Rubberwood Processing Manual

CFC/ITTO/72 PD103/01 Rev.4 (I)
“Demonstration of Rubberwood Processing Technology and Promotion of Sustainable Development in China and Other Asian Countries”

Research Institute of Wood Industry
Chinese Academy of Forestry
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Rubberwood Processing Manual

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“Demonstration of Rubberwood Processing Technology and Promotion of Sustainable Development in China and Other Asian Countries”

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Table of Contents

Foreword.................................................................................................................. 1

Chapter 1 Sawing of Rubberwood ................................................................. 3
  1 Sawing Equipments .................................................................................. 4
  2 Sawing technique.................................................................................. 8
    2.1 Quarter Sawn.................................................................................. 8
    2.2 Back Sawn................................................................................. 10
    2.3 Live Sawn.......................................................................... 13
    2.4 Radial sawn........................................................................... 13
  3 The implement of log’s breakdown...................................................... 15
    3.1 Preparative works.................................................................... 15
    3.2 Breaking down pattern......................................................... 15
    3.3 Sawing process......................................................................... 16
  4 Sawing problems and measurements.............................................. 17
    4.1 Saw running hot...................................................................... 17
    4.2 Thickness of flitch variation.................................................. 18
  5 Suggestions for Rubberwood sawing .............................................. 18
  6 Qualification of sawyer........................................................................ 21
  7 Glossary of Terms used in Sawmilling........................................... 21

REFERENCES........................................................................................................ 23

Chapter 2 Preservation of Rubberwood ................................................... 25
  1 Rubberwood degradation.................................................................... 26
    1.1 Insects..................................................................................... 26
    1.2 Stain and mold fungi............................................................... 26
  2 Treating method for rubberwood...................................................... 27
    2.1 Fungicides and insecticides for the temporary protection............... 27
    2.2 Long-term protection, preservatives and treating schedule............... 28
3 Quality control for boron preservative treated timber ...... 29
  3.1 Retention................................................................................. 29
  3.2 The relationship between concentration and density
of boric acid /borax solution...................................................... 31
  3.3 Determination of boron in solution or treated wood32
  3.4 Method for determining penetration of
boron-containing preservatives........................................ 34
  3.5 Quality control................................................................. 35
4 Equipment availability....................................................... 36
Appendix I Technical report of vacuum pressure treatment by
NaPCP free preservative during 2006-2007 ....................... 38
Appendix II Technical report of vacuum pressure treatment of
rubberwood timber in 1998 ..................................................... 42
Chapter 3 Drying of Rubberwood.........................47
  1 Air-drying of Rubberwood ................................................. 48
    1.1 Air-drying techniques.................................................. 49
    1.2 Forced air-drying ..................................................... 59
    1.3 Suggestions for Rubberwood Air-drying.............. 61
  2 Kiln Drying of Rubberwood............................................... 62
    2.1 Conventional drying kiln ........................................ 62
    2.2 Conventional drying techniques .............................. 66
REFERENCES ............................................................................. 75
Foreword

The rubber tree which is native to Brazil is widely planted for the production of latex in South East Asia, mainly in Indonesia, Malaysia and Thailand. The total rubber plantation area is about 9 million hectares in the world, and the area distributed in South-east Asian countries is about 90% of the total. And the Rubberwood was also planted in southern part of China; it is mainly distributed in Hainan, Yunnan, Guangdong, Guangxi and Taiwan provinces. The annual Rubberwood volume can reach to 300,000 m$^3$, the high efficiency utilization of Rubberwood can decrease the dependence to the imported wood from other countries.

The height of Rubberwood is about 10 ~ 20 m, the basic density is 450-550 kg/m$^3$, and the air dry density is 560-640 kg/m$^3$. The rotation period is about 25 to 30 years when the production of latex is uneconomical; the trees are fallen for replanting. Previously the felled trees were of low commercial value and were mainly used as fuelwood, Since the mid 1980s rubberwood is one of the most popular timbers for making furniture and other wood based products and is an important resource for the timber industry and has now become one of the major money earners for this industry.

The main reason for the popular of rubberwood rest with its light color, beautiful grain, even properties, low shrinkage rate, and good dimensional stability. The strength of the lumber is also good, and it is easy to process, such as sawmilling, peeling, drilling, adhesion and painting.

The disadvantages are also evident in Rubberwood, (1) fast
biodegradation and susceptibility to insect infestations after felling, the rubberwood logs must be sawn as soon as possible or preservation. (2) Comparison to other species, the dimension of rubberwood lumber is small, so the jointing technology is often used. (3) Drying defects are easy occurred, such as warp, twist, bow and splitting. (4) The left latex inside logs can clog the saw teeth. (5) The lumber recovery is low, it is about 15 – 35% in small sawmill, the average lumber recovery is about 25%.

To improve the processing technology and efficiency, this training manual is compiled for the technicians, operators and other rubberwood processing related persons. This work is supported by project CFC/ITTO/72 PD103/01 Rev.4 (I) “Demonstration of Rubberwood Processing Technology and Promotion of Sustainable Development in China and Other Asian Countries”, which was financed by ITTO and CFC, and executed by Research Institute of Wood Industry, Chinese Academy of Forestry. This manual covers the field of sawing, preservation and drying technology in utilization of Rubberwood.
Chapter 1 Sawing of Rubberwood

China is one of the countries in which processing capacity of wood production are the biggest. The productions are exported to many countries. And the processing equipments such as drying kilns and downstream processing machines are similar with other countries, but the sawing technology was very low in comparison with other developed countries, and the quality of lumber can not compete with other countries though the labor cost is low. It is urgent to improve the current sawmilling equipment and technology in China.

The sawing is directly related to the quality of wood production and profits of enterprises. The production recovery will be different with different sawing techniques, and the drying characteristics of lumber is also different with different sawing pattern. The sawing is the first processing procedure, and it is also the most important procedure, the core is to process the lumber in accordance with enterprises standard or meet the needs of consumers. The aim is to improve the lumber recovery with high lumber quality, and make the profits maxim for enterprises.

The normal sawing line always consist of transport of logs, primary sawing with headrig bandsaw with carriage, secondary breakdown of cant with small bandsaw, and processing of flitch with small bandsaw. The technics flow is shown in figure 1.
1 Sawing Equipments

The sawing equipments are the main influenced factor in sawing process besides sawing technics and operating, such as the stability, precision, velocity of saw, and thickness of saw blade. Table 1 shows the main properties of single saw and multi-saw.

<table>
<thead>
<tr>
<th></th>
<th>Single saw</th>
<th>Multi-saw</th>
</tr>
</thead>
<tbody>
<tr>
<td>flexible</td>
<td>Saw line only parallel to the pith of log</td>
<td></td>
</tr>
<tr>
<td>Accurate feeding of carriage is needed</td>
<td>Balance the releasing of growth stress</td>
<td></td>
</tr>
<tr>
<td>Flexible to quartersawn or backsawn</td>
<td>Only backsawn</td>
<td></td>
</tr>
<tr>
<td>Good training is needed</td>
<td>Easy operating</td>
<td></td>
</tr>
<tr>
<td>Good quality</td>
<td>High productivity</td>
<td></td>
</tr>
<tr>
<td>Conventional carriage</td>
<td>Straight saw</td>
<td></td>
</tr>
<tr>
<td>Band saw or circular saw</td>
<td>Rip saw</td>
<td></td>
</tr>
<tr>
<td>Horizontal bandsaw</td>
<td>Canter or integrated saw</td>
<td></td>
</tr>
</tbody>
</table>

The headrig bandsaw with carriage is the most popular in log sawing. The carriage transport the log through bandsaw, a piece of lumber is sawn off after one pass, and the operating skills are always needed with the headrig bandsaw operation. It is flexible
for the sawing of quarter sawn or back sawn lumber.

The twin-saw system with carriage is popular in some developed countries. The productivity can be improved evidently. But the sawing can not been conducted on the base of log’s properties, and the sawing line can’t parallel to the bark of log. It is suitable for the logs without big taper.

The chipping canter and multi-blade saw have higher efficiency, it can finish the log’s sawing only through one pass, the productivity is very high. It is suitable for the condition when the dimension of log is similar and the amount is huge.

The secondary breakdown equipments include: main-force small bandsaw, the semi-automatic table bandsaw and common bandsaw with feeding installation. And the common bandsaw and table-type bandsaw always been used as assistant bandsaw.

![Figure 1-2 headrig bandsaw for primary sawing](image)

The proper tension is the most important factor to the bandsaw. The sawing quality is not good if the width of saw blade is big, for the proper tension is not easy to meet the needs with wide saw
blade. The amount of setting of blade teeth also influence the sawing rate, the bigger the amount of setting, the higher the sawing rate. The sawing rate is even with motor as driving force. The sawing equipments are listed in figure 1-2 to figure 1-6.

Figure 1-3 Small bandsaw for secondary breakdown

Figure 1-4 Horizontal bandsaw
Figure 1-5 Log processed to Cant by twin-saw

Figure 1-6 Multi-saw equipment
(The cant was processed to lumbers through one pass)
2 Sawing technique

The sawing technique is important to processing efficiency, lumber quality, and add value to products. The improvement of sawing can influence the cost, lumber recovery and competence of production. There are many ways to saw a log, first of all, the dimension should be confirmed depend on the needs of enterprises or consumer, and then sawing logs with suitable sawing patterns. The general sawing patterns include quarter sawn and back sawn, and live sawn is also commonly used. The radial sawing pattern is a new way in sawing small logs.

The sawing technique depends on not only the lumber grade, but also the production recovery and quality of products. For example, the shrinkage rate of quarter sawn lumber is 50-60% of that in back sawn lumber, the big shrinkage of quartersawn lumber occurred in the thickness, and that of backsawn lumber occurred in the width. The drying stress is evident in drying high shrinkage lumber, and this can result in surface checks and degrade of lumber.

The sawing efficiency could be decreased if the sawing technique is not suitable to logs, this can result in the long time for delivery. It is better to select the optimum sawing pattern depends on the needs of consumer and the sawing equipments, so the efficiency and production quality could be improved, and the profits of enterprises could be maximum.

2.1 Quarter Sawn

Quarter sawn, timber cut with the growth rings at right angles to the wide face of a board. The lumber with the angle beyond 45
degree is commonly called quarter sawn lumber (figure 1-7). The lumber quality is high, but more overturn of log is needed in sawing process, and lumber recovery rate is low. The typical quarter sawn pattern is displayed in figure 1-8.

![Figure 1-7 Quarter sawn lumber](image1)

![Figure 1-8 Quarter sawn pattern](image2)

The width of quarter sawn lumber is small; it is less than the radial dimension of log. The drying defects are less. The key point of quarter sawn is putting the central part of log to the side of lumber, which is easy to occur for the drying defects. The disadvantage in quarter sawn is as follows, the spring defects, and the thickness is not even, and this should be corrected by planing to the surface of lumber after drying.
The wider side of lumber is radial surface, the growth ring could be seen;

The quarter sawn pattern is suitable for the big diameter logs, or the width of lumber could be very small, for the width of lumber is less than the radius of log;

The lumber recovery is low when radius of log is less than 40 cm;

The sawing cost is high for small diameter log.

Advantages:

- The surface check and internal check are not evident for the collapse species lumber;
- The thicker lumber could be produced for the shrinkage rate in width is lower;
- The surface grain is even;
- The abrasion resistance of surface is good, it is suitable for flooring and furniture;
- The bow and twist are less in drying process;
- It is easy to conditioning.

Disadvantages:

- The deformation from growth stress is big;
- Drying time is long;
- It is easy to split for nailing.

### 2.2 Back Sawn

Back sawn, timber cut with the growth rings lying parallel to the wide face of a board. The lumber with the angle below 45 degree is commonly called back sawn lumber (figure 1-9). The overturn in sawing is not too many as that in quarter sawing; it is not suitable
for the sawing of logs with higher growth stress. The main waste is from the drying degrade. The figure 1-10 displays the typical back sawn pattern.

The commonly used cant sawing and three sides sawing are all belong to back sawn methods. The width of back sawn lumber is big, and drying rate is high, but the drying defects are easy to occur in drying process.

- The wider side of lumber is tangential surface;
- Good texture could be seen in wider face;
- It is easy to process wider lumber from flitch;
- The influence of diameter is not big to lumber recovery;
- The sawing cost is not high.
Advantages:
- Sawing efficiency is high and cost is low;
- Drying rate of lumber is high;
- Beautiful texture in surface;
- It is not easy to split in nailing;

Disadvantages:
- The drying degrade is high;
- Shrinkage rate in width direction is high;
- Warp and twist are main drying defects;
- It is difficult to steaming for the collapse species lumber.

The sawing pattern should be confirmed in accordance with the species and final usage of lumber. The back sawn pattern could be used in sawing low shrinkage rate species, and the lumber degrade is low; and the quarter sawn pattern should be used in sawing high shrinkage rate and collapse species, but the lumber recovery is low for small diameter logs, and the width is small. The quarter sawn lumber’s movement in service is lower than that of back sawn lumber. The difference between back sawn and quarter sawn lumber is listed in table 1-2.

<table>
<thead>
<tr>
<th></th>
<th>Quarter sawn lumber</th>
<th>Back sawn lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>Low</td>
<td>high</td>
</tr>
<tr>
<td>Lumber recovery</td>
<td>10% lower than back saw</td>
<td>high</td>
</tr>
<tr>
<td>Dimension</td>
<td>Small than radius of log</td>
<td>Near diameter</td>
</tr>
<tr>
<td>Heartwood with knot</td>
<td>Influence many lumbers</td>
<td>Less influenced</td>
</tr>
<tr>
<td>Deformation</td>
<td>Spring</td>
<td>Bow</td>
</tr>
<tr>
<td>Drying degrade</td>
<td>Easy control</td>
<td>Difficult control</td>
</tr>
<tr>
<td>Growth rings</td>
<td>Even surface</td>
<td>Special Surface texture</td>
</tr>
<tr>
<td>Stability</td>
<td>Good</td>
<td>Problems</td>
</tr>
</tbody>
</table>
2.3 Live Sawn

In live sawing the log is not turned during the production process. It is the cheapest milling method but produces the lowest quality timber, being a mixture of quarter sawn and back sawn. Its sawing pattern is displayed in figure 1-11.

![Figure 1-11 Live sawing pattern](image)

2.4 Radial sawn

Radial sawn technology is patented by Radial Timber Australia, it is called a revolutionary method in sawing plantation logs in Australia. The wedge shape lumber is produced, it has advantage in sawing small diameter logs, the growth stress problem could be overcome and lumber recovery is higher than conventional methods. The figure 1-12 displays the radial sawing for quatersawn and backsawn lumber. Radial sawing is based on natural growth rings’ sequence, growth stresses are controlled during breakdown
and distributed evenly into each wedge sector. The wedges are then re-sawn to backsawn lumbers, the drying stress is also distributed inside lumber evenly.

**Figure 1-12 the backsawn lumber (left) and quartersawn lumber (right) by radial sawing**

- After breakdown, each piece is a wedge, and the widest lumber is from sapwood, the pith or heartwood is in the corner of wedge;
- Lumber recovery is high with radial sawing, and backsawn lumber recovery is high.

**Advantages:**
- The backsawn lumber recovery is higher than that of conventional sawing;
- The dimensional stability of lumber is good;
- It is difficult to warp or twist;
- The wastage from sawing is less.

**Disadvantage:**
- Low productivity;
- The cross section is wedge, it is difficult to utilize;
- It is difficult to stack;
- The utilization is limited for the narrow width of lumber.
3 The implement of log’s breakdown

3.1 Preparative works

The following works should be done before sawing of logs.

- Understand and master the occupational health and safety regulations relevant to the sawing of logs;
- Pre start-up checks are completed on sawing and transfer equipment;
- Ensure that all waste material (off cuts) is regularly cleared away, or the harm to operators or the sawing equipments will happen.

3.2 Breaking down pattern

The sawing pattern should be confirmed according to the identity of the equipments and logs.

- Plan the sawing line and sequence of cuts;
- Position logs right, feeding and sawing log in planning sequence;
- Operating equipments correctly to avoid harm to persons, logs and equipments.
- The sawing line is controlled to decrease waste, and increase lumber recovery;
- The defects inside logs should be observed, and adjust sawing technique in time;
- The products and lumber quality should be recorded for enterprises’ reference.
3.3 Sawing process

3.3.1 Primary breakdown

Primary breakdown is the first cutting to logs; it is to saw a face side for the downstream processing, or to process log to cant or slabs. The weight and dimension of log is reduced after primary breakdown, so it is easy to cut in secondary sawing equipments.

First of all, the properties of log should be assessed, and then sawing pattern could be confirmed for high grade lumber and high lumber recovery. Each section of log has its special feature, it can be seen on the surface, but the real properties can’t be seen until the log is sawn. The first cutting is very important to the sawing of log, the position of first cutting should be considered according to the following factors.

- The dimension of log, i.e. diameter and length of log;
- The shape of log;
- The needs of enterprise (special dimension etc.)
- The defects of log, end-checks, sweep and taper etc.

The other defects such as knot, insect hole etc. can also be observed. The high grade can be differentiated from low grade in this stage. The 3rd cutting in figure 1-13 is unsuitable, if the first cutting is in the position, the lumber recovery should be lower.

![Figure 1-13 the first cutting position in primary breakdown of log](image)

16
3.3.2 Secondary breakdown

It is the most important procedure in sawing of log, the position and sequence of cutting is the decisive factor to the lumber quality and sawing efficiency. It should be confirmed according to the consumer’s order and the requirements of enterprises. And the influence of slab cant and flitch’s irregular shape should be considered also.

4 Sawing problems and measurements

Sawing problems could encounter in sawing logs, such as saw running hot and thickness variation. The operators have a responsibility to ensure that an identified problem is investigated, and that corrective actions are implemented to maintain safety, quality and company standards.

4.1 Saw running hot

Some of the causes of the saw running hot, and ways to fix the problem include:

- Select optimize cutting speed. Speed up or slow down as required.
- Check saw is sharp enough to complete task. Sharpen if required.
- Check the flitch is not pressing against the saw by tension in the timber. Use of wedge may be necessary to prize timber open away from the blade whilst cutting.
- Check there is no object jammed against the saw and the guide board. Turn saw off to remove when necessary.
4.2 Thickness of flitch variation

To avoid the big variation of thickness, besides the right cutting in the primary breakdown (ensure correct orientation of log to the saw for the first cutting), the following measures could be adopted:

- Ensure the log in each of the bolster arms on the carriage is holding the log firmly.
- Ensure the log is directed in line with the saw, so the blade stands upright. Log may contact solid objects outside of moving carriage, deflecting log while in the cut, and forcing saw blade to lean over while cutting.
- If the blade is overheating it may snake along the log being cut. Run saw without cutting any log until the blade is cool enough to stand upright while running.
- Thickness of flitch may vary due to the sizing gauge being out of calibration. Check calibration of sizing gauge and adjust as required.

5 Suggestions for Rubberwood sawing

The main trouble in Rubberwood utilization could be its fast biodegradation and susceptibility to insect infestations after felling. So it is better to saw and protect lumber as soon as possible after its felling. The Rubberwood is easy to saw, but the latex left in lumber can clog the teeth of saw blade, this could be avoided by changing parameters of blade teeth properly.
Figure 1-14 the band saw for Rubberwood sawing
(LEZHONG wood company, Hainan Province)

The main equipment for sawing Rubberwood is bandsaw with manual carriage, but the performance of saw is different among different enterprises, and most of the equipments are second-hand (figure 1-14, 1-15). The equipments are simple, the quality is mainly controlled by sawyer’s experiences, so the lumber quality is unsteady. In most cases, the same sawing pattern is used to logs with different diameter, shape and inside quality. But the taper of Rubberwood is a little big, and has the following characteristics such as small diameter, more knots, big latex content, so the huge equipment is unsuitable for sawing Rubberwood. The sawing is labor intensive work, and most of transport and feeding works are manual (figure 1-16).
Figure 1-15 The bandsaw with manual carriage  
(CANGJIANG wood company, Yunnan Province)

Figure 1-16 The labor intensive work in sawing of Rubberwood

The main reason of low recovery in sawing Rubberwood is irrational sawing technique adopted. The commonly used sawing pattern is live sawing, the wood property is not even inside a piece
of lumber, so it is easy to occur the defects such as deformation, twist etc. the sawing pattern should be adjusted to meet the requirement of enterprises.

6 Qualification of sawyer

- He can operate sawing equipments safely with high efficiency;
- He can assess the quality of log correctly, and select suitable sawing pattern according log’s quality;
- He can deal with the problem in sawing process;
- He can amylase related sawing parameters of logs and lumbers correctly;
- He can write, draw or oral express to communicate with other persons;
- He can master related technical terms, so it is easy to communicate with technician and receive technical training.

7 Glossary of Terms used in Sawmilling

7.1 Bandsaw A machine that cuts using an endless steel blade with teeth along one edge. The blade is mounted on upper and lower wheels.

7.2 Back sawn Timber cut with the growth rings lying parallel to the wide face of a board (the angle less than 45 degree also called back sawn lumber). This is done to improve recovery of the decorative quality of the boards.
7.3 **Box of the heart** Boards are cut from the outside of a log leaving the defective heart in a central rectangular section.

7.4 **Breaking down** A sawing process for converting logs to sawn timber. This is done using the headrig saw.

7.5 **Cant** A thick piece of timber sawn from a log which has two or more flattened surfaces. It is intended for resawing.

7.6 **Circular saw** A machine that cuts by means of a circular steel blade with cutting teeth around the circumference.

7.7 **Growth stress** Internal forces set up within a tree as it grows. It is common in fast growing trees. When such trees are sawn, the stresses are relieved and the resultant timber often develops spring or bow deformation.

7.8 **Quarter sawn** Timber cut with the growth rings at right angles to the wide face of a board (or the angle (growth rings’ tangent line to the wide face) is larger than 45 degree.

7.9 **Recovery** The volume of sawn timber recovered from a log. It is often expressed as a percentage of log volume.

7.10 **Spring** A distortion from the plane of sawing. It produces curvature along the length of a piece of timber in an edgewise direction.

7.11 **Taper** The term applied to the reduction in log diameter from butt to head.
REFERENCES

Joerg Balsiger, Jamal Bahdon, Adrian Whiteman, 2000, The Utilization, processing and demand for rubberwood as a source of wood supply, Asia-Pacific Forestry Sector Outlook Study, Forestry Policy and Planning Division, Rome, Regional Office for Asia and the Pacific, Bangkok.


Chapter 2 Preservation of Rubberwood

The fresh felled rubberwood is very susceptible to fungi and insects in sub-tropical area due to high content of carbohydrates in parenchymatous cells. The common preservative, a mixture of boric acid, borax and sodium pentachlorophenol (BBP), is widely used by the treating plants in Hainan and Yunnan Provinces. The sodium pentachlorophenol in BBP is highly toxic to human and animals and it is strictly restricted or prohibited in some countries. The procedure of treating rubberwood with preservative containing only boric and boric acid quickly followed by kiln drying, commonly practiced in Malaysia, is encouraged to be adopted probably by the industries in China. At present, rubber trees are usually felled, sawn into lumber, and the lumber impregnated and dried within about 7 to 10 days in most rubberwood processing plants in China. Few operators sprayed the logs with preservative; this could be the cause of the rather frequent occurrence of blue-stains which seriously affects the quality and value of the sawn lumber. As Hainan Island and coastal southern regions of China are prone to hurricane which could further delay delivery of logs to processing facilities, temporary protection of logs using cost-effective preservatives should be developed and promoted.
1 Rubberwood degradation

Freshly cut rubberwood is very susceptible to mold and stain fungi, due to the relative high content of carbohydrate (such as starch) in the tissues and the high moisture content. When rubberwood is dried, mold and stain fungi stop occurrence.

1.1 Insects

Fresh or seasoned rubberwood is easily attacked by termite and insect borers mainly from bostrychidae (powder post beetles), platypodidae (ambrosia beetles), scolytidae (ambrosia beetles) and lyctidae (powder post beetles). Ambrosia beetles attack fresh logs and fresh sawn timber, but powder post beetles prefer seasoned timber and finished woodwork producing a fine powder from bore holes and tunnels. Platypodidae and scolytidae are the main insect pests of freshly felled rubberwood logs, fourteen species of platypodids and 51 species of scolytids were identified infecting green rubber wood according to FRIM report.

1.2 Stain and mold fungi

Fresh felled logs and timber are susceptible to stain fungi belonging to fungi Imperfecti. *Botryodiplodia theobromae* Pat. is the common fungi responsible for the bluish color of rubberwood. The hypha is found both in fiber and vessel lumina. A variety of molds can live on the surface of rubberwood, these fungi thrive on carbohydrates in the parenchyma cells of rubberwood, and they do not breakdown lingo-cellulosic components of wood, so they do not affect the strength of wood.
2 Treating method for rubberwood

Untreated fresh rubberwood log and timber is susceptible to stain fungi, which discoloration of the wood, and insects which reduce the quality and durability of timber. So rubberwood should be treated, especially for furnisher making. The log should be cut into timber in 3 days, otherwise, fungicides and insects should be applied for temporary protection.

The timber should be treated by pressure or diffusion process promptly after it is cut for preventing stain fungi and insects. Rubberwood protection is classified by temporary protection and long-term protection.

2.1 Fungicides and insecticides for the temporary protection

Commercial fungicides and insecticides for agricultural uses may also be used for bamboo temporary protection. Some insecticides are included: deltamethrin, cypermethrin, permethrin, cyfluthrin, bifenthrin, chlorpyrifos, imidaclorpid, fipronil, Chlorfenapyr, etc. Some fungicides are listed as: chlorothalonil, copper oxine, MBT, TCMTB, Carbendazim, benomyl, IPBC, isothiazolinone, fenpropimorph, quatery ammonium chloride, propiconazole, etc.

The fungicide formulations should be in emulsions, solutions, wetable power. Contents of active ingredients and user’s guide for the suitable concentration and strength should be included on the label of the containers.
Commercial fungicides and insecticides can be chosen according to their availability and effectiveness by the processing plants. Sodium pentachlorophenol is not recommended for its high toxicity. And its use has been strictly restricted or prohibited in some countries such as Japan and some European countries.

2.2 Long-term protection, preservatives and treating schedule

When the rubberwood is dried, no stain and mold fungi as well as decay fungi occur but power beetles can attack it, so diffusion process or pressure treatment allow the preservative to be fully penetrated into sapwood and give long term protection. Boron is the common preservative for the treatment for its high diffusion ability. The treated products can only be used indoor circumstance for it is leachable in rain.

The schedule of vacuum pressure of treatment is described as follows:

1) Initial vacuum: let the air inside the cell out for the preservative penetrate easily. Fill in preservative ----fill the preservative under vacuum condition;

2) Pressure: release the vacuum after filling the preservative, pressure for a period of time, until the retention reach the target.

3) Pump excess preservative: release the pressure, pump out the preservative from the vessel.
4) Final vacuum: keep vacuum for a period to recover the excess preservative or the remaining preservative on the wood surface back to the preservative store cylinder.

The treating schedule will depend on the length of the timber and the moisture content of the timber before treatment. During the vacuum pressure treatment, the MC of timber may be 50-100%.

Table 2-1 Schedule for the rubberwood Vacuum / Pressure treatment

<table>
<thead>
<tr>
<th>Phase</th>
<th>Vacuum / Pressure (Mpa)</th>
<th>Duration (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial vacuum</td>
<td>0.083-0.099</td>
<td>30-45</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.2-1.4</td>
<td>60-120</td>
</tr>
<tr>
<td>Final vacuum</td>
<td>0.053-0.086</td>
<td>10-20</td>
</tr>
</tbody>
</table>

3 Quality control for boron preservative treated timber

3.1 Retention

According to LY/T1636-2005 “Use category and specification for preservative-treated wood”, Table 2-2, 2-3 and 2-4. Retention of $B_2O_3$ 2.8 kg/m$^3$ is equivalent of the retention 6.0 kg/m$^3$ of boric acid/borax (10 H$_2$O) at ratio 1:1.

Based on: B content 11.3% in Na$_2$B$_4$O$_7$-10H$_2$O; B content 17.5% in H$_3$BO$_3$; B content 31% in B$_2$O$_3$. 
For example, if the treated wood is used at C1, when preservative absorption is 220 kg/m³, Concentration of boric acid/borax should be 2.7%, Weight of boric acid/borax for preparing 1000kg should be 13.5 kg each, fungicide F2 is required 0.7-0.9 L (discount during winter).

| Table2-2 Use category for preservative-treated wood |
|---------------------------------|---------|----------------|----------------|
| Use category | Service conditions | Biological agents | Typical usage |
| C1 | Interior, dry | Wood-boring beetles and termites | Framing |
| | | | Roof timbers |
| C2 | Interior, damp | Wood-boring beetles and termites and decay fungi | Framing |
| | | | Roof timbers |
| | | | basement |

| Table2-3 Boron retention at different use class |
|---------------------------------|----------------|
| Use category | Retention(B₂O₃ kg/m³) |
| C1 | ≥2.8 |
| C2 | ≥4.5 |

| Table2-4 The correlation between preservative absorption at C1 and the concentration of total boric acid/borax (1: 1) |
|---------------------------------|-------|----------------|----------------|
| Preservative absorption (kg/m³) | Concentration of boric acid/borax (%) | Weight of boric acid/borax (kg) for preparing 1000kg boric acid /borax solution |
| 200 | 3.0 | boric acid 15, borax 15 |
| 220 | 2.7 | boric acid 13.5, borax 13.5 |
Table 2-5 The correlation between preservative absorption at C1 and the concentration of total boric acid/borax (1:2)

<table>
<thead>
<tr>
<th>Preservative absorption (kg/m³)</th>
<th>Concentration of boric acid/borax (%)</th>
<th>Weight of boric acid/borax (kg) for preparing 1000kg boric acid/borax solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>3.24</td>
<td>boric acid 10.8, borax 21.6</td>
</tr>
<tr>
<td>220</td>
<td>2.95</td>
<td>boric acid 9.8, borax 19.7</td>
</tr>
</tbody>
</table>

3.2 The relationship between concentration and density of boric acid /borax solution

Concentration of boron solution can be tested by density meter. If the preservative just contain boric acid, Concentration of boric acid can be tested by weight of solid boric acid. Of course titration or atomic adsorption spectrometer are recommended for analyzing the concentration of boron if possible.

The relationship between concentration and density of boric acid /borax (10 H₂O) solution at weight ratio of 1:1 is listed in Table 2-6.

Table 2-6 The relationship between concentration and density of boric acid /borax (10 H₂O) solution at weight ratio of 1:1

<table>
<thead>
<tr>
<th>Concentration/density</th>
<th>20°C</th>
<th>30°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5%</td>
<td>/</td>
<td>1.005</td>
</tr>
<tr>
<td>2.0%</td>
<td>1.009</td>
<td>1.0073</td>
</tr>
<tr>
<td>2.5%</td>
<td>/</td>
<td>1.0086</td>
</tr>
<tr>
<td>3.0%</td>
<td>1.013</td>
<td>1.010</td>
</tr>
<tr>
<td>3.13%</td>
<td>/</td>
<td>1.012</td>
</tr>
<tr>
<td>4.7%</td>
<td>/</td>
<td>1.0194</td>
</tr>
</tbody>
</table>
Table 2-7 The relationship between concentration and density of boric acid /borax (10 H₂O) solution at weight ratio of 1:2

<table>
<thead>
<tr>
<th>Concentration/density</th>
<th>30°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.8%</td>
<td>1.0071</td>
</tr>
<tr>
<td>3.0%</td>
<td>1.0148</td>
</tr>
</tbody>
</table>

3.3 Determination of boron in solution or treated wood

3.3.1 Determination of boron trioxide in sodium borate wood preservatives and the treating solutions (Adopted from AWPA A2-07)

Reagents:

Mannitol powder - A.R. grade;
Hydrochloric acid, about 0.5N - Standardization not needed;
Sodium hydroxide, about 0.5N - Standardize using reagent grade boric acid and precisely determine normality, refer to as Nbase;
Phenolphthalein indicator - 1% solution in ethanol (methanol or propanol may be used in place of ethanol);
Methyl red, indicator (sodium salt) - 0.1% solution in ethanol (methanol or propanol may be used in place of ethanol);
Distilled or deionized water.

Procedure:

(1) Dissolve about 1.0 g of solid preservative in about 100 ml of water, record the exact mass of solid used. Refer to this as grams of sample. Gentle heating may be necessary, but cool to: room temperature before titrating.
(2) Add 3 drops of methyl red indicator and stir. Add HCl until solution turns pink then add about 1 ml of excess acid.

(3) Gently boil this solution for 3 minutes to remove CO₂ and cool in an ice bath to room temperature.

(4) Titrate the solution with standardization NaOH to a peach-yellow color (the methyl red neutral point). Up to this point, the volumes of acid and base do not have to be recorded.

(5) To the solution now add 6 drops of methyl red indicator, 8 drops of phenolphthalein, and excess mannitol powder (approximately 30-35 g), and stir to dissolve. The solution will turn a red/pink color.

(6) Titrate the solution with standardized NaOH. The color will change from red/pink to yellow and back to red/pink, which is the end point. Care should be taken to titrate slowly so as not to miss seeing the yellow color entirely.

(7) In order to be sure that the titration is complete, add approximately 10 g of mannitol powder to the solution and stir to dissolve. If the solution changes back to a yellow color, then continue to titrate. If there is no color change upon mannitol addition, then the titration was complete after step 6. Record the volume of NaOH added in step 6 and 7, in ml, as Vbase.

(8) Alternatively, to analyze the treating solution, accurately weigh out (to 0.01 g) 5 to 7 g of treating solution into a 250 ml Erlenmeyer flask. Refer to this as grams of sample. Add distilled water to bring the total volume to approximately 100 ml; swirl to mix and then analyze as before starting with Step 2.

**Calculations:**

\[
\% \text{ B}_2\text{O}_3 = 3.481 \times (V_{\text{base}}) \times (N_{\text{base}}) / \text{grams of sample}
\]
3.3.2 Determination of boron in treated wood by titration

Following standards are used for determination of boron in treated wood:

AS/NZS1605.3:2006 Determination of boron in preservative-treated timber;

AWPA A2-07 Determination of boron in treated wood using azomethine-H or carminic acid;

AWPA A40-06 Standard methods for determination of boron trioxide in treating solutions and treated wood by potentiometric titration with sodium hydroxide.

3.4 Method for determining penetration of boron-containing preservatives

Reagents

Solution 1. Extract 10 grams turmeric with 90 grams ethyl alcohol. Decant or filter to obtain clear solution.

Solution 2. Dilute 20 ml. of concentrated hydrochloric acid diluted to 100 ml. with ethyl alcohol and then saturate with salicylic acid (about 13 grams per 100 ml.).

Procedure

The sample for penetration assay shall be dried prior to making the final cut to expose the surface for spraying.

A smooth surface shows the results of the spot test better than a rough surface. The surface must be dry, otherwise the test will not be satisfactory.

Solution 1 is applied, preferably by spraying, or with a dropper,
to the surface to be treated. The surface being treated is then allowed a few minutes to dry.

Solution 2 is then applied in a similar manner to the areas that have been colored yellow by the application of Solution 1. The color changes should be observed carefully and will show up a few minutes after application of the second solution. In the presence of boron, the yellow color of the turmeric solution is turned red.

After reagent application, placing wood in warm oven accelerates and intensifies the color reaction to better differentiate between treated and untreated wood.

![Fig2-1 color test of boron (Red-Present of boron; Yellow- without boron)](image)

**3.5 Quality control**

The following are the requirement for get success treatment:

1) The concentration of the preservative before treatment

   Weight the solid boric acid or borax precisely and correctly. It is recommended to use 50kg (±1-10g) electronic balance. The water
volume added should be calculated by water meter. Titration or atomic adsorption spectrometer are recommended for analyze the concentration of boron.

2) The record during treating process

Detailed record should be included: date and time, charge number, volume of the wood, the absorption of preservative, the concentration of the preservative, the retention of the preservative, the operator etc, the retention should be calculated by windows excel form.

3) Brand of the treated rubberwood

Example of brand of treated rubberwood is given in Figure 2-2.

<table>
<thead>
<tr>
<th>ABCD</th>
<th>-----Trade mark of the treating plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>-----Preservative</td>
</tr>
<tr>
<td>C1</td>
<td>-----Use class of the treated timber</td>
</tr>
<tr>
<td>HAB</td>
<td>----- <em>Hevea brasiliensis</em></td>
</tr>
<tr>
<td>2.8</td>
<td>-----Retention of preservative</td>
</tr>
</tbody>
</table>

Fig 2-2 Brand of the treated rubberwood

4 Equipment availability

1) The surface of the treating vessel or contacted with the preservative should be coated for prevent corrosion.

2) Measurement equipment for preservative absorption and computer should be available for calculating the retention of preservative and recording detail of each charge.

3) Sheds for air drying should be available. The treated
rubberwood should be stacked regularly in shed for preventing deformation of timber, any rain and direct sunshine as well as preservative loss.

4) The volume of drying kilns should be matching the volume of treating vessel. If the treated wood can not be drying kilns promptly, fungicides should be added to the boron compounds for prevent stain fungi. The timber should be stacked properly for air ventilation, and prevent stain and mold fungi and wrest of timber.
Appendix I Technical report of vacuum pressure treatment by NaPCP free preservative during 2006-2007

--ITTO PD103/01 Rev.4(I) “Demonstration of Rubberwood Processing Technology and Promotion of Sustainable Development in China and Other Asian Countries”

Based on the output of ITTO PD 3/96 Rev. 2(I), pilot test of vacuum pressure treatment of NaPCP free preservative was conducted during 2006-2007.

1 Materials and method

1.1 Materials

Fresh rubberwood timber.

1.2 Preservatives

The active ingredients of formulations are described in Table 2-8.

Table 2-8 The active ingredients of each vacuum pressure treatment formulations (a. i. %)

<table>
<thead>
<tr>
<th>Formulations</th>
<th>Boric acid</th>
<th>Borax</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.50</td>
<td>1.00</td>
<td>0.035-0.045</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>0.20</td>
<td>0.035-0.050</td>
</tr>
</tbody>
</table>
1.3 Test sites


1.4 Treating procedure

Vacuum pressure treatment was used in the following procedure.

Site 1: Initiate vacuum 0.08 M Pa for 15 min, 1.2 M Pa pressure for 35 min, final vacuum 0.085 M Pa for 10 min. The average absorption was 200-250 kg/ m$^3$. The treated timber was stacked.

Site 2: Initiate vacuum 0.08 M Pa for 15 min, 1.1 M Pa pressure for 60 min, final vacuum 0.08 M Pa for 15 min. The average absorption was 200-250 kg/ m$^3$. The treated timber was stacked.

Fig 2-3  Rubberwood timber before treatment
(Lezhong Wood Factory, Hainan Nongken Wood Co, Aug, 2006)
Fig2-4 Preservative (boric acid/borax/F2)  
(Lezhong Wood Factory, Hainan Nongken Wood Co, Aug, 2006)

Fig2-5 Preservative (boric acid/borax/F2)  
(Cangjiang Wood Plant, Xishuangbanna, Yunnan Province, Aug, 2006)

Fig2-6 Air drying after treatment  
(Cangjiang Wood Plant, Xishuangbanna, Yunnan Province, Aug, 2006)
2 Results

This test indicated that F2 could prevent the treated timber for 15-20 days from stain and mold. At Lezhong Wood Factory, Hainan Nongken Wood Co, there was only small mold occurrence during air drying in May 2007. At Cangjiang Wood Plant, there was only small mold occurrence during air drying from Sept to Oct, 2006. The reason is that: some treated timber was direct exposed to exterior for the leaching of preservative after the raining, for there are limited sheds for air drying.

3 Conclusion

Fungicide (F2) can be used for stain and mold control instead of NaPCP.
Appendix II Technical report of vacuum pressure treatment of rubberwood timber in 1998

--ITTO PD 3/96 Rev. 2(I) “Development and Extension of Rubberwood Processing and Utilization Technology”

According Project document of ITTO PD 3/96 Rev. 2(I), the activity 1.1:

— Conduct a survey to identify and categorize the insects and fungi attacking rubberwood in rubber growing areas of China.

— Develop and promote cost-effective and efficient temporary protection techniques.

— Develop cost-effective and efficient preservation techniques based on borax and boric acid preservative.

Vacuum pressure treatment of rubberwood sawntimber had been conducted in Hainan by CRIWI experts based on the laboratory and pilot test of stain and mold control.

1 Materials and method

1.1 Materials

Fresh rubberwood sawntimber 3.5×6.5×50 cm

1.2 Fungicide formulations

The active ingredients of formulations are described as follows:
8 tone solutions of every formulation were prepared. F1 and F2 were chlorothalonil and carbendazim fungicide respectively.

Table 2-9 The active ingredients of each vacuum pressure treatment formulations (a. i. %)

<table>
<thead>
<tr>
<th>Formulations</th>
<th>Boric acid</th>
<th>Borax</th>
<th>F1</th>
<th>F2</th>
<th>NaPCP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.00</td>
<td>2.25</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>1.00</td>
<td>2.25</td>
<td>0</td>
<td>0.02</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1.00</td>
<td>2.25</td>
<td>0.0094</td>
<td>0.018</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>1.00</td>
<td>2.25</td>
<td>0.0088</td>
<td>0.017</td>
<td>0.075</td>
</tr>
</tbody>
</table>

1.3 Treatment and survey method

Test site: Hainan Nanmiao plywood plant.


Temperature: 22-33°C.

Vacuum pressure treatment: initiate vacuum 0.09 M Pa for 30 min, 0.8 M Pa pressure for 1 hr, final vacuum for 20 min. The treated timber was stacked and would be in drying kiln in 3 days. 10 sawntimber of every treatment would be air drying for surveying fungal infections. Untreated timber was fresh timber. Three cubic meter of sawntimber would be treated in every treatment; the retention of every cubic meter timber was 160 kg solution.

2 Results

Two of 10-strip timber treated with formulation 1 (borax/boric acid) infected white mold and Trichoderma sp. after 12-day exposure. One of 10 strip timber treated with formulation 2 (borax/boric acid/F2) infected by a spot of white mold and
Trichoderma sp. after 12-day exposure, and another mold spot appeared after 15 day exposure. One of 10-strip timber treated with formulation 3 (borax/boric acid/F1/F2) infected by a spot of Trichoderma sp. after 15-day exposure, and this spot disappeared after 18 days. None of 10 strip treated timber with formulation 4 (borax/boric acid/F1/F2/NaPCP) after 21-day exposure. Some white mold appeared on the surface of the untreated timber after 3 day-exposure, heavy mold and stain appeared after 6-day exposure, and the timber almost completely infected with mold and stain after 9-day exposure (Table 2-10).

<table>
<thead>
<tr>
<th>Preservatives</th>
<th>3</th>
<th>6</th>
<th>9</th>
<th>12</th>
<th>15</th>
<th>18</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.05</td>
<td>0.05</td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.02</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CK</td>
<td>2</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

### 3. Conclusion

This test indicated that F2 could prevent the treated timber for 12 days from stain and mold and the mixture of F1/F2 could keep the treated timber for 15 days from stain and mold in air drying procedure under the above concentrations. The higher concentrations of F1/F2 might keep the treated timber for longer time from stain and mold. The formulation of F1/F2 for temporary protection of log and timber instead of sodium pentachlorophenol might be suggested for industry use.
4. Suggestions for the rubberwood processing industry

The potential for export of rubberwood furnisher in China is big even the current amount is small; this may be affected by NaPCP treated wood.

Suggestions for the rubberwood processing industry

(1) Change drying procedure

Rubber trees are felled, sawn into lumber, and the lumber impregnated and dried within about 1 to 3 days, no fungicides are necessary for stain control.

(2) Adopt fungicides for temporary protection

If the few operators sprayed the logs with preservative, this could be the cause of the rather frequent occurrence of blue-stains which seriously affects the quality and value of the sawn lumber.

Rubber trees are usually felled, sawn into lumber, and the lumber impregnated and dried within about 7 to 10 days in China.

The cost of fungicides is almost equivalent with NaPCP, will be acceptable by local treat plants.
Chapter 3 Drying of Rubberwood

The keys to prevent rubberwood from stain fungus or decay rely on not only chemical treatment but also immediate drying so that the moisture content (MC) reaches a low level to destroy the live conditions of fungus.

Combining the pre-drying with conventional kiln drying is a practical way to prompt drying quality and reduce drying cost. The pre-drying methods include lower temperature pre-drying and air-drying. Lower temperature pre-drying must be conducted in a large pre-drying room until the moisture content reduces to 25%-30%. The advantages of low temperature pre-drying are that of free from climate infection, drying time under control and good drying quality.

Air-drying is a pre-drying method which is popular to apply in practical production for its various advantages. Air-drying rubberwood can contribute to not only shorten drying time, reduce drying cost but also cut down energy consumption.

Kiln drying is a drying method which is practiced in a building or a metal vessel with controlled conditions of drying temperature, humidity and air velocity. The desired drying quality and final moisture content can gained if the proper drying technology is taken. Kiln drying includes conventional drying and high-temperature drying according to drying temperature.
1 Air-drying of Rubberwood

To dry timbers in the air is called natural drying, shortly called air-drying. With this drying method, timbers are stacked in an open yard or a shed yard, and are dried by absorbing the heat in atmosphere. Air-drying has been used widely in practical production for its various advantages, such as easily to conduct, lower drying cost and etc. As usual, air-drying works as a pre-drying for kiln drying. And practice results show that air pre-drying can not only reduce drying cost and get even MC distribution, but also provide the good preparation for kiln drying if the reasonable air-drying conditions are taken. Two kinds of air-drying yards are showed in Figure 3-1 and Figure 3-2.

![Figure 3-1 Air-drying with shed](image)

Air-drying is mainly governed by air conditions instead of man control conditions. And air conditions are associated with climate, season, daytime or nighttime etc. But air temperature, humidity and airflow work as the main factors. The climate is various in China for its vast territory. Such as, in south sea-area it is warm and humidity, so air-drying can be conducted all year; In summer,
air temperature is high, so it’s a quickly air-drying season except the very high humidity days; In winter, air-drying slows down for the lower temperature; Spring and autumn are the most proper seasons for air-drying because of the suitable air conditions, which means, there’s enough air heat power to drive water out from timbers, and at the same time, the proper humidity keep the timbers from mould, stain and drying cracking. In the all, air conditions should be taken into consider whenever air-drying is conducted.

**Figure 3-2 Air-drying yard in the open air**

In addition, the microclimate which formed in timber yard is another factor to affect air-drying. This microclimate is associated with water evaporation intension, drying temperature and air circulation speed, and can affect air-drying quality and air-drying speed.

**1.1 Air-drying techniques**

Some air-drying techniques must be taken into account to obtain the desired drying quality during the drying. The techniques
include how to arrange the timber yard, how to stack and how to control the drying time etc.

1.1.1 Timber yard

Timber yard is the place where the timbers are stacked. In a same timber yard, the water evaporation intension of timbers is changeable in different position. The evaporation intension is stronger at the edge of yard than that in the center of the yard; On the other hand, in a same timber stack, water evaporation speed of timbers is the fastest and slowest respectively at the top and the bottom of the stack, and at the middle of stack, the evaporation intension is one-fifth of that outside of stack. But in the foggy cold night, the water evaporation speed is faster inside than outside because of its high temperature inside of stack; In addition, the water evaporation intension in a sunny-windy day is stronger than that in an un-windy day. So there are some special requirements when the timber yard is selected and arranged.

1) The floor of timber yard must be flat and dried with slope of 0.2%～0.5% for well draining. And draining establishment must be equipped around the yard as well, besides there is no high building around the yard for well ventilation.

2) Timbers should be arranged in different stack groups in one timber yard according to species and sizes. Usually, there are 4～10 small stacks in one group. All stack groups are separated by vertical and horizontal alleyway, and vertical alleyway should be faced north to south to avoid the straight sunlight. At the same time, the vertical alleyway must be paralleled the direction of main-wind and the length of stack. The details are showed in Figure 3-3.
3) Timber yard must smooth without weed. Draining channel must be underground. The timbers must be separated apart once they are aggrieved by fungus or mould.

4) Timber yard must be far away from residential area, boiler and high building to avoid potential fire trouble. The distance from boiler chimney must be more than 100 m, and from residential area more than 50 m. In addition, proper fire control equipments must be set around timber yard.

1.1.2 Timber stack

Timber stack must be arranged in the timber yard according to some techniques. Timbers which are thin or easy to be stained should be piled in the middle of yard. And timbers which have been infected by fungus must be stacked at the corner of the yard. Thus the followings must be considered when the stack is arranged.

1) The foundation of stack: The foundation of the stack is usually made of reinforced concrete, brick or wood. It is a base which can not only keep some space under the stack for well ventilation but also keep the stack stabilizing. Usually, the distance
between ground and foundation is 0.4m~0.75m, but in south of China it should be 0.5m~0.75m because of the high rain water level. The size of foundation is showed in figure 3-4. Figure 3-5 shows a wooden stack foundation which covered with something like pitch to avoid decay. In the more, there are some crossbeams on the foundation, the distance between two crossbeams is 1.3m~1.6m for thinner one and 1.6m~2.1m for thicker one.
2) The size of stack: The sizes of stack are changeable with the different piling methods. The width of the stack with stickers between two layers should be less than 4m~4.5m so as to get the even drying. The size of the square stack with timbers self-crossing is governed by the length of timbers. In another way, the width of stack is affected by species and other factors. The width of stack for hard wood should be 0.9m~1.8m so that the timbers at lower layers in the stack can be dried at the same time; For very wide stack, an central air channel which is showed in figure 3-6 must be kept in the center of the pile. If a stacking machine is used to pile, the width of stack is governed by the capacity of the machine, usually the width is 1.3m. If the kiln drying is needed after the air pre-drying, the width of stack should be matched with the drying kiln. The height of stack is governed by the intensity of the foundation and stacking methods, height of 2.7m~4.8m with handwork stacking and height of 6m~9m with machine stacking.

3) The space in the stack: The space in the stack is different according to the weather, yard and species. Timbers should be kept sparseness if the climate is humidity and air is bad ventilation; Timbers of hard to be dried should be stacked closely. The cracks between timbers are mainly determined by moisture content of timbers, size, specie and drying season. Usually, the cracks should be 20%~50% of width of timber, but less than 100% so that both the good ventilation and maximum yard capacity utilization can be available. The details about cracks are showed in table 3-1. The cracks along the width of stack should form vertical flue, and the width of the flue should be 20% of that of stack.
Table 3-1 The cracks in a stack

<table>
<thead>
<tr>
<th>The width of timber /cm</th>
<th>The size of crack</th>
<th>The width of timber</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25</td>
<td>1/2 ~ 3/4</td>
<td></td>
</tr>
<tr>
<td>25 ~ 45</td>
<td>1/3 ~ 1/2</td>
<td></td>
</tr>
<tr>
<td>&gt;45</td>
<td>1/5 ~ 1/3</td>
<td></td>
</tr>
<tr>
<td>The timber easy to be face check</td>
<td>1/12 ~ 1/6</td>
<td></td>
</tr>
</tbody>
</table>

4) Sticker: Reasonable using of stickers can not only keep the pile stabilizing and make sure the nice drying quality but also build a fitting horizontal air pass for well ventilate. As usual, thick stickers are used for timbers with thin and high MC, and stickers used at the lower position of stack should be a littler thicker than that at the top of the stack. The more space between stickers, the better ventilation it will be, but the more warp deformations are easy to occur at the same time. In addition, timbers should not reach out of stickers for nice drying quality, and tickers should keep the same level up and down. The details about the size and space of sticker are showed in table 3-2.

Table 3-2 The size and space of sticker

<table>
<thead>
<tr>
<th>Thickness of timber /mm</th>
<th>the space between sticker /mm</th>
<th>the thickness of sticker /mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 ~ 20</td>
<td>300 ~ 400</td>
<td>20</td>
</tr>
<tr>
<td>20 ~ 25</td>
<td>400 ~ 500</td>
<td>25</td>
</tr>
<tr>
<td>40 ~ 50</td>
<td>500 ~ 600</td>
<td>30</td>
</tr>
<tr>
<td>50 ~ 65</td>
<td>700 ~ 800</td>
<td>35</td>
</tr>
<tr>
<td>65 ~ 80</td>
<td>900</td>
<td>40</td>
</tr>
<tr>
<td>&gt;80</td>
<td>1000</td>
<td>45</td>
</tr>
</tbody>
</table>

5) Making air pass in the stack: Air pass in stack includes cracks (the space between timbers), stickers spacing, vertical flue and
horizontal flue. The size of air pass is closely associated with drying speed and drying quality. Small air pass make timbers easy to be infected by fungus, but large one can reduce the drying capacity.

Vertical flue is the air pass which is set along the height direction of stack. There are two kinds: one kind is that the air pass has a same width up and down, and the other is that narrow is above and wide is below. The vertical flue is different with the difference of stack width, height and cracks. As usual, the width of the first kind of vertical flue should be 3 times width of the crack, and the width of the other kind should be about 20cm and 50cm above and below respectively. The height of vertical flue should be as the same height of the stack or just as 2/3 of the stack. Two or three vertical flues should be setup in a stack so that the rapid drying can be obtained at lower position of the stack.

Horizontal flue is the air pass which is set along the width of stack in order to enhance the ventilation in transverse direction. As usual, one horizontal flue with height of 10cm~15cm is setup every 1 meter from first layer. Horizontal flue can be made by sticker or timbers themselves.

6) The roof of stack: The roof must be setup over the stack. The slope of about 12% is needed when the roof is made to keep the rain out. In addition, roof must reach out to the stack about 0.75m in front and 0.5m in other sides. It is displayed in figure 3-5.

7) Piling methods: There are many kinds of piling methods in a yard. They are flat piling (figure 3-6), slope piling (figure 3-5), triangle piling, furcation piling and well piling (figure3-7) etc. But flat piling and slope piling are very popular because of their good drying quality.
Figure 3-6 Stack with central air channel
(Notes: 1-foundation; 2-crossbeam; 3-sticker; 4-timber; 5-central air channel)

Figure 3-7 Piling for short timber

For the unusual size of timbers, the piling method should be special so as to make sure the good drying quality. Timbers used in furniture and construction are piled like figure 3-7, and short timbers of roughcast are piled like figure 3-8.
In the practical production, if timbers are flat piled, long radial timbers should be put in the sides of stack, short tangential ones are put in the center of stack..

8) Managing the stack: Putting a mark board on the stack with specie, size, quantity and date on it so that the details of air-drying conditions can be obtained in time.

1.1.3 Air-drying time

Air-drying speed is fast in the first month whenever it is. But the drying speed distinctly slow down when moisture content reach the fiber saturation point (FSP). In this condition, drying speed is mainly governed by the climate, and the final moisture content is associated with local equilibrium moisture content. About the average monthly equilibrium MC for Haikou and Kunming are showed in table 3-3.

<table>
<thead>
<tr>
<th>Table 3-3 The average monthly equilibrium moisture content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Haikou</td>
</tr>
<tr>
<td>Kunming</td>
</tr>
</tbody>
</table>
1.1.4 Air-drying defects and protecting methods

<table>
<thead>
<tr>
<th>Table 3-4 The protecting methods on air-drying defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-drying defects</td>
</tr>
<tr>
<td>checks</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>warp</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>discoloration</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Drying defects such as check, warp and decay are easily to happen during the air-drying. Checks mainly include end check, small end-to-surface check. They are caused by tensile stress which produced because of the fast water loss at the end of timber. Warp deformation often shows as bow, crook, cup and twist etc.
They are mainly caused by the different shrinkage among the cross texture, radial and tangential texture. On the other hand, warp deformation are also associated with strong sun light, misused stickers and etc. Rubberwood is particularly susceptible to degradation by mould and fungus. Thus quick drying the fresh rubber timber is very important. The details about air-drying defects and corresponding protecting methods on how to keep timbers from degradation are showed in table 3-4.

1.2 Forced air-drying

Some fans are equipped near the stack in order to enhance the air circulation speed, this method is called the forced air-drying. It is the development of air-drying. It differs from the kiln drying with stacking in the open air yard or shed yard without controlling the air conditions. And it differs from normal air-drying with forced air circulation to quick the drying speed. The drying time of forced air-drying is shorter than that of normal air-drying, but the drying cost is higher than that of normal one. Some forced air-drying methods are available in figure 3-9 to figure 3-14 according to the location of fans.

1）Figure 3-9, Fans deliver air at the bottom of stack;

2）Figure 3-10, Fans deliver air between stacks;

3）Figure 3-11, Fans draw air between stacks;

4）Figure 3-12, Fans deliver air from side of stack;

5）Figure 3-13, Fans deliver and draw air with fans moving;

6）Figure 3-14, Fans deliver and draw air with air circulation
Figure 3-9 Fans deliver air at the bottom of stack

Figure 3-10 Fans deliver air between stacks

Figure 3-11 Fans draw air between stacks

Figure 3-12 Fans deliver air from sides of stack

Figure 3-13 Fans deliver and draw air with fans moving

Figure 3-14 Fans deliver and draw air with air circulation

Usually, forced air-drying time is $1/2 \sim 2/3$ of that of normal air-drying if air circulation speed is 4m/s. Forced air-drying is effective when the air humidity is lower than 90% and air temperature higher than 5°C. But the cost of forced air-drying is 1/3 higher than that of normal air-drying. Forced air-drying is often used in practical production for easy discoloration and soft wood.
1.3 Suggestions for Rubberwood Air-drying

The fresh timbers must be chemically treated before air-drying so as not to be decayed. Air-drying time is different with the difference of remedies and treatment methods. So some special attentions should be taken during rubberwood air-drying.

1) Choosing the yard: The air conditions (including temperature, air circulation and humidity) of yard mainly govern the air-drying speed and quality. Thus the well ventilating yard must be chosen for the pre-treated timbers with chemical remedies.

2) Air-drying time: Air-drying time is different with the difference of remedies and treatment methods. For examples, if the timbers are treated with Parachem in a simple pool, they can resist stain fungus for 10~30 days; But if timbers are treated with the same remedy but in a vacuum pressure chamber, the timbers can resist stain fungus for about two months. The air-drying time of rubberwood should not last too long especially in humidity season. The test results are showed that the proper air-drying time for rubberwood should be less than two months, and the proper final MC should be 30%~20%.

3) The stacking: Stacking methods are very important for rubberwood which is particularly susceptible to degradation by mould and fungus. Thus stickers should be ordered according to the special requirements, such as stickers must keep vertical up and down in the stack and stickers must be put close to the ends of timbers in as possible in the stack; Timbers with almost a same size are piled in one stack; Marked board with treatment time, stacking time, initial MC and final MC etc. should be stick on the stack.
4) Choosing sticker: Thick stickers are used to air-drying the thin timbers so as to enlarge the air pass in horizontal direction. When timbers with high thick are dried, the timbers can be used as stickers themselves.

5) The arrangement of stack: There are many stacks in one yard, so stacks should be arranged in proper order so that the following serial productions can be taken out smoothly, such as the first air-dried timbers enter for the kiln drying first. In addition, stacks should be arranged along the direction of main wind; The distance from ground to the bottom of stick should keep as 50cm ~ 70cm.

6) Adjusting stack: When the air-dried timbers will be re-dried in the kiln, it’s better to unload the stack so as to adjust the MC in the stack and remove timber stress. On the other hand, unloading the stack can make sure same size timbers with close MC enter for the same kiln to dry so as to get a good drying quality with less cost.

2 Kiln Drying of Rubberwood

Kiln drying is the main wood drying method because it is more mature and widely used for long time. The drying temperature of conventional kiln is always within 100℃. Because of medium drying temperature and humidity adjustable, it can be used to dry almost any wood, sometimes bamboo or even medicine herbs.

2.1 Conventional drying kiln

In all conventional drying kilns, about 98% are periodic production pattern, and only 2% are continuous production pattern.
And among the periodic production pattern conventional drying kilns, more than 75% are forced circulation compartment kilns, and less than 25% are natural circulation compartment kilns. And the forced circulation compartment kilns can be classified into line-shaft kiln style, cross-shaft kiln style, motor inside kiln style, side-fan kiln style and end-fan kiln style by the fan’s pattern and location inside kiln; and can be classified into steam kiln style, hot water kiln style and furnace gas kiln style by the heating sources, and can be classified into trolley loading kiln style, fork loading kiln style by the stack loading methods, and also can be classified into all-metal kiln style, brick and concrete kiln style, etc. by the kiln body patterns. Among all these patterns, the forced circulation compartment conventional kilns with top-fans and motors inside, heating by steam or hot water are the most widely used.

Figure 3-15 Trolley loading conventional kiln (Simpson, 1991)
The typical trolley loading and fork loading conventional kilns are showed in Figure 3-15 and Figure 3-16.

![Diagram of a conventional kiln](image)

**Figure 3-16 Fork loading conventional kiln (Simpson, 1991)**

A conventional drying kiln usually consists of following parts:

1. **Kiln body and door:** Kiln body patterns include all-metal body, brick body, and brick body with aluminum panel inner wall etc. All-metal body kiln using stainless or aluminum alloy as structure framework, prefabricated aluminum panel with polyurethane insulator as kiln wall, and long life duration silicon rubber as seal on the vertical lifting door, is a typical all metal body drying kiln, usually with good insulation and air proof performance.

2. **Air circulation system:** The air inside kiln is circulated by fans, which are directly connected with motors, and located in the upper, side or end position inside the kiln. The air circulation speed is usually 1-3 m/s. To make the circulation uniform, a series of
oriented boards are put on reasonable position in the air way. To assure the durability, the air conductors should made of aluminum of stainless panels, and fans are usually made of molten aluminum or aluminum alloy.

(3) Heating and spraying system: The heat sources are steam or hot water. To reduce the cost, sometime the hot smoke from wood waste burning can be directly to use as heat source. The radiator is usually with steel pipe inside and aluminum coat and fins outside. This kind of radiator has advantages of high heat transfer efficiency, rot resistant, and long durability.

(4) Temperature and humidity system: The temperature and humidity could be controlled manually, semi-automatically, or whole automatically. Nowadays some kilns made in China use imported whole automatically controlled system, but semi-automatically controlled systems are commonly used because of precise controlling and easy to operate and use. The temperature and humidity detection usually use dry and wet bulb temperature method, and the moisture content detection could use weighing or electric resistance methods, of which the former one is more precise, and the latter one is more intuitionistic.

(5) Stacking and stack transportation system: This system consists of folks, or stacking machine, stack trolley, and unstacking machine.

(6) Lab equipments: All the equipment in drying lab should meet the requirement of drying procedures, including electric oven with fan inside, electric balance, moisture content meter, air speed meter, saws, ruler, digital vernier calipers, and record paper, etc.
2.2 Conventional drying techniques

The conventional drying could be divided into following 3 stages:

Pre-heating stage: Pre-heating means to heat the wood to a reasonable temperature before wood drying starts. During pre-heating stage, the moisture inside wood keep not being dried because of really high relative humidity environments. The preheating temperature should be 8-10°C higher than the first stage drying temperature. When the wood moisture content is above 30%, the 100% of relative humidity can be used in preheating stage, and when the wood moisture content is below 30%, the value of relative humidity can be a little higher than the EMC corresponded relative humidity. And the pre-heating time is based on the wood species, thickness, and outside climate, and the basic rule is to keep the temperature inside wood is 5-8°C higher than the first stage drying temperature.

Drying stage: The drying stage just begins right after pre-heating ends. Firstly the free water inside wood evaporates at a fixed rate, and then absorptive water starts to evaporate with slowing down rate. At this stage, conditioning treatment is necessary if too much drying stress occurs; it is also called intermediate treatment. When the moisture content drops to the final required value, equalization treatment can be used to release drying residual stress and moisture content difference, and it is also called final treatment.

Cooling stage: After the final treatment, all the drying stage ends. Then close all heating and spraying valves, stop all motors and keep the vent open. The wood can be unload out of kiln when the wood cooling down.
Both inside China and abroad, the dominated drying method is conventional drying. The techniques and requirements during rubberwood drying are described as follows.

2.2.1 Reasonable stack

To ensure good air circulation inside kiln, and also to reduce distortion and end checking, the rubberwood boards need to pile into stacks as following requirements:

1) Pre-sorting the initial moisture contents of every rubberwood boards, if they are too much different, piling them into different stacks and drying separately.

2) The two ends of each rubberwood board needs to be sealed to prevent them from end checking.

3) The thickness of stickers should be uniform, renewing them at once if problem happened after use.

4) To pile the rubberwood boards with same or similar thickness in the same layer of stack.

5) The stickers near two ends of stack should be closed as near as to the ends of boards, the sticker space should be kept within 0.5 meter, and at least 3 rows of stickers should be put along the length direction of stack.

6) Keep the same row stickers in different layers of stack should be kept in one vertical line.

7) Heavy load should be put on the top of stack to reduce distortion during drying (seeing Fig. 3-17).

8) The rubberwood to be dried in one kiln should be with similar size and initial moisture content. In practice, if two different size boards are put into same kiln to be dried, the executed drying schedule should use that of the thicker ones.

9) If the total amount of rubberwood is less than the capacity of
drying kiln, it is recommended to reduce the width of wood piles inside kiln, meanwhile keep no spare space in length and height directions.

10) The rubberwood board with pith is easy to occur checks and distortion during drying, so it is recommended to separate these boards from the normal ones during stacking, and then piling them in one stack. When these stacks are enough for the capacity of one kiln, drying them with special drying schedule.

![Figure 3-17 The stack for fork-loading kiln](image)

2.2.2 The sample board and moisture content measurement

The rubberwood moisture content could be measured by portable electric resistant or electromagnetic wave meters. The all automatically controlled kiln usually is usually equipped with online moisture content detection system, and can automatically execute and adjust the parameters according to the detected moisture content value and the drying schedules which have been stored into the system before drying.
In the semi-automatic controlled kilns, the moisture content is needed to detect manually. To make the detected moisture content more precise, the sample board should be made before drying, and it should be located to the position easily to fetch (Fig. 3-18).

Sample boards include moisture content sample board and stress sample board. Before drying, the initial moisture content of sample boards should be measured and calculated. During drying, with the weight change of sample boards, its corresponding moisture content value could be calculated, and when it reaches the final moisture content requirement, the drying process could be ended. Usually two stress sample boards are prepared and one is put to the positions in a stack which drying rates is the fastest, and the other one is put to the mean drying rate position in a stack. If needed, the residual drying stress could be measured using moisture content.
sample boards after drying ended. The moisture content and stress sample boards could be prepared as showing in Figure 3-19.

![Sample board and MC sections](image)

**Figure 3-19 Drying sample and MC sections**

The sample board should be selected from the rubberwood sawntimber with no bark, no rot, no knot and no pith, and it should be at least 0.3 meter far away from the two ends of sawntimber. Usually 4 moisture content sample boards are selected before drying, of which two tangential boards with high initial moisture content, one tangential board with low initial moisture content, and one radial board with high initial moisture content. The two tangential boards with high initial moisture content can be put to the low drying rate position or other easy to fetch position in stack, using as moisture content detection for controlling. The tangential board with low initial moisture content and the radial board with high initial moisture content can be put to the positions with fast and low drying rates respectively, using to decide the final equalization treatment. The length of sample board is 1.0 meter, and the thickness of sample board is the same with rubberwood sawntimber, and the width of sample board is the average width of rubberwood sawntimber. After the sample board is cut from rubberwood sawntimber, it should be weighing and sealed with waterproof materials to the two ends immediately. If stacks are still not put into drying kiln, the sample boards could be packaged by plastic film and waiting for use.
During the moisture content sample board making, two moisture contend slices with thickness of 10 to 12 mm are cut from the two ends of it. The average moisture content value of these two slices can be regarded as the initial moisture content of the sample board.

The oven dry weight could be calculated using formula (1).

\[
G_g = \frac{(100 \times G_c)}{(100 + W_c)} \quad \text{(1)}
\]

Of which: \( G_g \) — oven dry weight, g; \( G_c \) — initial weight, g; \( W_c \) — initial moisture content, %.

During drying, the moisture content of sample board could be calculated using formula (2).

\[
W_d = \frac{(G_d - G_g)}{G_g} \quad \text{(2)}
\]

Of which: \( W_d \) — the current moisture content, %; \( G_d \) — the current weight, g; \( G_g \) — oven dry weight, g.

If use electric resistance moisture content meter to detect the moisture content, it is recommended to adjust and revise the meter with rubberwood. To get the mean moisture content of a board, the pins should be inserted into the 1/5 of board thickness.

2.2.3 The drying characteristics and schedules of rubberwood

According to the results of 100 ℃ drying tests, the initial checking characteristics of rubberwood is grade 2, and both internal check and cross section deformation characteristics of rubberwood are grade 1. The rubberwood can be dried with relatively fast drying rate comparing with other hardwoods, and some very tiny checks may occurred on the surface, but can be easily removed after planing. The rubberwood sawntimber with pith is easy to occur long and wide surface checks or split, and also to form distortion. So it is recommended to cut pith out from board during sawing, and straight grain board will be good for drying.
The common used drying schedules of rubberwood with different thickness are listed in table 3-5 and table 3-6.

### Table 3-5 Drying schedules of rubberwood (Thickness: 25 mm)

<table>
<thead>
<tr>
<th>MC (%)</th>
<th>Dry bulb temperature(℃)</th>
<th>Temperature depression(℃)</th>
<th>EMC (%)</th>
<th>Treating time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-heat</td>
<td>65</td>
<td>0-1</td>
<td>20.1</td>
<td>4-5h</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>60</td>
<td>3</td>
<td>15.3</td>
<td></td>
</tr>
<tr>
<td>50-40</td>
<td>60</td>
<td>4</td>
<td>13.8</td>
<td></td>
</tr>
<tr>
<td>40-30</td>
<td>62</td>
<td>5</td>
<td>12.4</td>
<td></td>
</tr>
<tr>
<td>30-25</td>
<td>65</td>
<td>8</td>
<td>9.7</td>
<td></td>
</tr>
<tr>
<td>25-20</td>
<td>70</td>
<td>12</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>20-15</td>
<td>75</td>
<td>15</td>
<td>6.3</td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>85</td>
<td>20</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Final treatment</td>
<td>85</td>
<td>5</td>
<td>11.4</td>
<td>4-5h</td>
</tr>
</tbody>
</table>

### Table 3-6 Drying schedules of rubberwood (Thickness: 50 mm)

<table>
<thead>
<tr>
<th>MC (%)</th>
<th>Dry bulb temperature(℃)</th>
<th>Temperature depression(℃)</th>
<th>EMC (%)</th>
<th>Treating time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-heat</td>
<td>60</td>
<td>0-1</td>
<td>20.0</td>
<td>6-10h</td>
</tr>
<tr>
<td>&gt; 50</td>
<td>55</td>
<td>3</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>50-40</td>
<td>55</td>
<td>4</td>
<td>14.0</td>
<td></td>
</tr>
<tr>
<td>40-30</td>
<td>57</td>
<td>5</td>
<td>12.6</td>
<td></td>
</tr>
<tr>
<td>intermediate treatment</td>
<td>65</td>
<td>1.5-2</td>
<td>17.1</td>
<td>10h</td>
</tr>
<tr>
<td>30-25</td>
<td>65</td>
<td>9</td>
<td>9.8</td>
<td></td>
</tr>
<tr>
<td>25-20</td>
<td>65</td>
<td>12</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>20-15</td>
<td>70</td>
<td>15</td>
<td>6.4</td>
<td></td>
</tr>
<tr>
<td>&lt;15</td>
<td>80</td>
<td>20</td>
<td>4.9</td>
<td></td>
</tr>
<tr>
<td>Final treatment</td>
<td>85</td>
<td>5</td>
<td>11.6</td>
<td>10h</td>
</tr>
</tbody>
</table>
2.2.4 Unloading stacks and quality inspection

When all moisture content sample boards meet the final moisture content requirement, the drying process could be ended. By closing heating and spraying valves, stopping the fan motors, and opening the vents to cool down the rubberwood, and when the temperature difference between inside kiln and outside kiln is lower than 30°C, the rubberwood stacks could be unload from kiln.

The final drying quality could be detected and measure according to the national standard Sawntimber Drying Quality GB/T 6491-1999.

![Figure 3-20 The positions of moisture content samples](image)

Figure 3-20 The positions of moisture content samples

The drying quality parameters need to be measured include
average value of final moisture content, final moisture contents deviation among different position in kiln, moisture gradient along thickness direction, residual drying stress and all visible drying defects (distortion and checks).

The final moisture content detection sample positions could be designed as Figure 3-20 showing, at least 9 samples are must and 10 to 27 samples are necessary when the kiln size is very big.

2.2.5 The dried rubberwood board storage

The wood after being dried could be stored by the following 4 ways: the first one is storage in open air; the second one is storage under shed; the third one is storage in dried board room; and the fourth one is storage in the special dried board room with EMC being adjusted. For dried rubberwood storage, one of these four ways could be selected according to the different environment and different final usage.

For storage in open air method, it is suitable for storage dried rubberwood in dry seasons for short time; meanwhile on top of wood piles should be covered to prevent them from rain, which could cause water absorption and preservative losing problems.

For storage under shed method, it is also suitable for storage dried rubberwood in dry seasons for short time. Though the rain has no direct influence on dried rubberwood, long time storage in humid climate may cause the moisture content of dried wood changing and increasing.

For storage in dried room method, it is suitable for storage dried rubberwood in dry seasons for long time with moisture content stable, because this room keep the dried wood isolated from outside environment.
For storage in the special dried board room with EMC being adjusted method, it is suitable for storage dried rubberwood in very humid seasons for long time. Because heating or dehumidification systems is equipped, the EMC inside the storage room could be adjusted and controlled, no moisture content changing occurs in this situation. This method is recommended to be used when the environment is very humid and the rubberwood is stored for glue joinery solid wood products.

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