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(INBAR)

TRANSFER OF TECHNOLOGY MODEL
(TOTEM)

BAMBOO MAT BOARD

by

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CONTENTS

TRANSFER OF TECHNOLOGY MODELS (TOTEMS) 4

BAMBOO MAT BOARD AT-A-GLANCE 6

PART ONE: INTRODUCTION

1. Bamboo mat board 8
2. History of development of bamboo mat board technology 8

    2.1 International development efforts 8
    2.2 Diversification of manufacturing technologies of bamboo based panels 9
    2.3 Development of bamboo mat board: the Indian experience 9

3. General development attributes and advantages 10
4. Suitable agro-ecological regions 11
5. Target groups 11
6. Applicability 11
7. Scope for small enterprise development 12
8. Limitations of the technology 12
9. Requirements for success 12
10. Potential improvements and research needs 13

Concluding remarks 13

PART TWO: MANUFACTURING PROCESS FOR BAMBOO MAT BOARD

1. Introduction 15
2. Production of bamboo mats 15

    2.1 Harvesting bamboo 15
    2.2 Splitting bamboo 17
    2.3 Knot removal 17
    2.4 Sliver making 17
    2.5 Drying and weaving 17

3. Storage of mats 18
4. Resin manufacturing 18

    4.1 Chemical ingredients 18
    4.2 Resin manufacturing process 18
    4.3 Properties of PF resin 19

5. Board manufacturing 19

5.1 Resin application 19
5.2 Resin dilution with water for dipping 19
5.3 Quantity of PF resin required 20
5.4 Stabilization and drying of resin coated mats 20
5.5 Assembly 20
5.6 Hot pressing 20
5.7 Trimming and checking 20
5.8 Testing 20

6. Comprehensive inputs 21

6.1 Plant layout 21
6.2 Capital investment 21
6.3 Recurring costs 21

Appendices 23

TRANSFER OF TECHNOLOGY MODELS (TOTEMS)

Transfer of Technology Models (TOTEMs) are highly focussed educational tools providing relevant information and distance training on one specific area of bamboo/rattan management, processing or utilization. They are a means of technology transfer between similar regions throughout the world, with the emphasis on South-South transfer for livelihood development. They enable those involved in the management and use of bamboo and rattan resources to more efficiently and effectively develop and use skills relating to these resources.

They are primarily intended as practical information resources and teaching aids for those at the local extension level in their communities, who can utilize them to assist local community development through the establishment of appropriate rural enterprises. Each TOTEM consists of a detailed written report of the technology, a PowerPoint presentation, a film, and, where relevant, a set of technical photographs. They also include information on target users, financial analyses of sample set-ups from the partner country preparing the report, and information on where to source particular technologies (such as equipment). The TOTEM thus provides all the information required for establishing similar technologies within interested countries and regions.

- The **report** contains all the technical details of the process being studied, as well as other relevant information for establishing the technology such as costs of business establishment, running costs and cash flows.

- The **PowerPoint** presentation contains details of the relevant technologies and their applications, and is intended to provide an overview of the potential of the technology for development.

- The **film** provides a visual guide to the processes involved and helps to bring them alive in the minds of the learners.

The different parts of the TOTEM are targeted at slightly different audiences, via the local extension workers. The report and film are intended to be the main means of extension to the individuals and communities who will implement the technology and who will directly benefit from it. The PowerPoint presentation is primarily intended as a tool for the extension worker to sell the technology and its role in development to those who provide the infrastructural, policy and financial support for its implementation, such as government departments, donors and NGOs. There is considerable flexibility, however. Local extension workers will be able to incorporate the TOTEMs in their own work as they wish and adapt and develop the TOTEM to suit their particular requirements and conditions.

This TOTEM on **bamboo mat board** has been produced by the Indian Plywood Industries Training and Research Institute (IPIRTI), Bangalore, India. It may be used alone, or in conjunction with the TOTEM on the Bamboo Splitting and Slivering Unit, which has also been produced by IPIRTI and the TOTEM on bamboo roofing panels, produced by the Forest Science Institute, Hanoi, Vietnam.

This report describes the technology for producing and establishing Bamboo Mat Board (BMB) - making facilities for rural development in regions where bamboo is available as a raw material. It is intended to be used in conjunction with the illustrative film included in this TOTEM package. The first part of the report introduces the technology, discusses its history, its development attributes and its benefits and limitations. The second part of the report provides detailed information on the technical aspects of the manufacture of BMB. **Appendixes I - III** provide full financial analyses for establishing and running a bamboo mat board-making enterprise. **Appendix IV** lists companies presently producing matboard. **Appendix V** lists source companies producing the machines and materials required for mat board making. Finally **Appendix VI** gives national standards for matboard from India and China.

The mat board production technology and methods presented in this report are not the only means of producing bamboo mat board, but have been tried and tested and are currently in commercial use. Using the information in this TOTEM it will be possible to establish a successful mat board factory. For the sake of completeness, brief notes are given at important points in the text where alternatives are suitable, and the user referred to the bibliography for further details if required.

This TOTEM is one of the first to be produced by INBAR/IPIRTI and your feedback is most welcome - kindly contact INBAR or IPIRTI with your comments or suggestions.

Note 1: This TOTEM has been edited at INBAR and differs slightly from the form in which it was received from IPIRTI.

Note 2: All financial calculations are in Indian Rupees (Rs). At the time of writing 1 USD = 46 Rs.
One lakh Rs = 100, 000 Rs.

BAMBOO MAT BOARD AT-A-GLANCE

What is Bamboo Mat Board?

Bamboo mat board (BMB) is a plywood-like wooden board made from layers of woven bamboo mats that have been pressed together. It is usually made of three layers of mats and is about 3 mm thick. It can be produced in a range of standard sizes.

What can it be used for?

Bamboo mat board has similar properties to plywood, and is sufficiently rigid and flexible to substitute for it in a wide range of applications. Bamboo mat board can be used for paneling, ceilings, prefabricated shelters, packing cases, storage bins, roofs, doors and door panels, furniture and household utensils such as trays and plates. BMB is also used in concrete formwork.

How is it produced?

Bamboo mat board is produced by the following stages:

1. Bamboos are split into thin slivers
2. Slivers are woven into mats
3. Mats are soaked in adhesive resin
4. Mats are allowed to drain and dry
5. Mats are pressed together under high temperature and pressure to from boards
6. Boards are trimmed to shape.

What is the market for bamboo mat board?

The market for BMB is large and ever increasing although figures are not presently available. The wide range of uses to which it is put means the market has considerable potential for expansion and BMB also has significant export potential.

What is bamboo mat board's role in development?

The production of mats is labour intensive and difficult to mechanise. Bamboo mat board has enormous income generating potential for the rural poor and particularly for women, who make up the vast majority of weavers. By 1997 in India the eight BMB factories in operation were generating 2.5 million workdays per year for matweavers and during the five years to 1997, demand was such that the price for individual mats increased from 17 Rupees each to 55 Rupees. Substituting BMB for plywood also reduces the pressure on timber forests.

How do I establish a bamboo mat board-making enterprise?

Establishing a bamboo mat board making enterprise requires a regular supply of bamboo mats, electricity, labour and access to markets. A BMB small enterprise with a capacity of 100 moulded trays per day may be established with as little as USD 20,000 (in India), or a unit with a capacity of 129, 000 sheets per year established for USD 400, 000.

PART ONE

INTRODUCTION

DEVELOPMENT ATTRIBUTES, TARGET GROUPS and BENEFITS of

BAMBOO MAT BOARD TECHNOLOGY

1. Bamboo mat board

Bamboo mat boards (BMB) are produced from woven mats of bamboo that are soaked in adhesive resin and then pressed firmly together in a hot press. They were the first of the wide range of different panel boards presently available that use bamboo as a raw material, but they are the simplest to produce, involve only bamboo raw materials and have great income generating potential for the rural poor, who are able to weave the mats from which they are formed. The technology for the manufacture of BMB in India has been developed by the Indian Plywood Industries Research Institute (IPIRTI), Bangalore, who have developed a technically feasible and commercially viable technology for its manufacture. BMB is gaining in popularity and there are currently a handful of BMB factories in operation in India and 16 in China.

Bamboo mat board is very versatile and can be produced up to 6 mm thick by varying the number of mat layers used; boards are usually formed of 2, 3, 5 or 7 mats. For thicker laminated boards, wood veneers are interleaved with the bamboo boards to produce bamboo mat-veneer composite boards (The production of these is not covered in this TOTEM). BMB is at least as durable and stable as wood-based plywood and is very resistant to pest attack, extreme climatic conditions and fire. It can be used for many of the uses to which plywood is now put such as paneling, ceilings, prefabricated shelters, packing cases and storage bins, roofs, doors and door panels, furniture, and household utensils such as trays and plates. BMB is much more flexible than wood-based-plywood and can be used in structural applications such as stressed skin panels, wall bracings and web beams for which plywood is not suitable.

2. History of development of bamboo mat board technology

2.1 International development efforts

The first recorded production of bamboo based panels was in China during the mid 1940s where bamboo mat board bonded with casein (enamel) glues was used in the interior of aeroplanes as an alternative to aircraft-grade plywood. At about the same time research was initiated in India to develop synthetic resin-bonded bamboo mat board, for which the technology became available a decade and a half later. Since then, research has been carried out in several countries and over 30 types of panel products have been developed - some made of bamboo only and others of bamboo in combination with wood, lignocellulosic materials and inorganic materials. Research and development efforts have been mostly confined to countries of the Asia-Pacific region i.e. China, India, Indonesia, Japan, Laos, Malaysia, Philippines, Taiwan, Thailand and Vietnam. Canada (in collaboration with Costa Rica) is the only country outside Asia where research on bamboo panels is being carried out.

Although there was some pioneering work in Taiwan and innovative products such as plybamboo (bamboo glue-lam) were developed, the bamboo board industry is reported to

be facing extinction there due to the sharp increase in wages and shortages of raw materials. In Thailand, the only product manufactured is bamboo mat board glued with Urea Formaldehyde (UF) resin and this is mainly produced for export. In countries such as Laos, the Philippines and Vietnam, interest in bamboo matboard production is relatively new, and the industries there are presently in the phase of exploratory studies and experimental or pilot scale production.

2.2 Diversification of manufacturing technologies of bamboo based panels

Bamboo is gaining importance as a replacement for wood in flooring and roofing panels and other housing components (such as windows, doors and partition panels), in furniture and in packing cases. Some of these products are made of bamboo mat board, some have a core of bamboo mats with thin veneer facings and others are made of laminated bamboo slabs/strips of different sizes and shapes (bamboo parquet and floorboards). In some products, wood veneer or shavings are used to give a wood-like appearance to the surface.

At present, China has developed the largest number of bamboo based panel products and produces annually approximately 250,000 cubic metres in about 250 manufacturing units. The most popular panel product is bamboo mat plywood (about 100,000 cubic metres) followed by bamboo curtain board, bamboo strip board, bamboo lath board, bamboo based particle board, bamboo flooring panels and bamboo moulded products.

Bamboo based panels developed in some countries, particularly China, have been covered under patents and details are usually not available.

2.3 Development of bamboo mat board: the Indian experience

In India, research efforts to make panels from bamboo were initiated in the mid 1950s at the Forest Research Institute, Dehra Dun. In the 1960s this institute developed the first manufacturing process. However, high production costs inhibited commercialization of the process. Research and development efforts were revived at IPIRTI in 1979 and a second and cost-efficient manufacturing process was developed for the production of bamboo matboard. In 1985 a factory was established in Angamally where the Kerala State Bamboo Corporation produces boards based on this new process. However, due to some inherent deficiencies, which will be noted in section 10, this technology was still not very suitable and did not become popular for enterprise development.

For this reason, in 1990 IPIRTI undertook new studies to develop improved BMB under a project sponsored by the International Development Research Centre (IDRC), Canada. Under this project, a third, innovative and appropriate technology was developed for the production of high quality, economical BMB up to 6-mm thickness. This time IPIRTI was successful in solving the deficiencies and developing a suitable manufacturing process. According to a feasibility analysis conducted by the Agricultural Finance Corporation Ltd. (AFC), Mumbai, the current process is technically feasible and

financially viable. In this way the potential of the BMB as a wood substitute has been demonstrated, as well as the techno-economic feasibility of its' manufacture.

An updated annotated bibliography on bamboo-based panels was compiled based on these experiences and a manual was produced for the production of BMB. Some units in Meghalaya and Orissa States in India have successfully implemented the new technology.

As a sign of it's appropriateness, the International Selection Commission of the World Expo 2000 earmarked the BMB technology developed at IPIRTI as an exemplary demonstration of the practical implementation of AGENDA 21. Consequently, the technology was registered as a World Project for Expo 2000.

3. General development attributes and advantages

As explained previously, the BMB technology is suitable for the production of "eco-friendly" alternative panel products to substitute for wood and help conserve forest resources. Moreover, the technology can serve as a basis for economic development in rural areas.

The main development attributes of the technology are as follows:

- Reduced dependence on timber resources and natural forests due to an increased use of wood substitutes, leading to environmental protection.
- Rehabilitation of degraded forests and other waste lands through increased areas of bamboo plantation.
- Creation of employment opportunities in mat weaving, particularly for rural and tribal women, and in bamboo growing.
- Improvement of peoples' skills, and enhancement of their earning capacities, leading to improved welfare of the economically weaker sections of society.
- The production of mats is flexible in time and place, favoring part-time and homebound weavers (such as young and old people and housewives) who can continue working close to their own houses whenever they are free from other engagements

Apart from the above development attributes, BMB has several advantages above other panel materials. The advantages of the BMB developed at IPIRTI are:

- BMB is a very versatile panel material, is highly popular and "environmentally friendly".
- The boards posses physical and mechanical properties on a par with waterproof plywood and have an excellent internal bond strengths, a high plane rigidity and hence high racking strength.
- They are as durable and resistant to boiling water, weather and biological agencies (decay, insects and termite attack) as phenolic-bonded plywood.

- They have better scratch and stain resistance properties than plywood.
- They are as fire resistant as fire-retardant treated plywood.
- They have a rich natural appearance.

4. Suitable agro-ecological regions

The BMB technology is suitable for bamboo-growing regions with sufficient raw material that are inhabited by traditionally skilled crafts people, or other (potential) bamboo mat weavers. Apart from regions with natural bamboo forests, BMB could be produced in regions where bamboo is grown on plantations or in homesteads. The technology is particularly suitable in regions where bamboo plantations are desirable for the restoration of degraded forests or wastelands such as abandoned shifting cultivation areas. The production of mats requires the use of large culmed species and the unit is therefore particularly suitable for tropical, subtropical and warm temperate regions where larger bamboos grow.

5. Target groups

The direct beneficiaries of the BMB technology will be the many traditionally-skilled rural and tribal people who make their living of weaving a variety of products from bamboo. In India the beneficiaries are especially housewives and young and very old people, who have time to spare, but who are unable to leave the house or are unfit to perform hard work. In areas where the depletion of natural forests results in the expenditure of foreign exchange for the import of wood, this money will be saved and the government and the nation will also benefit. The unit will also create employment opportunities for unskilled, semi-skilled and technically trained personnel who can be recruited locally.

6. Applicability

A major reason to use bamboo as an alternative in wood applications such as panels is the authenticity of the material and the cultural history of its use in bamboo-rich countries. In many parts of India, for example, bamboo is an important cultural feature. Since the beginning of civilization, bamboo has played an important role in the daily lives of Indian people. Bamboo craftwork is one of the oldest cottage industries primarily due to the versatility, strength and lightness of bamboo and to the ease with which it can be worked with simple hand tools. Bamboo has been put to use in various applications ranging from construction to household utensils. There are more than 1000 documented uses including an important industrial use in paper and pulp manufacturing. For this reason it is easy to involve local people in the making of bamboo mats and in the manufacturing of bamboo boards.

7. Scope for small enterprise development

Given the benefits for the many people involved, including governments and consumers, the market conditions for the production of bamboo matboards and for the development of related industries and businesses are favorable. As will be shown in the final sections of this report, the establishment of a small BMB-producing enterprise/factory/plant requires a considerable investment, while the BMB can be manufactured in an existing plywood factory with very few additional facilities and investment. All that is required in this case is a resin applicator and, eventually, a drying chamber.

For the establishment of a new bamboo mat board-manufacturing unit the estimated capital investment (including land and building) is Rs.153.36 lakhs (approx. USD$ 333, 000) (**Appendix I)** and the estimated running costs are shown in **Appendix II.** In India, the establishment of such a unit would take place in the Small Scale Sector, and it would thereby become eligible for all incentives provided by the Government for this sector.

8. Limitations of the technology

As mentioned in the section on the history of the BMB technology, the earlier manufacturing processes developed in India, suffered from several drawbacks and resulted in low quality bamboo panels. These deficiencies were:

- High quantities of resin required
- Non-uniform bonding due to inadequacy, or even absence, of resin on slivers in the overlapped areas of mats
- Unseemly appearance caused by resin pushed to the surface through the intersliver spaces during hot pressing
- Frequent application of releasing agent required to prevent panels from sticking to metal caul plates
- Limited durability.

With the new process of BMB production, presented in part two of this report, most of these deficiencies can be overcome. Nevertheless, while initiating the production of such boards in a new factory, one should be aware of the potential shortcomings listed above.

9. Requirements for success

The essential requirements for successful implementation of BMB technology are:

- Sustained availability of bamboos suitable for making BMB mats.
- Traditionally skilled bamboo craftspeople with formal training to produce BMB mats.
- Appropriate technologies, machinery and technically trained personnel to manage a BMB production unit.

- Mechanisms to identify suitable markets and promote the sale of BMB in domestic and export markets.
- Continued research and development support during commercialization to solve problems arising during the transfer of technology from laboratory to production unit.
- The availability of inexpensive labor is essential to the viability of a bamboo matboard based on the manual weaving of mats. As has been shown in Taiwan, the financial sensitivity of the labour input is high.

10. Potential improvements and research needs

- Concerted efforts are required to explore the possibilities of value addition through appropriate end use applications.
- Further research and development efforts are required to commercialize the technologies already developed in laboratory-scale experiments, and to explore the potential of this versatile material to the fullest extent.
- Additional research and development efforts should be employed to analyse and improve the activities, skills and benefits of the different people involved in the BMB production chain.
- Extension and training activities could enlarge the efficiency and sustainability of the production of bamboos, matweaving and commercialization, and improve the income effect and distribution of benefits for the people involved.

Concluding remarks

The bamboo mat board technology is a commercially and socially effective means of processing bamboo into quality endproducts for the construction, packaging and transport sectors. Its development attributes imply considerable scope for income and welfare improvement for rural poor people. In addition it enables governments and wood-based industries to cope with the problem of wood shortages and to reduce environmental degradation due to overharvesting of timber trees. If properly organised and guided by private enterprises, state agencies and/or NGOs, the technology as well as its backward and forward linkages can increase the income and welfare of many people in a sustainable manner.

PART TWO

MANUFACTURING PROCESS FOR

BAMBOO MAT BOARD

1. Introduction

Bamboo mat board is produced by a simple technical process comprising the following main steps:

1) Mat making (raw material preparation).
2) Application of adhesive/binder to mats.
3) Assembling of mats in preparation for pressing.
4) Formation of boards by hot- or room temperature-pressing under pressure (curing).
5) Cutting to size (dimensioning).
6) Finishing (such as coatings or lamination).

The following sections will describe in detail the different stages of the manufacturing process for BMB as depicted in the flow chart on page 16:

2. Production of Bamboo mats

2.1 Harvesting bamboo

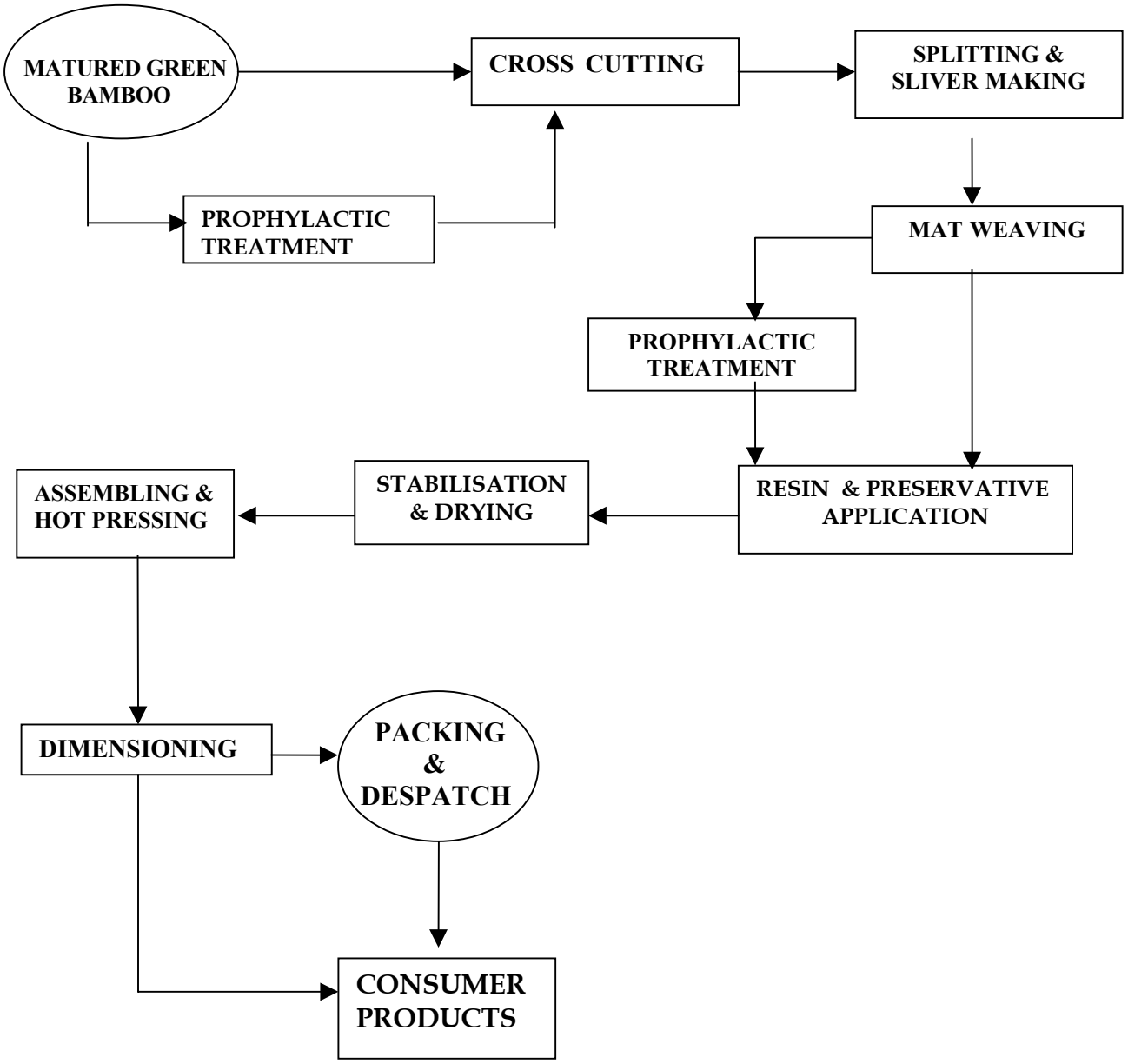
Matured bamboo culms are extracted following the locally prescribed silvicultural methods and crosscut into convenient lengths varying from 50 to 250 cms. The nodal portions are retained in species with short internodes, such as *Dendrocalamus strictus* (30 cms), whereas in species with long internodes such as *Ochlandra travancorica* and *Melocanna baccifera* (50 to 100 cms), the nodal portions are removed. The splits of long-internoded species, such as *Ochlandra travancorica* are of a more even thickness than those of short-internoded species such as *Dendrocalamus strictus*. Although both species are suitable for mat making, about 40% more resin is required for bonding mats made of *D. strictus* and other similar short-internoded species.

During the course of the IDRC-sponsored BMB research project at IPIRTI, several bamboo species were studied for BMB manufacture. All were found to be suitable. Some of the physical characteristics of these species are given in **Table 1.**

Table 1 BMB-use bamboo species and their culm characteristics

Species of Bamboo	**Physical Characteristics**		
	Culm ht. (m)	**Culm dia. (cm)**	**Internode length (cm)**
Bambusa bambos	15-30	15-18	20-40
Bambusa nutans	6-15	5-10	20-45
Bambusa tulda	7-23	5-10	40-70
Dendrocalamus brandisii	19 – 33	13–20	30-38
Dendrocalamus hamiltonii	12-25	10-18.5	30-50
Dendrocalamus strictus	8-16	2.5-8	30-45
Melocanna baccifera	10-20	3-7	50-100
Ochlandra travancorica	2-6	2.5-5	45-60
Oxytenanthera nigrociliata	5-8	2.5-5	20-30

BMB PRODUCTION FLOW CHART



2.2 Splitting bamboo

The crosscut bamboo lengths can be split by the following methods:

1) With a machete
2) With hand splitting knives or
3) With a splitting machine

When using a splitting machine the bamboo pole is fixed longitudinally in front of the set of splitting knives and a mechanical pushing device pushes the bamboo over the knives to produce splits of a uniform size. The number of splits produced depends upon the number of knives present in the splitting knives set. In general the width of the splits varies from 10 mm to 15 mm depending on the species and quality of bamboo. The splits are then allowed to dry in the air or in artificial ventilation to reduce their moisture content to around 30%.

2.3 Knot removal

It is necessary to remove the nodes to maintain an even thickness of sliver and to facilitate further processing. The inner and outer knots are removed from the splits either manually with a sharp knife or mechanically with a knot removal and width-sizing machine. This machine also sizes the width of the splint and planes the surface.

2.4 Sliver making

The green epidermal layer of the splints is removed using a sharp knife and can be set aside and used for making other products. It is not suitable for making into slivers. Slivers 0.6 mm thick (±10%) and 12-16mm wide are made manually from splints using a sharp knife or a slivering machine. Keeping the variation in thickness of the slivers to within 10% is very important. Higher variation than this results in increased requirements for resin.

2.5 Drying and Weaving

Slivers are dried to around 15% moisture content[1]. The dried slivers are **manually** woven into mats of different sizes and patterns depending on the specific requirements set. The two most common weaving patterns are the herring bone pattern (45^0) and the rectangular pattern (90^0). The most common sizes of the mats are 250cm x 125cm, 180 cm x 125cm, and 180 cm x 150cm.

Further details of bamboo splitting and sliver making are available in the INBAR - IPIRTI TOTEM on the Bamboo Splitting and Slivering Unit.

[1] **Note**: Prior to mat weaving the slivers are sometimes dyed or bleached to produce decorative mat boards. Further details are available in reference X and a brief summary given in the bibliography.

3. Storage of Mats

Woven mats can be air-dried further and stored without any treatment for 3-4 weeks. Prophylactic treatments must be applied if they are likely to be stored for a longer period. The simplest and most effective treatment for mats, if they are not likely to be exposed to water, is to spray them with a 1% solution of a mixture of boric acid and borax in a 1:1 ratio. Spraying can be done with a hand sprayer or a knapsack sprayer. Alternatively the mats can be soaked in the solution for about 10 minutes.

Treated mats are dried either in the air or in a drier, and stored under cover. Treated mats should not come into contact with the ground and hence it is advisable to store them on wooden pallets of 12 to 18 cm (4 to 6 inches) above ground level. Treated bamboo mats can be stored for 3 to 4 months without deterioration. They must be stored in well-ventilated locations with low relative humidity and negligible changes in humidity. The chances of fungal or insect attack are increased if the relative humidity is very high. Mats should be resprayed once every three months and should be checked regularly (at least once per fortnight) for any signs of fungal growth, mould and/or borer attack.

4. Resin manufacturing[2]

Phenol formaldehyde (PF) resin is generally used for manufacturing BMB. The resin is prepared in a resin kettle or batch resin reactor made of either mild steel or stainless steel. The most suitable resin formulation and method of production is given below:

4.1 Chemical ingredients

Phenol: Pure phenol is a white crystalline solid with a melting point of 43^0C. It should conform to IS: 538-1968, Specification for phenol (carbolic acid).

Formaldehyde: Formaldehyde is a gas usually available as formalin which is a solution of 37% concentration (by weight) in water with methyl alcohol as a stabilizer. It should conform to IS: 3321 - 1973, Specification for formaldehyde.

Sodium hydroxide: Sodium hydroxide is available in pellets as well as in flake form. It is white in colour, hygroscopic and highly soluble in water.

4.2 Resin manufacturing process

One hundred parts by weight of phenol is charged into a resin kettle followed by 150 to 200 parts by weight of 37% formalin and stirring is commenced. Between five and fifteen parts by weight of sodium hydroxide dissolved in double the quantity of water is then

[2] Urea formaldehyde (UF) is more commonly used in China. Phenoltannin formaldehyde (PTF) is also used.

added. Stirring is continued. The chemical reaction starts after the three components have been mixed and takes about 90 minutes to complete. The temperature of the reaction mixture is maintained between 82^0C - 85^0C. During the course of the reaction, the flow time of the resin is checked periodically using a B-4 cup as described in IS: 3944. The reaction is stopped when the flow time increases to around 15 seconds when the resin is hot. The resin is then cooled to room temperature by circulating cold water in the jacket of the kettle. The cooled resin is discharged from the kettle and stored in airtight containers.

4.3 Properties of PF resin

The cooled resin should have the following properties for optimum results.

(a) Viscosity - 65 ± 20 mPas at 25^0 C.
(or)
Flow time in a B-4 cup (IS: 3944) - 27 seconds ± 5 seconds at 25^0C.

(b) Water tolerance - 1:6 to 1:20 depending on quantity of sodium hydroxide used.
(c) Solids content - 48% ± 2%.
(d) Pot life - 2-3 weeks at 25^oC.

5. Board manufacturing

5.1 Resin application

Application of resin to bamboo mats is one of the most important steps, both from the point of view of quality and economy. Most crucial at this point are a) the amount of resin applied, b) the mode of application, c) the duration. Resin application is done by dipping.

5.2 Resin dilution with water for dipping

Approximately **200 kg of PF resin** is poured into the resin applicator, which is sufficient for the production of about 575-600, 3-layered boards. Two kilograms of sodium octaborate tetra hydrate dissolved in 400 kg of water is added to the resin as a preservative. The concentration of sodium octaborate tetra hydrate is one per cent by weight of the liquid PF resin. This boron compound penetrates into the slivers along with the resin, is fixed during hot pressing, and confers resistance to fungus and insect attack on the BMB. About 60 mats are dipped into the resin solution each time and are **dipped for five minutes**. Resin soaked mats are removed from the resin solution and kept in an inclined position for about 30 minutes to allow excess resin to drain away.

5.3 Quantity of PF resin required

The quantity of PF resin required per unit area of BMB depends upon the number of bamboo mat layers in the board. The average quantity of resin required for BMB is in the range 0.33 to 0.35 kg PF liquid of 50% solids/m^2 for a 3-layered board. However it will be necessary to proportionately increase the quantity of resin used if the variation in sliver thickness is beyond the prescribed limits.

5.4 Stabilization and drying of resin coated mats

Resin coated mats are laid one above the other for at least 2 hours after treatment for stabilization. The stabilized mats are dried in either a drying chamber or industrial dryers such as a band dryer, at a temperature of $95^0 \pm 5^0$C until the moisture content falls to 10% ± 2%.

5.5 Assembly

Dried resin-coated mats are assembled on aluminium metal cauls that are thoroughly coated with a releasing agent, such as silicone - 17 compound. The number of mats assembled depends upon the required thickness of the board. The releasing agent used to coat the metal cauls should be reapplied after 15 to 20 hot pressing cycles.

5.6 Hot pressing

Hot pressing melts the resin in the mats and bonds them together tightly. The assembled mats are first loaded on to the hot press and the mats pressed according to the following protocol.

Pressure	-	16 kg/cm^2
Temperature	-	145^0C ± 5^0C
Time	-	6 minutes for 3 mats (with 1 minute extra for every additional mat layer)

5.7 Trimming and Checking

The hot pressed boards are trimmed to the required size in a DD saw.

5.8 Testing

Bamboo mat boards are tested for conformity as per IS: 13958, 1994, specification for bamboo mat board for general purposes (Indian standard).

6. Comprehensive inputs

6.1 Plant layout

Bamboo mat board can be manufactured in a plywood factory with very few additional facilities. All that is required is a resin applicator and a drying chamber if a band dryer is not already available.

6.2 Capital investment

A bamboo mat board-manufacturing unit can be established in the Small Scale Sector and thereby become eligible for all incentives provided by the Government for this sector in India. The estimated capital investment (including land and building) is Rs.153.36 lakhs (USD$ 333, 000) as shown in **Appendix I**.

6.3 Recurring costs

Recurring costs involved are for 1) raw material, 2) energy, 3) machinery and equipment maintenance, 4) managerial and labour and 5) postproduction activities. These estimates are given in **Appendix II.**

The recurring costs are estimated on the assumption that:

- The unit works one shift of 8 hrs per day.
- The number of working days in a year is 300.
- The unit works to 50% of installed capacity in year 1, 75% in year 2 and 100% from year 3 onwards.

Summaries of capital investment, production costs, working capital requirements, break even analysis, sales, profit and return on investment, and a cash flow statement are shown in **Appendix III**. **Appendix IV** lists some companies presently producing matboard. **Appendix V** lists companies producing the machines and materials requires for mat board making and **Appendix VI** gives national standard for mat board from India.

APPENDICES

APPENDIX I

Project costs

Sl. No.	Item	Estimated cost (Rs. In lakhs)
I	**Land and Land Development**	
1.	Land 8000 sq.m. (0.8 ha.) @ Rs.2.5 lakh/ha.	2.00
2.	Development cost @ Rs.62500/ha.	0.50
3.	Approach Road and Internal Road approx. 1000 sq.m. @ Rs.300/sq.m.	3.00
	Sub- Total - I	**5.50**
II	**Civil Work**	
1.	Fencing with barbed wire and live fencing @ Rs.150/- per meter	0.55
2.	Two gates with RCC pillars @ Rs.37,500/- per gate	0.75
3.	Building of 1000 sq.m. @ Rs.2000/sq.m. (1000 x 2000)	30.00
4.	Water storage, distribution/drainage and general elimination, piping	3.50
5.	Electrification	2.00
	Sub-Total - II	**36.80**
III	**Plant and Machinery**	
1.	Hot press, 10 day light	17.50
2.	Drying chamber - 2 Nos. (6m:W x 5m: L x 3m: H)	5.00
3.	Steam boiler (1 tonne capacity)	5.00
4.	Scissors lift - 2 Nos.	2.00
5.	D.D. saw – 2 Nos.	2.50
6.	Measuring instruments (Auto)	2.00
7.	Conveyor	0.75
8.	Blower with stand for cooling cauls – 2 Nos.	0.35
9.	Storage tank for formalin (10,000 liter capacity) – 2 Nos.	2.50
10.	Weighing machine (1 tonne capacity)	0.15
11.	Standby generator 125 KVA	8.00
12.	Sprayer for prophylactic treatment of mats	0.10
13.	Air compressor	0.25
15.	Resin kettle – 1 No. 1.5 tonne capacity	3.25
16.	Resin applicator with trolley – 2 Nos.	2.00
	Sub - Total III	**51.35**
IV	**Infrastructure facilities**	
1.	Electrical installation 125 KVA load	8.0
2.	Water supply including storage tank of 5000 liter capacity, borewell and pump and overhead tanks – 2 Nos.	5.0
	Sub – Total IV	**13.00**
V	**Miscellaneous**	
1.	Vehicle (Mini Truck)	6.50
2.	Jeep	3.50
3.	Communication	1.20
4.	Office equipment	3.50
5.	Furniture and Fixture	4.50
	Sub – Total V	**19.20**
VI	**Total Capital Cost (I to V)**	**125.85**

VII	Preliminary and preparative expenses	30.00
VIII	Margin money for working capital	46.0
IX	Contingencies	0.15
	(A) Total Project Cost	**202.00**

APPENDIX II

RECURRING COSTS

(Rs. In lakhs)

Sl. No.	Item	Cost	Cost per annum
I	**Raw Material**		
1.	Bamboo Mats Number of mats required per day = 1296 (rounded off to 1300/day) @ Rs.60/mat = 1300 x 60 = Rs.78,000/- per day Rs.78000 x 300 days (100% capacity) = 23400000 (per year)		234.00
2.	PF resin liquid (48% solids) required per day 520 kgs		
	Phenol 100 kg @ Rs.50/kg	5000	
	Formalin 185 kg @ Rs.10/kg	1850	
	Sodium hydroxide 7.5 kg @ Rs.20/kg + 15kg Water	150	
	Resin yield 300 kg	7000	
	Miscellaneous (chemicals for preservative treatment)	500	
	Sub-Total	**7500**	
	Cost of resin and other chemicals = 7500/300 = 25.00		
	Cost per year = 25.00 x 520 kg x 300 days =3900000 3870000		39.00
3.	Aluminium caul releasing agent		2.00
4.	Aluminium cauls of 2 mm thick of size 2.5m x 1.25m after accounting for scrap value		5.00
	Total cost of Raw materials		**280.00**
II	**Energy**		
1.	Electricity coverage 800 kWh/day x 300 days @ Rs.3.5/Unit	8.40	
2.	Light diesel oil 75 lt./hr x 8 hr/day x 300 days @ Rs. 16 per lt.	28.80	

	Total cost of energy		**37.20**
III	**Maintenance**		
	Maintenance cost of machinery and equipment		3.88
	Sub-Total		**3.88**
IV	**Management and Labour**		
A	**Managerial staff**		
1.	General Manager 1 No.	10,500	
2.	Manager Production – 1 No.	7,500	
3.	Chemist and Quality Controller – 1 No.	6,000	
4.	Maintenance Engineer – 1 No.	6,000	
	Sub-Total	**30,000**	**3.60**
B	**Supervisory staff**		
1.	Supervisor – 3 Nos. (3 x Rs.4500/-)	13,500	
2.	Electrician - 2 Nos. (2 x 4500)	9,000	
3.	Boiler Technician No.1	2,750	
4.	Asst. Supervisor – 4 Nos. (4 x 2500)	10,000	
5.	Asst. Electrician – 1 No. (1 x 3000)	3,000	
	Sub-Total	**38,250**	**4.59**
C	**Administrative staff**		
1.	Commercial Manager –1 No.	7,500	
2.	Office Manager –1 No.	7,500	
3.	Accountant – 1 No.	4,500	
4.	Clerk/Typist – 5 Nos. (5 x Rs.3000)	15,000	
5.	Attendant – 2 Nos. (2 x Rs.2000)	4,000	
6.	Driver – 2 Nos. (2 x 3000)	6,000	
7.	Security guards – 6 Nos. (6 x 2000)	12,000	
	Sub- Total	**56,500**	**6.78**
D	**Labour**		
	Semi-skilled labourers 65 x Rs.60/ day		11.70
	Sub-Total		11.70
	Total Salaries from A to D		**26.67**
E	**Social Overheads**		
	Social overheads like Bonus, P.F., LTC, Medical benefits, Production incentives @ 35% of total management and labour cost		9.34

	Total cost of Management and Labour		**36.01**

Appendix III (1)

Capital Investment at-a-glance: BMB Unit

		Rs. in lakhs
1. Equipment and machinery	See Appendix I	**83.55**
2. Land and buildings	See Appendix I	**42.30**
3. Working capital margin	See Appendix III (3)	**46.00**
4. Preliminary and Pre-operative costs		**30.00**
5. Contingencies		**0.15**
	TOTAL	**202.00**

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Appendix III (2)

Production costs: BMB unit

I	Raw Material							
		Bamboo Mats		234.00				
		Adhesive		39.00				
		Aluminum Cauls Releasing Agent		2.00			Rs.275.00	Lakhs
II	Energy and Other Manufacturing Costs							
		Electrical Energy		8.40				
		Fuel (LDO)		28.80				
		Aluminum Cauls		5.00				
		Maintenance Charges		3.88			Rs.46.08	Lakhs
III	Salaries, wages and Overheads							
		Salaries						
		Managerial Staff		3.60				
		Supervisory & Technical		4.59				
		Administration		6.78				
		Social Security to Staff		9.34				
		Wages		11.70		Rs	36.01	Lakhs
IV	Sales Promotion and Commission to Dealers					Rs.	108.75	Lakhs
	Total Production Cost for 1,29,000 Boards					Rs.	465.84	Lakhs
		Production Cost Per Sq. M				Rs.	125.39	
	Add Depreciation							
		Buildings	Rs.	0.75	Lakhs			
		Machinery	Rs.	4.17	Lakhs	Rs.	4.92	Lakhs
	Add Interest							
		Term Loan of Rs. 135 lakhs @16%	Rs.	21.6	Lakhs			
		Working Capital loan of Rs.138 lakhs @ 18%	Rs	24.84	Lakhs	Rs.	46.44	lakhs
		Total manufacturing cost				Rs.	517.20	Lakhs
		Production cost per square meter				Rs.	139.21	
		Production cost per board				Rs.	401.00	

Appendix III (3)

Working Capital requirement: BMB Unit

(Based on requirement for three months production)

	Rs in lakhs
Bamboo mats	58.50
Resin, releasing agent and aluminium cauls	10.50
Semi processed goods	9.68
Finished goods	32.25
Sundry debtors	72.56
TOTAL	**183.49** (say **184**)
Loan for Working capital	
75% of the above.	138
Margin money	46

* Based on 15 days production @ Rs. 150 per board
** Based on 1 month production @ Rs. 300 per board
*** Based on 45 days credit @ Rs. 450 per board

Appendix III (4)

Break even analysis: BMB unit

		Unit	Amount Rs.	Amount Rs.
I	Variable costs			
	1) Bamboo mats	Rs. per sq. mtr	62.98	
	2) Adhesive	Rs. per sq. mtr	10.50	
	3) Aluminum cauls and releasing agent	Rs. per sq. mtr	1.88	
	4) Maintenance costs	Rs. per sq. mtr	1.05	
	5) Electricity	Rs. per sq. mtr	10.01	86.42
II	Fixed Costs			
	1) Salaries, wages and benefits	Rs. per sq. mtr	9.69	
	2) Sales promotion and commission to dealers	Rs. per sq. mtr	29.27	
	3) Depreciation	Rs. per sq. mtr	1.33	
	4) Interest	Rs. per sq. mtr	12.50	52.79
	Total manufacturing cost	Rs. per sq. mtr		139.21
III	Estimated selling price	Rs. per sq. mtr		156.25
IV	Less: Variable costs	Rs. per sq. mtr		86.42
V	Unit contribution			69.83
VI	Total annual fixed costs	lakhs		196.12
VII	Break even point	Sq. mtrs.		280974
VII	Installed capacity	Sq. mtrs.		371520
IX	Break Even Point	% of capacity		75.63
X	Safety margin	%		24.37

Appendix III (5)

Sales, Profit and Return in Investment: BMB Unit

Sl.No	Item	Unit	
1	Sales	Sq.m	371.52
2	Value at Rs.156.25 per Sq.m	Lakhs	580.50
3	Less Production Cost (Excluding Depreciation & Interest)	Lakhs	465.84
4	Gross Profit Before Depreciation and Interest	Lakhs	114.66
5	Total Investment	Lakhs	202.00
6	Gross Return on Investment	%	56.76
7	Less Depreciation & Interest	Lakhs	51.36
8	Operating Profit before Taxation	Lakhs	63.30
9	Tax Payable at 40%	Lakhs	25.32
10	Net Profit	Lakhs	37.98
11	Net Return On Investment	%	18.80
12	Add Depreciation	Lakhs	4.92
13	Net Cash Flow	Lakhs	42.90
14	Total Return on Investment	%	21.24
15	Payback Period	Years	4.71 (Say 5)

Appendix III (6)

Cash flow statement for BMB unit (Rs in lakhs)

	Year 1 construction period Total investment	Year 2 (Ist year of production)	Year 3 (2nd year of production)	Year 4 (3rd year of production)	Year 5 (4th year of production)	Year 6 (5th year of production)	Year 7 (6th year of production)	Year 8 (7th year of production)	Year 9 (8th year of production)	Year 10 (9th year of production)	Year 11 (10th year of production)	Year 12 (11th year of production)	Year 13 (12th year of production)
INCOME; Sale of Boards			435.38	580.50	580.50	580.50	580.80	580.50	580.50	580.50	580.50	580.50	580.50
Less: Production cost			349.38	465.84	465.84	465.84	465.84	465.84	465.84	465.84	465.84	465.84	465.84
Gross trading profit		57.33	86.00	114.66	114.66	114.66	114.96	114.66	114.66	114.66	114.66	114.66	114.66
Less: Interest charges			40.23	42.12	32.40	22.68	12.96	3.24	0.00	0.00	0.00	0.00	0.00
Less: Depreciation		2.46	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92
Profit before taxation			40.85	67.62	77.34	87.06	97.08	106.50	109.74	109.74	109.74	109.74	109.64
Less: Tax @ 40%		8.34	16.34	27.05	30.94	34.82	38.83	42.60	43.90	43.90	43.90	43.90	43.86
Net profit	-202	12.51	24.51	40.57	46.40	52.24	58.25	63.90	65.84	65.84	65.84	65.84	65.78
Add: Depreciation		2.46	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92	4.92
Positive cash flow		14.97	29.43	45.49	51.32	57.16	63.17	68.82	70.76	70.76	70.76	70.76	70.7
Less: Loan repayments:													
Term loan			27.00	27.00	27.00	27.00	27.00						
Working capital				30.00	30.00	30.00	30.00	18.00					
Net cash flow		14.97	2.43	-11.51	-5.68	0.16	6.17	50.82	70.76	70.76	70.76	70.76	70.7
Cumulative reserves / Surplus		14.97	17.40	5.89	0.22	0.37	6.54	57.36	128.12	198.89	269.65	340.42	400.58
IRR							18%						
PV of Net profit (in lakhs)							Rs. 284.48						
NPV of Net Profit (Rs. In lakhs)							Rs. 82.48						
BC ratio (PV of net profits/ investment)							1.41						
Term Loan	135	135.00	108.00	81.00	54.00	27.00							
Working capital loan		103.50	138.00	108.00	78.00	48.00	18.00						

Appendix IV

Some companies presently producing mat board in India*

1. M/s Cosmicraft Industries (P) Ltd.,
   Bawri Mansion, Dhanketi,
   Shillong – 793 001, Meghalaya.

2. M/s Kerala State Bamboo Corporation,
   Post Bag No. 20, Angamally South – 683 573
   Eranakulam District, Kerala.

3. M/s Gramvikas,
   Mohuda Village, Brehampur – 760 002
   Orissa

4. M/s Supernatural Ply Pvt. Ltd.,
   S/o Badrinarayana & Sons,
   Sriram Ward, Chandrapur,
   Maharashtra

5. M/s Timpeck Pvt. Ltd.,
   15th Main, G.S. Road,
   Burnihat – 793 101, Meghalaya (In the process of being established)

Note: Inclusion or exclusion in this list in no way implies approval or disapproval by INBAR or IPIRTI of these companies or of those not included. The list is intended merely for information purposes.

Appendix V

Sources of materials and machines

I Hydraulic Press manufacturers

1. M/s. Srichakra Engg. Equipment
   No.A –21, Phase II,
   Peenya Industrial Area,
   Bangalore – 560 058.

2. M/s. Bamco Hydraulics Ltd.,
   Udyanbag,
   Belgaum – 590 008.

3. M/s. Padgo Hydraulics
   Survey No.69, (Opp. VST),
   Whitefield road,
   Mahadevapura Post,
   Bangalore – 560 048.

4. M/s. Sterling Hydraulics Co.,
   142-146, S.V. Road,
   Jogeshwari,
   Mumbai – 400 102.

5. M/s. Pressweld Engineers,
   II Floor, Near Carnac Bridge,
   Lakhraj Building,
   20, L.M.T. Road, Mumbai – 400 003.

6. M/s. Ambika Hydraulics (P) Ltd.,
   Regd. Off. 601, Silver Oaks,
   Mahalaxmi, Paldi,
   Ahmedabad – 380 007.

II Drying Chambers

1. M/s. Super Heat Furnaces,
   Regd. Off. & Factory
   E-23, 6th Phase,
   SIDCO Industrial Estate,
   Hosur – 635 126.
   Tamilnadu.

2. M/s. Appropriate Technologies
   C-3B, Gowdanna Palya Pura Road,
   Bangalore – 560 061.

3. M/s. Intercom Engineers Ltd.,
30/55, Industrial Area,
Suburb Yeshwanthpur,
Bangalore – 560 022.

4. M/s. Technoheat Ovens & Furnace (P) Ltd.,
L-1, 7th Cross, Ist Stage,
Peenya Industrial Area,
Bangalore – 560 058.

III Veneer Dry clippers

1. M/s. Ferro Foundaries (Pvt.) Ltd.,
Yelwal Road,
Belvadi P.O.,
Mysore – 571 186.

2. M/s. L.M. Engineering Company,
321, Lake Town, Block – A,
Calcutta – 700 055.

3. M/s. B.S. Engineering Corporation,
Office and Factory,
No.1, 117, Raja Dinendra Street,
Calcutta – 700 004.

IV Wide Belt Sanders

M/s. HBR Consultants,
53, 10th Cross,
West of Chord Road,
Bangalore – 560 086.

V Veneer Dryers

1. M/s. L.M. Engineering Company,
321, Lake Town, Block – A,
Calcutta – 700 055.

2. M/s. B.S. Engineering Corporation,
Office and Factory,
No.1, 117, Raja Dinendra Street,
Calcutta – 700 004.

VI Air Compressors

1. M/s. Elgi Equipment Ltd. India House,
Coimbatore
Tamilnadu

2. M/s. Victor Compressors (P) Ltd.,
233, Acharya,
J.c. Road,
Calcutta – 700 020.

VII Resin Kettles

1. M/s. Vijaya Industrial & Engg. Works
45/4, 7th Cross, 80ft Road,
VI Block, Rajajinagar,
Bangalore – 560 010.

2. M/s. Bhaskar Engineer (P) Ltd.,
20, Biren Roy Road West,
Calcutta – 700 005.

3. M/s. Energy Machines
C1B-423, GIDC IV Phase,
Vithal Udyog Nagar,
121, Taluka, Anand.

4. M/s. Fab Metal Works
46, Mission Road Cross,
Bangalore – 560 027.

5. M/s. SIECO Engineers (P) Ltd.,
25, Bommasandra Industrial Area,
Hosur Road, Bangalore – 562 158.

6. M/s. Engineering Design & Services,
99, 14th Cross, West of Chord Road, II Stage,
Bangalore – 560 023.

VIII Dust Extractors

1. M/s. APCON Systems,
Kottigepalya,
Magadi Main Road,
Bangalore – 560 091.

2. M/s. Industrial Hygienic Systems,
73/1, Hosur Road,
Adugodi,
Bangalore – 560 030.

3. M/s. Flakt India Ltd.,
71, Sona Towers,
Miller Road,
Bangalore – 560 052.

4. M/s. Advanson Engineering Co.,
6, New Owners Colony,
Rajawadi Ghatkopar,
Mumbai – 400 077.

5. M/s. Indabrater Limited,
NSE Compound, Goregaon (E),
Mumbai – 400 063.

IX Thermic Fluid Heaters

1. M/s. Thermax Limited,
Thermax House,
4, Mumbai Poona Road,
Shivajinagar,
Pune – 411 005.

2. M/s. Thermax Limited,
9, Community Centre,
Basant Lok,
New Delhi – 110 057.

X Resin Applicators

1. M/s. Prasanth Enterprises,
No.155-B, 2nd Stage Peenya Industrial Area,
Bangaloare – 560 058.

2. M/s. Energy Machines
CIB-423, GIDC IV Phase,
Vithal Udyog Nagar,
121, Taluka, Anand

3. M/s. New Uma Engg. Works,
91, Industrial Town, 3rd Main Road,
Rajajinagar,
Bangalore – 560 044.

XI Fork Lift Trucks

1. M/s. Escorts Limited,
Tractor & Engineering Division,
18/4, Mathwa Road,
Faridabad, Haryana.

2. M/s. Mahindra Stiler Auto Trucks Limited.
Sector 27A, Part II,
Mathura Road,
Faridabad, Haryana.

XII Glue Spreaders

1. M/s. Intercom Engineers Limited,
   30/55, Industrial Area,
   Bangalore

2. M/s. B.S. Engineering Corporation,
   No.1, 117, Raja Dinendra Street,
   Calcutta – 700 004.

3. M/s. Gurunanak Mechanical Works (P) Ltd.,
   Makum Road,
   Tinsukia – 786 148.
   Assam.

4. M/s. Rhino Engineers
   A.T. Road,
   Tinsukia
   Assam.

XIII Trimming Saws

1. M/s. L.M. Engineering Company,
   321, Lake Town, Block – A,
   Calcutta – 700 055.

2. M/s. B.S. Engineering Corporation,
   No.1, 117, Raja Dinendra Street,
   Calcutta – 700 004.

3. M/s. Ferro Foundaries (Pvt.) Ltd.,
   Yelwal Road,
   Belvadi P.O.,
   Mysore – 571 186.

Appendix VI

Indian National Standard for mat board