

WOOD PROCESSING NEWSLETTER

forest  *research*

ISSN 0113-6224

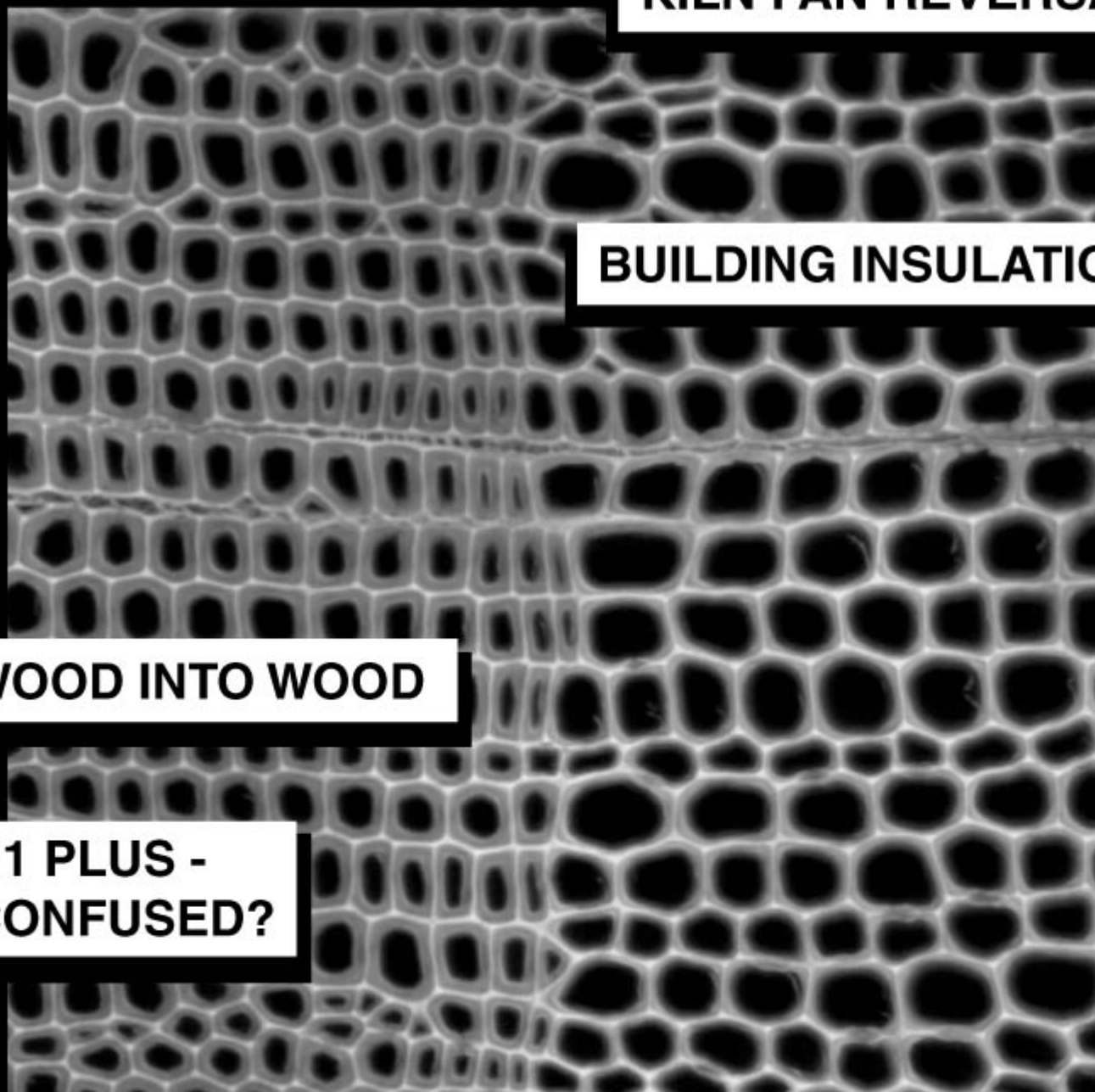
Issue No. 34 January 2004

KILN FAN REVERSAL

BUILDING INSULATION

WOOD INTO WOOD

**H1 PLUS -
CONFUSED?**



INSULATION VALUE OF BUILDING MATERIALS AND COMPONENTS

Louw van Wyk and Mike Collins

With the growing interest in thermally efficient buildings and the involvement of Forest Research in both energy research and built environment research, it may be useful to define some of the common terms used for insulation.

The insulation value of a material is called the Thermal Resistance, **R**, of the material and is measured in $\text{m}^2 \cdot \text{C}/\text{W}$.

When that material is incorporated into a building component such as a wall, the Total Thermal Resistance of the construction is also called the **R-value** and normally includes the thermal resistance of the air layers immediately adjacent to the internal and external surfaces.

For convenience, these inside and outside surface thermal resistances are standardised at $0.3 \text{ m}^2 \cdot \text{C}/\text{W}$ and $0.9 \text{ m}^2 \cdot \text{C}/\text{W}$ respectively. The thermal resistance of the construction is then called the Standard Total Thermal Resistance. This is normally simply abbreviated to the “**R-value**” of the wall, roof, or floor.

The term **R-value** is also commonly used to describe the effectiveness of insulation products but when that product is incorporated into a building component, the **R-value** of the building component will generally be different from that of the material on its own. This difference is due to the additional materials in the wall which may both add and subtract from the **R-value** of the insulation product, and also the surface effects referred to above. It may be that an insulation product with an **R-value** of $1.8 \text{ m}^2 \cdot \text{C}/\text{W}$, when installed in a wall results in a wall **R-value** of $1.5 \text{ m}^2 \cdot \text{C}/\text{W}$. The lower value is the result of thermal bridging of the insulation by the lower **R-value** studs and plates.

Heat is transferred by radiation, conduction, and convection. The use of bulk insulation materials such as fibreglass, cellulose fibre, polystyrene foam, etc. slows down heat transfer by way of conduction and convection and has some effect also on radiation. Reflective insulation products, such as metal foil, reduce heat transfer through radiation.

The higher the **R-value**, the greater the material’s resistance to heat flow and the better its insulating value.

R-Value = (Temperature difference \times Area) / rate of heat transfer where:

- temperature difference is in degrees Centigrade,
- area is in square metres,
- heat transfer is in watts

If you know the **R-value** of a partition, you can use this formula to find the heat gain or loss.

Be aware that **R-values** are often expressed in imperial units when listed in tables. (To convert thermal resistance from USA Imperial **R-values** ($^{\circ}\text{F ft}^2 \text{ h}/\text{BTU}$) to metric ($^{\circ}\text{C} \cdot \text{m}^2/\text{W}$) multiply by 0.176.)

The inverse of the **R-value** is area thermal conductance, or the **U-value**. The **U-value** is a measure of the area thermal conductivity through a material or assembly. In windows, the **U-value** may be expressed for the glass alone or the entire window, which includes the effect of the frame and the spacer materials. For a wall assembly, the **U-value** typically reflects all the components such as studs, concrete blocks, insulation, and wall board. The lower the **U-factor**, the greater the material’s resistance to heat flow and the better its insulating value.

Thermal conductivity, or **k**, of a material is calculated by dividing the thickness by the **R-value**.

R-Values tell only part of the story. Unfortunately, they don’t tell you how well the insulation will perform in your home. **R-value** is a laboratory measurement and does not effectively measure all three methods of heat transfer that occur in any situation: radiation, convection, and conduction. Your home loses and gains heat in these three ways:

Radiation

Definition: The transfer of heat in the form of long wave electromagnetic waves.

Example: Heat can be transferred from the roof to the uninsulated ceiling by radiation.

Convection

Definition: The transfer of heat by moving air or liquid.

Example: Warm air rises and transfers heat from within the room to the ceiling.

Conduction

Definition: The transfer of heat through a solid material.

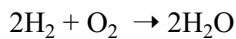
Example: Heat is transferred through a wall from the warm internal lining, through the bulk insulation to the cooler outside cladding.

A LAYMAN'S GUIDE TO THE COMBUSTION OF WOOD

Louw van Wyk and Per Nielsen

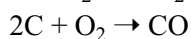
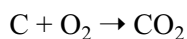
Although the combustion of wood is a complex phenomenon it can be simply described as the rapid oxidisation of wood accompanied by release of energy and an increase in temperature. Only two elements found in wood have heat value: carbon and hydrogen.

The combustion process is shown in the following two equations:



i.e., burning hydrogen produces water,

and



Burning carbon produces carbon dioxide (the fizz in a soft drink) and carbon monoxide (a deadly gas).

The combustion process requires 8 kg of oxygen or 34.56 kg air to burn 1 kg of hydrogen producing 9 kg of water. It also requires 2.66 kg of oxygen or 11.5 kg air to burn 1 kg carbon. The combustion process requires about 25% excess air, which means about 6 kg of air are required to burn 1 kg of wood. The weight of air is 1.3 kg/m³ which means about 5 m³ of air are required to burn 1 kg of wood.

The energy content of radiata pine is about 20 GJ/kg (5.56 kWh/kg) oven-dry (bone dry) wood but fuel wood is seldom oven-dry and some heat is lost in flue gases. The net usable heat value of 1 kg wet wood

(say 50% oven-dry wood and 50% water) is about 7 GJ/kg wet wood.

To keep things simple let's look at burning wood in a domestic wood burner:

A 5 m³ truck load of firewood (volume thrown) equals about 3 m³ stacked or 2 m³ solid. A typical price of firewood is \$50/m³ thrown volume or \$125/m³ solid. The oven-dry density of pine is about 400 kg/m³, which means firewood costs about \$0.31/kg (\$0.05/kWh) oven-dry wood. Burning wood will produce about 2 to 4 kWh of heat energy per kilogram of wood, depending on the moisture content of the wood. Operating a wood fire costs about 8c/kWh using dry wood and 16c/kWh using wet wood. If you buy your firewood and burn it wet you might just as well use an electric heater.

A typical wood burner produces between 6 and 20 kW of heat, and to run for 3 hours at 6 kW will require at least 5 kg of dry wood per evening and cost about \$1.55.

Burning this wood will require 23 m³ of air. A typical wood burner gets its air supply from inside the house and the replacement air is leaking in at doors and windows. No wonder the bedrooms are cold when you retire from a warm lounge. The warm air in the house has been fed to the wood burner and replaced by cold air from outside.

VISITING SCIENTISTS

Professor Sang-Sik Jang is enjoying sabbatical leave from Chungnam University in Daejeon, Korea, to undertake a project funded out of the Wood Processing Strategy.

This project is to write a Korean version of the New Zealand light timber framing standard, NZS 3604, plus a training/explanatory manual to go with it. He is

also organising a seminar on wood processing in the Korean wood industry for next April. The objective of this work is to enhance the value of radiata logs sold into Korea and create the opportunity for direct sales of house-building materials from New Zealand.

In Korea, single family detached houses require no building consent, only planning consent, so there is a

large potential opportunity for radiata pine to be used in holiday style homes in Korea. An even bigger market is medium-rise timber frame condominium construction, and the Americans have been working hard to promote that in Korea also.

The biggest problem in Korea is their fire regulations, which prohibit the use of combustible construction materials. Once the Americans have persuaded the authorities that fire ratings can be achieved with gypsum board/woodframe construction, then that market should open to New Zealand manufacturers too, provided the viability of our system has been proved in single family homes.

Prof Jang is here for 1 year, with his wife and son.

Ali Bahadori Jahromi is a visiting Ph.D. student from Napier University’s School of the Built Environment in Edinburgh, Scotland. In his 6 month stay at Forest Research, he will be manufacturing prototypes of a new patented structural engineered timber system called ‘Composite Insulated Beam’ or CIB (A. Bahadori Jahromi, A. Kermani 2003). Ali’s project collaboratively with staff from Forest Research could be summarized in four phases:

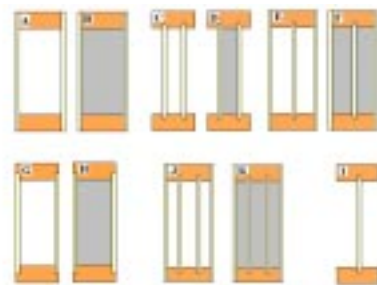
- Developing the manufacturing process according to the latest industrial standard for the newly designed profiles
- Investigating the structural performance of CIB beams through series of comprehensive experimental tests
- Undertaking long-term durability testing to establish structural degradation over time, through the accelerated ageing method

- Joint publication of the testing undertaken in New Zealand.

Ali has received funding from the Royal Academy of Engineering, and the Royal Society of Edinburgh to undertake his project at Forest Research. The Institute's superior testing facilities will enable him to complete the necessary experimental requirements for his studies.



Assembling one of the beam designs



Cross-section of beam designs, with and without insulation infill, to be compared with the I beam.

POURING WOOD INTO WOOD

Dr Robert Franich

“Wouldn’t it be great if radiata pine could look and behave like a stable hardwood?”

This is the question that launched Forest Research on a mission in 1985 to create a new material using radiata pine as the base. Briefed by the New Zealand Furniture Makers Federation, scientists looked to replace the existing petrochemical-based wood hardening technology with one using more biologically-sourced raw material. The vision was to create a new biomaterial that was dense, hard, and stable, with the concept of “pouring wood into wood”.

At the time, existing wood hardening technology involved the impregnation of wood material with synthetic chemicals. This process, known as vinyl polymerisation chemistry, was first developed in the 1960s, and became the benchmark for hardened wood products. The resulting material was very hard and of high density, but could not be wood-worked using conventional wood-working practice and machinery. Forest Research aimed to enhance the performance of solid wood using an engineered biomaterial derived using a different chemical process, condensation polymerisation chemistry. To ensure that this new

technology would be accepted by industry and developed into a fully commercial product, the following constraints were applied:

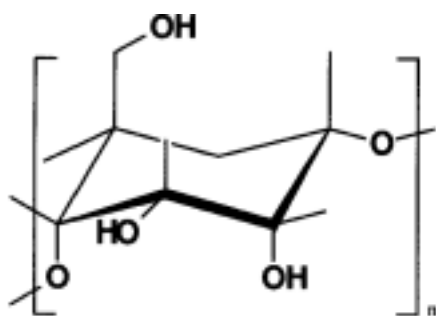
1. The new “wood into wood” process had to be chemically simple and economical in order to achieve scale-up to full commercial production.
2. The process had to fit into existing solid wood processing practice, pressure vessels, drying kilns, etc.
3. The final hardened wood material had to be workable using conventional tools and machinery.

By 1991, Forest Research had developed a completely new wood hardening process that met the criteria. The new chemical process fulfilled the concept of “pouring wood into wood”. This meant modifying the wood cell walls and filling the natural spaces within wood cells with biopolymers instead of petrochemicals. The resulting patented technology, the Indurite™ process, has been commercialised and further developed by Pacific Hardwood Ltd (a subsidiary of Carter Holt Harvey Ltd) and is growing in commercial production. The new hardened product is marketed under the brand **Green Seal™**, *the sustainable solidwood*.

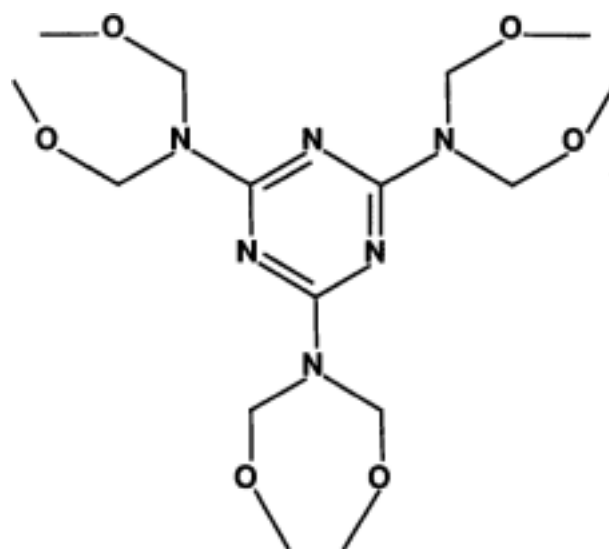
Chemical process

By understanding the relationship between wood material molecular structure and properties (cellulose for tensile strength and hemicellulose and lignin for compressive strength), Forest Research chemists designed the new wood hardening process using chemical building blocks analogous with those of natural wood:

- (a) a hemicellulose analogue from starch (maltodextrins) derived from agricultural residues
- (b) a lignin analogue using melamine chemicals (petrochemical based)

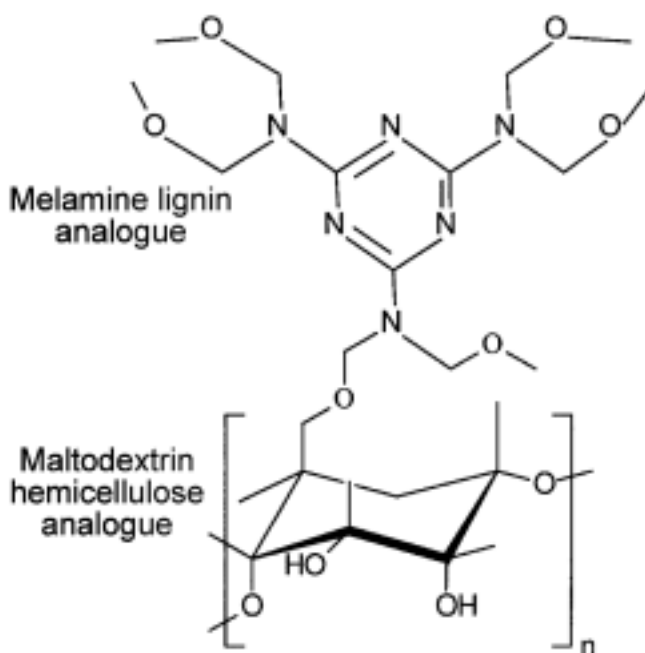


Maltodextrin from starch



Melamine product
(derived from petroleum chemistry)

By combining these together using condensation polymerisation chemistry, Forest Research has created an “artificial ligno-hemicellulose polymer”. When produced within wood, this provides high compressive strength and creates a dense, hard material that is compatible with standard manufacturing processes.



By joining more maltodextrins and melamines together using condensation polymerisation chemistry, a very high molecular weight polymer is obtained which comprises the “wood poured into wood” material.

FILLET STAIN

Ian Simpson and Steve Riley

Fillet stain in kiln drying often refers to discoloration on the board surface due to interaction between the fillet and the board. We occasionally receive technical enquiries about this problem and think it is useful to summarise available knowledge. More strictly, fillet stain is a form of drying degrade that causes dark patches under the fillets during drying. The stained board has a stripe where the fillet was positioned, which is darker in appearance than the rest of the board. The stain often penetrates the board deeply enough so that it is still present after dressing.

Our response to the broad problem of fillet stain can be divided into three groups:

Drying radiata pine with radiata pine fillets

In this case we have found that the so-called fillet stain is actually a manifestation of kiln brown stain, where under the fillet there is an absence of brown stain often highlighted by an intensification either side of the fillet. After machining, the light fillet area and the darker area each side of it are still visible. This type of discoloration is a brown stain problem and our

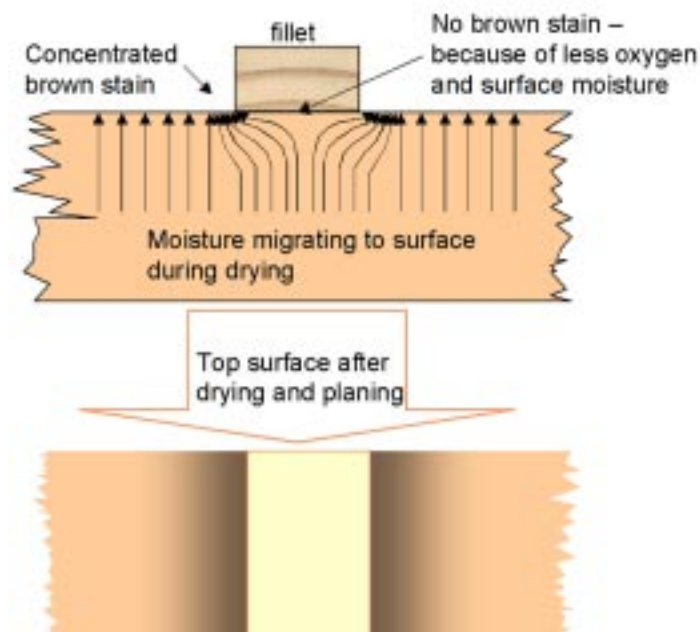
knowledge in this area was summarised in Newsletter 23. Work on brown stain is continuing.

Drying radiata pine with hardwood fillets

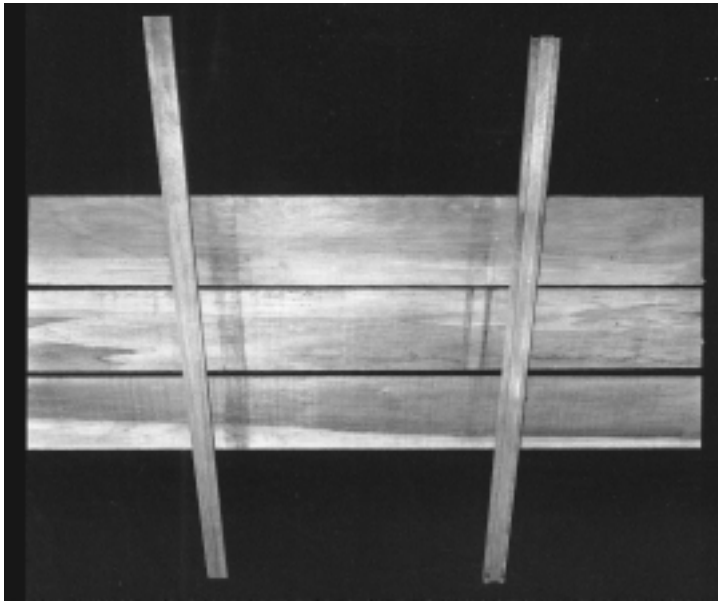
Chemicals in the extractives in the moisture of different woods can react to cause colour problems. This is usually exacerbated when wet fillets are used. This is not a large problem as generally radiata pine fillets are used. No problems have been reported with commercially available hardwood fillets. Our recommendations when problems are encountered are to use dry fillets or to change fillet type.

Drying other species

In the past fillet staining was a huge issue especially in the drying of rimu, and our archives have many instances of work done in this area. Recently some enquiries have been received and have been dealt with by referring to the rimu work. A significant amount of work has been done in North America on fillet staining. Recommendations arising from work done on rimu drying at FR can be summarised: -



- Ensure that fillets are kept dry between kiln charges.
- Do not use green fillets.
- Do not use rimu fillets with rimu timber.
- It is likely that fillet stain will be reduced by the use of dry radiata pine fillets and by allowing the surfaces of the rimu timber to dry to some extent before filleting. Both factors should be applied if staining is to be within an acceptable standard.



Fillet stain in rimu

- Grooved fillets may reduce fillet stain as the fillet covers less of the surface of the board.
- The use of non-wood fillets (aluminium or plastic) may be warranted if the loss from fillet stain is high. Non-wood fillets may prevent fillet stain, as the fillets would not contain moisture.
- Studies at Forest Research failed to detect any fungal attack in stained areas and the stained areas appeared to have an accumulation of resinous material.

Overseas research with other species has shown that:

- The mechanism of fillet stain in North American hardwoods is not fully understood.
- Fumigation reduces the amount of staining in North American hardwood species by killing the parenchyma cells.
- Stains result from coloured matter forming in the ray and axial parenchyma cells.
- Stains are associated with slow air-drying under mild conditions.
- Extended log storage during warm weather, or holding sawn lumber without stickering, may increase the incidence of stains.
- Some marketing organisations consider that fillet stain is not a degrading feature.

UNDERSTANDING WATER IN WOOD AND EQUILIBRIUM MOISTURE CONTENT

Chris Lenth and Hamish Pearson

The science that we undertake in order to understand and improve the drying and processing of wood is essentially the science of wood and water. The relationship between a wood element (board, veneer, fibre, or table leg) and the water (either liquid or vapour) in its local environment is arguably the most significant factor affecting its behaviour in both manufacture and service.

The parameter most often used to quantify the wood-water relationship is **moisture content** or MC. Moisture content is the proportion of the wood weight that is water and it is calculated as the ratio of the weight of the moisture in the wood to the oven-dry wood weight. Various electronic sensing configurations exist for measurement of wood moisture content and accurate assessments can be made using the oven-dry method.

Wood is a porous material that is hygroscopic. Simply speaking, this means that dry wood will adsorb, or pick up, moisture from a humid environment. Likewise, wet wood will desorb (lose) moisture to a dry environment. It could be said there is a *contract* between the relative humidity of an environment and the moisture content of the wood in it. As the humidity of an environment fluctuates, the moisture content of the wood in it will follow, as required by this contract.

Instability is the physical manifestation of the humidity-MC contract. The fact that wood shrinks/ swells with moisture loss/gain adds a spatial dimension to the wood-water relationship. The natural tendency of wood to expand/contract with changing humidity can result in large distortions. When a board is restrained in a structure or installation, small

changes in environmental conditions can lead to deformation or failure with extremely costly implications. The importance of matching the seasoning process to the raw material and particularly to the end-use environment is paramount. Stability-induced failures and degrade are often a result of neglecting to do just this.

One essential piece of information for minimising negative consequences of the wood-water relationship is an understanding of what level of moisture content a piece of timber will ‘balance out’ at in an environment of constant humidity. Constant humidity environments are not common in service; however, previous knowledge of the humidity-MC contract is essential in minimising stability-related problems. Moisture content-relative humidity relationships over a range of conditions have been recorded for remarkably few species. These few tabulated results have been applied to essentially all species and situations.

One such data set of MC results for North American Sitka spruce has become the foundation upon which nearly all MC predictions are made. The Forest Products Laboratory of the United States Department of Agriculture published this data set. Textbooks and kiln drying guides for raw materials ranging from New Zealand radiata pine to western Canadian softwoods base their recommendations upon this MC data set.

In Figure 1 the USDA MC data at 21°C are given along with data for Australian klinki pine collected by K.E.Kelsey in 1956. Two MC vs RH relationships for New Zealand radiata pine, are also displayed. As illustrated, there are considerable differences among the different MC results. Especially surprising are the large discrepancies between the two data sets for radiata pine. The differences between the USDA data for Sitka spruce, and the FR relationship for radiata pine are also significant, especially at very high humidities. This mismatch between radiata pine and the USDA data has important implications. It means that errors are induced when tabulated MC values are used to determine experimental and process targets. An MC study currently being undertaken at the University of Canterbury should lend some clarity to this situation for users of radiata pine.

The primary factor that determines MC is relative humidity; however, temperature, mechanical stress, density, and chemical composition also influence it. The MC is also

affected by the drying history of the piece. High-temperature drying, as well as ACT drying, causes chemical changes within the wood that significantly alter its moisture sorption behaviour. The direction from which ‘equilibrium’ is approached is also important. The phenomenon of sorption hysteresis is based on the observation that wood achieves a higher MC in desorption (losing moisture) than it does in adsorption (gaining moisture). In addition, timber that has never been dried, exhibits a higher moisture content in desorption than timber that has been dried and re-wetted.

The moisture content achieved under a given set of humidity and temperature conditions has traditionally been treated as species independent. Certainly the widespread application of the limited available data to essentially all species and processes has been done under this assumption. In reality this is not the case. Variation in wood chemistry and structure will result in considerable differences between published MC results and actual values. If accurate predictions are necessary, then actual MC data for the specific material in question, under similar environmental conditions, are needed.

Temperature is known to have a significant influence on MC. Increasing the temperature generally reduces the MC. However, this reduction is not uniform across the humidity or temperature range. This represents a serious limitation in our understanding, which in turn restricts our ability to advance the science and practice of drying wood.

Unfortunately, the harsh experimental conditions encountered in collecting MC data that are relevant to the drying environment have thus far prevented adequate study. The hot environments dictate that very robust equipment and techniques be used. Experimental data on the MC behaviour of wood at

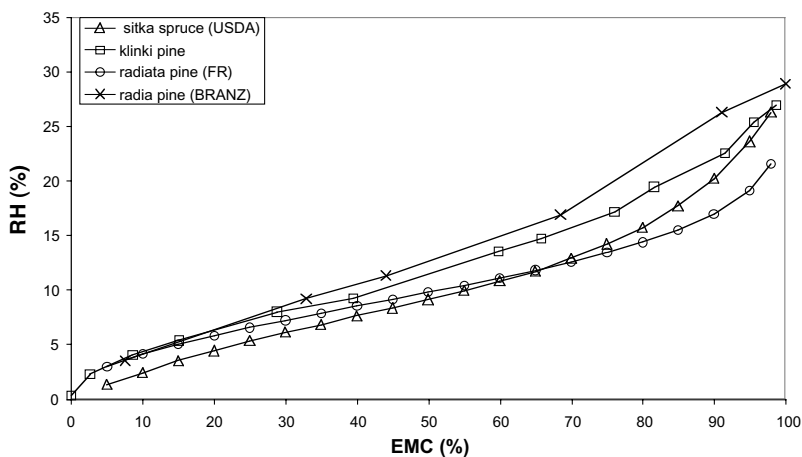


Figure 1: Moisture content as a function of relative humidity from several data sources.

temperatures above 100°C are, therefore, very scarce. As a part of our PGSF-funded research into the basic wood science of the drying process, Forest Research is committed to further study of the wood-water relationship at high temperatures.

Any characterisation of wood-water relations must be built upon accurate measurements of the moisture level in the test environment. The measurement of relative humidity in hot, moist environments is a point where limitations in the available technology currently restrict the range of conditions at which the wood-moisture relationship and other material properties can be evaluated. International options for off-the-shelf solutions to this dilemma have been exhausted. Forest Research is currently developing humidity sensing technology in-house to suit this purpose. Hamish Pearson is leading this effort.

8TH INTERNATIONAL IUFRO WOOD DRYING CONFERENCE **Transylvania University of Brasov, Romania, 24–29 August 2003**

Nawshad Haque

The International Union of Forestry Research Organisations (IUFRO) organises the “International Wood Drying Conference” every 2 years in a different location. The gathering is the most prestigious meeting in this field of research. This year the 8th conference was held in Romania, organised by the Faculty of Wood Industry, Transylvanian University of Brasov. A gathering of 116 scientists from 28 countries attended the conference. The aim is to provide a forum for international researchers to exchange information on wood drying research programmes, covering fundamentals of wood-water relationships, drying methods, and serviceability of wood as a result of drying operations.

There were two keynote addresses: “The Role of Wood Anatomy in the Drying of Wood: Great Oaks from Little Acorns Grow” by Patrick Perre (France) And “High Frequency Heating Combined with Vacuum Drying of Wood” by Helmut Resch (Austria). These were an excellent start to the technical programme of over 50 oral presentations and 28 posters. Sessions covered Drying Modelling, Stress and Strain Behaviour, Properties of Wood Related to Drying, Fast Drying Procedures, Heat and Mass Transfer, Kiln Control, Drying Quality, Wood and Coloration During Drying.

MULTICLIENT DRYING RESEARCH GROUP REPORTS AVAILABLE

The latest reports and presentations from the December meeting are now available on the Forest Research web page. Members will need their username and password for access. Reports are available on cooling timber stacks for steaming, stack weights, and vent heat exchangers.

For further information about the Forest Research Multiclient Drying Research Group, contact Steve Riley or Ian Simpson at Forest Research.

The main focus was on optimisation of the drying process, through schedule development, lumber sorting, high-frequency vacuum drying (both radio-frequency and microwave), and drying emission.

A general consensus was that future drying technology will move towards fast continuous single-board processes, and should minimise manual lumber handling.

The conference was complemented by an in-conference industry tour, involving visits to two large manufacturers dealing respectively with sliced veneers and steamed and unsteamed beech timber exported to other European countries.

Forest Research was represented by:

- Steve Riley: “*Liquid Condensate Emissions from Kilns Drying Radiata Pine.*”
- Nawshad Haque: “*Mathematical Modelling of Solar Kilns for Drying Hardwood Timber.*”

The Conference Proceedings are available as pdf-files on the conference website:

<http://webe.unitbv.ro/il/iufro2003modific/postiufro.htm>
or by contacting Dr. Mihaela Campean at the Transylvania University of Brasov, Romania.
Email: campean@unitbv.ro
Fax: 0040 268 419581.

HOW OFTEN SHOULD FANS BE REVERSED?

Nawshad Haque and Steve Riley

How often to reverse fans during drying is a question that is frequently asked. The answer involves many complex factors and, in practice, the frequency and the length of the period between reversals are generally determined from trial and error. In the US, most mills reverse their fan directions every 3 hours, although occasionally a 2- and 4-hour reversal may be found. Some mills reverse only once, two-thirds or so through the schedule. In New Zealand, conventionally, the airflow is reversed every 4 hours to dry radiata pine timber using the high-temperature drying schedule of 120°/70°C.

At least three reversals during the HT drying period were recommended by Forest Research in their publication *FRI Bulletin No.206*. Recently the policy of reversing every 2 hours or even every hour has been employed in newly designed kilns. There are also claims that high frequency of reversals has a beneficial effect on stress in the timber.

This issue will not be laid to rest easily, but we can offer some useful insights from our drying modelling work. Extreme care must be used in the interpretation of the results of mathematical models, but with many variables interacting, the ability to hold specific variables constant and compare effects offers a way to progress. The *Forest Research Kiln Model* which

simulates the drying of complete stacks, was used to compare three schedules, drying identical 2.4-m stacks of 40-mm-thick material where the average initial green moisture content of each board was 150% (oven-dry basis), and the basic density was 450 kg/m³. Simulation results are shown in Table 1.

Concentrating solely on drying time and final MC variation, which are the principal factors in a volume driven industry, we can see that reversal interval affects both of them. Since drying time changes, it is more appropriate to consider the number of reversals. Thus Figures 1 and 2 show drying time and MC standard deviation plotted with respect to number of reversals.

These Figures show that generally large numbers of reversals (low reversal period) tend to increase drying time, but the effect on MC variability is not so simple. As the number of reversals is decreased there is a slight minimum in standard deviation, then a dramatic rise at around two reversals, followed in some cases by dramatic decrease at one reversal. The minimum at one reversal is highly dependent on picking the precise (optimum) reversal period. This precise reversal period will be highly dependent on an exact air velocity, actual DB and WB, actual MC distribution, stack width, etc. As well, this minimum

Table 1 – Effect of fan reversal intervals on the drying time and moisture content variation for 100 × 40-mm boards, air velocity 8 m/s, target final average MC 12%.

Drying schedule DB/WB (°C)	Reversal interval (hour)	Drying time (hours)	MC standard deviation (%)	MC maximum (%)	MC minimum (%)	MC range (%)
90/60	1	20.7	1.7	14.5	8.4	6.1
	2	19.8	1.5	15.0	9.3	5.7
	3	19.1	1.5	14.1	8.8	5.3
	4	18.9	1.6	15.6	8.9	6.7
	5	18.7	1.8	16.8	8.9	8.0
	6	17.0	2.6	17.8	5.5	12.2
120/70	1	12.1	1.8	14.5	8.5	6.0
	2	11.6	1.9	15.1	8.0	7.1
	3	11.3	2.0	15.4	7.5	7.8
	4	9.7	5.0	19.5	4.9	14.6
	5	9.3	4.1	17.6	5.9	11.7
	6	9.8	3.1	16.1	6.1	9.9
140/90	1	10.2	2.1	15.6	8.2	7.4
	2	9.7	1.9	14.6	8.3	6.2
	3	9.0	3.1	15.7	3.5	12.2
	4	7.7	4.2	18.1	6.1	12.0
	5	8.3	2.9	15.7	6.4	9.3
	6	8.9	1.9	14.4	8.3	6.2

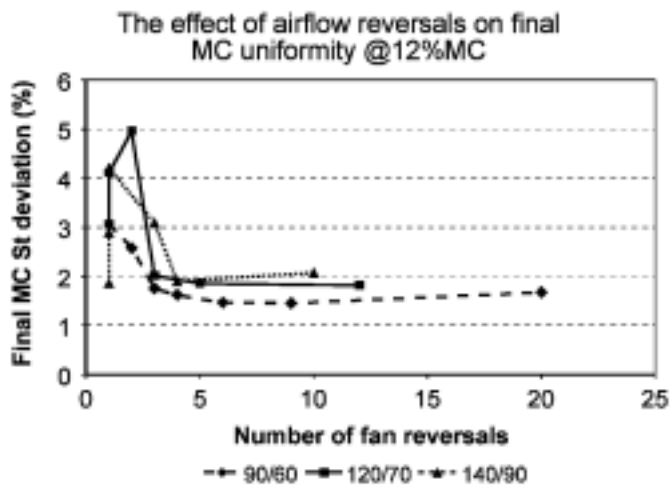


Figure 1: Effect of fan reversal on final MC variation for three schedules (2.4-m-wide stack, air velocity 8 m/s, 100 × 40-mm boards).

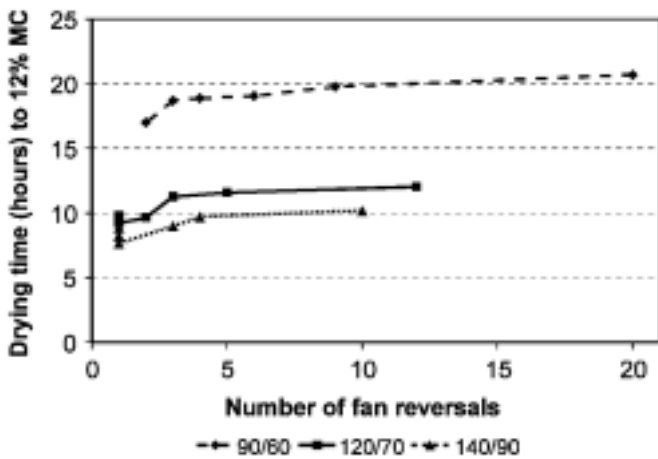


Figure 2: Effect of fan reversal on drying time for three schedules (2.4-m-wide stack, air velocity 8 m/s, 100 × 40-mm boards).

standard deviation is accompanied by an increase in drying time with respect to the minimum seen at three to four reversal changes. Thus, this result tends to confirm the empirical rule of thumb proposed by FR since the 1980s, that it is best to have at least three reversals during the drying time. It also illustrates, with two minima in MC variation, why past empirical results have been difficult to interpret.

The issue of stress being affected by multiple changes to local stack humidity during reversals will need to be left until our work on the mechano-sorptive effects is completed.

The effect of fan reversal on drying time and MC is a complex issue, and this study has modelled only regular reversal intervals; however, it has provided some insight on the issue. The main conclusions at this stage, considering only drying duration and MC variation, are:

- Fan reversal intervals and number of reversals have a significant effect on drying time and mc uniformity.
- The Forest Research ‘rule of thumb’, that there should be at least three fan reversals during the drying schedule, has been confirmed.
- There was no positive effect of adding fan reversals beyond the recommended three.
- For some charges a single fan reversal applied at the optimum MC will be adequate, but finding this optimum point for any charge is not a practical option for the operator.

For more information on this modelling of drying, contact the authors at Forest Research.

PRESERVATIVE-TREATED WOOD H1.1, H1.2, “H1 PLUS”, H3.1, H3.2 CONFUSED? WHAT DOES IT ALL MEAN?

Mick Hedley

The “H1 Plus” concept has been around for a while. It was originally promoted by manufacturers of EIFS (Exterior Insulated and Finish Systems), of which “chilly bin” construction is an example. It was intended to be a treatment which gave better protection against decay than untreated material, but it would remain outside the scope of the timber preservation standard (NZS 3640). Its purpose was to provide temporary protection to the timber should it get wet enough to decay if a building leaked. This protection was intended to last only until such time as leaks were detected and permanently rectified. The level of protection was considered sufficient to prevent any structural damage to the timber through decay, so that the framing would not need replacing if leaks eventuated. It was not intended to be a treatment to protect framing over the entire 50-year life of a building should it remain damp over much of that time period.

For various good reasons it was impractical to exclude this treatment from the wood preservation standard, mainly because of the difficulties this would pose in developing an enforceable specification and in implementing a quality assurance system for the product. If it remained outside the scope of the standard or not covered by the NZ Timber Preservation Council’s Woodmark® Quality Assurance Scheme, then it would also create difficulties for other standards (e.g., NZS 3602 which calls up NZS 3640) and the Building Code, which also calls up NZS 3640 as a reference for preservative treatment required for building timbers.

So in the recent revision, in order to accommodate these treatments within the standard it was necessary to split the H1 Hazard Class into two sub-classes — H1.1 and H1.2.

H1.1 and H1.2

H1.1 is essentially the same as the previous H1 Hazard Class — purely insecticidal treatment for timber which could be guaranteed to remain dry, or

for that which is not structural and requires a minimum life of only 5 years, such as interior trim.

H1.2 is for timber which may be subjected to occasional wetting which will result in the risk of wood moisture contents conducive to decay. Approved preservatives and retentions are those which to date have proved effective in recent accelerated decay resistance trials using model framing units established at Forest Research (*see* Wood Processing Newsletter No. 30).

H3.1 and H3.2

Within all Hazard Classes from H1 to H6, H3 caters for the widest variety of commodities and preservative types. Critically, it includes materials, such as weatherboards, fascia, and exterior joinery (i.e., products which are normally painted in use) which require a minimum of 15 years’ service life, and those such as exposed joists which require a minimum of 50 years’ durability and which are not normally painted in use. After much debate in Standards NZ Committee meetings, it was concluded that LOSP treatments, which have become increasingly popular for all H3 treatments, were unlikely to guarantee 50 years’ durability. Much of the argument which led to this conclusion was the fact that LOSP were never intended to be used for the treatment of structural, largely unpainted, members of a building and there is no long-term history of satisfactory performance when used in those situations.

The outcome was a division of H3 into two sub-classes:

- H3.1 which includes those materials requiring a minimum of 15 years’ durability
- H3.2 which includes those materials requiring a minimum of 50 years’ durability
- H3.2 is limited to waterborne preservatives CCA, Copper Azole, and Alkaline Copper Quaternary, whereas LOSP preservatives TBTO and TBTN may be used for H3.1

Identification of Treatment

The Standard requires all timber above a minimum cross-sectional size to be branded to identify the Hazard Class to which it has been treated, to identify the plant which undertook the treatment, and now a number to identify the preservative used for the treatment. The commonest (and simplest) form of branding is burn branding the ends of each stick of wood at the plant immediately prior to treatment. An alternative method is strip branding one face of the stick with ink or incising rollers at the planer head. Again, this is done immediately prior to treatment.

There are two problems associated with such branding of framing timber:

- (1) Ends are almost invariably docked or hidden when house frames are constructed, either at a frame and truss manufacturer's yard, or on site, so that it is nigh impossible to use end branding to identify the treatment once the frame is completed.
- (2) These days a great deal of framing timber is treated under contract at plants remote from the manufacturing source. Producers are rightly loathe to strip brand at the manufacturing stage since there is the distinct possibility that the

branded timber will be diverted to structural uses before it receives treatment. The brand could therefore identify treatment which the timber hasn't actually received. Strip branding at the treatment plant immediately prior to treatment is impractical and would be prohibitively costly.

Colour Coding

A solution to the treatment identification problem is colour coding to identify the preservative and level of treatment. So in addition to end branding, and after some consideration, all interested parties (manufacturers, treaters, BIA and SNZ) agreed to the following scheme:

- H1.1 (boron and LOSP (Permethrin)): No additional colouring
- H1.2 (LOSP TBTO, TBTN, IPBC): Blue
- H1.2 (boron): Pink/red
- H3.1 (TBTO, TBTN): no additional colouring if strip branded, green if not. The green colour is to be distinctly different to the green colour imparted to wood when treated with any of the H3.2 treatments (CCA, Copper Azole, Alkaline Copper Quaternary).

CHEMICAL IMPREGNABILITY OF WOOD CELL WALL IS RELATED TO ITS NANO ARCHITECTURE

Adya Singh, Ralf Möller, Bernard Dawson, and Robert Franich

Proper evaluation of fibre-based products requires a thorough knowledge of the organisation of wood cell walls at various levels, including their submicroscopic structure. Advances in technologies based on chemical impregnation of wood or fibre cell walls will benefit from a better understanding of the extent of chemical impregnation and the pattern of chemical distribution in cell walls. While it is common knowledge that molecular size of impregnating chemicals and cell wall porosity are the two most important factors which determine the amount of chemical uptake by cell walls, little is known about how chemical molecules are distributed within cell walls — i.e., whether they are distributed uniformly or in a patterned way.

Recent studies by our group using electron microscopy suggest that, at least within the S2 layer, which comprises the bulk of wood and fibre cell walls, impregnated chemicals are not likely to be distributed uniformly. This view is based on our

observations showing nano-level inhomogeneity in the distribution of lignin in the S2 layer of radiata pine and of spruce wood cell walls. Some parts of the S2 layer have greater concentration of lignin than others, resulting in a radial texture across this layer. This implies that delignification of cell walls, such as in kraft fibres, would result in a cell wall texture of variable porosity.

Here we show by electron micrographs that there is a close correspondence between the pattern of distribution of silica in the S2 layer of radiata pine kraft fibres, which had been impregnated with sodium silicate using a novel impregnation method to enhance their stiffness, and that of the nano-level inhomogeneity in lignin distribution in this layer of radiata pine tracheids.

The tracheid wall from sound radiata pine appears to be striated across the S2 layer (indicated by sinuous lines in Figure 1). This is because of the presence of

nano-level inhomogeneity in lignin distribution in a sinuous radial profile (indicated by arrowheads in the higher magnification micrograph in Figure 2). The ultrathin sections used to produce the illustrations in Figures 1 and 2 were stained with potassium permanganate, an agent which has been widely used to enhance the contrast of lignin in wood cell walls in electron microscopy preparations. Thus, darker cell wall regions correspond to those areas which have greater lignin concentration than the lighter regions.

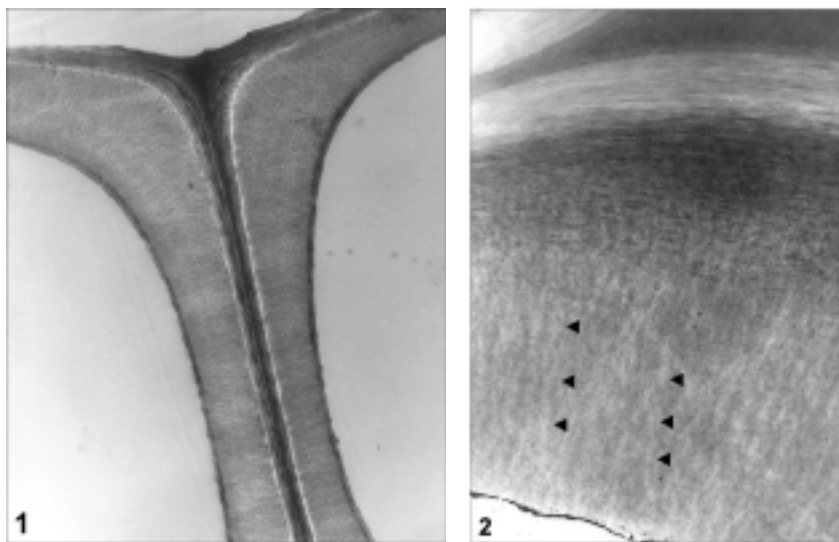


Figure 1: Transverse section through part of a double wall between adjoining tracheids in sound radiata pine wood. The S2 layer has a striated appearance (dark, sinuous lines). Transmission electron micrograph.

Figure 2: Transverse section through part of a tracheid wall in mild radiata pine compression wood. The distribution of lignin in the S2 layer is inhomogeneous, in a sinuous radial pattern (arrowheads). Transmission electron micrograph.

The prominent silica profiles in the wall of a silica-impregnated radiata pine kraft fibre (shown in Figure 3) mirror the orientation of radial striations. We think that fibre wall regions with greater silica concentration correspond to regions of the tracheid

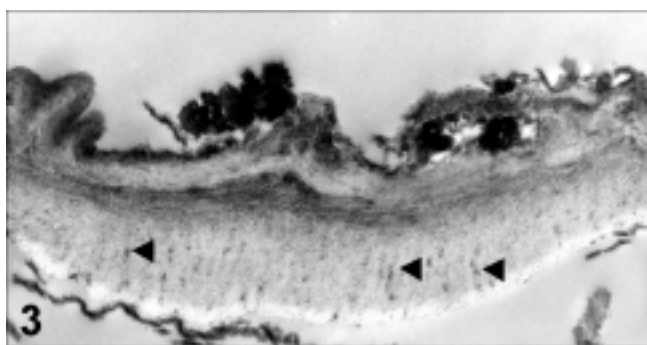


Figure 3: Transverse section through part of a radiata pine kraft fibre which had been impregnated with silica. Note the radial pattern of silica distribution (dark material indicated by arrowheads), corresponding to the pattern of lignin distribution shown in Figure 2. Transmission electron micrograph.

wall showing greater lignin concentration. This is because lignin removal from the cell wall during kraft pulping would have altered cell wall porosity. Thus the regions with greater lignin concentration become more porous than those with lower lignin concentration, allowing greater silica impregnation in the more porous regions of the fibre wall.

The pattern of silica distribution within the wall of a kraft fibre supports our cell wall model (Figure 4)

based on nano-level inhomogeneity in the S2 layer of wood cell walls. This model predicts that microfibrils in the S2 layer are tightly grouped to form bundles, and that bundles are distributed randomly across this layer, resulting in sinuous profiles of microfibril groupings. Because of the close juxtaposition of microfibrils, cell wall porosity within the bundle is more restrictive than elsewhere. This is the likely basis for the presence of nano-level inhomogeneity in the distribution of lignin in the S2 layer.

The observations presented provide a good example of the influence cell wall architecture may have on the extent and

pattern of chemical impregnation into wood and fibre cell walls, and emphasise the need for a greater understanding of cell wall architecture in order to achieve the desired gains in performance and quality of wood-based products.

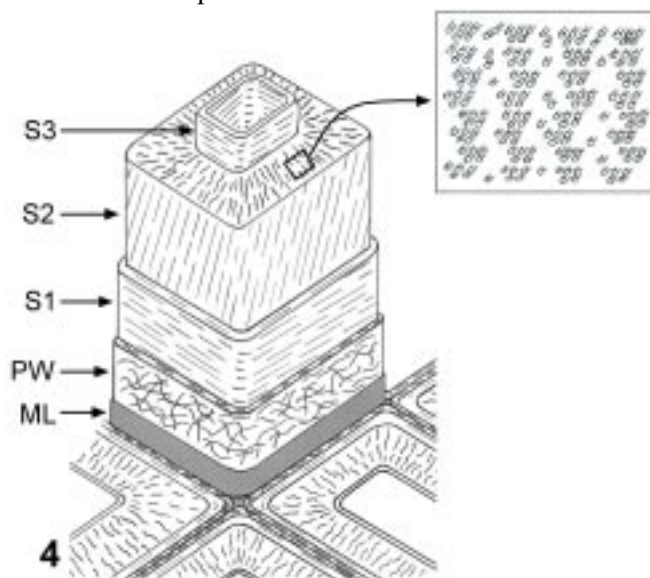


Figure 4: A diagram (modified from Fengel and Wegener) of cell wall organisation in conifer woods. ML, middle lamella; PW, primary wall; S1, S2, S3, secondary wall layers. The boxed region of the S2 layer is enlarged (curved arrow) to show the predicted pattern of distribution of microfibril bundles (sinuous, radial profiles).

CONFOCAL MICROSCOPE A USEFUL TOOL FOR EXAMINING THE WOOD-COATING INTERFACE

Adya Singh, Bernard Dawson, and Jacqueline Bond

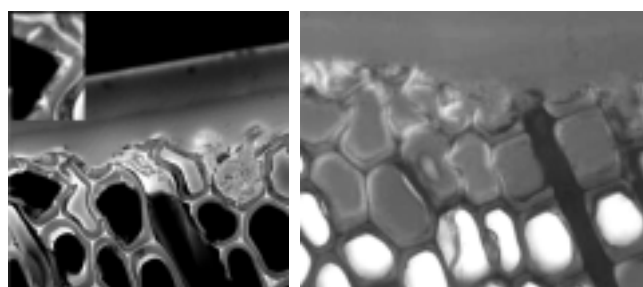
Polymers applied to wood surfaces to enhance the service-performance of wood are known as protective coatings. They come in various chemical formulations, and are oil-, solvent-, or water-based. Some are opaque to light, such as paints, and are generally used in outdoor applications. As they prevent solar radiation from reaching the wood surface, protection of wood is long lasting. Semi-transparent coatings, such as stains, are less viscous and thus easier to apply, and can be used in both indoor and outdoor applications, but they have a shorter life span than paints. Coatings that allow much light or solar radiation to get through to underlying wood surfaces are referred to as clear or transparent coatings. Understandably, clear coatings have only interior applications. However, they have the potential to be used in outdoor applications or those indoor parts of buildings which are continually exposed to solar radiation.

At Forest Research we are presently developing technology to widen the scope of clear coatings to extend their application in exterior situations. Photostabilisation of wood surface is the first step in the process. Then various clear coatings are used to create a wood-polymer composite surface. Our interest stems from the fact that wood surfaces are clearly visible through such coatings, exposing the natural beauty of wood grains. We are using a range of microscopy techniques to monitor the durability of these new, high performance, wood-polymer composite products, in addition to gaining fundamental knowledge of why clear coatings have a much shorter life in outdoor applications than do paints or stains.

Understanding wood-coating interaction is the key to success in developing these high-value products. Confocal microscopy is proving to be a very valuable tool in this work, having distinct advantages over conventional light microscopy, particularly in visualising the interface where the coating attaches to the wood. Good coating adhesion to wood is one of the most important factors affecting coating performance.

A comparison of the two illustrations provided shows that confocal imaging (left) is clearly superior to the light microscope image (right) because (1) confocal imaging enables the coating and underlying wood tissues to be visualised in the same focal plane, (2) the greater resolution of the confocal microscope enables the fine features to be clearly resolved. The confocal

image (left side) provides evidence of coating penetration into the cell lumen and also cracks within the cell walls (inset) in the surface layer of wood (wood cell walls are grey and the penetrating coating is a much paler grey). Under the actual microscope the coating appears crimson and wood cell walls purple. In the insert, the fine cracks in the cell wall penetrated by the coating (pale grey) are more easily seen. In comparison, the presence of coating only in the cell lumen can be resolved in the light micrograph (right side) — coating appears grey (actual colour bright red) and unfilled lumen white. Based on these high definition images we are able to conclude that the applied clear coating (a varnish) is in close contact with wood structures, penetrating cell wall cracks in the outer layer produced during surface preparation.



Left: Confocal image with enlarged insert showing penetration of coating into wood cell walls. Right: Conventional light micrograph.

Sample Preparation and Viewing

Light microscopy

The radiata pine wood-polymer composite was sectioned at a thickness of about 60 μm with a sliding microtome. A combination of two different stains was used to stain wood and the clear coating. Aqueous Toluidine blue stained the wood (bluish green) and Sudan IV stained the coating (bright red). The stained sections were observed with a conventional light microscope.

Confocal microscopy

Sliding microtome sections cut at the same thickness as for light microscopy were examined unstained and after staining with Toluidine blue and Sudan IV. They were imaged with a Leica TCS/NT confocal laser scanning microscope. Confocal images were acquired using an argon/krypton laser, excitation wavelengths of 488, 568 and 647 nm and a 16x multi immersion lens with a numerical aperture of 0.5. Selected regions were zoomed to about 3 times. Images were collected at 600 and 665 nm.