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The New Zealand Pine User Guide is produced by the New Zealand Pine Remanufacturers’ Association, in co-operation with: the NZ Forest Research Institute, the NZ Ministry of Forestry, the NZ Forest Industries Council, the NZ Trade Development Board and the NZ Forest Owners Association. © 1996

Based on the hugely successful New Zealand Radiata Pine User Manual, first published in 1992, the new edition includes:

- updates of all original technical chapters,
- new performance tables, graphs and charts,
- new sections to cater for the increasing diversity of application,
- full-colour photography throughout,
- a new, more user-friendly design.

Our scientists, technicians and forest industry professionals have over the past 60 years accumulated more in-depth knowledge of New Zealand pine (Pinus radiata) than any other country. Many of those experts have contributed directly to this publication.

We are confident, therefore, that whether you are a regular or first-time user, this guide will add significantly to the value you derive from the product.

An estimated 200,000 people read the first edition – many in conjunction with trade promotions and in-market technical seminars and workshops conducted by New Zealand pine exporters.
Comments received and closer observation of the special needs and conditions of markets throughout the Asia-Pacific region have been taken into account in compiling the second edition.

In a world where many traditional sources of industrial wood have been depleted or are declining, New Zealand is gaining international recognition as a supplier of a sustainable and expanding resource of high quality wood.

New Zealand pine is, increasingly, the natural choice for buyers in Pacific Rim countries looking for an alternative species offering versatility of application and quality performance.

**Special Features**

**It Is Natural** – New Zealand pine solidwood products are created by selective sawing and processing, with low manufacturing energy inputs. The result is a natural wood product from a renewable resource.

**It Is Sustainable** – The planted forests of New Zealand are expanding and maturing at a rate which provides an increasing volume of plantation pine for the future. Extensive new plantings are increasing the overall yield and providing security of supply.

**It Is Advanced** – A well established process of genetic improvement and advanced forest management expertise produces a wood resource with superior yield and consistent characteristics.

**It Is Strong** – The strength of New Zealand pine compares favourably with most traditional construction lumber. Tailored cutting patterns ensure that the high-strength wood fibre near the outside of the log is sawn for strength applications.

*continued overleaf*
It Is Adaptable – For appearance and interior applications, New Zealand pine is kiln dried to produce stable and long-lasting products. Preservative treatment ensures longevity across an impressive range of external applications.

It Is Versatile – New Zealand pine is excellent for an impressive range of structural and appearance applications – from clearwood components for the furniture industry to housing products and highly engineered structures.

The Future Solution

Market trends toward the use of more composite products in engineered applications, the ‘additions and alterations’ business, hardwood substitution and in direct sales to consumers all signal excellent potential for New Zealand pine.

In keeping with those more complex uses is the need for good and clear communication between manufacturer, distributor and customer to ensure the performance characteristics and wood properties of the product are used to best advantage.

The New Zealand Pine User Guide has been designed to assist with this communication.

International Standards

To ensure full benefit is gained in importing countries, it is important that the wood is processed efficiently and used correctly. Wherever possible, we have shown where New Zealand pine products comply with international standards and, more particularly, how it can be processed. We have been greatly assisted in that respect by the scientists and staff of the New Zealand Forest Research Institute and the New Zealand Ministry of Forestry. Both agencies have enjoyed a long association with universities, government laboratories and industrial companies worldwide. They also have direct experience of wood industries in many countries.

Further Information

For further information on products, processes and technology referred to in this publication, we offer the following recommended points of contact:

Commercial Enquiries

Nearest regional office of the New Zealand Trade Development Board:
- Tokyo – Japan, Korea & China
- Singapore – Asean countries, Taiwan and Vietnam
- Los Angeles – North America & Mexico
- Santiago – South America
- Hamburg – Europe
- Sydney – Australia
- Wellington – New Zealand

Technical Enquiries

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Private Bag 3020, Rotorua, New Zealand
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Phone: +64-7-347 5899

The Ministry of Forestry
Forestry Development Group
PO Box 1340, Rotorua, New Zealand
Fax: +64-7-347 7173
Phone: +64-7-348 0089

Remanufacturing Enquiries

NZ Pine Remanufacturers’ Association
PO Box 256, Motueka, New Zealand
Fax: +64-3-528 6220
Phone: +64-3-528 6006

Further Information

For further information on products, processes and technology referred to in this publication, we offer the following recommended points of contact:
Management methods are continually being improved to ensure a reliable supply of high-quality raw material for the full range of wood users.

**Sustainable Plantation Forestry**

New Zealand soils and climate are well suited to forest growth, and much of the country was originally covered in natural forest. Until about 1940, wood users were almost entirely dependent on supplies from this natural forest, which now occupies about 24% of the total land area.

Since the mid 1800s trees from around the world had been introduced to provide farm shelter and lumber for local uses. One of these introduced species was New Zealand pine (*Pinus radiata D. Don*) from California which adapted well to local conditions.

Since the 1920s large scale plantings of introduced species have been established for commercial uses and have progressively replaced the harvest from the natural forests, ensuring New Zealand continued to be self sufficient.

The plantation forest area of New Zealand is continuing to expand and is currently about 1.5 million hectares. The dominant species is New Zealand pine, which grows more rapidly than other species in most situations. Natural forests still make up 90% of the forest area in New Zealand, but their future uses will be mainly for soil and water conservation and for recreation. Although the plantation forest area is relatively small by world standards, it will ensure a perpetual supply of raw material for both domestic consumption and export.

Plantation forestry has developed rapidly in New Zealand. In 50 years, the country’s industrial wood supply has changed almost completely from natural forests to managed forest plantations, emphasising New Zealand pine (*Pinus radiata*) as the primary species.
Size, Age, & Distribution

The benefits of plantation forests have been fully established and for the past 30 years growers have created forests specifically for future exports. Sixty % of the plantation area is still under 15 years of age. The forests are widely distributed throughout the country, with nearly 40% (by area) in the central North Island.

Emphasis has been on concentrations of forest to sustain industries based on exports. Ownership of the current 1.5 million hectares of forests is mainly with large companies. Smaller plantations are owned by individuals, syndicated investment groups, trusts and regional government organisations. As much as 75% of all new planting over recent years has been undertaken by non-corporate organisations.

Present & Future Production

The present uneven age distribution and rate of new annual planting ensure expanding production for the foreseeable future. Projections indicate that the annual harvest may reach 25 million m³ by about the year 2005 and as much as 60 million m³ by 2025 if current new planting levels of 70,000 hectares per year continue. New Zealand’s domestic demand is constant so much of this extra volume will be available for export in one form or another.

Forest Management

New Zealand forestry companies have not relied entirely on the climatic conditions to ensure good yields of high quality logs and lumber. They have also applied tree breeding methods and intensive silvicultural practices to produce uniform stands of high quality logs for domestic use and export.
They are concentrated on the proven species, New Zealand pine and Douglas fir, and are dispersed geographically. Stands are progressively composed of genetically improved seed stock. The growth and form of the trees planted in the 1990s are also substantially improved over those in earlier plantations and those found in their original Californian habitat.

**High Technology Forestry**

New Zealand’s pine plantations are among the most intensively managed in the world, and are capable of yielding large volumes of high-quality logs on rotations of 25-30 years. Quality in the short term is maintained by planting genetically improved seedlings on the most suitable land, normally thinned and pruned to encourage the growth of the best trees. New Zealand pine does not readily shed its branches in plantations, but by removing the limbs from the lower part of the stems at an early age, foresters are able to produce large volumes of “clearwood” or defect-free wood for high-value sawn lumber and veneers.

Standard management methods include pruning (removal of bottom branches) a large percentage of trees to be left to the full notation age (about 30 years) and thinning out unwanted trees. The typical tree resulting from this treatment will be about 35 metres tall at harvest with a tree volume of about 2.5 cubic metres.

Advanced management tools, including computer simulation of forest growth, log quality, and processing options, are used to ensure that the best decisions are made for each plantation. The use of genetic engineering and modern tissue culture techniques is opening up prospects for matching the wood properties of New Zealand pine to the requirements for specific end uses. The forests are continually monitored to ensure that they remain healthy and free from attack by pathogens.

It is now one of the world’s most widely planted plantation species, but there are few places where the species is managed to its greatest potential. New Zealand is one of those places.
A variety of log types available from plantations gives the log buyer the opportunity to specify logs according to requirements.

**Wood Quality**

The quality of plantation-grown trees is influenced by genetic selection, silvicultural practice, site selection and rotation age. Over the last 60 years there have been many changes in forestry practices which have resulted in greater control over the type of wood produced.

New Zealand pine forests are established with genetically selected stock and managed to provide a predictable, premium quality log resource for a wide range of world markets. Ideal growing conditions and appropriate management permit the harvesting of large logs (up to 80 cm diameter) on rotations of approximately 30 years. The logs are typically healthy, containing no decay, internal splits, or growth stresses.

Plantation grown New Zealand pine is sometimes referred to as a ‘sapwood’ tree because of the relatively small proportion of heartwood. At 30 years of age, 80% of the tree volume is sapwood, with a fresh moisture content of about 150%, measured as percentage of “oven dry” wood weight. This results in an average weight of about 1 tonne/m³. If the logs are left too long without protection before processing they are prone to infection from bluestain fungi.

As with other softwoods such as Douglas fir, wood properties of New Zealand pine are influenced by geographic location and tree age. Basic wood density of the mature wood zone is, therefore, variable but averages between 400 and 420 kg/m³ at rotation age.

Within the tree there are defined quality zones which need to be recognised during processing. Juvenile wood (or corewood) is typical of the inner 10 growth rings and it can have an impact on stability. In addition to lower density, juvenile wood has wider growth rings, shorter wood cells, higher longitudinal shrinkage and increased spiral grain. Surrounding the juvenile zone, wood properties are more ‘mature’, i.e. higher wood density, narrower growth rings, and straighter grain.

New Zealand pine does not shed its branches when grown under the regimes of wide initial spacing, early thinning, and the 30 year rotation now common practice in New Zealand. However trees can be artificially pruned and the “knotty core” restricted to a small cylinder, around which defect free ‘clearwood’ is produced.
Pruning is restricted to the butt log with variable heights of between 4 and 8 metres.

**Impact on Wood Utilisation**

Adaptability of New Zealand pine to varying site and management regimes results in the production of a range of log types. Grades based on quality characteristics are used in New Zealand to allow buyers to specify the preferred quality. The key to the appropriate use of these logs is to recognise associated quality variations and to match them to the intended process and product.

Log quality is a function of size (diameter, length) shape (straightness, ovality, taper), and other external (branching) and internal (wood properties) features which can affect the suitability for a particular end use.

The wood of New Zealand pine has medium density, even texture, and average shrinkage for softwoods. The logs yield the full range of lumber grades from long-length clearwood to industrial grades. The strongest, most stable wood for structural uses is derived from the outer region of the log, while lumber from the juvenile zone is suited to packaging and similar products.

Contrary to popular belief, the wide growth rings typical of managed plantations of New Zealand pine are not a reflection of poor wood quality. Correctly graded, New Zealand pine conforms to grade requirements for structural lumber worldwide.

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**Some Log Types**

<table>
<thead>
<tr>
<th>Process &amp; Product Options</th>
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<tbody>
<tr>
<td><strong>Pruned Peellers</strong></td>
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<tr>
<td><strong>Industrial Peellers</strong></td>
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<tr>
<td><strong>Pruned Sawlogs</strong></td>
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<td><strong>Small Branch Sawlogs (S)</strong></td>
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<tr>
<td><strong>Large Branch Sawlogs (L)</strong></td>
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<td><strong>Posts and Poles</strong></td>
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<td><strong>Residual Logs</strong></td>
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</tbody>
</table>

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**Extensive research and experience in plantation forestry has provided a good understanding of how New Zealand pine log quality can be influenced by genetic selection, silviculture and the method of conversion.**
**Conversion**

Diameter and shape (sweep, taper, ovality) do not usually limit the kinds of processing systems which can be used. Sawing of logs is the most common processing method used. Peeling and slicing and the manufacture of a range of reconstituted wood products are increasing in importance.

Excellent results have been obtained with bandsaws, circular saws, frame saws and chipper canters in all the common sawmill configurations. New Zealand pine is similar to other medium-density softwoods in that more saw tooth side clearance is required than for hardwoods. A good surface finish can be achieved with appropriate feed speeds and sharp saws.

The full range of breakdown methods can be used with New Zealand pine and the conversion levels achieved are dependent on the log and product mix and the mill efficiency level. Cutting patterns are selected according to the machinery available, the log size and quality, and the products required.

**Conversion Patterns**

Most traditional conversion patterns can be used with New Zealand pine, provided the quality zones are recognised

**Grade sawing** – commonly applied to high-value pruned logs. Boards are removed around the log to maximise the recovery of high-value clearwood

**Cant sawing** – commonly used to segregate the wood quality zones in unpruned logs. The juvenile wood zone is isolated in the inner boards. Suitable for small and medium-size logs

**Live sawing** – used where only basic equipment is available or when wide boards are needed. This pattern allows recovery of some quarter-sawn boards

**Peeling** – standard method for plywood and LVL production, used on pruned and industrial peeler grades.

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**Log Quality & Conversion**

**Outerwood & Corewood In New Zealand Pine**

<table>
<thead>
<tr>
<th>Mature wood</th>
<th>Juvenile wood</th>
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<tr>
<td>Properties:</td>
<td>Properties:</td>
</tr>
<tr>
<td>– mainly sapwood</td>
<td>– mainly heartwood</td>
</tr>
<tr>
<td>– higher density</td>
<td>– lower density</td>
</tr>
<tr>
<td>– more stable</td>
<td>– less stable</td>
</tr>
<tr>
<td>– fewer knots</td>
<td>– many small intergrown knots</td>
</tr>
<tr>
<td>– narrower growth rings</td>
<td>– wider growth rings around pith</td>
</tr>
</tbody>
</table>

Uses:

– high quality structural
– clear lengths for furniture
– decorative boards
– preservative treated lumber

– industrial packaging
– decorative boards
– formwork
– knotty furniture
– low strength structural
– reconstituted products
Logs are generally sound, with no decay, heartshake, or insect attack. The wood saws easily, and high lumber recovery can be achieved, dependent primarily on saw pattern, log diameter and shape.

Freshly sawn lumber is prone to bluestain and should be treated with a stain control chemical directly after sawing, unless immediate kiln drying is intended. This is very important in warm and humid climates.

Sawn lumber dries easily and can be kiln dried rapidly from green. The wood can be readily treated with preservative to comply with all durability levels.

**Lumber Grades**

Through good silvicultural management, New Zealand pine logs come in a range of qualities capable of yielding lumber grades to meet almost any requirement.

**Appearance grades (board grades):** for finishing and furniture uses can be either clear of knots or contain minor blemishes and tight knots. They include:

- **Clear lumber** free of knots and blemishes, used for high quality joinery, furniture and mouldings.

New Zealand pine is a light coloured, medium density softwood with a moderately even texture that produces sawn lumber with excellent working properties.
Lumber & Grades

Visual grading of random width lumber

Cuttings grades for reprocessing to produce shorter clear lengths with excellent machining, and gluing properties. These grades contain large knots and blemishes which are removed by cross-cutting and ripping. The resulting clear components are often finger-jointed and edge-glued to produce mouldings and furniture.

Structural grades (framing grades): used primarily for construction where strength and stiffness are important. The main factor influencing a structural grade is the size and location of knots. Grades limit such defects to meet specified strength requirements.

Industrial grades: used in packaging for various products such as pallets, cable drums, and concrete formwork. Grades contain a range of knot sizes compatible with the final use.

New Zealand exporters are able to grade to most customer requirements, however, common export grades include:

- Australia – Standards Association of Australia F5 and F7 structural grades (visual and machine stress graded)
- United States – Western Wood Products Association random width lumber specifications including mouldings and better, shop and factory grades.
- Japan – JAS structural grade specifications (which also include glue-laminated and plywood grades). Industrial grades are also produced including thinboard and a range of other grades to buyer specifications.

Grading Methods

There are two commonly used grading methods available in New Zealand.

Visual grading: where the incidence of visible characteristics is visually assessed by a trained grader. This method is used for appearance, structural and industrial grades and is the most commonly used.

Characteristics present in New Zealand pine and which may be specified in visual grades, include: knots, bark and resin pockets, resin streaks, pith and associated juvenile wood zone, needle fleck (birds eye), grain deviation and bluestain.

Knots are the major characteristic encountered in New Zealand pine which affect quality and grade. The type, position, and condition of knots permitted varies considerably between grades. In long-length appearance grades, encased knots (surrounded by bark) are more severely limited than intergrown ones. In strength grades, the type of knot is largely irrelevant. It is the size and position of the knot or group of knots (coupled with wood density) that influences strength through the combined effect of the knot and associated grain deviation.

Machine stress grading: where the lumber is passed through a machine which measures its bending stiffness and assigns a grade on the basis of predetermined relationships between strength and stiffness. This method is used for structural grades, is more precise than visual grading, and therefore very reliable.

New Zealand pine may be graded to any grading rules, but those which recognise its particular characteristics are generally the most effective. Rules which recognise the juvenile and outerwood properties of New Zealand pine, and the improvement in structural properties that occur as distance from the centre of the log increases, are more effective than rules which make distinctions on the basis of growth rate as measured by ring width.

Most countries group species according to their structural properties and assign the same design values to all species in the
group. In Australia, New Zealand pine (known in Australia and some other countries as radiata pine) is grouped with western hemlock, cypress pine, red meranti, loblolly pine, maritime pine and Australian grown Douglas-fir. In Japan, New Zealand pine is grouped with merkuzii pine and those species in the spruce-pine-fir (SPF) classification used in the United States and Canada. In Britain, the strength class assigned to New Zealand pine are closest to those assigned to British grown Corsican pine, Canadian SPF, European redwood/whitewood, and Scots pine.

For decorative uses, New Zealand pine compares well in North America with ponderosa and yellow pines for the moulding and millwork markets.

**Grade Recoveries**

Grades of lumber that can be recovered from New Zealand pine logs are strongly influenced by the log quality. Variables which have most effect are: log diameter, sweep, internode length, branch size, knotty core size (in pruned logs), and wood density.

Branch size and spacing have an important effect on the recovery of visually graded lumber. As the branch size and/or number of branch whorls increases, the recovery of better grades decreases.

For machine stress grading the most important factors affecting recovery are density and increased branch size.

It is useful to include a restriction on juvenile wood – i.e. approximately 10 growth rings from the pith (the growth centre of the log) in higher structural grades. This specific provision recognises that ring width limitations applied to other species are not appropriate to New Zealand pine. Limitations on knots and juvenile wood control 60% of the variation in lumber strength. The remaining variation is controlled by factors such as density and slope of grain, which are difficult to assess visually.

Machine stress grading, which measures stiffness, directly eliminates any concerns about ring width and low density juvenile wood.

**Mechanical Properties**

The mechanical properties of sawn lumber are closely related to knot size and density. Because density increases with increasing distance from the centre of the log, mechanical properties also increase. Ring width generally decreases as distance from the centre of the log increases. Thus, mechanical properties increase as ring width decreases but the effect is primarily due to density. Studies in Japan have shown that wood from forests which have been thinned some time before harvesting can have wide growth rings but good strength and stiffness.

In graded lumber, a ring width limitation has very little effect on the weaker pieces which govern design strength. Studies on structural grades in New Zealand based on lumber graded to Japanese grading rules have shown that if the maximum ring width permitted in the grade is reduced from 20 mm to 6 mm, the recovery of 100x50 mm lumber drops by 50% while the design strength increases by only 10%.
Freshly cut sapwood is particularly vulnerable to attack as its high moisture content (60% to 200%) and available supply of simple nutrients provide an excellent substrate for fungal growth. Wood species vary in susceptibility to fungal attack; New Zealand pine is less susceptible than rubberwood, but more susceptible than Douglas fir.

Chemical or physical control regimes can be used to prevent attack. Chemical control (commonly known as “antisapstain treatment”) involves application of fungicides to the surface of wood. There are two methods of physical control: kiln drying sawn lumber or ponding logs to keep moisture content above a level at which fungi can develop (the same effect can be achieved by sprinkling water on to logs). Kiln drying has the significant advantage that once wood is dry, (provided correct handling practice is observed to prevent re-wetting,) sapstain and other fungal attack is permanently prevented. Ponding logs is a temporary control measure since sapstain will occur if wood is allowed to dry out. Antisapstain fungicides only provide temporary protection.

The choice of treatment depends primarily on market requirements. If a guarantee of sapstain-free wood is demanded, and strict control of the time it takes to get the lumber to the customer cannot be achieved, then kiln drying is the only satisfactory method of control. Chemical control can be very reliable if lumber is delivered to the customer within an appropriate time frame. The maximum period that sapstain can be prevented

Plastic wrapping to protect dry plywood or lumber
depends on a number of factors, such as climate and handling practices, and individual cases may require expert advice at the time. In general for sawn lumber the maximum period that protection can be achieved is 4 months and for logs it is 3 months.

Effective control of sapstain depends not only on correct handling after treatment but on rapid processing before treatment. When conditions for establishment of sapstain are optimal it is necessary to process the logs within 1-3 days. It is critical that anti-sapstain chemical is applied as soon as a fresh log is debarked or when lumber is cut from logs. There is no point in treating wood which is already infected as that will not prevent further fungal growth.

**Fungal Degradation Organisms**

Whilst sapstain is usually the most commonly recognised type of attack there are other types of fungal degrade that it is necessary to control.

- **Sapstain** develops after wind-borne or insect-borne spores have germinated on the wood surface. The developing fungus in the form of fine threads penetrates the entire sapwood. When these threads are in large numbers, they give a blue-black coloration to the wood, most often seen as wedge-shaped bands on the cross-cut ends of logs and sawn lumber. Sapstain has very little effect on strength properties.

**Protection Of Logs**

If logs are to be protected against fungal degrade, they should be peeled and treated against fungal degrade within 1-3 days of the trees being felled. Even with careful anti-sapstain application and log handling, protection is not long-term – generally not more than 3 months. Therefore, it is important to get logs to the sawmill, and to process them, as promptly as possible. This is particularly true for imported logs, which will have been in transit for some time. Further storage should be avoided since any delays could cause a loss of wood quality. After 6 months from felling it is unlikely that any unblemished lumber will be produced.
Mould fungi also penetrate wood but with colourless fungal threads. Masses of coloured spores are produced on the wood surface without discolouring the wood itself. Blue, green, pink, yellow, and black are common colours. The spores can often just be brushed or planed off.

- Decay fungi can be difficult to recognise, but usually appear on sawn lumber as white strand-like or fan-shaped structures. In early stages, decayed wood is often discoloured orange-brown. As decay proceeds there is substantial loss of wood strength and drying becomes increasingly difficult.

Antisapstain treatment

Sawn lumber must be cut from uninfected logs if anti-sapstain treatment is to be successful. Because machined lumber is less absorbent than sawn lumber, concentrations of anti-sapstain treatments must be higher for machined lumber than for sawn lumber.

Most anti-sapstain formulations are used as suspensions or emulsions rather than true solutions. As such, they are prone to settling at the bottom of dip tanks, absorption on to sawdust if this is present in excessive amounts, or on to other contaminating material in baths. It is, therefore, essential that baths be regularly agitated, kept free of extraneous materials, and have excessive sawdust removed at frequent intervals.

Protection time will be reduced during warm, wet, or humid conditions. Under such circumstances, the chemical concentrations should be increased two-fold in order to achieve acceptable protection.

Application Methods

- Sorting-chain dipping
  Sawn lumber passes through a bath containing the chemical immediately before sorting. The advantage of this procedure is that boards pass through the bath singly, so even coverage of chemical on each board is readily achieved.

- Tank dipping
  Sawn lumber is first sorted into packets and the complete packet is immersed in the chemical. The main advantage is that there is no handling of wet boards.

- Spraying
  In the past, spraying systems have not been commonly used because of difficulties in maintaining even coverage of the chemical over the target, settling of suspensions in piping, and clogging due to accumulation of sawdust in piping. New systems with low volume spray applications have been designed to overcome these problems.

Protection of Sawn Lumber

Kiln Drying

If lumber is kiln dried and handled to prevent re-wetting, it can be stored indefinitely without risk of fungal attack. When sapstain-free lumber is demanded and delivery to the customer within 4 months of felling cannot be guaranteed, kiln drying is the only satisfactory method of processing.
New Zealand pine is one of the easiest wood species to dry. With appropriate drying equipment, it can be dried rapidly with little degrade. However, wood from close to the centre of the log (corewood) can tend to twist because of spiral grain. If the wood is correctly dried to, and installed at, the appropriate moisture content for the end use, it will be stable in use.

**Drying Properties**

The properties of New Zealand pine that affect its drying can be summarised as follows.

- The wood is predominantly sapwood of high moisture saturation (moisture content 100-220%, depending on the density), the heartwood having a much lower moisture content (about 40-50%).
- The sapwood is highly permeable and, therefore, capable of drying rapidly. Heartwood, although less permeable, has a lower initial moisture content and drying takes slightly less time than for the sapwood. The high initial moisture content and rapid drying may cause difficulties where drying equipment has insufficient heating, airflow, or venting capacity.
- New Zealand pine is harvested exclusively from plantations, and can vary from about 25 years to 35 years old when felled.
- The wood is of moderate density.
- Wood from within the first 10 rings of growth (juvenile wood or corewood) presents a special warping problem as spiral grain can cause twist.
- High-temperature drying and stack weighting of 500-1000 kg/m² of stack surface, should be used to reduce the distortion of this material.
- As with most species, the sapwood is prone to infection by fungi. Anti-sapstain treatment is essential for short-term protection against stain and mould. The risk of infection by decay fungi during air drying, especially with large-section lumber or round produce, must be minimised. Kiln drying, if carried out very soon after sawing, will avoid the need for anti-sapstain treatment. Dry lumber will not be infected by stain and mould fungi, provided it is kept dry.
- Water-borne preservatives are widely used to offset the low natural durability of New Zealand pine. Pressure preservation processes using copper-chrome-arsenate (CCA) preservatives, change the drying properties of the wood markedly, and re-drying after treatment is slower and more difficult, and gives a more variable final moisture content.

**The performance of any wood species used for the manufacture of high quality products is greatly influenced by moisture content.**

**It must be properly dried or it will shrink & twist.**

**New Zealand pine is no exception.**
## Drying

### Kiln Drying Summary Table for 50 mm Thick Lumber

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<thead>
<tr>
<th></th>
<th>Low temperature</th>
<th>Conventional</th>
<th>Accelerated conventional</th>
<th>High temperature</th>
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<tr>
<td></td>
<td>Kiln*</td>
<td>kiln</td>
<td>kiln</td>
<td>kiln</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>40-60</td>
<td>70-80</td>
<td>80-100</td>
<td>120-140</td>
</tr>
<tr>
<td>Airflow (m/s)</td>
<td>1.5</td>
<td>3.0</td>
<td>4.5</td>
<td>5.0-8.0</td>
</tr>
<tr>
<td>Drying time</td>
<td>15 days</td>
<td>5 days</td>
<td>2.5 days</td>
<td>13-20 hours</td>
</tr>
<tr>
<td>Minimum final MC (%)</td>
<td>10-11</td>
<td>6</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Capital cost/m³ dried</td>
<td>low</td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td>Typical annual production/dryer (m³)</td>
<td>2,000</td>
<td>3,600</td>
<td>6,000</td>
<td>18,000</td>
</tr>
<tr>
<td>Operator skill</td>
<td>average</td>
<td>skilled</td>
<td>skilled</td>
<td>skilled</td>
</tr>
<tr>
<td>Maintenance requirements</td>
<td>low</td>
<td>high</td>
<td>high</td>
<td>medium</td>
</tr>
<tr>
<td>Sterilises lumber</td>
<td>generally</td>
<td>required</td>
<td>required</td>
<td>required</td>
</tr>
<tr>
<td>Conditioning period</td>
<td>not required</td>
<td>(in kiln)</td>
<td>(in kiln)</td>
<td>(separate chamber)</td>
</tr>
<tr>
<td>Stack weighting to reduce distortion</td>
<td>no</td>
<td>possible</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

* Low temperature kiln includes heat pump dryers.

**Example: accelerated conventional drying schedule for 50 mm thick New Zealand pine.**

<table>
<thead>
<tr>
<th>Operation</th>
<th>Kiln conditions</th>
<th>Time (hours)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat up</td>
<td>90°C/90°C</td>
<td>4</td>
<td>Vents closed during heat up</td>
</tr>
<tr>
<td>Dry</td>
<td>90°C/60°C</td>
<td>36-48</td>
<td>Until target moisture content reached</td>
</tr>
<tr>
<td>Final steam</td>
<td>100°C/100°C</td>
<td>2-3</td>
<td>Vents closed (time on setting)</td>
</tr>
<tr>
<td>Fan reversals</td>
<td></td>
<td></td>
<td>At least three times</td>
</tr>
</tbody>
</table>

Total drying time 42-45 hours. Stack weights of 600 kg/m² should be used and left on during the cooling down period of at least 12 hours.

### Drying Methods

A full range of drying methods can be used for New Zealand pine, from air drying to high-temperature kiln drying. These methods can be classified simply in terms of drying temperature.

- **Ambient temperature drying** – air drying and forced air drying.
- **Low temperature dryers (up to 60°C, usually 40-50°C)** – heated forced-air dryers and low temperature kilns including most heat pump dryers (dehumidifiers).
- **Conventional kilns** (usually temperatures of 60-80°C for New Zealand pine).
- **Accelerated conventional-temperature kilns** operating at temperatures of 80-100°C.
- **High temperature kilns** (temperatures above 100°C, usually 120°C or higher).
- **Vacuum drying**, which is new to New Zealand, offers the potential of rapid drying and minimising discoloration of high quality lumber.

### Drying Practices

**Air drying** – The lumber stacks should be at least 300 mm above the ground, separated by 300-400 mm, and aligned parallel to the prevailing wind to promote rapid drying. Fillets should be of uniform thickness between 19 and 25 mm, and evenly spaced and aligned.

Warping and surface checking are adequately controlled by good stacking, avoiding overhanging ends, and using stack covers.

**Low-temperature drying** – This includes heat pump dryers and dehumidifiers.
Preliminary air drying to 60% moisture content reduces the drying time, lessens the risk of moulds and fungal stains, and results in a more uniform final moisture content. An airflow of at least 1.5 m/s is required and for heat pump dryers the compressor size may need to be increased above that normally used to 0.5 kW/m³ of lumber to avoid prolonged drying times with lumber green off the saw. Stress relief is not possible with this drying method.

Conventional kiln drying – Design requirements associated with the higher operating temperatures of these dryers are an increase in the heat input rate, venting capacity and airflow, and airflow reversal capability. These features are necessary to avoid slow and uneven drying. An airflow of 3 m/s or higher is required. The recommended kiln schedules involve a single step with EMC of 8-9% for untreated lumber or for lumber treated by boron. Lumber preservative treated with CCA requires a multi-stepped schedule.

When final moisture contents are to be lower than 12%, final wet-bulb depressions of 15-20°C should be used during the later stages of drying.

At the end of drying, it is essential that the lumber be given an effective final steam conditioning to relieve drying stresses and reduce the moisture content variation within and between pieces. Steaming should be done at 5°C above the final dry-bulb setting, with maximum possible relative humidity. Steaming time should be four hours per 25 mm thickness.

Accelerated conventional-temperature drying – Structural and furniture grade lumber can be dried using these schedules. The permeability of New Zealand pine permits the use of higher temperatures and airflows to reduce drying time while maintaining quality. Successful drying can be achieved by:

- Heat up period 2-4 hours.
- Air flow at least 4.5 m/s.
- Final steam conditioning at 100°C, 100% relative humidity for 2 hours per 25 mm thickness.
- Stack weights 500 kg/m².

If surface checking occurs, a more mild multi-stepped schedule should be used.

High temperature drying – Most widths of 25 mm and 50 mm thick lumber can be dried at high temperature with extremely rapid drying rates.

High temperature drying of furniture grade lumber should not be undertaken on a day-to-day commercial basis unless a very high standard of kiln operation can be maintained. High temperature drying is not recommended for sawn squares or pressure-treated lumber, unless it is to be used for construction purposes where the increased incidence of surface and internal checking may not be important. Kiln construction must be of a high standard, with fan capacity sufficient to achieve a uniform airflow of at least 5 m/s through the load, and heating system sufficient to reach operating temperature in 2 hours and maintain the drying conditions thereafter. Increasing the air flow to 8 m/s will reduce drying times by a further 20%. A final period of steam conditioning is essential to relieve drying stress and reduce the variability of final moisture content.

For successful conditioning, the lumber must first be allowed to cool to below 100°C, but conditioning must be started within 12 hours of the finish of drying. It is important that fully saturated steam is used. Careful kiln stacking is essential and top weights of at least 500 kg/m² are recommended to control warping in the top layers. Weights of 1000 kg/m² are essential for drying lumber containing corewood. The weights should be left in place during conditioning and a 24-hour cooling period.

Storage & handling

In common with most species of wood, dry New Zealand pine, especially at moisture contents below 15%, can rapidly pick up moisture on exposure to air. Exposure of dried lumber, in particular after kiln drying, must be minimised.

This means that:

- Kiln stacks must be defilted within 24 hours of the finish of drying, then block-stacked, and stored under cover. Although it is possible to protect dried lumber by using tarpaulins, sheds are preferable as they are more effective in preventing rain wetting. They should be sufficiently air tight to minimise air exchange.

- If long storage periods are anticipated, individual packets of kiln-dried lumber should be wrapped in plastic. Careful handling of New Zealand pine lumber, especially during transport, will minimise damage. This means that:

  - High value lumber must always be protected either by covers or wrapping. Packets containing lumber of different lengths should be formed so that the short lengths are securely housed within the body of the packet.
  - Where wire strapping is used, protective corner shields should be used to prevent the wire cutting into the lumber.
  - Adequate support should be provided to the lumber packets to minimise any induced distortion or breakage.
Drying

Radiata Correction Figures for Electrical Moisture Meters

<table>
<thead>
<tr>
<th>Meter type</th>
<th>Type of wood &amp; treatment</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
<th>19</th>
<th>20</th>
<th>21</th>
<th>22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance</td>
<td>Untreated wood</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Boron-treated sapwood</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>CCA-treated sapwood</td>
<td>–</td>
<td>–</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>12</td>
<td>13</td>
<td>13</td>
<td>14</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>19</td>
</tr>
<tr>
<td>Capacitance –</td>
<td>Untreated wood</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>18</td>
<td>20</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>23</td>
<td>24</td>
<td>25</td>
</tr>
<tr>
<td>Wagner 1600DF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Moisture Measurement

There are two main methods to determine the moisture content of New Zealand pine lumber:

- The standard oven drying method.
- Use of electrical moisture meters.

The oven-drying method is quite accurate, provided the lumber has not been treated with organic solvents and is not highly resinous. One of the main disadvantages of this method is the length of time required for a result. Oven drying can be speeded up by using thin samples and a microwave oven.

In the range from approximately 6% moisture content to 24%, electrical resistance and capacitance moisture meters can be used. Most meters are calibrated for one species and must be corrected for other species and treatments.

The correction figures given here for treated and untreated New Zealand pine are for resistance meters which are calibrated to the following standard resistance relationship:

8% - 5,010 M, 12% - 180 M, 16% - 19 M.

Moisture Content Targets

There are two main drying situations:

- Final moisture content less than 19%, to minimise degrade from moulds and fungi, and provide some guarantee of stability for structural products.
- Final moisture content in the range 5-15% depending on the equilibrium moisture content (EMC) of the end use situation.

In drying to below 19%, either air or kiln drying can be used. However, the low final moisture contents (less than 15%) necessary for high-quality uses can be obtained only by kiln drying. The required final moisture content will depend on a number of factors, and appropriate standards should be consulted.
The Need To Treat With Preservatives

As with most softwoods, New Zealand pine is not a naturally durable species and its use in New Zealand for structural purposes has gone hand-in-hand with the development of an efficient wood preservation industry.

Unlike many traditional softwoods of commerce such as spruce, hemlock, and Douglas fir, the sapwood of New Zealand pine is very permeable to wood preservatives, particularly in the radial direction. Complete penetration of the sapwood is always achievable, resulting in very extensive service lives for such commodities as small electric power or telecommunications transmission poles. Such total penetration of preservatives is rarely achieved with other softwood species.

New Zealand pine has unique properties among softwood species, in that total treatment of sapwood is always achievable.

It is very amenable to manipulation of preservative treatment processes, which are environmentally acceptable, and still give a reliable standard of treatment.
CHEMICALS FOR PRESERVATIVE TREATMENT

To a large degree, in-service exposure conditions dictate the types of preservative one can use to treat New Zealand pine.

Boron salts

Boron compounds are used in situations where the main hazard is insect attack (e.g. Lyctus and Anobium spp.) and where exposure conditions will not result in leaching the chemical out of the wood. Boron salts are also toxic to termites, although they are rarely used for treating lumber against termite attack.

Copper-chrome-arsenate (CCA)

CCA has universally been found to be a very effective wood preservative. It is very suitable for treatment of New Zealand pine which will be used in moderate or high decay hazard environments. Although solutions of CCA are highly toxic, once the solution is in the wood, complex chemical reactions occur which firmly bind CCA to the wood, making it exceedingly resistant to washing out.

Processes have been developed to accelerate this fixation process to minimise or even eliminate the possibility of environmental contamination associated with the use of CCA.

However, where environmental or health legislation has forced restrictions on lumber treated with CCA, there are alternative formulations which are ideally suited for treatment of New Zealand pine. These include amoniacal copper quaternaries (ACQ), copper azoles, copper HDO and copper dimethylidicarbonate (DMDC).

Creosote

Creosote is used for treating railway cross-ties and electric power transmission poles. Creosote treatment of sawn New Zealand pine is particularly effective because deep penetration of the heartwood can be achieved.

Light Organic Solvent Preservatives (LOSP)

LOSP are used for the treatment of fully machined componentry and fabricated commodities. Their main advantage is that, unlike water-borne preservatives, they cause no swelling of the wood during treatment and require no secondary air or kiln drying after treatment.

### Comparative Treatability Of Some Commercial Softwoods

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Maximum possible uptake (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>40</td>
</tr>
<tr>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>60</td>
<td>100</td>
</tr>
</tbody>
</table>

- New Zealand pine
- Redwood (California)
- Douglas fir
- Sugi (Cryptomeria)
- Sitka spruce
Preservative Treatment Processes

An important feature of New Zealand pine is that it can be treated easily. In New Zealand and around the world the Bethell (full cell or vacuum/pressure) process is the most widely used. This process involves applying a vacuum of -85 kPa to the wood, flooding with preservative solution at this vacuum, and then pumping solution into the wood at 1400 kPa. The treatment is complete only when the wood absorbs no more solution.

Not only is the sapwood of New Zealand pine easy to treat, but the relatively small amount of heartwood present can be treated as well. Research has shown that penetration of preservative into heartwood is improved by high-temperature drying or by steam-conditioning before treatment. In fact, complete preservative penetration in New Zealand pine sapwood and heartwood can be achieved consistently. New Zealand pine may be unique in this respect.

Because New Zealand pine is so permeable to wood preservatives, treating processes can be readily developed in response to environmental and economic pressures associated with traditional processes. These include processes to treat partially seasoned wood, to accelerate CCA fixation, to reduce post-treatment drying costs and to promote rapid throughput.

Virtually all pressure treatment is done with CCA preservative. However, the future international importance of boron as a wood preservative, and the processes used to apply it, cannot be ignored. As well as giving insecticidal protection, boron treatment imparts some decay resistance to the treated wood.

<table>
<thead>
<tr>
<th>Commodities</th>
<th>Australia/ New Zealand</th>
<th>America</th>
<th>Africa</th>
<th>Europe</th>
<th>Japan</th>
</tr>
</thead>
<tbody>
<tr>
<td>Framing &amp; flooring lumber</td>
<td>H1/H2</td>
<td>H1</td>
<td>H1</td>
<td>1</td>
<td>K1/K2</td>
</tr>
<tr>
<td>Sillplates or bottom plates</td>
<td>H2/H3</td>
<td>H2</td>
<td>H3</td>
<td>2</td>
<td>K2/K3</td>
</tr>
<tr>
<td>Windows, barge/fascia boards</td>
<td>H3</td>
<td>H2</td>
<td>H3</td>
<td>3</td>
<td>K3</td>
</tr>
<tr>
<td>Decking, fence boards</td>
<td>H3</td>
<td>H3</td>
<td>H3</td>
<td>3</td>
<td>K3</td>
</tr>
<tr>
<td>Fence posts, garden edging &amp; landscaping</td>
<td>H4</td>
<td>H4</td>
<td>H4</td>
<td>4</td>
<td>K4</td>
</tr>
<tr>
<td>Wood foundations, transmission poles</td>
<td>H5</td>
<td>H5</td>
<td>H5</td>
<td>4</td>
<td>K5</td>
</tr>
<tr>
<td>Marine piles, breakwaters</td>
<td>H6</td>
<td>H6</td>
<td>H6</td>
<td>5</td>
<td>–</td>
</tr>
</tbody>
</table>

Preservative Treatment for Specific End-use Conditions

There are a number of ways of writing standards or specifications for preservative treatment. Most common are Commodity Standards (e.g. USA), Process Specifications (UK), and Hazard Class Specifications (New Zealand, Australia).

With hazard class specifications, the nature of the biodegradation risk (decay, wood-boring insects or termites) is first determined from the wood exposure conditions (e.g. indoors, protected from the weather, outdoors, in ground contact) and the preservative retention and penetration into the wood are varied to reduce the risk of biodegradation to an acceptable level.

In New Zealand, roundwood (posts and poles), sawn lumber, and plywood are treated to the following six hazard class levels. Preservative treatment requirements are generally equivalent to or exceed those of other countries which have formal wood preservation standards.

H1 – Sawn lumber used in situations continuously protected from the weather. The purpose of preservative treatment is to protect against attack by wood-boring insects. Boron is the main preservative used and treatment would comply with all relevant standards for insect protection.

H2 – Sawn lumber and plywood used in interior situations where there is a slight risk of decay and a risk of termite attack. CCA and LOSP are the main preservatives used. Treatment to this hazard class is solely for lumber and plywood which will be exported to Australia.

H3 – Sawn lumber and plywood which will be used in exposed exterior situations but not in contact with the ground. CCA and LOSP are the main preservatives used.

H4 – Sawn lumber, roundwood and plywood used in ground contact in non-critical situations. CCA and creosote are used in New Zealand for wood in this category.

H5 – Sawn lumber, roundwood and plywood used in ground contact with extreme decay hazard or critical end-use requires greater protection - mainly for house foundation piles and transmission poles. CCA and creosote are approved for this use. Preservative retentions are 33% higher than those of Hazard Class H4.

H6 – Sawn lumber and roundwood used in a marine environment. Only CCA is used and the main New Zealand pine commodity treated is marine piles.
The benefits of applying surface coating to New Zealand pine will vary according to the end use.

**Exterior benefits:**
- Surface deterioration is greatly decreased, particularly discolouration and loosening of surface fibres from the combined effect of rain, wind, sun and grey or black staining mould fungi.
- The wood will be protected from excessive checking and dimensional change caused by water entry.

**Interior benefits:**
- The natural grain appearance will be enhanced.
- Chemical, heat and wearing resistance is increased.
- The in-service product will be protected from excessive dimensional change caused by swelling/drying resulting from seasonal climate variations.

**Exterior Situations**

New Zealand pine is not naturally durable in exterior situations and, therefore, should be preservative treated to the appropriate decay rating as detailed in the ‘preservation’ chapter. Where the wood is well painted and generally protected from direct wetting, preservation to a low decay hazard rating may be used. Surface coatings can retard the rate of change of moisture content and, therefore, can reduce fluctuations in product dimension. This depends, however, on the type of coating. For example, paints are more impermeable to water vapour than stains.
and oil-based paints more impermeable than water-based ones. Paint systems are either solvent-based (e.g. alkyd) or water-based (e.g. acrylic). Although exterior alkyd paints provide wide variation in gloss and their films may be more impermeable to water, modern adhesion-promoting acrylic paints are superior on pine in exterior uses. Acrylic paint films are permanently flexible, expanding and contracting with dimensional changes in the wood. As a result, acrylic, has better long-term water-proofing ability than alkyd paints that are more liable to becoming brittle and cracked with age.

**Interior Situations**

For interior applications, New Zealand pine is very suitable for appearance grade products such as furniture, componentry, joinery and mouldings.

**Preparation**

Good preparation is essential for the effective and attractive staining and coating of all wood. Desired surface characteristics are:

- finely-sanded (150 grit at least),
- defects smoothed over with fillers,
- sharp edges and corners rounded,
- dust, dirt and water free.

**Staining**

New Zealand pine is an extremely versatile wood and is tolerant of the many available stains. This allows it to be stained to look like other species, with colour-matching being particularly effective. Water-based stain systems can also be effective on pine, though solvent-based systems avoid grain raising.

**Coatings**

Four coating types have traditionally been used on New Zealand pine furniture - nitrocellulose, precatalysed and acid-catalysed resin systems and two-pack polyurethanes. In New Zealand, precatalysed and acid-catalysed coatings are most widely used.

**Environmentally friendly coatings**

Environmental pressures world-wide are resulting in low volatility organic compound (low VOC) coatings gaining favour. In Europe and North America, the move has been toward low VOC and low formaldehyde coating types. Consequently, in those markets, nitrocellulose, precatalysed and acid catalysed coatings use is down, while polyurethane (isocyanate control is possible through automated finishing lines), water based and ultraviolet-cure coatings use has increased.

**Performance Enhancement**

**Wood hardening**

New Zealand pine’s natural surface hardness is comparable with other medium density softwoods, but after treatment with a process developed at New Zealand Forest Research Institute its overall hardness can be increased to the level of hardwoods such as mahogany & oak. (see also the ‘Furniture & Components’ section).

The product accepts normal stains and clear finishes evenly and has excellent dimensional stability. It is ideal for high wear uses such as furniture, flooring and
MACHINING

Characteristics

Machining tests have confirmed that New Zealand pine compares favourably with a variety of other internationally traded lumbers.

Most wood products require machining in one form or another. The machining characteristics of any wood species can be as important as its strength, hardness, or durability in deciding which species is best for a given end use. The most common form of machining is planing, closely followed by shaping and turning. Cross-cutting, boring, mortising and sanding are also common types of machining.

The average density of New Zealand pine is 350 kg/m³ in early wood and 550 kg/m³ in late wood, reflecting the comparatively even texture of the wood. It is this small variation in density within the growth ring and gradual transition from early wood to late wood which confer on New Zealand pine its excellent machining, painting, and staining properties. These figures are compared with other species in the table below:

<table>
<thead>
<tr>
<th>Species</th>
<th>Density of Late Wood (kg/m³)</th>
<th>Density of Early Wood (kg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Zealand pine</td>
<td>550</td>
<td>350</td>
</tr>
<tr>
<td>Ponderosa pine</td>
<td>580</td>
<td>315</td>
</tr>
<tr>
<td>Douglas fir</td>
<td>690</td>
<td>300</td>
</tr>
<tr>
<td>Western hemlock</td>
<td>615</td>
<td>390</td>
</tr>
</tbody>
</table>

As with all wood species, care must be taken in planing to ensure that knives are kept sharp, especially when dealing with knotty material. Dry, short grained lumber may be planed successfully at 100 metres/minute using medium cutting angles (around 20°). The accumulation of wood resin on planer knives is not normally a problem but, when it does occur, it can be handled by regular cleaning of the knives with a suitable solvent.
The superior machining properties of New Zealand pine are a result of its even texture and relatively small difference in density between early wood and late wood. Ease of moulding, turning and planing are strong features.

Comparative Studies

“A Comparative Study of New Zealand Pine and North American Timbers” was carried out by the New Zealand Forest Research Institute in collaboration with the University of California, Berkeley. New Zealand pine and 13 North American timbers were tested to assess the various species suitability for panelling, mouldings, joinery, and furniture manufacture. Fourteen criteria were used to rate each species, including planing, shaping, turning, sanding, and gluing. The quality of primary machining is critical to the manufacture of high-value products. While most finishes do require sanding, the severity and type of defect resulting from the primary machining will impact on the cost, time, and effort required to bring the product to an acceptable finish. New Zealand pine’s performance confirms its suitability for a broad range of uses. It’s fast growth does not adversely affect its working properties and good results can be obtained with all types of hand and machine tools. Further details of this study are available from the New Zealand Ministry of Forestry.

Studies comparing New Zealand pine with English and European species were also carried out and confirmed by the Buckinghamshire College of Higher Education in England.
Suitability For Construction

New Zealand pine (Pinus radiata) is a preferred material for construction both as sawn lumber or as engineered products such as glue-laminated timber, plywood and other panel products.

Chief amongst these properties are its medium density and uniform grain which confer good fastening and working properties. New Zealand pine’s strength and stiffness, ease of drying, and suitability for treatment with preservatives and fire-retardant chemicals are also advantageous for construction.

It is a relatively stable wood and kiln drying further improves its stability.

In common with other natural forest or plantation-grown softwoods, grading of the sawn lumber is important in order to meet required structural properties. Ring widths can be large in comparison with natural forest lumber without compromising strength. For this reason, ring width is not a good indicator of strength properties compared with other grading criteria.

Wood Frame Construction

New Zealand pine is the preferred species for wood frame construction (the 2x4 system) in New Zealand and Australia. This system uses dimension lumber of 35 mm to 45 mm thickness and widths up to 300 mm. The system is common in North America and is finding increasing acceptance in the United Kingdom, Japan and other significant markets. A particular advantage of the 2x4 system is the extensive load sharing that occurs between the individual framing members. This allows the use of lumber with relatively large defects (knots up to half the cross section) because any weakness in one member will be compensated for by strength in an adjacent member. Another advantage is the lateral restraint provided to the framing members by the exterior claddings, interior linings, flooring and ceilings. This lateral restraint increases the strength of the completed structure.
New Zealand pine sawn lumber is a versatile structural building material which is well suited to the 2x4 building system. It is used equally successfully in larger buildings as glue-laminated lumber and for many other structural applications.

Exterior & interior cladding

Finger-jointed, preservative treated New Zealand pine can be used as exterior weatherboard cladding, provided it has a well maintained protective coating of paint or semi-transparent coating called stains. Plywood panels machined to look like vertical boarding, also make an excellent cladding, with the advantage that it requires less maintenance than weatherboards. Feature interior finishings are also used in New Zealand.

Bracing

The best system of bracing in the 2x4 system is plywood cladding on all walls. Other methods are used, such as diagonal metal strap or angle members. These are nailed to the framing members at each end and wherever they cross a framing member. Interior sheet cladding such as gypsum plasterboard also adds considerable bracing to structures.

Subfloor & foundations

Because New Zealand pine can easily be treated to last permanently in ground contact, it is excellent for foundation piles and poles. Bearers are easily attached to the piles to support floor joists.

Flooring

The composite materials of particle board, plywood or medium density fibreboard (MDF) are commonly used with a clear coating or overlay. They have a cost advantage due to the speed of construction and a practical advantage in that there are few joints.

Studs

New Zealand pine is excellent for the vertical wall framing members called studs. Usually, a lower grade of lumber is used for the construction of non-load bearing partitions.

Joists

The stiffest grades of New Zealand pine are required for floor joists to minimise flexibility in floors under load. Kiln drying of joists is recommended before installation to minimise distortion allowing accurate floor surfaces to be formed.

Rafters

Lumber of an intermediate grade is appropriate for use as roof framing. It has moderate strength to resist wind uplift if lightweight roofing is used, or to resist high gravity loads imposed by tiled roofs. New Zealand pine’s excellent fastening properties are advantageous too, enabling the roof to be constructed of trusses or framed in a more traditional manner.

Post & Beam Construction

The building system that uses members of 75 mm or more in thickness as the primary framework is found throughout Japan, Europe and parts of Asia. It requires lumber of high strength because each member carries a significant load. The wood must be inherently stable because the system provides little restraint against possible distortion. Where it is exposed to view in the interior of the building it must have high visual appeal. New Zealand pine can fulfill all these requirements particularly if it is glue-laminated.

Excellent gluing characteristics mean that a permanent decorative veneer of another species is easy to apply.
Beams
Laminated New Zealand pine makes excellent beams for this system. Such beams may contain many finger-joints in the laminations where defects have been removed to achieve the high strength and good appearance needed. High stiffness will be achieved if the laminations are selected by a grading machine.

Bracing
Diagonal bracing members in the post and beam system usually carry high loads when the building is subjected to earthquake or typhoon conditions. Properly designed metal fastening systems are needed to transmit these loads through the framework. The excellent resistance of New Zealand pine to splitting and shear forces means that such metal fastening systems perform well. A better method for providing bracing in this system is to use plywood nailed to the horizontal and vertical wall framing members.

Sills
Sill members are exposed to decay conditions because they are close to the ground and will become damp unless special moisture barriers are used. New Zealand pine, preservative treated to appropriate levels, will permanently withstand attack from insect and decay and provide the anchorage needed for the framing members attached to them.

Flooring
As for the 2x4 system, the most cost effective type of flooring is particle board or MDF.

Roof framing
The roof framing can be a trussed system of dimension lumber. If heavy framing members are used, glue-laminated members are appropriate.

Solid Wood Systems
Traditional solid timber wall type of construction and modern variations of this are popular forms of construction in New Zealand. The best-known system is the Lockwood type which uses laminated machined planks of 63 mm thickness for the external walls, and non-laminated planks of 43 mm thickness for the internal walls. This system has a well proven cyclone and earthquake resistant performance.
CONSTRUCTION

Strength Properties

New Zealand pine compares favourably with other species in bending strength, bending stiffness, and fastening (properties which relate well to density). The grade used for most structural framing in the 2x4 system in Japan is the JAS 600 No. 2 and better grade. The same practice is followed in North America. Under JAS 600 New Zealand pine is rated as equivalent to spruce-pine-fir and better than western red cedar.

Shear strength is particularly good, a further benefit gained from its uniform texture.

Prefabrication Systems

There are many varieties of panelised prefabricated housing systems in production. Kiln dried New Zealand pine is excellent for these systems which use a lumber frame overlaid with sheet materials because it is dimensionally stable, adequately strong and stiff, and has good fastening characteristics.

Commercial & Industrial

Multi-residential condominium developments up to 5 stories have been built in the 2x4 system. Sound insulation in floors is achieved using a lightweight concrete topping over a floor of plywood or particleboard. Fire protection and sound insulation between tenancies is achieved by building walls with staggered studs and multiple layers of gypsum plasterboard.

The success of New Zealand pine in housing is matched by its success in industrial building. Various structural forms using glue-laminated lumber in the form of curved arches, portal frames, or straight beams are used in larger industrial buildings.

New Zealand pine roundwood treated with preservatives also has its place in house construction as foundation piles or pole frames, and in industrial pole buildings. Pole columns supporting glue-laminated beam rafters are a very efficient form of warehouse building. In horticultural and agricultural uses, New Zealand pine poles and sawn lumber play a vital role in crop support structures, stock fencing and yards, and agricultural buildings.

Built-up beams using plywood box construction have been made in spans up to 50 metres. Other composite beams using metal webs and lumber chords are competitive in the long-span purlin market.

Trusses assembled with toothed metal plates have come to dominate the domestic roofing market in many countries using the 2x4 building system, and radiata pine is

continued overleaf
commonly used in these trusses. In commercial structures, New Zealand pine trusses up to 30 metres span are routine and even larger trusses have been built and used successfully.

**Code Acceptance**

New Zealand pine is fully accepted as a structural lumber in the construction codes of New Zealand, Australia, and the United Kingdom.

In Japan, it is included in the JAS 600 grading rules for structural lumber, in JAS 2054 for glue-laminated lumber and in JAS 1516 for plywood. It is acknowledged as a suitable construction material by the Ministry of Construction.

**Fastening Properties**

Uniform texture gives better fastening properties than coarser-grained woods such as Douglas fir and larch. There is less difference between the density of the spring wood and summer wood bands within each growth ring. Thus, for a given average density, the spring wood bands in New Zealand pine are of a higher density than those in coarser-grained species.

These higher-density spring wood bands give excellent resistance to splitting and so the lumber can be nailed at relatively close centres. This means that New Zealand pine can be nailed green or dry.

Similarly, the lower-density summer wood bands, compared with coarser-grained species, make nailing and drilling easier. The uniform grain structure allows nails to drive true without any tendency to follow the growth rings, as can happen in coarser-grained woods such as Douglas fir.

Other mechanical fasteners such as truss plates, nail plates, and screws also perform well in radiata pine.

Uniform density and low extractives content ensure strong glued joints for both laminated and finger-jointed lumber.

Glued joints may be made with preservative-treated lumber provided it is planed within a few hours of gluing.

Development of the GreenWeld process at the NZFRI allows New Zealand pine to be glued when green to produce structural fingerjoints which are as strong as joints made with dry lumber.

The glue-laminated lumber portal frame made with moment-resisting knee joints has been successful in enabling industrial portal frame buildings in wood to compete with their steel or concrete equivalents. These knee joints have been made with nailed plywood or steel gusset plates and can develop the full strength of the members joined. Close spacing of nails possible with New Zealand pine assists the efficiency of these joints.

Cross-lapped glue-laminated lumber portal frame knee joints in New Zealand pine have been researched by Dr Kohei Komatsu at the NZFRI and a design method has been developed.

The most recent development in jointing has been to fasten threaded steel rods into the timber with epoxy adhesive. An embedment depth of 10 times the bar diameter is sufficient to develop the full strength of the steel. Joints with completely hidden steel bars can be made to give good appearance, good ductility, and good fire resistance.

**Other Structural Uses**

The versatility of New Zealand pine structural wood products, together with the high durability conferred by modern preservative treatment processes, has enabled the species to be used in a number of applications other than buildings. Examples include marine piles for wharfs and marinas, landscaping lumber for retaining walls, wooden water-reservoirs, cable drums and packaging, and railway sleepers.

In bridge construction, New Zealand pine has been used as glue-laminated lumber both for the main beams and for decking, although nail-laminated sawn lumber is also used for decking.
GLUING, FINGER-JOINTING & LAMINATING

Gluing

New Zealand pine can be glued with many adhesive types, provided that care is taken to establish correct process control of wood properties, adhesive formulation and pressing and curing variables. It is being glued and used extensively in a range of wood products from structural uses to high value furniture and interior fittings.

Adhesive types

Many different types of adhesives have been used successfully across a wide range of glued products, including furniture, joinery, wood panels, overlaid laminates, finger-jointed lumber for interior and exterior use and structural laminated lumber. Care should be taken to select adhesives appropriate to the production process, for the colour of the end product, and also for their ability to withstand both end use and changes in environmental conditions during transport. If preservation treatment is required the adhesive should be compatible with the chosen form of treatment.

Preservative treatment

Glue laminated products treated with appropriate preservatives either before or after gluing have very high resistance to decay – for example a bridge made from CCA-treated, glue laminated New Zealand pine has given good service since 1961. Preservative treatment of lumber after the gluing operation is commonly undertaken, particularly when using LOSP systems.

Wood preparation

Standard practices for gluing softwoods should be observed when gluing New Zealand pine. Its high permeability aids curing by allowing solvents to move out of the glueline. However, the wood will absorb moisture very quickly when dry.

Adhesive Types Used With New Zealand Pine

<table>
<thead>
<tr>
<th>Exterior</th>
<th>Occasionally Damp</th>
<th>Interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resorcinol*</td>
<td>Melamine*</td>
<td>Urea</td>
</tr>
<tr>
<td>Phenol*</td>
<td>Aqueous Polymer Isocyanate*</td>
<td>Casein</td>
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<tr>
<td>Epoxy*</td>
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<td>PVA</td>
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</table>

* A joint with good structural properties can be obtained using these adhesives.

New lamination & finger-jointing technologies are increasing the use of New Zealand pine in a wide range of products – from small mouldings to huge engineered beams.

* Image of a person gluing wood and a table with adhesive types used with New Zealand pine. *
Gluing, Finger-jointing & Laminating

This is different from the hardwood species that many manufacturers are more familiar with. It is important that glue mixes are not too low in viscosity, otherwise the glue may migrate away from the joint. Likewise, standing times between applying the glue and pressing for cure should be shorter for New Zealand pine.

There are no known chemical problems gluing New Zealand pine because it has a low extractives content. With most adhesives, a wood moisture content of 10-16% is acceptable. For products that are to be radio frequency cured, moisture content must not exceed 15%. Care should be taken to ensure that the glued product moisture content is comparable with the equilibrium moisture content where the product is to be used.

The temperature of the wood must not be too low while gluing as some adhesives can be de-activated by cold, while others will not cure rapidly enough. Surface preparation by planing is the most effective method of obtaining a clean, flat surface for gluing. Due to surface de-activation with time, surfacing should be carried out as close to gluing as possible. 24 hours is considered a maximum time for preservative treated lumber and 72 hours for untreated lumber.

Finger-jointing

New Zealand pine compares favourably with other softwood species for producing fingerjointed products. It machines well, producing smooth, clean cuts with a minimum of crushing or splintering at the cut surface or face. High production rates can be achieved and wear on the machine cutter knives is low. Machining quality and the uniform colour have lead to its increasing acceptance for finger-jointing.

Products Incorporating Finger-jointed Timber

<table>
<thead>
<tr>
<th>Structural uses</th>
<th>Appearance uses</th>
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</thead>
<tbody>
<tr>
<td>Laminated beams</td>
<td>Door &amp; window components</td>
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<tr>
<td>Wooden I beams</td>
<td>Door cores</td>
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<tr>
<td>Trusses</td>
<td>Interior trim, moldings</td>
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<tr>
<td>Ladder stock</td>
<td>Exterior trim, fascia &amp; siding</td>
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<td>Decking</td>
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<tr>
<td>Wall studs &amp; dimensional lumber</td>
<td>Furniture components</td>
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<tr>
<td>Posts</td>
<td>Edge-glued panels</td>
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<td></td>
<td>Picture frames</td>
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<td></td>
<td>Table tops</td>
</tr>
<tr>
<td></td>
<td>Banisters, stair treads &amp; rails</td>
</tr>
</tbody>
</table>

Product types

Finger-jointed products supply two main market segments. Structural wood products are produced with the joints designed to have high tensile strengths. Finger-jointing provides a greater degree of stability than single, large dimension lumber pieces which can in certain circumstances be prone to distortion. The structural joints for New Zealand pine use finger lengths of 10mm through to 25mm, though shorter finger lengths of 10mm are preferred. Adhesives used in structural jointing such as phenol resorcinol and melamine urea-based glues must meet strict exterior and exposure tests. New Zealand finger-jointed pine meets the requirements of New Zealand, Australian, Japanese, US and British structural testing standards. Extensive qualification to recognised national standards and in-house quality control tests are conducted by finger-joint manufacturers to verify the on-going strength and reliability of the timber joints.

Finger-jointed lumber is used for a wide range of products where appearance is important. For this end use the 4mm “micro joint” is offered by New Zealand manufacturers for Australasian markets as it is easily jointed, it provides a high quality finish and results in higher timber yields. When clear adhesives are used, unblemished lengths of fingerjointed timber can be produced for high value end uses.

Processing types

New Zealand pine can be jointed using either the face-to-face (vertical or European joint) or the edge-to-edge (horizontal or North American joint) machine types.
The horizontal joint, where the fingers are oriented so that they can be seen on the edge or side of the board, are generally preferred in the US for moulding and millwork operations, and the vertically milled joint for structural applications.

**Innovative technologies**

In 1995 a new process was developed in New Zealand, allowing lumber to be finger-jointed before drying. This leads to significant savings to manufacturers through reduced processing costs and increased kiln drying efficiencies. Sawmill yields can be improved by recovering short, unseasoned lengths of sawn wood which would otherwise be chipped or wasted. In addition to producing a high quality, high strength joint, the new process produces a product that can be handled almost immediately (5 minutes) after jointing compared with up to 24 hours with conventional systems.

**LAMINATING**

The ease of gluing New Zealand pine has helped open many market opportunities for glue laminated products.

**Product types**

**Structural uses**: New Zealand pine has been used in structural building applications for nearly four decades in New Zealand and Australia. It has demonstrated excellent performance in service. Laminated products are finding increasing acceptance in markets such as Japan and Hong Kong. New Zealand-designed and fabricated wood structures have been erected in Africa, Hong Kong, Spain and throughout the Pacific. (see also the section on Construction.)

**Edge glued panels**: More rapid production techniques, such as clamp carriers and RF presses, are commonly used to produce high quality edge glued panels. By selecting the correct adhesive the resulting product is light coloured with colourless gluelines. The panels are used in products ranging from fine furniture to intricately routed decorative panels. The light colour and product quality have helped secure markets in Japan and Korea, as well as local use.

**Face glued products**: The successful face laminating of New Zealand Pine to produce posts, squares, rails and many other interior fittings has resulted in increased volumes being used in traditional Asian homes. Most of these products are non-structural and used mainly for decorative purposes. It is well suited for this application with its light colour and ease of gluing.

Laminated New Zealand pine is moulded and used as hand rails in both interior and exterior applications.

**Processing types**

Successful gluing depends on the full control of each variable in the process. Variables such as moisture content, climatic conditions, mix formulation, adhesive spread, standing times and method of curing (ambient temperature, hot press or radio frequency cure) are specific to each glue type and often specific to individual manufacturing operations. Minimising the time taken between surfacing and gluing can be very important for some adhesive systems.

Fillers such as nut shell flours and extenders such as wheat flour can be used with advice from glue suppliers to control mix viscosity and moisture flow during cure. Glue line pressure during curing of a joint in solid New Zealand pine should be 700 kPa.

The press system to be used will depend largely on the adhesive and its nature of cure under ambient or accelerated conditions.

For a specific product, careful trials and consultation with an adhesive supplier should establish the base variables. On-going quality control is then needed to ensure that good bonds continue to be made.

Glued and laminated timber products with high strength, durability and quality finish can be obtained by selecting the correct adhesive type and preservative treatment for the desired end use.

**Wide span laminated beams**
All products are available in solid clear, as well as in finger-jointed and laminated forms. Knotty products are suitable as core for overlaying with veneer or other materials. Generally, the knot structure of New Zealand pine is not suitable for ‘knotty pine’ appearance products such as are traditionally produced from Scandinavian pine.

A number of properties of New Zealand pine contribute to the ready acceptance for these products.

**Texture & Appearance**

One of its unique properties is its uniform density, i.e. the small variation in density between spring wood and summer wood within a growth ring. It is this property which confers on New Zealand pine its excellent machining, painting and staining properties.

Consisting mainly of creamy white sapwood, with prominent fine resin canals, it presents a uniform appearance with little colour variation between pieces. This is an advantage for subsequent finishing.

**Machining**

Comprehensive tests undertaken at the New Zealand Forest Research Institute, Buckinghamshire College of Higher Education in England, and University of California, Berkeley (USA) have shown that New Zealand pine has machining properties (cross-cutting, turning, planing, moulding, boring, sanding) equal or superior to many of the internationally traded softwoods. Its fast growth does not adversely affect its working properties and good results can be obtained with all types of hand and machine tools.

**Finishing**

The full range of interior and exterior stains, oils, varnishes and paints may be used on New Zealand pine. The absence of high concentrations of extractives prevents any incompatibility with finishes and eliminates the need for special primers. A very high standard of finishing can be obtained.

The wood can be stained to resemble a wide range of traditional timber species.

**Fastening**

Being of medium density and even texture and having a good resistance to splitting, New Zealand pine can be nailed particularly well. The same properties allow the production of efficient joints using other systems, e.g. screws and proprietary connections.

Low extractives content and uniform density allow achievement of above-average glued connections, e.g. dowels and finger-joints. The high strength of glued dowel joints (compared to other species, e.g. meranti) is due to the contribution from the end grain to the joint.

**Dimensional Stability**

This is a crucial wood property for interior fittings and joinery uses. New Zealand pine has a low shrinkage which contributes to its stability.

However, stability is also affected by a number of other properties, including: equilibrium moisture content, straightness of grain, spiral grain, rate of moisture uptake, permeability to liquids and gases.

Long term movement is the property which best describes the dimension changes which occur when joinery is exposed to dry summer conditions and later to wet winter conditions.

The dimensional response of cladding and joinery when exposed to fluctuating weather conditions, such as alternating rain wetting and sunshine, is best described as short-term movement.

Because of the presence of spiral grain, the corewood of New Zealand pine should not be used where stability is vital to performance.
Dimensional performance can be increased by use of finger-jointing, and/or lamination. Such highly processed laminated, finger-jointed clear products are used widely in Japan where maximum stability is required, e.g. sliding door tracks (kamoi and shikii), mouldings, and door frames.

**DURABILITY**

New Zealand pine must be preservative-treated for exterior uses. However, it is one of the most permeable wood species and can, therefore, be acceptably treated by pressure impregnation, double vacuum and simple immersion methods. LOSP treatments are very successful for joinery.

New Zealand pine is being successfully used for a wide range of interior fittings and fixtures, including: windows, doors, frames and jambs, mouldings, stairs, cabinetry and bench tops.
The remanufacturing sector is now a vital part of the industry, with products entering the markets of Asia, North America and Europe.

The availability of New Zealand pine as a sustainable and renewable resource makes it an attractive and acceptable alternative to lumber species from the world’s dwindling natural forests.

**Wood Properties**

Comparative tests undertaken by New Zealand’s Forest Research Institute (NZFRI), in conjunction with universities in North America and England, have shown conclusively that New Zealand pine machining properties (e.g. planing, sanding, moulding, turning) compare very favourably with those of most internationally traded softwoods.

In addition it performs very well in gluing and finger-jointing because of the even density within growth rings, good permeability and low extractives content.

The full range of interior and exterior stains and oils can be applied to enhance the wood figure, and this can be followed by a clear finish. The absence of high concentrations of extractives prevents any incompatibility with finishes and eliminates the need for special primers.

As with all species, high value New Zealand pine products such as furniture should be manufactured from kiln dried wood with a moisture content appropriate to the particular product and market (see also the Drying section in this guide). Accurate drying is particularly important for furniture manufacture as it will avoid delayed shrinkage, warping and end splitting or opening of glue joints. Protection of raw wood to avoid moisture pick-up during manufacture is also important.

**Performance Enhancement**

New Zealand pine’s natural surface hardness is comparable with other medium density softwoods, but after treatment with a process recently developed by the NZFRI its overall hardness can be increased to the level of hardwoods such as mahogany and oak.

The process consists of pressure impregnating New Zealand pine (or other woods) with a densifying non toxic chemical which is then cured in a kiln.

The product has extremely good machining and gluing properties, excellent dimensional stability, and accepts stains and clear finishes evenly. It is ideal for high wear uses such as furniture, flooring, and cabinetry.
**Furniture Design**

The performance characteristics and wood properties of New Zealand pine combine to provide a raw material easily adaptable to most furniture styles. Designers and manufacturers accept that its good technical properties and ease of finishing in natural or enhanced colours provide enormous flexibility in creating furniture styles.

Whereas New Zealand pine has been quite acceptable for so called ‘low end’ furniture for many years, manufacturers are now finding the demand in upper and middle segments of the furniture market is increasing. This has generally resulted from collective industry efforts such as exhibiting at offshore trade fairs and bringing leading northern hemisphere designers to New Zealand.

Opportunities for furniture made from New Zealand pine MDF are also increasing.

**Components**

In addition to manufactured furniture, the demand for components either partly processed or fully processed is increasing. These are all kiln dried in New Zealand and protected against moisture pick-up and in-transit damage.

A very large range of products includes blanks, edge glued panels, clear and finger-jointed cutstock for further remanufacture, and mouldings, stair parts, door and window parts, and furniture components for assembly.

New Zealand pine usage has increased with the rapid growth of the do-it-yourself (DIY) market. The most commonly manufactured items include ready-to-assemble furniture for home and office, interior wall units (shelving, cupboards, etc) entertainment centres, dining room furniture and computer desks. It has become obvious that customers get immense satisfaction from assembling and finishing pine furniture purchased in kitset form.
PALLETS

New Zealand pine has been used with great success in New Zealand and overseas for many years for the manufacture of pallets. Even without preservative treatment, pool (re-usable) pallets often have an economic life of over five years.

Worldwide, more than half of all pallets are used by pallet “pools”. Many users agree that the performance of New Zealand pine is comparable with that of American southern yellow pine.

GOOD DESIGN & GRADING ESSENTIAL

The design of the pallet is very important, as a poor design may reduce the useable life or cause failure in use. When pallets are stacked or stored in racks, failure can be dangerous and cause extensive damage.

The strength and stiffness of New Zealand pine varies depending on factors such as the latitude and altitude at which the trees were grown, silviculture and saw patterns used. For best results it is suggested that the lumber is kiln dried to a moisture content below 20% and either visually or machine graded. Suitable anti-sapstain chemicals can be applied beforehand to protect the light colour of the wood.

For most applications a simple mechanical bending test of deckboards, bearers and stringers will be sufficient.

The relationship between deckboard deflection and lumber grade in terms of knot size and wood density for a standard kiwifruit pallet manufactured in New Zealand is illustrated. The maximum knot and knot group recommended is one-third of the board width, which is the same as for No. 1 framing grade as specified in New Zealand Standard NZS 3631:1988.

WOODEN CRATES & BOXES

A number of New Zealand sawmills specialise in sawing of thin boards and framing for industrial packaging crate and box uses to sawing tolerances of ±0.5 mm. As machinery sizes vary, sawmills are willing to cut lumber components to the sizes required by the crate manufacturers.
The performance of New Zealand pine for crate and box uses is again a function of wood density and lumber grade, based on maximum allowable knot size and moisture content. In the box/crate sector there is ongoing potential for both New Zealand pine lumber and plywood, specifically in the one-way export sector.

Increasing use of CAD for box and crate packaging makes New Zealand pine an attractive wood material because of the species’ known strength characteristics.

Throughout the whole range of industrial packaging, New Zealand pine has a unique advantage in its very good nailing properties. Its ease of nailing, resistance to splitting and the holding properties of ring shanked nails make it ideal for this end use.

**Cable Drums**

New Zealand pine accounts for much of the industrial lumber used for the manufacture of cable drums in Japan. Many New Zealand sawmills are equipped with facilities to saw industrial grade squares for resawing.

Knot size is not a limiting factor for drum sides, as the board thickness can be increased and double thicknesses used in load sharing situations on large cable drums. Relative to steel and plastic drums, wood has the advantages of low cost, ease of repair, workability and size/dimension flexibility.

The performance of New Zealand pine when used for pallet construction is a function of wood density and lumber grade based on maximum allowable knot size.

For a given density and grade, New Zealand pine is stronger but less stiff than several other species. This makes it very suitable for applications where shock loadings may occur.

New Zealand’s first major export of plantation grown New Zealand pine was to Japan for use as industrial wood. That was over 30 years ago & the species has since become a first choice in many parts of Asia.
**Building With New Zealand Pine**

New Zealand pine is not naturally durable for exterior uses. But when preservative treated it is totally accepted by architects, engineers, builders, and consumers for virtually all uses which in the past have required lumber of high natural durability.

More than 40 years’ research in evaluating the performance of preservative-treated New Zealand pine has resulted in detailed specifications for both the preservation operation and for treated products in New Zealand.

In all tests controlled by the New Zealand Forest Research Institute (NZFRI), performance has been equal to or has exceeded that expected of naturally durable species from throughout the world. Long term experience has been gained through extensive field testing of a wide range of treated products.

**Field Testing**

Results from tests carried out by the NZFRI at a range of sites around New Zealand have shown that preservative treatment can make New Zealand pine last a long time, even if small stakes are used and the test is very severe.

Field testing is carried out not only on small stakes but at a range of outdoor structures which have been commercially treated. Detailed records of the performance are kept at the NZFRI, and the condition of the structures is assessed regularly. Any deterioration caused by either physical or biological agents is carefully recorded. Tests continue until an accurate assessment can be made of the probable service life of the structure, or until it is obvious that the structure will not deteriorate significantly during its required life.

CCA is the most widely used water-borne preservative in New Zealand and throughout the world. It is possible to treat New Zealand pine with CCA to a high standard, for any end use. LOSP are also used for the treatment of New Zealand pine, particularly for exterior building components which are to be painted or stained, such as finishing wood, plywood and windows.

Tests of CCA-treated products have been installed at various times since the late 1950s and no significant deterioration or failure of any components either through decay or insect attack has been recorded.

**General End Uses**

Preservative treated pine has been established in commercial, industrial, and domestic buildings including foundations, flooring, framing, exterior cladding, joinery and roofing shingles. It is also used in a range of outdoor furniture, landscaping, garden and farm situations such as posts, poles, reinforcing, and fencing.
Cooling tower structural and interior lumber, glue laminated beams for bridges and arches, and plywood are also suitable outdoor uses for treated New Zealand pine.

Most wood in contact with the ground or actually in the ground and treated with CCA is expected to have an average service live exceeding 30 years. House foundation piles are expected to have service lives of 50 years or more.

An impressive application of preservative treated New Zealand pine is as silencers for bore holes in geothermal energy systems. In this application it has had three to four times the life of concrete silencers which failed because of the intense heat and corrosive nature of the effluent.

**Marine & Fresh Water Piles**

CCA-treated New Zealand pine has been thoroughly tested for use in marine and fresh water situations. Average lives in excess of 20 years are expected for marine piles and results indicate an average 35 years plus for piles in fresh water.

**Transmission & Building Poles**

Tests have examined the effect of CCA preservative retention and treatment method on durability of transmission and building poles. Results have shown that poles treated appropriately will have expected average service lives in excess of 50 years.
Plywood properties can be optimised by using veneer grades and the distribution of density within the tree. Japanese research has shown New Zealand pine to be a favourable species for LVL.

**Manufacture**

Within a single growth ring, New Zealand pine is uniform in density. The soft spring wood is more than half the density of the summer wood, whereas in Douglas fir, the density of the spring wood is only one-third that of the summer wood. This means that New Zealand pine is easier to peel than some other species.

Veneer should be dried to an average 5% moisture content before gluing.

The gluing process needs careful control in the factory, according to site conditions and the type of adhesive. Daily records are necessary to identify changes in wood quality and climate in the factory for each product type. Plywood in New Zealand is manufactured to the joint Australian/New Zealand standard AS/NZS 2269.

**Peeler Logs**

New Zealand pine has a low-density core zone in the centre of the log. This zone has a tendency to distort on drying. From about ring 10, the wood is of much higher density.

![Diagram of Plywood & LVL](image-url)
In plywood manufacture, the central peeler core may be diverted to other uses. The density of the wood available for peeling is, therefore, better than the log average. When peeler lathes cut down to small cores, the veneer from the low-quality core should be sorted out and used only in the inner plies of the panel. Veneer from the outerwood is of higher density and strength. Older trees have greater quantities of higher-density, higher-strength outerwood. A typical pruned log in the age range of current production has a knotty core of 18-26 cm, and diameters range from 35-75 cm at age 30.

Typical recoveries of dry veneer are 60-65% of underbark log volume. The quantity of different grades varies according to log diameter and for unpruned logs it also depends on the branch sizes. With improved mill efficiencies and better sites, pruned logs may yield 15-50% clear veneer and 30-60% useable knotty grades.

Unpruned logs also yield good quantities of useable veneer. The smaller the branch size, the better will be the veneer recovered. Stand and mill surveys should be carried out to determine likely recoveries.

**Strength of Wood**

The clearwood strength of New Zealand pine compares well with other species traditionally used for making plywood. In many uses, plywood supports its load through its resistance to bending.

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**Comparison of Strength Properties**

<table>
<thead>
<tr>
<th>Species</th>
<th>Specific gravity</th>
<th>Modulus of rupture (kg/cm³)</th>
<th>Modulus of elasticity (kg/cm³)</th>
<th>Compression strength (kg/cm³)</th>
<th>Shear strength (kg/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Englemann spruce</td>
<td>0.35</td>
<td>650</td>
<td>91,000</td>
<td>310</td>
<td>85</td>
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<tr>
<td>Siberian larch</td>
<td>0.48</td>
<td>950</td>
<td>128,000</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Douglas fir (coast)</td>
<td>0.48</td>
<td>870</td>
<td>137,000</td>
<td>520</td>
<td>80</td>
</tr>
<tr>
<td>Douglas fir (interior north)</td>
<td>0.48</td>
<td>920</td>
<td>125,000</td>
<td>490</td>
<td>99</td>
</tr>
<tr>
<td>Douglas fir (interior south)</td>
<td>0.46</td>
<td>840</td>
<td>105,000</td>
<td>440</td>
<td>106</td>
</tr>
<tr>
<td>Lauan</td>
<td>–</td>
<td>800</td>
<td>114,000</td>
<td>410</td>
<td>86</td>
</tr>
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<td>New Zealand pine (low-density sites)</td>
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<td>870</td>
<td>101,000</td>
<td>380</td>
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</tr>
<tr>
<td>New Zealand pine (med-density sites)</td>
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<td>930</td>
<td>108,000</td>
<td>400</td>
<td>107</td>
</tr>
<tr>
<td>New Zealand pine (high-density sites)</td>
<td>0.50</td>
<td>1,000</td>
<td>117,000</td>
<td>440</td>
<td>115</td>
</tr>
</tbody>
</table>

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**Comparison of Plywood Properties Tested To JIS, JAS And ASTM Test Methods**

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Properties of New Zealand pine compare well with other species. It has excellent strength and can be used to make plywood to meet required national standards.
Higher density New Zealand pine has a density and stiffness close to Douglas fir. For bracing and plywood web-beams, shear properties are important.

Different densities have different values for strength (modulus of rupture) and stiffness (modulus of elasticity). New Zealand pine should be selected for density if these properties are important. For many uses, high strength is not essential and lower density can be used.

**Plywood Standards**

New Zealand pine has been accepted provisionally as a Group 2 species for use with US Product Standard PS1-83. With careful selection and grading, higher classification is possible. For Japan, plywood made from different densities of New Zealand pine will have a modulus of elasticity values range as shown in the test figures. Each bar shows the range of stiffness values expected for 90% of the production from high, medium and low density forests. Plywood made with New Zealand pine veneer from high or medium-density forests should have no problem meeting the requirements of JAS 1516.

**Plywood Strength**

The bending strength of plywood is determined almost entirely by the veneers parallel to the span that are most distant from the neutral axis. These outer veneers carry almost all the load. This means that they determine the performance.

Faces and backs should be of high grades, such as clear high-density New Zealand pine or hardwood species. The inner veneers can be of much lower quality. But if high properties perpendicular to the face grain are desired, the first cross bands should also be of high quality.

**Stability**

The thickness and quality of the outer veneers are important for panel stability. If distortion-prone wood is used in a lower-quality core, internal stresses can be set up by moisture movement.

These stresses will distort the panel unless the face and back veneers are thick enough and of sufficient quality to resist the stresses. Thinner face veneers can lead to distortion problems but thicker, higher-quality, outer veneers can help to increase the recovery of lower-quality veneer for use in the core.

**Utilisation**

New Zealand pine plywood is very easy to saw, shape and fabricate into a full range of structural components. Professor Motoaki Okuma of University of Tokyo has tested New Zealand pine, Lauan and Douglas fir plywood. New Zealand pine was found to have bending properties similar to the other species, but it had better shear properties.

It is easy to nail and has good nail-holding power compared with Lauan plywood.

Shear strength of plywood is important in beams of for bracing to resist winds or earthquakes. Knotty veneer has better shear strength than clear veneer and can be used in the core of panels.

**Laminated Veneer Lumber (LVL)**

LVL has been manufactured from New Zealand pine since 1991 by a Japanese company at a number of factory sites. Tests on LVL of many species at the Forestry and Forest Products Research Institute at Tsukuba have shown that New Zealand pine is very suitable for laminated veneer lumber.

In compression, New Zealand pine LVL had superior performance and New Zealand pine nail plate joints gave the highest load resistance.
Veneers & Overlaid Products

Clear and natural veneers are laminated on to MDF or used in engineered door stiles, while fingerjointed mouldings are overlaid with paper, foil, and plastic.

Veneer

New Zealand pine can be sliced or peeled to produce high quality natural clear veneer for a variety of products, such as engineered door stiles, curved plywood, and overlaid panels, to give the appearance of solid wood. The product is well suited to rotary peeling and slicing as the relatively small difference in density between early wood and late wood provides less problems to peeling/slicing and drying than other softwoods. The clearwood silvicultural regimes used in New Zealand produce a pruned log which gives natural clear veneer for high value end uses.

Whole log slicing produces veneer typically 0.6 mm thick, and is mainly used as an overlay on panel products such as MDF and particleboard, or to overlay mouldings. Overlaid panels are used in hard furniture and flush door manufacture. Whole log slicing in New Zealand is used to produce mainly clear veneer and slicing stops when the defect core is reached, leaving a central flitch. Whole log slicing produces 500 m² of face grade veneer from 1 cubic metre of pruned log, yielding a 30% conversion. A further 5-20% of back grade veneer, and 10-20% flitch is also produced.

Slicing ‘blanks’ are cut from boards in a remanufacturing plant. The blanks are high quality, long length clear components recovered to add value to a lower cost resource. New Zealand pine veneer can be sliced from either green or kiln dried blanks. Pre-grading of blanks ensures a high recovery of top quality veneers and a conversion from blank to veneer of nearly 100%. The veneer is typically 2.1 mm thick and is used in engineered products such as door styles or jambs.

The versatility of New Zealand pine is demonstrated by its use as both veneer and substrate in overlaid and engineered products.
Peeled veneer comes in thickness ranging from 1 mm to 4.2 mm, and is typically used in curved plywood for furniture manufacture. New Zealand pine provides equal proportions of face veneers and back veneers when a pruned log is peeled to a 60-95 mm core, yielding an overall recovery of 50-60% from log to finished product. Further recovery can be achieved with a smaller core.

**Substrate For Overlays**

New Zealand pine can also be used as a substrate for overlaid products. In Japanese homes, the most common of these are kamachi steps and kamoi top slides. Blocks from a remanufacturing plant are finger-jointed and then laminated into large sections which provide significant stability and strength. These are then overlaid with a veneer and used as steps from the foyer to the rest of the house or door lintels. Similarly, laminated structural grades are covered with veneer and then used as hashira posts in Japanese homes. New Zealand pine veneers could also be used to overlay the New Zealand pine core.

Another type of substrate is fingerjointed mouldings overlaid with paper, plastic, or foil, or direct printed, to make them look like another species. Overlaid mouldings are used in furniture manufacturing and as interior fittings. Ease of profiling and quality of surface finish make the application of an overlay to New Zealand pine much easier. The use of overlaid products is increasing as traditional solid wood supplies decrease and are replaced by engineered solutions.
Although in existence for 30 years, the demand for medium density fibreboard (MDF) produced in New Zealand is still increasing. Due to its dense, uniform composition, flatness and versatility it has become highly sought after, for both fine cabinetry operations and for more routine applications such as a lining material.

New Zealand MDF is made almost exclusively from New Zealand pine. It has in a very short time achieved a reputation for its consistent high quality, its light colour (good for overlays) and in particular the high quality of its surface finish. The New Zealand MDF industry has also been very innovative, leading in developing new features or product configurations targeted at special applications. An example is a panel with high density outer layers resulting in a product with very high bending strength ideal for load-carrying applications such as flooring or shelving. Similarly, the development of lower density boards provides a lower weight panel still retaining the excellent surface and machining properties. Thin boards (3mm thickness) are also a more recent development and have found application as lining materials, able to compete with hardboard and with the advantage of the light colour.

With an annual production of about 600,000 m³ annually, New Zealand is in the top five MDF producers in the world.

Reconstituted panel products

made from New Zealand pine have earned a good reputation for consistency and these products are sought after in many countries.
MANUFACTURE

The raw material for New Zealand MDF varies according to the specific plant, but typically consists of New Zealand pine logs chipped on site, or wood chips produced from local wood processing plants. The chips are washed to remove foreign material and softened using steam before being refined to produce the small fibres characteristic of the product. Adhesives, typically urea formaldehyde or melamine urea formaldehyde, are added after the refining stage, along with wax. The resultant resinated fibres are dried, formed into large mats and then hot pressed to the final material dimensions, using either large batch (multi-daylight) or continuous presses. After pressing, the boards are cooled and sanded before stacking. Careful control of the pressing schedule allows introduction of the many characteristic properties, particularly the density profile through the board thickness.

PROPERTIES

New Zealand MDF has excellent working properties. This is attributed to the density profile that is developed during manufacture. The dense outer face provides the high quality surface feature and the high bending strength. The even density of the inner layer provides the uniform and excellent machining characteristics.

The above combination of attributes means that New Zealand MDF lends itself to a very wide range of uses. This includes: fine furniture, mouldings, shelving, stair treads, flooring overlays, shop fittings, cabinetry (kitchens and bathrooms), bedroom furniture and much more. Its high density and fine surface also assist applications requiring exacting detail such as in shaping or carving operations.

The lightness, flatness and uniform qualities of the surface make it an ideal substrate for overlays, veneering and paint finishes. The resultant product is suitable for either a very traditional or a very modern look.

WORKING WITH MDF

MDF can be machined without chipout. A saw cut can produce a very smooth edge, directly eliminating the need for subsequent sanding. The product also lends itself to routing or shaping. Very fine edges, sometimes almost razor sharp, can be produced. Tungsten carbide tipped cutters are recommended.

Jointing of MDF is also very easy with either adhesives or mechanical fasteners. MDF will accept a wide range of adhesives although gap-filling types such as PVA, urea formaldehyde or epoxies are preferred. Note should be taken of the particular manufacturer’s recommendations, but generally a light sanding, followed by removal of any surface dust is recommended prior to gluing.

MDF can also be jointed using traditional wood working joints such as dovetails, butt joints, or tenons. Dowelling is also popular but grooved dowels are recommended.

For screwing operations, straight shanked screws only are advised, preferably with wide sharp threads. A pilot hole is essential. If greater strength is required it is advisable to use longer, not larger, screws as larger, or thick, or tapered screws will promote splitting. Conventional woodscrews should not be used.

Veneering or painting should be carried out on both faces, otherwise differential moisture uptake will occur and the product will bend. Three coats of paint are also advised. Alkyd paints work best but if a water-based paint is used, sanding will be necessary after the first coat as the water solvent will produce some surface roughening.

New Zealand MDF is not intended for exterior use. Regardless of application, some coating, a paint or overlay should be applied. Just like the finest of woods the fine surface can stain or scratch easily so care should always be taken during product fabrication.

Before use the material should be acclimatised to its final use conditions. A few days storing will allow it to incrementally adjust its moisture content to that of its new environment.

During processing operations such as sawing or routing, care should be
New Zealand produces a range of panel products in addition to MDF based on New Zealand pine. They include particleboard, fine particleboard and an MDF-strandboard combination called Trideck.

Particleboard is manufactured from New Zealand pine chips from wood processing operations or from logs chipped on site. The particles are dried, mixed with glue, such as urea formaldehyde or melamine urea formaldehyde (where better moisture resistance is required), formed into mats and then hot pressed. New Zealand particleboard is predominantly used for flooring and less so for cabinetry and furniture. The fine surface boards are generally used with a variety of finishes and laminates, and with overlays for moisture resistant panels for use in areas with high humidity or occasional dampness.

Triboard is manufactured by combining processes producing MDF and strands. Mats of resinated MDF fibre and strands are laid up in a three-layer sandwich, with the MDF fibres in the outer layers. The mat is pressed in a steam injection press, prior to cooling and sanding. Product thicknesses up to 100 mm are possible. Triboard combines the stability associated with strandboard with the fine surface finish associated with MDF. Applications include wall sections, solid core door stock, stair treads and flooring, including specialist products such as computer room flooring.

Performance

New Zealand MDF has developed a very strong market acceptance, ideal for both traditional and new applications, for the small scale wood working enthusiast and large scale factory production operations. As the New Zealand MDF industry has a track record for continuous development and improvement, we can be sure of a very bright future for this product.
GLOSSARY OF ACRONYMS

LUMBER & GRADES
JAS – Japanese Agricultural Standard
SPF – spruce-pine-fir
MoE – modulus of elasticity (stiffness)

DRYING
MC – moisture content
EMC – equilibrium moisture content
m/s – metres per second

PRESERVATION PROCESSES
CCA – copper-chrome-arsenate
LOSP – light organic solvent preservatives
H1, H2 etc – Hazard Class Specifications

FINISHING, STAINING & PERFORMANCE ENHANCEMENT
low VOC – low volatility organic compound

GLUING, FINGER-JOINTING & LAMINATING
RF – radio frequency

FURNITURE & COMPONENTS
DIY – do-it-yourself

INDUSTRIAL USES
CAD – computer-aided-design
NZS – New Zealand Standard

Plywood & LVL
LVL – laminated veneer lumber
AS/NZS – Australian Standard/ New Zealand Standard
JIS – Japanese Industrial Standard
ASTM – American Standard Testing Method

Particleboard & Medium Density Fibreboard
MDF – medium density fibreboard
PVA – polyvinyl acetate
The Authors

Resource

Log Quality & Conversion

Lumber & Grades

Protection of Wood
1992 author – Mick Hedley. Updated by – Mick Hedley & Robin Wakeling – New Zealand Forest Research Institute

Drying

Preservation Processes
1992 author – Mick Hedley. Updated by – Mick Hedley – New Zealand Forest Research Institute & Jim Maud – Ministry of Forestry

Finishing, Staining & Performance Enhancement
1992 authors – David Plackett & Graeme Young. Updated by – Bernard Dawson – New Zealand Forest Research Institute & Jost Siegfried – Ministry of Forestry

Machining

Construction
1992 author – Mike Collins. Updated by – Brian Walford – New Zealand Forest Research Institute & Jim Maud – Ministry of Forestry

Gluing, Finger-Jointing & Laminating

Joinery & Interior Fittings

Furniture & Components

Industrial Uses

External Uses

Plywood & LVL

Veneers & Overlaid Products
Charles McIntosh – New Zealand Forest Research Institute & Phil Lindsay – Ministry of Forestry

Particleboard & Medium Density Fibreboard