FOREST RESEARCH INSTITUTE, DEHRADUN
वन अनुसंधान संस्थान, देहरादून

A Glimpse into some of the RECENT TECHNOLOGIES

By

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Foreword

Organized research in the field of timber products in India originated in 1920. The erstwhile Directorate of Forest Products Research and the reorganized Forest Products Division at FRI, Dehra Dun has significantly contributed to the development of wood based Industries in India. The Division pursues basic and applied research in addition to routine investigations on different aspects of wood and wood products utilization which includes composite materials from lignocellulosic sources also. To date, the Division has more than 3000 publications to its credit. This publication is an attempt to collate some of the recent technologies developed that would be useful to researchers, professionals and industries working in the fields of wood science and technology and wood utilization.

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Contents

Part 1

Established Technologies

A technique of wood plasticization for making bentwood furniture

Use of curved wood in furniture and housing is prevalent and is of key importance in many industries in India especially in those that manufacture furniture, sports goods, boats, ships and several decorative and utility articles. Steam has traditionally been used to soften wood for bending. Tests carried out earlier have indicated that only a few Indian timber species are amenable to steam bending. The steam bending technique has also limitations such as bending at sharp radius of curvature is not possible, long period is required for plasticization and drying of stock after bending etc. The works carried out at Forest Research Institute, Dehradun have shown that the above-mentioned limitations can be overcome by using vapour phase ammonia plasticization technique. This technique has enabled a wider choice of species for production of bentwood components for a variety of commercial products.

The FRI has designed and developed a pilot scale unit for the plasticization of wood through vapour phase ammonia treatment for making bentwood furniture components and other utility and fancy bentwood articles.

Bending results have indicated that several important timbers which are not amenable to steam bending can be bent successfully even to sharp curvatures by this technique. The technique would economize use of wood without affecting the functional requirements of the products, as the current practice to obtain bent wood components is from wider sections.

The Double cylinder for ammonia plasticization of wood

Further reading:

Saloni, P., D. Kumar and N. K. Upreti (2015). Plasticization of Mango and Poplar wood using vapour phase ammonia treatment. *Indian Forester*, **141** (11): 1137-1142.

Reconstituted wood from lantana *(Lantana camara)*

Lantana is a weed, available in different parts of the country. It grows under varying conditions of climate and soil. Lantana thrives in moist areas of high rainfall exceeding 500 cm and also in comparatively dry localities with 75 cm rainfall per annum. It is drought resistant, light loving and tolerates moderate shades. It regenerates quickly after cutting.

Due to its prolific growth and wide adaptability, lantana has overrun large areas in India and developed into a serious weed. Reconstituted wood developed from lantana offers a potential for processing of such raw material to a product for substitution of solid wood for structural use.

Scope: The process offers immense possibilities of utilization of lignocellulosic residue like lantana as a structural material. The process employed and machinery required is simple. The wastage of raw material is very little as compared to other panel materials. The amount of adhesive used is in the range generally used for particle board while the properties of reconstituted wood are comparable to natural wood. It will help in utilisation of *lantana camara*for development of structural wood which may ultimately help in the conservation of forest resources.

Techniques developed: Lantana sticks in green or wet condition with moisture content of 60-80 percent are passed through counter revolving rollers. The material is fully de-structured by narrowing the gap progressively between the alignments of the fibres in subsequent crushing till the material is crushed uniformly without disturbing the alignment of the fibres. The de-structured material is dipped in phenol formaldehyde resin (about 35 percent solid) in a tank without disturbing the fibre alignment so that the resin uptake is about 8 to 10 percent on solid basis. The resin treated material is then dried at a low temperature or sun drying to a moisture content of 6-8 percent. The packed material is then pressed in a cold press to

consolidate the material andthe final pressing is carried out in a hot press maintained at 140-150 ^{0}C at a pressure of 21-28 kg/cm^2 for about 30 minutes depending upon the density and thickness of the product required. After conditioning the board is then planned, trimmed and polished according to the requirement.

Advantages of Reconstituted Wood: The physical and mechanical properties of reconstituted wood developed from lantana compare favourably in most of the properties with durable timber like teak (*Tectona grandis*}. The product offers possibilities for use as a substitute for solid wood where directional strength properties are the main requirement as in structural timbers. It may be used for furniture, doors and window frames, beams and many loads bearing structure.

Furniture made out of reconstituted wood made out of Lantana

Properties of Reconstituted wood from Lantana

Property	**Reconstituted Wood from Lantana**	**Medium Density Particle board (IS:3087)**	**Teak wood**
Density g/cm^2	0.64	0.50 - 0.90	0.59
Volumetric Shrinkage % (Air Dry to Oven Dry)	4.26	-	4.05
Water absorption (%) 2hrs 24hrs	 18 36.6	 <25 <50	 - 15.7
Modulus of Rupture (Kg/cm^2)	817.4	>110	959
Compressive Strength (Kg/cm^2)	401.1	-	532
Shear Strength (Kg/cm^2)	82.1	-	102
Screw holding Power (Kg)	251	>125	326

Further reading:

Singh, S.P., J.P. Singh, A. Negi and S.S. Rawat (2001). Reconstituted wood from *Lanatana camara*. *Journal of Timber Development Association of India*, **47** (1&2): 42-46.

Chemical Seasoning of round bamboo handicrafts for avoiding cracks at nodes and surface wrinkles

Green bamboo may contain 50-150 % of moisture. As in the case of wood, seasoning of bamboo is necessary before its efficient utilization.

Seasoning of round bamboo poses considerable problem in several species of bamboo. Many species of bamboo are more or less liable to surface cracking during drying. Some species like *Bambusa nutans, Bambusa tulda* and *Dendrocalamus giganteus* crack more than the others. Unlike timbers, drying under mild conditions cannot always prevent cracking in round bamboo. End splitting, surface cracks and cracking at the nodes are common problems faced during air-drying even at slow rate of air seasoning and mild weather. Due to these problems, artisans are not able to use these species of bamboo for novelty items like flower vase, table-lamp stands etc. Chemical seasoning of bamboo properly solves the problem of surface cracks and wrinkles in bamboo.

The process of air or kiln seasoning the wood after treatment with anti-shrink chemicals, chiefly with the object of minimizing seasoning degrades, is known as "Chemical Seasoning". Chemical seasoning of round *Bambusa tulda* in green condition to avoid surface cracks, splitting and fungal discoloration has been tried. A solution made by dissolving 40 % urea and 2 % of boric acid (W/V) in water was used as anti-shrink and anti-borer treatment. This treatment enables forced-air-drying (using electric fans for 7-8 days) of the bamboo with negligible drying degrades whereas the untreated bamboo shows drying degrades unacceptable to be used in round from for novelty items like flower vases.

In this method, freshly felled green mature culms of bamboo (*Bambusa tulda*, *Dendrocalamus giganteus* etc.) are converted into small pieces of length 40-50 cms with one end open and another end with a node (example of flower vase).

The nodal partition was kept intact. These pieces are dipped for 72 hours in a mixed solution of urea (40% W/V) and boric acid (2% W/V) in water maintained at 45^0C initially for 8 hours. Temperature is used for creating a partial vacuum inside the bamboo so that absorption of chemicals would be increased. Boric acid treatment prevents borer attack in subsequent use of the bamboo. After treatment the treated pieces are wrapped in polyethylene sheets and kept indoors for better diffusion of chemicals. After a week these pieces are forced air dried using electric fans. After drying the product is coated with polyurethane coating in order to avoid problem of sweating during rainy season.

Chemical seasoning of Handicraft products

Flower vase made from chemical seasoned *D. giganteus*

Chemical seasoning method is very useful in avoiding cracks during drying of round bamboo. However, it is suggested that anyone planning to use the treatment commercially should make a series of tests on the species size and shape of specimens to be used, varying the chemical concentration and the treatment time in order to attain an optimum bulking concentration of the chemical.

Further Reading:

1. Upreti, N.K., V.S. Kishan Kumar and V.K. Jain (2005). Chemical seasoning of round bamboos for making value-added handicraft products.

ENVIS Forestry Bulletin, **5:** 43-47.

2. Upreti, N.K., M.C. Kukreti, R.P. Kandpal, Chetan Swaroop (2012-13). Chemical seasoning studies on *Acacia nilotica* and *Mangifera indica*. *J. Tim. Dev. Asso. of India, ,* **58-59** (1-4):1-5**.**

Bamboo cluster processing

An artisan friendly multipurpose and eco-friendly staining cluster treatment was successfully attempted for making decorative basketry and other products from bamboo. In this, the preservative (with borax-boric acid) treated bamboo slivers are stained using ammonia fumigation and bark extract of *Terminalia alata*. Moisture retardance of these slivers is achieved through linseed oil application. These slivers are quite soft to hands while making a product in addition to offering a wide variety of shades ranging from light brown to dark golden brown for decorative basketry. Such treatment was also found successful in working with green round bamboo for turnery purposes.

Some products made for demonstration purpose are shown below:

Basketry work from stained *Dendrocalamus strictus* slivers

A chair made with cluster treated turned round bamboo

Further reading:

Singh, S.P., Sachin Gupta and V.K. Jain (2005): Cluster treatment processing of green bamboo and utilization aspects. *ENVIS Forestry Bulletin*, **5:**38–42.

Part 2

New Technologies

Eco-friendly preservative ZiBOC
(Patent No: 257393 Year 2013)

Over the past few decades there has been a substantial global awareness of the danger posed to wood treatment workers by most of the conventional proprietary wood preservatives, like copper-chrome-arsenic (CCA), pentachlorophenol (PCP) etc. The environmental degradation by the same is becoming a matter of major concern worldwide. Most of the conventional wood preservatives of synthetic nature are difficult to dispose off and are non-degradable. Forest Research Institute, Dehradun being India's pioneer institution working in the field of wood preservation, initiated development of alternative wood preservative of eco-friendly nature like Cashew Nut Shell Liquor (CNSL), Chir Pine resin and cashew nut shell liquor salts (CRCNSL), Copper resinates, Bhilawan Nut Shell Liquor (BNSL) etc. for the protection of several temperate and tropical wood species. Most of conventional wood preservatives contain toxic metals like arsenic and chromium and attempts are underway to phase out such preservatives. In this context, copper, zinc and boron which are either categorized under essential trace metals or have very low mammalian toxicity were used to develop a product ZiBOC. Although many studies have been carried out on metaborates, the exact composition and ratios of metal salts exhibiting high efficacy are not reported so far. Till date double treatments of Zinc and copper metaborates are reported but none of the study reports single treatment of fixed composition of metaborates of zinc, copper and boron. The present composition is a fixed composition like CCA and it has exhibited excellent results against termites and fungi which is attributable to the presence of metaborates containing effective components of copper, zinc and boron in a fixed ratio. Because of fixed

ratio it had also exhibited excellent permanence. The present formulation is safe to human beings, toxic to wood decaying fungi and microbes, effective at very low concentration and very easy to handle. Metaborated developed by other researchers have not fixed composition of three salts. It is water soluble; no amine or other hazardous chemical was used to dissolve the chemicals. It was made from industrial grade chemicals so that it can be easily made by industry just like CCA and CCB. The fixed composition of boron, zinc and copper is developed for the first time. Many formulations were reported after CCA and CCB but none of them had same efficacy as CCA and CCB but the present formulation showed comparable performance with CCA and CCB. It is cost effective and can be easily made by a trained technician. The experiments were done in various conditions for variety of commodities and recommended for inclusion in BIS401. Thus, innovation and experimentation recommend its use on the basis of the following:

- For Bamboo protection and durability improvement ZiBOC without fire retardants as well as with fire retardants. A sample hut made from ZiBOC and fire retardant treated bamboo in 2008 is fullyprotected till today.
- Use of ZiBOC in plantation timbers like poplar, chir pine, eucalyptus, *Melia dubia* and imported timbers like Meranti, Douglas fir, *Pinus radiata* in exterior open , shade and ground conditions and cooling tower applications suggests it’s efficacy in enhancing the life span of wood.
- All results of ZiBOC were compared with conventional preservative and ZiBOC was found at par.
- Treatment of plantation species with ZiBOC will justify the necessityof

treatment of non-durable species for long lifespan products and also is an alternative to toxic preservative.

- No specific requirement for the treatment is required. All procedures opted for CCA are same for ZiBOC also.
- All routine methods work in bamboo and wood treatment with ZiBOC.

ZiBOC and fire retardant treated Bamboo hut constructed in 2008

Further reading:

1. Tripathi, S. (2010). Resistance of chemically treated *Bambus aarundinacea* against Fungi, termite and fire. *Chemistry and Industry of Forest Products*, **30** (4): 12-17.

2. Bhatt, S., S. Tripathi and D.P. Khali (2011): ZiBOC–an eco-safe preservative performance in plywood. *J. of Timber Development Association of India*, **57**: 8-12.
3. Tripathi, S. (2012). Treatability evaluation of Meranti (imported timber) with ZiBOC and CCA preservatives for efficient and utilization. *International Wood Products Journal*, **3** (2): 70-76.
4. Rawat, M.K., S. Tripathi and H. Pant (2015). Laboratory Evaluation of ZiBOC and CCA as an antisapstain on *Populus deltoides. J. Ecofriendly Research,* **10** (1):82-86.
5. Tripathi, S. and P.K. Poonia (2015). Treatability of *Melia composite* using vacuum pressure impregnation. *Maderas-Cienc.Tecnol.*,**17** (3):373-384.
6. Tripathi, S., S. Bhatt and H. Pant (2018). Performance of Treated Imported Timbers (ZiBOC, CCB and CCA) and their Natural Durability in Prototype Cooling Tower. *Indian Forester*, **144** (5):477-484.

Modified design solar kiln for drying of wood and other non-wood forest produce

The standard steam heated timber-seasoning kilns with boiler and complement of boiler operating staff and kiln operators are not economically appropriate for all situations. Drying of timber can be appreciably accelerated compared to air seasoning and at appreciably reduced seasoning costs compared to conventional steam heated kilns using solar seasoning kiln. Solar kilns are based on greenhouse principle. The solar kiln is normally operated during day light hours only. A single passed force air-drying arrangement is incorporated making use of the dry air available on warm summer nights. The traditional FRI solar kilns have been in use since 1930s. Forest Research Institute has now developed a modified solar kiln design having a charge capacity of 250 cft for one-inch thick planks. The design consists of a super structure of timber/metal frame, single sheathed on the roof; southeast and west wall 5.5 mm clear transparent glass. The north wall is sheathed with 9.5 mm BWR grade plywood. The kiln is oriented east west along its length. The roof is tilted towards the south at an angle to the horizontal equal to 0.9 times the latitude for maximum year-round absorption of solar energy. Corrugated blackened galvanized iron sheet is used for false ceiling and the entire structure is painted black on inside to absorb maximum solar radiation. Two electric fans are installed at the floor level in north wall for uniform air-circulation. The improved chimney type vents in south wall help in recovery of heat loss during venting operation. The modified design kiln is equally efficient and approximately 30 % cheaper compared to old version. The solar kiln can also be used for drying seeds, *bidi* leaves, raw material of ayurvedic medicines etc. The approximate cost of installation is about Rs. 8.0 Lakh for a 250-cft capacity kiln.

The single glass modified new Solar Kiln

Further reading:

1. Upreti**,** N.K., M.C. Kukreti and R.C. Kandpal (2009). A cost effective solar kiln for wood seasoning. *Journal of Timber Development Association of India*, **55** (1-4): 72-80.
2. Upreti, N.K., M.C. Kukreti, Chetan Swaroop and V.S. Kishan Kumar (2011). Solar kiln drying of timbers of *Eucalyptus tereticornis*, *Acacia nilotica* and *Dalbergia sissoo. Indian Forester*, **137** (8): 980-985.
3. Upreti, N.K. and M. C. Kukreti (2014-15). Drying of timber of *Dalbergia sissoo* in two different solar kilns. *Journal of Timber Development Association of India*, **60-61**: 62-68.
4. Ganguli, S. and N.K. Upreti, (2014-15). Drying studies on *Pleiogynium cerasiferum* and *Ailanthus excelsa* in Solar kiln. *Journal of Timber Development Association of India*, **60-61**: 41-51.

Vacuum kiln for wood seasoning developed at FRI

- Vacuum drying of timber is a new field of wood science in India. The technology has been commercialized only in a few developed nations.
- The vacuum kiln is costly affair as on date for Indian entrepreneurs due to absence of such indigenous equipment in the country.
- The technology is useful in the sense that it takes shorter time period to dry timbers to desired moisture content with lesser drying degrades compared to traditional technology of steam kiln.
- The Forest Products Division of the FRI has designed and developed a convection heating based vacuum kiln for wood seasoning. The kiln is capable of achieving a vacuum of 200 mm of mercury within 22 minutes. A lot of popular wood having 98 % moisture content could be dried in this kiln in 18 hrs 25 minutes only to a final moisture content of 11.2 % without degrades.
- The design of the developed kiln is simple and can be adopted by the wood industry easily.
- Kiln cost is almost $1/4^{th}$ of the cost of imported vacuum kiln.

The Vacuum Kiln Designed at FRI

Further reading:

Upreti, N.K,M.C. Kukreti, R. P. Kandpal and Chetan Swaroop (2013). Convection heating based vacuum kiln for timber drying and its performance. *Indian Forester*, **139** (1): 43-48.

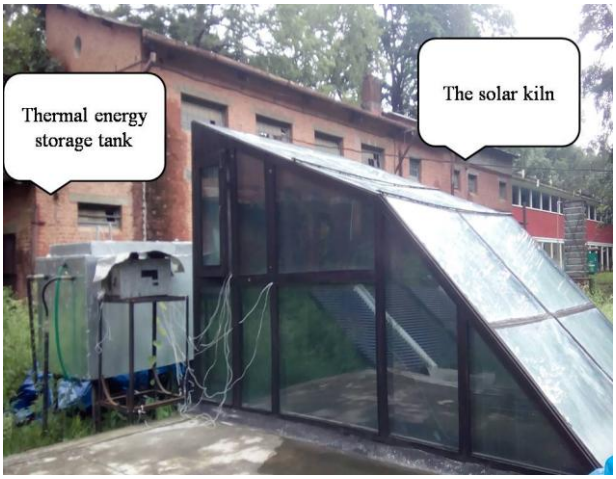
A dual inclination solar wood drying kiln with a solar thermal storage system

Wood can be satisfactorily dried using solar energy. FRI, Dehradun has developed a commercial solar kiln design in 1972. The main handicrafts hubs in India like Saharanpur, Moradabad, Jaipur, Jodhpur etc. are situated on such locations where availability of solar energy is in abundance. The manufacturers of these handicraft centres mainly use steam heated kiln for wood drying, which usually is run by boiler generated steam. Storage of solar thermal energy can make the utilization of this natural resource more attractive and reliable by neutralizing its intermittent nature of solar energy availability i.e. day and night.

A semi-green house type new, improvised design (double inclination) prototype of solar timber drying kiln was designed and constructed at Forest Research Institute (F.R.I.), Dehradun. The improvement in solar flux on new design kiln over old design solar kiln due is 132.9% in summers, 33.4% in winters and average 65.3% annually.

The roof and south facing wall inclinations of the kiln have been optimized in such a way that it receives higher solar flux even in the winter season. Roof and side walls of the kiln were made of double glass glazing as shown in figure.

The kiln performance has been tested and found to perform better under various test conditions. The kiln was able to attain 98.6^{o}C in summers and 70^{o}C in winters in empty run conditions. The drying performance of the kiln showed that it can be used efficiently for wooden handicrafts production.



The double inclination kiln with thermal storage system

A thermal energy storage system (TESS) based on latent heat of phase change materials (PCM) and sensible heat of water was designed and studied. The solar kiln was tested in the month of October 2016 for drying of a plantation originated *Melia dubia* wood. The results indicate that the empty solar kiln (without wood) fell to temperatures near 45^{o}C as early as 18:50 hrs in evening when no TESS was used. With the use of TESS, the empty kiln temperature reached 45^{o}C by 00:30 hrs and maintained at 45^{o}C for the rest of the night. Wood drying in the absence of TESS showed that the moisture content (MC) fell from 62% to 7.5 % in a continuous drying cycle of six days. Solar wood drying in the presence of TESS resulted in MC fall from 60% to 7.6% in a drying cycle of only three days. The MC reduction during the night time was significant, highlighting the role of TESS.

Further reading:

1. Shailendra Kumar and Kishan Kumar V.S. (2017). Charging-Discharging Characteristics of Macro-Encapsulated Phase Change Materials in an Active Thermal Energy Storage System for a Solar Drying Kiln. *Thermal Science*, **21** (6A):2525-2532.

2. Shailendra Kumar, Ramkishore and R.P. Kandpal (2015). Innovative Design, Construction and Performance Evaluation of a Small Solar Timber Drying Kiln. *Indian Forester*, **141** (11): 1176-1182.
3. Shailendra Kumar and V. S. Kishan Kumar (2016). Melting-solidification characteristics of phase change materials in two macro encapsulations for development of thermal energy storage system for a solar timber drying kiln. *Asia Pacific Journal of Engineering Science and Technology*, **2** (2): 58-70.
4. Shailendra Kumar and V. S. Kishan Kumar (2016). Thermal energy storage for a solar wood drying kiln: estimation of energy requirement. *Journal of Indian Academy of Wood Science*, **13**:33-37.
5. Shailendra Kumar and Kishan Kumar V.S. (2017). Performance Evaluation of a thermal Energy Storage assisted Solar Wood Dryer. *Journal of Basic and Applied Engineering Research*, **4** (6): 428-431.
6. Shailendra Kumar and V. S. Kishan Kumar (2017). Effect of container orientation on melt fraction and use of PCM in enhancing night temperature in a prototype solar kiln, *Indian Forester*, **143** (1): 43-47.
7. Shailendra Kumar and Kishan Kumar V.S. (2017). A new design solar wood dryer. *Journal of Basic and Applied Engineering Research*, **4** (6): 419-424.
8. Shailendra Kumar and V. S. Kishan Kumar (2017).A Latent Heat Based Packed Bed Thermal Energy Storage System for a Solar Wood Drying Kiln, *Indian Forester*, **144** (1): 84-89.
9. Shailendra Kumar and Kishan Kumar V.S. (2018). A solar dryer with thermal energy storage system for handicrafts industries of eco-sensitive zones. 12th Science and Technology Congress, 07-09 Mar, 2018, UCOST, Dehradun, Uttarakhand.

Defect (hollowness) detection of tree trunk by ultrasonic technique

Trees are valuable assets for providing ecological, aesthetic, social and economic benefits. Early hidden defect (hollowness and multiple cracks in the tree trunk) detection is of prime importance to the forest management for prescribing silvicultural treatment and maintaining a healthy forest. This aspect is also important to the industries in terms of making accurate quality assessment of timber (log). Non-destructive testing techniques based on different concepts are need of the hour to be used in the field conditions for defect detection mainly to identify hazardous trees, to prevent the spread of decay and to improve stand conditions. Among several non-destructive test methods, the vibration test technique (acoustic/ultrasonic) is employed to evaluate the elastic properties, presence of defects in wood and wood products as it has several advantages over traditional testing such as less time consumption, economical, reliable results and also easy to transport instruments to inspection sites. Sounding a tree by striking it with a tool can detect advanced decay or hollowness inside the trunk, but this method is not effective on large thick-barked trees. The non-destructive acoustic and ultrasonic techniques have proven to be effective for detecting and estimating deterioration in tree stems and wood structural members. These techniques are simpler and economic than other techniques. Since the propagation of stress waves is basically a mechanical phenomenon, this can be used to detect internal defects in wood. Forest Products Division of Forest Research Institute, Dehardun has developed an ultrasonic technique to detect the location and magnitude of the deterioration (hollowness) inside of the main tree trunks for different girths which will help either to take timely precautions for the safety of the valuable tree by giving suitable and effective treatment for conservation of trees or to get good yield (timber) for utilization purposes. This will also be helpful in urban forestry management and for State Forest Departments and for other agencies to take

timely decision for removal of hazardous trees which are at prime locations for the safety of life.

The testing involves the following procedure:

- Ultrasonic velocity is transmitted along multiple transverse directions of the tree trunk (as shown in figure).
- Ultrasonic velocity is measured along multiple transverse directions of the tree trunk.
- In the presence of hollowness, ultrasonic velocity decreases.
- Magnitude and location of hollowness in the tree trunk is estimated using EXCEL sheet.

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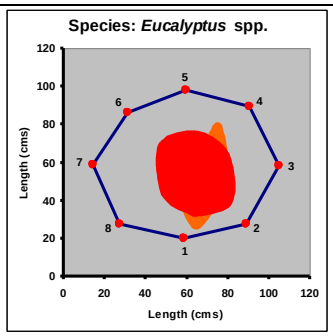
<td> 
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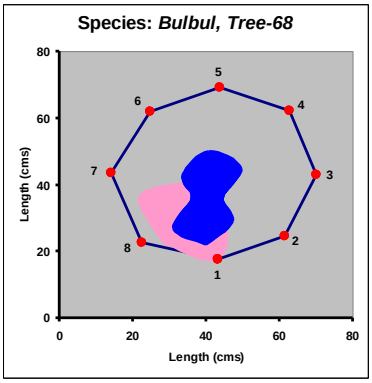
<td> 
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<tr>
<td colspan="2">Field testing and results</td>
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1. Dubey, Y.M. (2014-15). Preliminary study on quality assessment of *Eucalyptus* spp. by ultrasonic method. *J. Timber Dev. Assoc of India*, **60-61** (1-4): 14-24.
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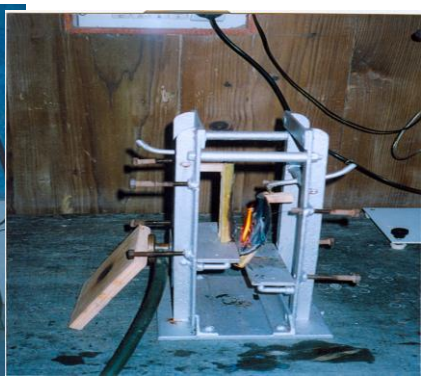
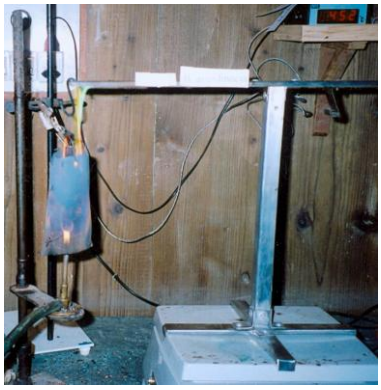
Fire retardant and preservative formulations for plywood

The use of panel products is increasing day by day due to various advantages over solid wood. These untreated composite panels being combustible in nature do not comply with the fire safety requirements. In order to overcome this weakness, plywood may be treated with fire retardant chemicals. Treatment of plywood with fire retardant chemicals requires pressure treating the plywood with chemicals for sufficient period to get desired retention. However, the pressure treatment requires installation of treatment cylinders of the size of plywood to be treated which might be a limiting factor. Three different fire-retardant compositions were prepared for the treatment of veneers and plywood was prepared from the treated veneers. The prepared plywood samples were tested for glue shear strength, flame penetration, rate of burning and flammability tests. It was found that the composition containing phosphoric acid was the best performer in fire retardance without compromising on the glue shear strength.

Flame penetration test



Flammability test



Rate of burning test

Further reading:

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Easy to apply vacuum press drying schedules for fast seasoning of *Tectona grandis* and *Populus deltoides*

Vacuum drying of wood has caught the imagination of wood seasoning industries due to the much lower drying times it offers. The technique is based on the fact that when the ambient pressure in which the wood stack is heated is lowered, the water in the wood boils at lower temperatures. In addition, a pressure gradient inside the wood is created which helps in faster moisture movement. Such a situation enhances the rate of drying especially through the end grain. A vacuum press dryer has the additional advantage of the wood stack being protected from warping due to the pressure applied from the top of the stack. Experiments at Forest Research Institute, Dehradun helped in developing easy to apply drying schedules for one-inch (25 mm) thick planks of *Tectona grandis* and *Populus deltoides* using this technique. The schedules for these species are given below.

Schedule for *Tectona grandis* (Teak):

MC range (%)	Temperature (C)	Pressure (mbar)
50-30	70	473
30-19	80	573
19-10	90	413

One can effectively bring down the moisture content of one-inch thick teak planks from an initial value of 50 % to a desired 12 % value using the above three temperature-pressure combinations. The approximate running time of the vacuum press dryer would be 29 hours in comparison with 360 hours that is required in a conventional steam heated kiln to dry this wood from 45 % to 12 %.

Schedule for *Populus deltoides* (Poplar):

MC range (%)	Temperature (C)	Pressure (mbar)
> 40	85	713
< 40	90	453

One can effectively bring down the moisture content of one-inch thick Poplar planks from initial values exceeding 40 % to a desired 12 % value using the above two temperature-pressure combinations. The approximate running time of the vacuum press dryer would be approximately 29 hours in comparison with 144 hours that is required in a conventional steam heated kiln to dry this wood from 45 % to 12 %.

Further reading:

1. Sachin Gupta, V.S. Kishan Kumar (2017). An easy drying schedule for *Tectona grandis* through vacuum press drying. *Ciência da Madeira (Brazilian Journal of Wood Science)*, **8** (3): 136-141.
2. Kishan Kumar V.S., N.K. Upreti and Sachin Gupta (2016). Scope of vacuum press drying for fast removal of moisture below fiber saturation point. *Drying Technology*, **34** (10): 1204–1209.
3. Kishan Kumar V.S., Sachin Gupta and C.M. Sharma (2008). Studies on vacuum press drying of *Populus deltoides*. *Indian Forester*, **134** (6), 835-42.
4. Kishan Kumar, V.S., Sachin Gupta and C.M. Sharma (2008). Preliminary attempts to season *Tectona grandis* using vacuum press drying – possibility of faster seasoning. In *Proceedings of Regional Workshop on Processing and Marketing of Teak Wood Products of Planted Forests* held at KFRI, Peechi during 25-28 September 2007, 284-288.