behind its hardwood counterpart, with respect to both level of technology and volume of production. It is also noted that there is no formal industry association catering for the rubberwood processing industry, which in effect makes it hard to obtain industry data. Moreover, an industry association could be highly instrumental in up-dating government planners to the needs of the rubberwood secondary processing industry.

c) The Malaysian Rubberwood secondary processing industry

(The following short description on the Malaysian rubberwood secondary processing industry is presented for comparison purposes only. A separate study on Malaysia's rubberwood industry is being prepared and will be published as a separate document of this project).

The rubberwood processing industry of Malaysia is recognized as one of the leaders, if not the leader, in the world's rubberwood processing industries. This is primarily due to the outstanding growth of its secondary processing sector. Although the volume of rubberwood processed is still below that of Thailand, the rate of increase in volume of rubberwood processed is greater than that of Thailand (see Table VII). It is the opinion of many industry leaders that the role of increase in volume of rubberwood logs converted to secondary processed wood products for the period 1988-1991 even surpassed the rate of increase posted by the industry during the period 1985-1987.

Table VII
Average rate of increase in volume of processed Rubberwood logs in the secondary wood processing sector

| Country | Volume of Rubberwood logs processed, all sectors | | Annual rate of increase in per cent |
|---|---|---|---|
| | Year | Volume processed ($1000m^3$) | |
| Malaysia | 1989 | 595* | |
| | 1987 | 898* | 25.46 |
| Thailand | 1985 | 1,394** | |
| | 1987 | 1,814** | 15.06 |

Sources: * "Availability of Rubberwood in Peninsular Malaysia", by Nor'ini Hj. Haron, et.al., presented at the International Rubberwood Seminar, organized by the Ruuberwood Research Committee, 21-22 May 1990, Kuala Lumpur, Malaysia

** Calculated from data contained in "Production and Utilization of Para-rubber Wood in Thailand", by Chavalit Urapeepatanapong, presented at the Workshop on the Expansion of Trade in Rattan and Rubberwood Furniture, organized by the Economic and Social Commission for Asia and the Pacific, 30 April-3 May 1991, Bangkok, Thailand

On-going research and development activities on the manufacture of rubberwood-based panels have led to the commercial production of particle board, blockboard, and cement bonded particle board using rubberwood as the principal raw material. Lately, significant progress has been achieved in the manufacture of MDF panels using rubberwood, parallel to efforts at FRIM to develop the technique of producing MDF panels from agricultural and industrial wastes (trunks of palm oil trees, woodwaste from sawmilling and woodworking plants).

The most remarkable among the factors that led to the tremendous growth of the rubberwood processing industry of Malaysia during the last 5 to 10 years appears to be the voluminous research and development activities of all government agencies involved in all phases of the industry: agricultural, logging, technical, marketing and financial sourcing. This explains the frequent reference to Malaysian sources by government and private sector industry leaders of other Asian countries for economic, agricultural and industrial data/statistics on all the phases of the rubberwood industry.

d) The Philippine Rubberwood processing industry

There is not much to know about the Philippine rubberwood secondary processing industry, for it is the youngest among the Asian countries covered in this study. There are about 24 rubberwood sawmills in the island of Minadanao, southern Philippines. Reliable data and information about the industry is not readily available. All of these sawmills convert their sawn timber output into pallets and fruit boxes. All of these products are sold to the fruit canning firms located in the area. It appears that the Philippine government has just begun to be interested in rubberwood processing, but has not yet translated its interest into concrete plans and actions. However, in view of the current lack of timber supply, the export-oriented furniture manufacturing industry in the southern Philippines has started to consider the use of rubberwood. The scarcity of rubberwood timber is further aggravated by the reluctance of the rubber estates (Sime Darby, Goodyear, Firestone, etc.) to replant during the the last five years due to the Comprehensive Agrarian Reform Program instituted by the Philippine government in the latter part of 1986.

e) Sri Lanka's Rubberwood processing industry

The rubberwood secondary processing industry of Sri Lanka is probably the oldest among the south and southeast Asian countries, for the timber-starved country gave considerable interest and support to the conversion of rubberwood into school furniture as early as the 1960's. In fact, the government policy giving priority to the purchase of rubberwood school furniture vis-a-vis other timber species is still in effect today. However, in spite of the existing rubberwood resources (about 200,000 hectares of rubber tree plantations), the corresponding secondary wood processing industry has not progressed in step with the major rubber producing countries of the region, both in volume and level of technology.

To-date, there are 20 rubberwood processing firms registered with the Industrial Development Board of Sri Lanka. The end products of the firms and the corresponding number of factories engaged in the manufacture of these end products are listed in Table VIII. Installed capacities (based on log input) and outputs, however, are not available. All the industry's output are sold in the domestic market, except for flooring, which is currently being exported.

Table VIII

Rubberwood secondary processing plants of Sri Lanka

| End product | Number of plants |
|---|---|
| Furniture and Toys | 12 |
| B o x e s | 3 |
| Handicrafts | 1 |
| Dried/Treated Sawn Timber | 4 |
| Parquet Flooring | 1 |
| T o t a l | 21 |

Information gathered from both government and private industry leaders indicate that the above number of processing firms has not changed during the last 5-7 years. Government policy on the development of the rubberwood processing industry, up to now, is not yet clear. Thus, the rubberwood secondary processing industry of Sri Lanka cannot be expected to sufficiently develop to help meet the country's timber needs of the country in the next 5 to 10 years.

f) <u>Rubberwood processing in Thailand</u>

The rubberwood secondary processing industry of Thailand is supplied with rubberwood logs obtained from the about 1,800,000 hectares planted with rubber trees. In addition, the furniture industry is supplied with particle board made from rubberwood by three plants in eastern Thailand and one newly commissioned plant in the south with a total installed daily capacity of more than 1,000 $m^3$. The sawn timber requirements of the country's furniture and joinery industries is supplied by more than 350 sawmills, of various installed capacities totalling more than 1.8 million $m^3$ per year. Of the more than 1,400 furniture and joinery products manufacturers in the country, less than 200 use rubberwood sawn timber as their principal raw material. The quality level of the finished furniture and building construction components produced from rubberwood is high enough to be well accepted in the world market, and compares favorably with that of Malaysia.

Although rubber trees were introduced in Thailand about 20 years later than that in Malaysia, the Royal Thai Government has given support to the growth of its rubber and rubberwood processing industry, thus keeping it abreast of the world's leading rubber producing countries. In fact, Thailand, together with Malaysia, are the only countries that provide direct financial subsidies to the rubber tree farmers in connection with their replanting activities. In addition the Royal Government, in cooperation with the rubber tree planters, is also providing financial and physical support to research and development activities aimed at maximizing the economic benefits from increased production of latex and optimization of the use of rubberwood.

These actions explain the tremendous growth of the Thai rubberwood processing industry during the last five years. Most remarkable of these developments if the growth of the rubberwood furniture export industry, from about US$34 in 1985, to a little more than US$100 million in 1987, and to more than US$ 200 million in 1990.

The Thai rubberwood secondary processing industry is equipped with the most modern wood processing machinery and equipment, including computer controlled machines and high-volume, fully conveyorized production lines. Thus the Thai rubberwood secondary processing industry can compare with the corresponding industries in any country in the world, both in volume and level of technology.

g. The Viet Nam's Rubberwood secondary processing industry

The rubber plantation industry of Viet Nam is large enough (approximately 220,000 hectares) to warrant a satisfactory timber supply to its rubberwood secondary processing industry. The secondary processing industry, as a whole, excluding the manufacturing and export operations of SATIMEX (Saigon Timber Export Corporation), is still way behind the corresponding Sri Lankan industry, both in production volume and level of technology. The principal product of the rubberwood processing plants are pallets, for use in the export of sheet rubber. In general, machinery and equipment are old and of crude design. Thus, outputs are low and product quality is also low. The industry needs a well defined rational programme of development; and to do so the rubber cooperatives must look up to SATIMEX as a model for the growth of their own rubberwood processing industries. The country's rubberwood secondary processing industry. This brings out another major requirement for the country's rubberwood secondary processing to attain a state of development comparable to Malaysia, Thailand and India: the need for skilled and highly skilled labour.

The SATIMEX rubberwood processing operations is a joint-venture enterprise between SATIMEX and a Japanese firm. Production and export operations started in 1985, with US$2.6 million worth of production equipment. Initially furniture and components were produced. Finger-jointed products were then introduced into the production line. The operations has progressed remarkably: finishing operations were introduced in 1991 and all products are now completely finished. The factory, located outside Ho Chi Minh City, has a work force of 500 workers trained under the supervision of the Japanese partners. The annual turnover is about US$ 1.6 million.

It appears that the Viet Nam government, encouraged by the success of the SATIMEX experiment, has launched a rubber industry development program with a target total area of 500,000 hectares planted to rubber trees by the year 2000. All rubber cooperatives under the direction and jurisdiction of the General Rubber Corporation of Viet Nam have correspondingly aligned their development programmes.

## 2. Cost Structure of the Rubberwood secondary processed products

The manufacture of secondary processed wood products out of treated/dried sawn rubberwood timber follows the same sequence of operations as that for hardwoods, for the same end product. The equipment complement is necessarily the same, also, for the same volume of production operations. However, additional production costs are entailed when rubberwood furniture or joinery components are either laminated (edge-glued) or finger-jointed in order to increase the utilization of the wood material. A Thai manufacturer of laminated and finger-jointed rubberwood products estimated that an additional 4 to 6 per cent (maximum) of material cost is incurred in the production of laminated or finger-jointed components.

The following cost estimates for secondary products made from rubberwood, based on unit cost structure of hardwood secondary products, are presented for reference purposes:

a) Production of mouldings

The cost structure for the production of mouldings given in Table IX is based on the operations of a moulding plant with a rated input capacity of 12 $m^3$ (5,000 bd. ft.) of sawn timber per day. The plant's facilities can produce moulding products with thicknesses from 12mm (1/2 in.) to 38mm (1-1/2 in.) and widths from 50mm (2 in.) to 150 mm (6 in.), with random lengths.

Table IX

Unit cost of production of Mouldings

| Cost Item | Cost per $m^3$ Output |
|---|---|
| Treated/Dried Rubberwood | US$ 221.20 per $m^3$ |
| Direct Labour | 20.10 |
| Indirect Labour | 5.20 |
| Machinery Depreciation | 3.40 |
| Administrative & other overhead costs (20% Direct Cost) | 48.26 |
| Total Unit Cost | US$ 298.16 per $m^3$ |

Note:
- i Cost of treated/dried rubberwood is as developed in previous sections of this document.
- ii All other unit costs are based on data from a moulding plant in southern Philippines.
- iii The above data need adjustments to fit local conditions, particularly labour and cost of installed machinery and equipment.

b) Production of dining table (laminated top, unfinished) and chairs

The cost structure for the production of dining sets (a table and six chairs per set) given in Table X is based on the operations of a medium size furniture plant with a rated input capacity of 24 $m^3$ (10,000 bd. ft.) of sawn timber per day. The plant's facilities can produce household furniture and fixtures; office furniture; school room furniture and furnishings, etc. However, the plant is supplied with laminated panel items by a local sub-contractor. Upon special arrangements, the plant mahcinery and equipment can be re-aligned to produce joinery products (window frames, doors and door jambs, etc.).

Table X

Unit costs of production for dining set (table and chairs for six persons)

| Cost Item | Cost per $m^3$ Output | |
|---|---|---|
| Treated/dried Rubberwood | US$ 223.41 | per $m^3$* |
| Hardware & Other Materials | 112.50 | |
| Direct Labour | 65.00 | |
| Indirect Labour | 12.40 | |
| Machinery Depreciation | 19.10 | |
| Administrative & other overhead costs (18% Direct Cost) | 72.16 | |
| Total Unit Cost | US$ 504.57 | per $m^3$* |

Note:

i * Cost of treated/dried rubberwood is as developed in previous sections of this document, with 1% added for use of laminated panel for the table top only.

ii All other unit costs are based on data from a export furniture factory in southern Philippines.

iii The above data need adjustment to fit local conditions, particularly labour and cost of installed machinery and equipment.

iv Twenty sets of dining table and chairs are produced from each $m^3$ of sawn timber.

## ANNEX I
## SAWMILLING COST ELEMENTS

A. Work Force

| Type of Job | Labour Grade* | No. of Workers | Daily Pay Rate | Total Daily Labour Cost |
|---|---|---|---|---|
| Sawyer | HS (DL) | 1 | US$ 20.00 | US$ 20.00 |
| Machine Operator | S (DL) | 2 | 16.00 | 32.00 |
| Machine Helper | SS (DL) | 3 | 12.50 | 37.50 |
| Material Handler | US (IDL) | 2 | 11.20 | 22.40 |
| Log Yard Crew | US (IDL) | 3 | 11.20 | 33.60 |
| Totals | | 11 | | 145.50 |

* HS=Highly Skilled; S=Skilled; SS=Semi-skilled; US=Unskilled; DL=Direct Labour; IDL=Indirect Labour

B. Equipment Cost and Depreciation Charges

| Type of Machinery or Equipment | No. of Units | Unit Cost | Total Cost |
|---|---|---|---|
| Vertical Bandsaw | 1 | US$ 2,100 | US$ 2,100 |
| Edger Circular Saw | 1 | 1,400 | 1,400 |
| Circular Cross-Cut saw | 1 | 1,200 | 1,200 |
| Total Cost, Production Machinery | | | US$ 4,700 |

Note:

i. No saw-doctoring equipment is provided as an outside service will sharpen and maintain the sawblades.

ii. Hand tools, material handling fixtures, and sawdust collection and discharge system, estimated at total of US$2,750.00, are taken up as "expense" items (included in the item: 'Administration and other overhead expenses' and thus, are not included in the depreciation costs)

Depreciation Schedule: straight line; 5-year period; with salvage value of 10 per cent of acquisition cost.
Machinery Installation Cost: Estimated at 8.5 per cent of acquisition cost, and included in depreciation charges.
Hence, total amount to be depreciated is:

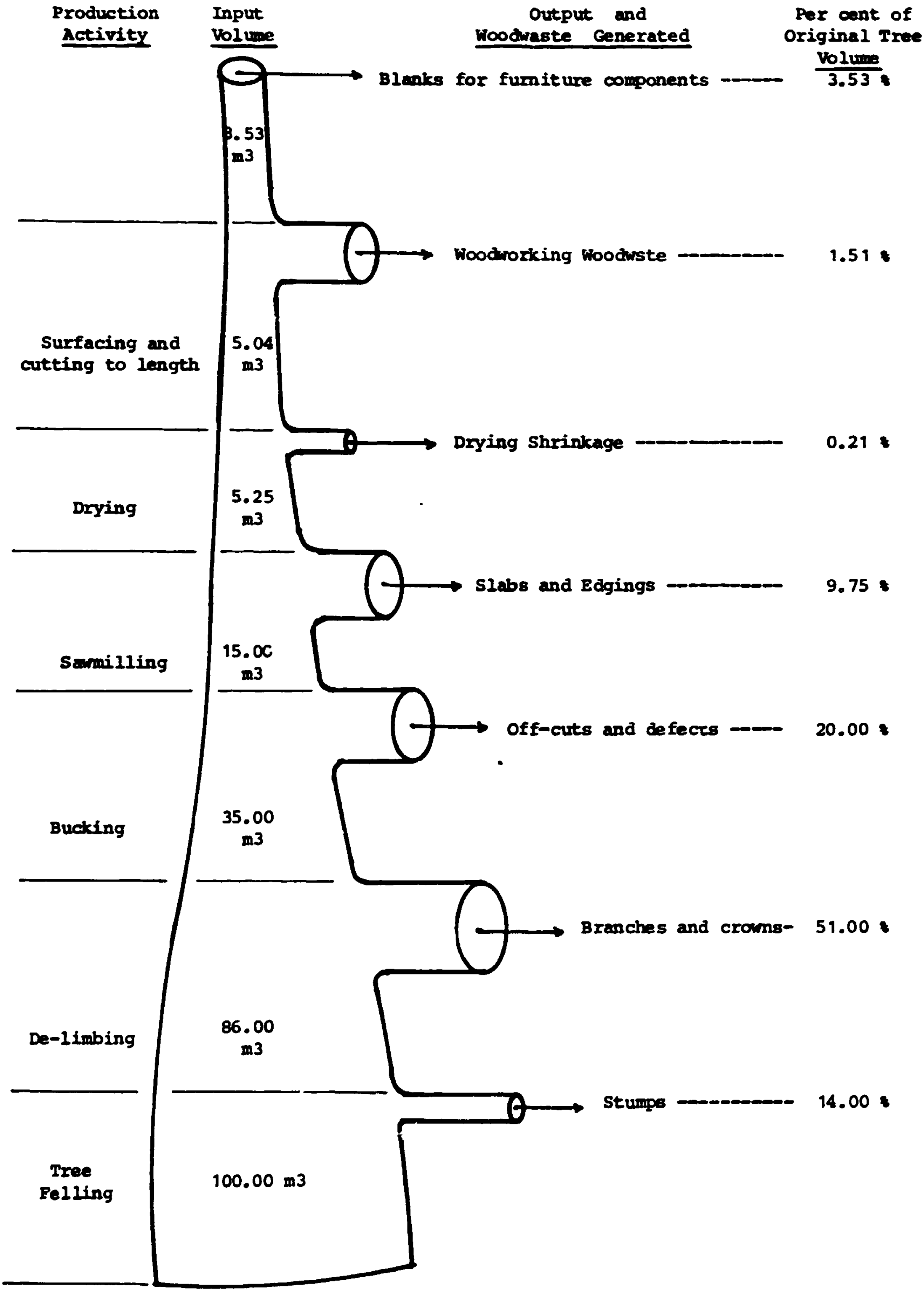
| | |
|---|---|
| Cost of machinery/equipment | US$ 4,700 |
| Installation Cost | 400 |
| Sub-Total | US$ 5,100 |
| Less: | |
| Salvage Value | 510 |
| Total Value to be Depreciated | US$ 4,590 |

Annual Depreciation Machinery/Equipment Depreciation Charges:

US$ 4,590 ÷ 5 = US$ 918 per year

Depreciation Charges per $m^3$ Lumber Produced:

US$ 918/yr ÷ (3 $m^3$/day x 300 days/yr) = US$ 1.02 per $m^3$




**Annex II**
Rubber Tree Utilization Chart

## Annex III
## COST ELEMENTS IN THE PRESERVATIVE TREATMENT OPERATIONS

### A. Work Force

| Type of job | Labour Grade* | No. of Workers | Daily Pay Rate | Total daily Labour Cost |
|---|---|---|---|---|
| Chem. Tech. | T (DL) | 1 | US$ 26.50 | US$ 26.50 |
| Machine Operator | S (DL) | 2 | 16.00 | 32.00 |
| Material Handlers | US (IDL) | 8 | 11.20 | 44.80** |
| Forklift Driver | S (IDL) | 2 | US$ 11.20 | 11.20 |
| Total | | 11 | | US$114.50 |

* Chem. Tech=Chemical Technician; T=Technician; S=Skilled US=Unskilled; DL=Direct Labour; IDL=Indirect Labour
** Only 50 per cent is charged to preservative treatment operations as the same crew is used by the drying operations.

### B. Equipment Cost and Depreciation Charges

| Type of Machinery or Equipment | No. of Units | Unit Cost | Total Cost |
|---|---|---|---|
| Vacuum/Pressure Plant, 10m$^3$ capacity, complete with controls | 1 Set | US$182,300 | US$ 182,300 |
| Forklift, 2-ton Capacity | 1 | 6,500 | 3,250* |
| Total Cost, Production Machinery | | | US$ 185,550 |

* Based on an offer of Messrs. RUBICO, the Rubber Industry Company, Viet Nam, dated 9 July 1992.
** Only 50% of the forklift's cost is charged to the treatment operations, as the use of the forklift is shared with the rubberwood drying plant.

Depreciation Schedule: straight line; 5-year period for vacuum /pressure plant and forklift; each with salvage value of 10 per cent of acquisition cost.

Machinery Installation Cost: included in cost of vacuum/pressure preservative treatment plant.

Hence, total amount to be depreciated is:
Cost of machinery/equipment-------------US$ 185,550
Less:
Salvage Value--------------------------- 18,555
Total Value to be Depreciated------US$ 166,995

Annual Depreciation Machinery/Equipment Depreciation Charges:
US$ 166,995 ÷ 5 = US$ 33,399 per year

Depreciation Charges per m$^3$ Lumber Treated:
US$ 33,399/yr ÷ (20 m$^3$/day x 300 days/yr) = US$ 5.57 per m$^3$

## Annex IV
## COST ELEMENTS IN DRYING OPERATIONS

A. Work Force

| Type of Job | Labour Grade* | No. of Workers | Daily Pay Rate | Total Daily Labour Cost |
|---|---|---|---|---|
| Drying Tech | T (DL) | 1 | US$ 26.50 | US$ 26.50 |
| Machine Operators | S (DL) | 3 | 16.00 | 48.00 |
| Material Handlers | US (IDL) | 8 | 11.20 | 44.80** |
| Forklift Driver | S (IDL) | 2 | 11.20 | 11.20** |
| Totals | | 14 | | US$130.50 |

* Drying Tech.=Drying Technician; T=Technician; S=Skilled US=Unskilled; DL=Direct Labour; IDL=Indirect Labour
** Only 50 per cent is charged to preservative treatment operations as the same crew is used by the preservative treating operations.

B. Equipment cost and depreciation charges

| Type of Machinery or Equipment | No. of Units | Unit Cost | Total Cost |
|---|---|---|---|
| Drying Plant, 10 $m^3$ capacity, complete with controls | 1 set | US$626,000 | US$ 626,000 |
| Forklift, 2-ton Capacity | 1 | 6,500 | 3,250** |
| Total Cost, Production Machinery | | | US$ 629,250 |

* Based on an offer of Messrs. RUBICO, to Rubber Industry Company, Viet Nam, dated 9 July 1992.
** Only 50 per cent of forklift's cost is charged to treatment operations, as the use of the forklift is shared with the rubberwood drying plant.

Depreciation Schedule: straight line; 5-year period for vacuum /pressure plant and forklift; each with salvage value of 10 per cent of acquisition cost.

Machinery Installation Cost: included in cost of rubberwood vacuum drying plant

Hence, total amount to be depreciated is:
Cost of machinery/equipment-------------US$ 629,250
Less:
Salvage Value--------------------------- 62,925
Total Value to be Depreciated-------US$ 566,325

Annual Depreciation Machinery/Equipment Depreciation Charges:
US$ 566,325 ÷ 5 = US$ 113,265 per year

Depreciation Charges per $m^3$ Lumber Treated:
US$ 113,265/yr ÷ (20 $m^3$/day x 300 days/yr) = US$ 18.88/$m^3$

## ANNEX V
## BACKSTOPPING OFFICER'S COMMENTS

This study reviews the situation of the rubberwood processing industry in five Asian countries (India, Indonesia, Philippines, Sri Lanka, Thailand and Vietnam). Rather than assessing the processing rubberwood (technology used, potential for development etc.) for each country, it covers all five countries in chapter dealing with the process, starting from logging and proceeding with preservation of logs, sawing, preservation of sawnwood, drying and ending with a brief description of the status of the secondary processing industry in these countries.

The study describes various options on the various operations, which provide useful guidelines for potential investors.

It also contains useful comparative information, e.g. on the various logging methods used. It also makes useful recommendations on sawing patterns that reduce internal stresses.

In conclusion, it is a very useful document to familiarize potential investors on the various options available to process Rubberwood.

## BIBLIOGRAPHY


Abdul Latif & Harun bin
Utilization of rubber wood and waste from preliminary wood-based industries for chips, The Malaysian Forester, No. 33, Kuala Lumpur, 1970

Ahmad Shakri & Abd. Rashid
Weathering tests of some exterior paints using rubberwood as the substrate, The Malaysian Forester, No. 49, Kuala Lumpur, 1986

Ali Bin Sujan al.
Some studies on fungal deterioration of rubber wood (*Hevea brasiliensis*), Note prepared for the 11th Annual Meeting of the International Research Group on Wood Preservation in Raleigh, U.S.A., May 1980

Ambrin bin al. Buang, et.al.
Current analysis of industry with special emphasis on marketing, Seminar Penggunaan Kayuh Getah Kedua, Kuala Lumpur, November 1985

Ashaari bin Haji Amin
The fiber length of two clones of rubberwood, The Malaysian Forester, No. 49, Kuala Lumpur, 1986

Ashaari bin Hj. Amin, et. al.
Utilization of new technologies for processing rubberwood, rattan and bamboo for rural Development, In: Radhakrishnan, S., Singh, M.M., John, C.K. editors, Proceedings: 2nd Asian Conference on Technology for Rural Development, Kuala Lumpur, December 1985

Brion, H.P. Demonstration of coconut wood utilization low-cost housing, UNIDO, DP/ID/Ser.B/484, Vienna, 1984

Brion, H.P. Demonstration of coconut wood utilization in pre-fabricated housing, UNIDO, DP/ID/Ser.B/538, Vienna, 1986

Burgess, H.J.
Resistance to termite; attack of certain Malayan commercial timbers, Malaysian Forester, No. 18, 1955

Burgess, H.J.
Rubberwood emerging as a practical species, World Wood, No. 27, London, 1986

Chan, K.Y., et.al.
Characterization of rubberwood-polymer composites, Proceedings - Malaysian Chemical Conference '87, Kuala Lumpur, October 1987

Cheow, L.T. Rubber as an alternative species in the mass production of knock-down furniture - an industrial experience, Seminar on Rubberwood Utilization, Malaysian Forester, Kuala Lumpur, June, 1982

Chew, C.H. & Teo, K. H.
A preliminary study on alkaline nitrobenzene oxidation of rubber wood meal (*Hevea brasiliensis*), The Malaysian Forester, No. 39, Kuala Lumpur, 1976

Choo, K.T. & Grewal, G.S.
Air-drying and movement characteristics of rubber wood, The Malaysian Forester, No. 46, 1983

Chin, P.S. & Khoo, T.C.
Research on the utilization of rubber wood, The Japan Industrial Technology Bulletin, Tokyo, 1985

Daljeet Singh et al.
The utilization potential of rubberwood, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Environnement Canada
Installations de preservation du bois au pentachlorophenol (impregnation thermique). Recommendations Techniques Pour La Conception Et L'Exploitation, Rapport SPE 2/WP/5, 1988

Environnement Canada
Installations de preservation du bois au pentachlorophenol (PcP), Recommendations Techniques Pour La Conception Et L'Exploitation, Rapport SPE 2/WP/2, 1988

FRIM Proceedings of the international rubberwood seminar, Rubberwood Research Committee, Kuala Lumpur, 21-22 May 1990

FRIM Proceedings of the second rubberwood seminar, Kuala Lumpur, 19-20 November 1985

Gan, L.T. Estimation of sawntimber yield from rubber plantings, Planter, No. 65, 1989

Gan, L.T. et.al.
Heveawood: sawn timber production and recovery Studies, Paper presented at the International Rubber Conference, Kuala Lumpur, October 1985

Gan, L.T. et.al.
Rubberwood: sawn timber production and recovery Studies, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Gnanaharan. R.
A simplified boron diffusion treatment for rubber wood, The International Journal of Wood Preservation, No. 2, 1982

Gnanaharan, R. & Varma, R.V.
Field evaluation of preservative treated rubberwood (*Hevea brasiliensis*) against subterranean termites, Material and Organismen, No. 24, KFRI Scientific Paper No. 169, Kerala Forest Research Institute, Peechi, Kerala, India, 1989

Grant, D.F. Exploitation of timber from rubber trees, The Malaysian Forester, No. 15, Kuala Lumpur, 1952

Griffin M.J., et.al.
The practical extraction of rubberwood, Seminar on Rubberwood Utilization, Malaysian Forester, Kuala Lumpur, June 1982

Habash Rubber wood processing - government assistance vital, Rubber Asia, No. 111, Kuala Lumpur, 1989

Haridasan, V.
Rubber wood - promise of the future, Rubber Board Bulletin, No. 25, Kottayam, 1989

Haridasan, V.
A study of rubber wood market, Rubber Board Bulletin, No. 22, Kottayam, 1988

Harris, E.M.
Utilization of wastewood as fuel and chemical resource, Planters Bulletin, No. 160, Kuala Lumpur, 1979

Ho, K.S. Current processing techniques of rubberwood, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Ho., K.S. & Choo, K. T.
Processing of rubberwood, Seminar on Rubberwood Utilization, Malaysian Forester, Kuala Lumpur, June 1982

Hoi, W.K. et.al.
Small-scale rubberwood charcoal production, Proc. et. al. RRIM Rubber Growers' Conference, Ipoh, Perak, October 1986

Hong, L.T. Rubberwood: processing and utilization, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Hong, L.T. Screening of preservatives against sap-stain and mould fungi from tropical hardwoods, I. Laboratory Tests Against Isolates from Rubberwood (Hevea Brasiliensis), The Malaysian Forester, No. 44, Kuala Lumpur, 1981

Hong, L.T. & P. Thillainathan
I. screening of preservatives against sap-stain and mould fungi from tropical hardwoods. II. First assessment of four proprietary formulations on rubberwood, The Malaysian Forester, No. 46, Kuala Lumpur,1983

Hong, L.T. et al.
Potential values of unused rubber effluent pond for Storing rubberwood logs, Proceedings - Rubber Growers' Conference, Kuala Lumpur, 1987

Hong, L. T., et.al.
Preservation and protection of rubberwood against Biodeteriorating organisms for more efficient utilization, Seminar on Rubberwood Utilization, Malaysian Forester, Kuala Lumpur, June, 1982

Hong, L.T., et al.
Protection and preservation options for rubberwood Sawn timber and finished products, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Hong, L.T. et.al.
The effectiveness of preservatives in the control of Sap-stain in rubberwood (hevea brasiliensis) logs, The Malaysian Forester, No. 43, Kuala Lumpur, 1980

Jose, V.T. et.al.
Preliminary studies on the preservation of Rubberwood by diffusion treatment, Rubber Board Bulletin, No. 25, Kottayam, 1989

Joseph, S. & Mathew, N.M.
Use of rubber wood for the manufacture of safety matches, Rubber Board Bulletin, No. 25, Kottayam, 1989

Kamala, B.S. & Rao Krishna
Physical and mechanical properties of *Hevea brasiliensis* (rubber wood) - a review, Rubber Board Bulletin, No. 25, Kottayam, 1989

Khoo, S.K. et.al.
Profitability of rubberwood - status and Availability, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Kroonen, J.G.
Gasification of hevea wood for the generation of caloric and electrical energy for rubber estates, Rubber Foundation, Amsterdam, 1984

Kroonen, J.G.
Gasification of hevea wood for the production of heat and power on rubber estates, Menara Perkebunan, No. 53, 1985

Kupusamy, V. & Srinivasan, V.
Copper-chrome-arsenic treated rubber wood - a case study, Rubber Board Bulletin, No. 25, Kottayam, 1989

Leong, D.P. Ali bin Sujan,
An economic reassessment of using rubberwood for SMR pallet construction, Paper Submitted for the RRIM/RISDA Rubberwood Utilization Committee, Kuala Lumpur, 1979

Lew, W.H. Perspective on present and future development of rubberwood, Warta Perdagangan Kayu, No. 14, Kuala Lumpur, 1985

Lew, W.H. Quality control of sawn rubberwood for export, Warta Perdagangan Kayu, No. 14, Kuala Lumpur, 1985

Lew, W.H. Rubberwood utilization - some views from the industry, Warta Perdagangan Kayu, No. 14, Kuala Lumpur, 1985

Lew, W.H. Market/product profile: the importance of treating rubberwood, Maskayu, Kuala Lumpur, December, 1983

Lew, W.H. The many uses of rubber wood, New Straits Times, Kuala Lumpur, October 1975

Lew, W.H. & Chew L. T.
Weaknesses and shortcomings of rubberwood as a product, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Lew, W.H. & Sim, H. C.
Rubberwood - present and potential utilization, The Malaysian Forester, No. 45, Kuala Lumpur, 1982

Lewis, D.A. & Spence, M.
The prophylactic treatment of green rubberwood, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Lopez, D.T. et. al.
Rubberwood - a study of recovery in production mills, The Malaysian Forester, No. 43, 1980

Mohd. Shukari
The abrasive resistance of rubberwood, The Malaysian Forester, No. 46, Kuala Lumpur, 1983

Mohd. Shukari et.al.
A comparative study on the gluing properties of rubberwood, Mengkulang, Kapur and Keruing species, The Malaysian Forester, No. 48, Kuala Lumpur, 1985

Newsam, A. et al.
Decay of rubber wood in a replanting and its effect on root disease. Journal of the Rubber Research Institute, Malaya, 1967

Ng, A.P. et. al.
Currents status on effects of planting density on the performance of *Hevea brasiliensis*, Proceedings-Rubber Growers Conference, Kuala Lumpur 1987

Nielsen, K.T.
Marketing challenges for malaysian rubberwood furniture, The Malaysian Forester, No. 46, Kuala Lumpur, 1983

Norhara bte. Hussein
A preliminary assessment of the relative susceptibility of rubberwood to beetle infestations, Malaysian Forester, No. 44, Kuala Lumpur, 1981

Odozi, T.O. Particle boards from underbarked natural rubber wood and lignocellulose byproducts, Industrial Engineering Chemical Research, No. 26, 1987

Ong, M.S. Rubberwood utilization - regulatory aspects, Malaysian Forester, Kuala Lumpur, 1982

Ooi, S.H. Development strategies for the rubberwood processing industries, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Peel, J.D. Pulp and paper manufacture in malaya, part III. The practicability of manufacturing fibreboard in Selangor, Malaysian Forester, No. 23, Kuala Lumpur, February, 1960

Peel, J.D. Research items: resin-bonded chipboard from Malayan woods, Malaysian Forester, No. 18, Kuala Lumpur, 1955

Peel, J.D. Rubber wood as a raw material for paper pulp or building boards, Planters Bulletin, No. 23, Kottayam, 1956

Peel, J.D. & Peh, T.B.
Para rubber wood (*Hevea brasiliensis Muell.-Arg.*) As a raw material for pulp; an account of laboratory experiments, Forest Research Institute Research Pamphlet No. 34, Kepong, 1956

Peries, O.S.
Rubber wood - a by-product of the natural rubber industry, Rubber Research Institute of Sri Lanka Bulletin, Colombo, 1980

Radzuan bin Abd. Rahman & Roselina bte. Johari
Prospects for integrating timber production into agricultural plantations and of timber trees as the next major agricultural crop, Planter, No. 65, Kuala Lumpur, 1989

Reghu, C.P. Preservative treatment and seasoning of rubber wood, Rubber Board Bulletin, No. 24, Kottayam, 1989

Reghu, C.P. et.al.
An account of tension wood with special reference to *Hevea brasiliensis*, Rubber Board Bulletin, No. 25, Kottayam, 1989

Reghu, C.P. et.al.
Wood anatomy of *Hevea brasiliensis (Willd. Ex adr. de Juss.) Muell. Arg.* 1: Distribution pattern of tension wood and dimensional variation of wood fibres, Indian Journal of Natural Rubber Research, No. 2, Kottayam, 1989

RRIM Rubberwood - a source of sawn timber and chemicals, (Editorial) Planters Bulletin, No. 160, Kuala Lumpur, 1979

Salamah bte. Selamat, et. al.
Dip-diffusion treatment of rubberwood, Proceedings - Malaysian Chemical Conference '87, Kuala Lumpur, October 1987

Salleh bin Mohd. Nor.
R & D for rubberwood, Warta Perdagangan Kayu, No. 14, Kuala Lumpur, 1985

Salleh bin Mohd. Nor
Control of fungal attack in rubber logs, Maskayu, No. 10, Kuala Lumpur,1981

Salleh bin Mohd. Nor & Sim. H. C.
Rubber wood for furniture, Paper presented at the 2nd NTC, Kuala Lumpur, March, 1979.

Samosorn, S. & Wasuwat, S.
Furniture: Thailand: tabling strong growth rates, Asia-Pacific Forest Industries, Kuala Lumpur, August 1990

Samosorn, S. & Wasuwat, S.
Para rubber wood, a major by-product of rubber replanting in Thailand, Paper presented at the IRRDB Symposium, Beijing, China, May 1983

Samosorn, S. & Wasuwat S.
Rubberwood: Malaysia's wonder wood, Asia Pacific Forest Industries, Kuala Lumpur, June 1990

Schalck, J. et. al.
Preservative treatment of rubberwood (*Hevea brasiliensis)* by pressure impregnation, Chemical and Biological Evaluations, Med. Fac. Landwouw. Rijksuniv. Gent, No. 45, 1980

Ser, C.S. & Lim, S.C.
Steam bending properties of rubberwood, The Malaysian Forester, No. 43, Kuala Lumpur, 1980

Sim, A.C. & Tan, A.G.
Rubberwood as a source of timber - with special reference to furniture manufacture, Paper presented at the International Seminar on Investment Opportunities in the Timber-based Industries in Malaysia, Kuala Lumpur, 1990

Sim, H.C. & Mohd. Arshad bin Saru
Moulding properties of rubberwood (*Hevea brasiliensis*), The Malaysian Forester, No. 43, Kuala Lumpur, 1980

Stacey, D.L.
Practical experiences in the use of rubberwood for the production of pulp and paper, Report delivered at the Pulp and Paper Expert Group Meeting held in Vienna by the UNIDO, September 1971, document No. ID/WG.102/15

Sujan, A. et. al.
Some studies on fungal deterioration of rubberwood (*Hevea brasiliensis*), Med. Fac. Landbouw. Rijksuniv. Gent, No. 45, 1980

Susanto, H. et. al.
Field experiences of 15 and 60 kw wood gasification for rural electricity, Paper presented at the ASEAN Conference on Energy from Biomass, Penang, Oct. 1986

T.A.E.K. Preservative treatment of rubber wood (*Hevea brasiliensis*) wood by the boron diffusion process, Cevcon Forester, No. 9, 1969

Tam, M.K. & Daljeet Singh
Preservative treatment of rubberwood by dip-diffusion, Seminar Penggunaan Kayu Getah Kedua, Kuala Lumpur, November 1985

Tan, A.G. Technical feasibility of manufacturing furniture from rubber wood, Rubber Research Institute of Malaysia Technical Series, No. 2, Kuala Lumpur, 1975

Tan, A.G. Control of fungal attack in rubber logs, Malaysian Forester, No. 43, Kuala Lumpur, 1980

Tan, A.G. Rubberwood - from fuelwood to a major timber species, Planters Bulletin, No. 191, Rubber Research Institute, Malaysia, Kuala Lumpur 1987

Tan, A.G. Towards a wider use of rubber wood, Planters Bulletin, Kuala Lumpur, 1974

Tan, A.G. & Khoo, S.K.
Recent developments in rubberwood utilization in Malaysia, Planters' Bulletin, No. 200, Rubber Research Institute, Malaysia, Kuala Lumpur, 1989

Tan, A.G. & Lopez, D. T.
Sawing of rubber wood - recovery and production studies in two sawnmills, Planters Bulletin, No. 160, Rubber Research Institute, Malaysia, Kuala Lumpur, 1979

Tan, A.G. & Mohd. Ali bin Sujan
Preservative treatment of poplar, beech and rubber wood, RRIM Technical Service Report No. 7, Kuala Lumpur

Tan, A.G. et.al.
Bio-deterioration of rubber wood and control measures, Planters Bulletin, No. 160, Rubber Research Institute, Malaysia, Kuala Lumpur, 1979

Tan, A.G.et. al.
Preservative treatment of green rubberwood (*Hevea brasiliensis*) by vacuum-pressure impregnation, Malaysian Forester, No. 46, Kuala Lumpur, 1983

Tan, A.G., et. al.
Rubber wood for parquet manufacture, Planters Bulletin No. 163, RRIM, Kuala Lumpur, 1983

Tan, A.G., et.al.
Rubber wood for furniture manufacture, The Planter, No. 15, Kuala Lumpur, 1982

Tan, A.G.,et. al.
Rubber wood for SMR pallet manufacture, Planters Bulletin, No. 167, RRIM, Kuala Lumpur, 1981

Tan, Y.E. & Hong, L. T.
Components for rubberwood house construction, FRIM Technical Information, No. 1, Kepong, 1989

Thankamma, L.
Pre-felling pressure injection of rubber trees for preservation of rubberwood - a new concept, The Planter, No. 66, Kuala Lumpur, 1990

Thong, H.L. et.al.
Protection and preservation options for rubberwood sawn timber and finished products, Proceedings of the Second Rubberwood Seminar: Kuala Lumpur 1985, Forest Research Institute Malaysia, Kepong, 1987

Tillekeratne, L. M. K.
Insect infestation of tsr pallets. Rubber Research Institute of Sri Lanka Bulletin, Vol. 11, Colombo, 1976

Wong, C.N. Preliminary assessment of rubberwood (*Hevea brasiliensis*) for plywood manufacture, The Malaysian Forester, No. 42, Kuala Lumpur, 1979

Wong, W.C. & Ong, C. L.
The production of particle board from Rubberwood, The Malaysian Forester, No. 42, Kuala Lumpur, 1979

Wycherley, P. R.
Developing a winner from rubberwood (Editorial), Warta Perdagangan KayuNo. 14, Kuala Lumpur, 1985

Wycherley,P. R.
Timber of old rubber trees, Sci Malaysia, No. 1, Kuala Lumpur, 1968