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Forest and Wood Products Research and Development Corporation

Australian Hardwood Drying Best Practice Manual *Part 2*

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Australian Hardwood Drying Best Practice Manual *Part 2*

Air drying
Pre-drying
Reconditioning
Controlled final drying
Dry milling
Storage
Information assessment
Drying quality assessment
Moisture content monitoring
Glossary

Prepared for the
Forest & Wood Products
Research and Development Corporation

by

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Introduction

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Introduction

Across Australia, hardwood producers process and dry a wide variety of native hardwood species into high quality visual and commodity structural products.

Like the species they process, these producers vary considerably in their skill, capacity and potential. However, to produce stable timber to an acceptable market grade consistently and profitably, they all face the same challenges:

- Australian hardwoods are natural materials with variable properties. This variability has to be recognized and managed;
- The timber from Australia's hardwoods must be dried from its original unseasoned condition to a moisture content suitable for its intended use if it is to remain stable;
- The timber must generally be dried slowly and with care. If the timber is subject to significant adverse conditions at any time as it dries, it may be damaged and lose value; and
- The producer needs to recover the maximum volume and value of dry material efficiently from the wood resource they have available.

To address these, the drying process must be managed and conducted effectively and efficiently. This is not the job of a single person. It must be the responsibility of everyone involved in the process. This requires that a 'best practice' approach be used.

Aim of the manual

'Best practice' in hardwood drying is a set of operations established and conducted to achieve high grade results in product quality and recovery, flexibility, innovation, cost, and competitiveness, through the cooperation of management and employees in all key aspects of the process.

This manual aims to provide guidance in establishing this set of operations. It outlines:

- economic and feasible technologies for increasing recovery and reducing avoidable loss during processing from the log to the finished board; and
- mechanisms that allow production value to be optimised in mills of disparate size.

The manual only deals with issues that materially affect the practice of drying timber. However, guidance in some sections is limited by:

- the diversity of producer capability, location, equipment and products;
- the range and variability of the species processed; and
- the state of knowledge. In many areas, it has not been possible to verify the benefits of one method of practice over another at all location.

Introduction

The manual structure

This manual is arranged into modules that generally match the major work areas of the hardwood drying processes, such as the log yard and air drying.

Each module is generally designed to be a self contained document. Each module is then structured into discrete parts:

Objectives:	This part includes a description of actions covered in the module and lists the performance requirements for those actions. The performance requirements provide the gauge by which any practice should be judged.
Management:	This part includes a general description of the theory, background and equipment relevant to the actions covered in the module. It then details the management decisions relevant to the performance requirements, the procedures that need to be in place and the information that should be collected.
Operations:	This part includes a brief description of the background to action in the area and the things that need to be done to comply with the performance requirements. It also lists things that need to be checked and paperwork that needs to be completed.
Checklists:	This part includes checklists that can be used in assessing performance in the actions covered in the module. Not all sections have checklists.
Avoidable Loss:	This part shows what goes wrong when the practice does not match the performance requirements. It shows why certain things should be done, and why others should be avoided.
References:	This part lists the references used in preparing the module.

Introduction

Acknowledgements

Preparation of this manual has been a collaborative effort from all levels of the Australian hardwood industry.

It contains contributions from research and industry hardwood drying specialists from all over Australia and draws from the research results of many organisations. At the same time, it contains contributions from the managers and operators of many of Australia's hardwood mills who made their skill and experience available. In particular, the authors acknowledge the cooperation of:

Boral Timber

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Forests & Forest Industries Council

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Hyne & Son Pty Ltd

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Neville Smith Timber Industries Pty Ltd.

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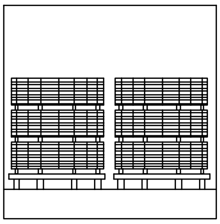
Finally, the authors acknowledge the contribution of overseas publications, especially the hardwood drying publications of the United States Department of Agriculture Forest Service.

8.0: – AIR DRYING



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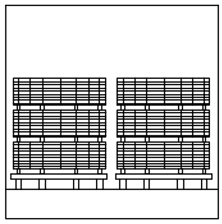
8.0: – AIR DRYING



8.1 Objectives

The objective of air drying is to dry timber in racks in natural conditions to a moisture content suitable for further processing with minimal inappropriate degrade.

While uncontrolled, the natural conditions experienced by racks can be moderated by the orientation and placement of racks in the open, or by their placement in buildings or shelters.

8.1.1 Functions & Performance Requirements

1. Placing the rack in the drying yard or sheds

Stack locations are ordered to standard procedures.

Batch characteristics of rack are assessed and used to control processing.

Racks are adequately and evenly supported and restrained in assembled stacks.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or foundations.

2. Protecting the racks and stacks from physical and drying damage

Stacks are protected from adverse drying conditions.

The spacing and support of assembled stacks allows the airflow through each rack in the stack to be as uniform as practicable.

The airflow through arranged stacks is appropriate for the size, grade, and intended product area of the boards.

Racks stored for further processing or in transport are protected to minimise drying degrade.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

3. Monitoring moisture

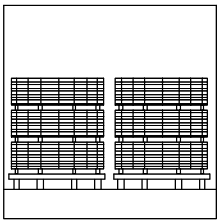
When air drying is complete, the moisture content of timber in the racks should be suitable for the next intended production process.

4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively.

5. Identifying & reporting problems for correction

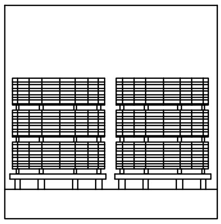
Details of individual and systemic problems are identified and distributed.



Problems are corrected.

6. Management of staff and equipment

Staff and equipment are available to conduct air drying activity safely and efficiently.



8.2 Management

8.2.1 Overview

Activity during air drying is to dry timber in racks in natural conditions to a moisture content suitable for further processing with minimal inappropriate degrade.

Air drying is the process of placing stacks of racked timber in the prevailing natural conditions so that they dry evenly to a suitable moisture content. While uncontrolled, natural conditions experienced by racks can be moderated by:

- the orientation and placement of racks in the open;
- the use of buildings and other major elements as buffers from the sun and wind in the racking yard;
- the use of local environmental protections, such as hessian or shade cloth, over or around the racks; and
- by placing the racks in buildings or shelters.

Air drying works because air moving through the gaps between the racked timber dries moisture from the surfaces of the board. As it does so, moisture is drawn from the interior of the board to the surfaces where, in time, it also dries. This can be relatively quick until the timber reaches fibre saturation point, depending on the thickness of the timber, and its diffusivity. Beyond fibre saturation point, drying becomes progressively slower but will continue until the moisture content in the timber is in equilibrium with the prevailing natural conditions. During this process, the weight of other timber in the stack restrains each board and limits deformation.

Air drying is used to:

- dry the timber initially before it is placed into a predryer. Usually no definite moisture target is set for this;
- dry the timber to somewhere below fibre saturation point, when it can then be placed into either a reconditioner or a high temperature kiln for reconditioning or final drying respectively. The target moisture content in this case is 18-20%; or
- dry the timber to an equilibrium moisture content, usually between 10 & 15%.

Air drying is a low capital and low energy method of drying timber. However, it can only be cost effective if conditions during air drying do not lead to significant grade reduction in the boards through checking, collapse, or deformation. Generally, grade reduction occurs because the timber is dried too fast.

1. Acceptable air drying

For cost effective and efficient air drying, the unseasoned timber being air dried has to be placed in conditions that will dry it evenly and at an acceptable rate.

That is, slow enough to avoid degrade and fast enough to maintain economic and cost effective production.

The rate of drying that can be sustained without degrade is not constant. Slower drying rates are often required in the initial stages.

Four main factors influence the acceptable rate and duration for air drying timber. These are:

- **The characteristics of the timber batch.**
  The rate the timber can be dried without loss of grade is determined by factors that affect its shrinkage, strength, diffusivity, such as species and age, and the grade, thickness and sawing orientation of the board;
- **The local climate.**
  This includes factors that determine the absolute rate of drying on a mill site: the temperature, humidity, the prevailing winds and the season;
- **The exposure of timber in the drying yard.**
  The prevailing natural conditions can be moderated by the arrangement of the yard, sheltering stacks in buildings, grouping stacks together and by protecting individual stacks with covers or shades; and
- **The scheduling of exposure.**
  This includes the periods stacks spend in the various locations in the yard and their progress to the next production process. It also includes the scheduling of production of various sizes and grade to avoid exposing them to adverse seasonal conditions.

For acceptable air drying in a mill, these four factors have to be understood and used to adjust air drying practice in a responsive way.

While many batches of sawn boards can be air dried economically, others can not. For example, while it is possible to commercially dry quarter sawn select grade regrowth 'Tasmanian Oak' boards, it is almost impossible to air dry back sawn material of the same size and species without unacceptable grade loss.

2. The characteristics of the timber batch

As explained in detail in Module 1, characteristics of the timber batch influence the acceptable drying rate. Major factors include:

2a. Species

Timbers dry at different rates both within and across species. The rate at which timber dries is a function of the diffusivity of the species and the thickness of the board. The strength and shrinkage characteristics of the species and the piece affect the type and extent of degrade.

2b. Age

The drying characteristics of timber of the same species can vary considerably depending on its age, and the rate and location of growth. Generally, faster grown timber and younger regrowth timber is less dense than older and more slowly grown material and dries more quickly. It may also be far more prone to degrade, such as internal and surface checks and collapse.

2c. Thickness

The thicker the board of a particular material, the slower it dries. The moisture in the centre of the board takes time to make its way to the surface and evaporate. This adds to the total time required for the moisture content of thicker boards to even out. Also, the shrinkage and associated stresses that results when parts of a board dry before others means that thick boards have to be dried slowly or they will degrade.

2d. Sawing orientation & other factors

Quarter sawn timber dries more slowly than backsawn timber. The structural arrangement of the wood in a back sawn board aids the movement of moisture. Timber generally shrinks more tangentially than radially, but is also less stiff tangentially. As they tend to shrink more on the wide face and are less stiff backsawn boards are more prone to the formation of surface check than quartersawn boards.

2e. Grade

Structural grade products can be dried more quickly than appearance grade products with the same size section. Features that result from fast drying, such as checking, are generally more acceptable under structural grading rules. Anything but minor surface checking is not generally permitted under appearance grading rules. Checking on milled appearance grade boards reduces value considerably.

2f. Summary

The movement of moisture within timber during air drying is mostly determined by the diffusivity of the timber. In turn, this is related to other factors such as species or age. The rate at which a board dries is also affected by its thickness and sawing orientation. The rate at which a board may be dried with acceptable level of degrade, to meet a particular grade requirement, is also affected by timber properties such as shrinkage and strength.

For acceptable air drying, these combine to two simple principles:

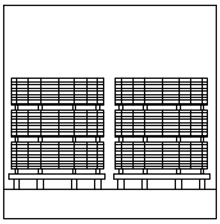
- the better the quality or thicker the material, the slower drying should be; and
- the most important stage of drying to prevent degrade is initial drying.

A detailed description of what happens in this stage of drying is included in Module 1. Drying Overview and Strategy.

3. The local climate

The absolute rate of air drying is primarily influenced by the prevailing weather conditions at the mill site: the temperature; humidity; and the prevailing wind speed.

8.0: – AIR DRYING



These factors influence the ability of the air around the timber to absorb moisture. Warm air with a low humidity can dry water from the surfaces of the board quickly. However, without some air movement, this air quickly cools and its ability to absorb further moisture drops. With sufficient air movement, this cooler and moister air is continuously replaced with dry warm air, and drying of the timber is able to continue.

To plan and achieve acceptable air drying, it is important to develop an understanding of local weather conditions. This can be done by using available weather information or by directly monitoring climatic conditions on site.

In Australia, detailed weather information is available from the Bureau of Meteorology. Information is available for a wide range of locations and includes average maximum and minimum temperature, rainfall, and less frequently, the direction, speed and frequency wind.

The Bureau of Meteorology also makes available up to date maps of rainfall over time and the results of evaporation modelling. This can be accessed free of charge from the Bureau of Meteorology's Internet site at: www.bom.gov.au.

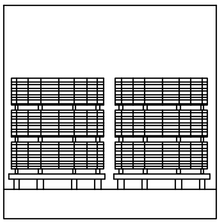
Summary information for Australian sites is included in Table 8.01. Note that not all information is available for all sites.

The weather conditions at a mill site may vary considerably from neighboring weather monitoring sites. Local topographical features have a large influence. Open elevated sites have more wind and higher temperatures than lower and sheltered sites. Low sites near bodies of water will have higher relative humidity than surrounding areas. Hills can funnel wind over a site or can shelter it.

An understanding of site conditions can be developed by observation and measurement. Regular observation over an extended period is effective for a qualitative evaluation of air movement on a site. Simple aids like flags or windsocks assist this. On an even, open site, the wind over the whole site is likely to be relatively consistent. On a sheltered site, or one broken by a gully, creek, or vegetation, wind can be funneled along the creek or around the hill to create localised areas with a high drying rate. The affects of these have to be accommodated and utilised in any yard design and layout.

Direct measurement of conditions can confirm observations. This can include measurement of wind speed, temperature, relative humidity, and dew point temperature. Domestic and commercial grade sensors are available from a range of distributors.

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Launceston (Airport) Tas.												
Mean Daily Max Temp (C)	23.2	23.1	21.0	17.3	13.9	11.4	10.8	12.0	14.0	16.4	18.7	21.2
Mean 3pm Relative Humidity (%),	45	45	50	57	67	72	71	66	61	57	53	49
Mean 3pm Wind Speed (km/hr)	21.7	20.6	19.5	18.2	16.1	14.9	16.3	18.7	21.6	22.1	22.6	23.1
Mean Daily Evaporation (mm)	6.9	6.4	4.6	2.7	1.5	0.9	1.0	1.6	2.5	3.8	5.1	6.5



Hobart, Tas												
Mean Daily Max Temp (C)	21.5	21.6	20.1	17.3	14.4	11.9	11.6	13.0	15.0	16.9	18.6	20.2
Mean 3pm Relative Humidity (%),	54	55	56	59	63	67	65	60	56	56	55	58
Mean 3pm Wind Speed (km/hr)	19.4	18.4	16.5	14.9	13.2	12.5	13.6	14.9	17.2	18.2	19.5	19.8
Mean Daily Evaporation (mm)	4.8	4.4	3.2	2.1	1.4	0.8	0.9	1.4	2.2	3.0	3.7	4.3
Smithon, Tas												
Mean Daily Max Temp (C)	21.0	21.5	20.2	17.7	15.4	13.5	12.8	13.4	14.5	16.3	17.8	19.4
Mean 3pm Relative Humidity (%),	60	61	64	69	75	76	77	73	69	65	63	63
Mean 3pm Wind Speed (km/hr)	20.7	19.5	17.9	14.1	12.5	12.2	15.3	16.2	19.5	20.6	21.7	21.5
Latrobe Valley Airport, Vic												
Mean Daily Max Temp (C)	25.6	26.5	24.0	20.3	16.8	14.0	13.5	14.7	16.5	19.1	21.1	23.6
Mean 3pm Relative Humidity (%),	49	46	50	54	63	68	67	61	60	56	55	50
Mean 3pm Wind Speed (km/hr)	20.1	17.8	16.5	15.6	13.7	15.1	17.1	18.9	19.1	20.1	18.5	20.1
Alexandra, Vic.												
Mean Daily Max Temp (C)	29.3	29.3	26.0	20.5	15.8	12.1	11.7	13.8	17.0	20.3	23.8	27.3
Mean 9am Relative Humidity (%),	55	60	68	81	88	91	90	87	79	70	60	58
Mean 9am Wind Speed (km/hr)	6.9	10.3	8.3	5.5	5.6	1.7	5.1	5.3	7.3	8.7	13.6	11.4
Patterson (Tocal), NSW												
Mean Daily Max Temp (C)	29.2	28.5	26.8	24.1	20.6	17.5	17.2	19.1	21.9	24.7	26.3	29.0
Mean 3pm Relative Humidity (%),	54	57	59	56	60	59	55	48	48	50	51	49
Mean 3pm Wind Speed (km/hr)	13.6	11.5	11.0	11.2	11.3	14.1	15.3	18.3	18.1	16.3	16.3	15.8
Mean Daily Evaporation (mm)	6.0	5.2	4.2	3.4	2.4	2.2	2.5	3.4	4.4	5.2	5.9	7.0
Grafton, NSW												
Mean Daily Max Temp (C)	30.0	29.2	28.3	26.2	23.0	20.7	20.3	21.9	24.6	26.5	28.0	29.6
Mean 3pm Relative Humidity (%),	57	60	58	54	57	53	48	43	43	50	51	53
Mean 3pm Wind Speed (km/hr)	12.6	13.4	12.2	12.1	9.3	10.9	9.9	12.8	14.2	18.0	14.5	15.5
Casino, NSW												
Mean Daily Max Temp (C)	31.3	30.4	29.1	26.8	23.8	21.4	21.1	22.8	25.5	27.9	29.8	31.1
Mean 3pm Relative Humidity (%),	55	58	57	55	59	54	50	44	42	47	50	52
Mean 3pm Wind Speed (km/hr)	14.0	14.0	14.9	12.3	10.1	11.2	11.5	14.4	16.7	16.8	16.9	14.4
Maryborough, Qld												
Mean Daily Max Temp (C)	30.7	30.1	29.2	27.3	24.6	22.3	21.9	23.3	25.6	27.7	29.3	30.5
Mean 3pm Relative Humidity (%),	60	63	61	60	59	55	51	48	48	53	57	58
Mean 3pm Wind Speed (km/hr)	21.0	20.5	19.7	18.4	15.9	15.2	15.8	17.2	20.2	21.1	20.9	20.7
Manjimup, WA												
Mean Daily Max Temp (C)	27.0	26.9	24.5	20.9	17.3	15.2	14.2	14.9	16.4	18.7	21.7	24.7
Mean 3pm Relative Humidity (%),	41	42	47	57	66	71	71	67	63	55	51	45
Mean 3pm Wind Speed (km/hr)	11.4	11.0	10.6	9.6	9.1	10.1	10.2	11.4	11.2	11.6	12.2	11.9

Table 8.01. Climatic indices for selected sites -
Source: Bureau of Meteorology

4. Exposure in the drying yard

Conditions in the yard can be manipulated to some degree to ensure that the timber is dried uniformly and at an acceptable rate. This includes managing the arrangement of the stack, the layout of the drying yard and the use of buildings and drying shelters.

4a. Stack.

The basic element in air drying is the stack of timber; a number or racks positioned one above the other. For uniform and efficient drying, the stack should be protected from undue sources of moisture and drying, and exposed to even air movement.

4b. Undue moisture and drying

The main sources of undue moisture for the stack are water ponding after rain and ground water. The more water that the atmosphere has to evaporate from the ground and any standing water, the less it can dry from the timber. Also, ground moisture can encourage damp conditions at the bases of stacks and slow the drying of the bottom racks. All drying yards should include good surface and ground drainage.

The sun, wind and rain acting on the top rows of the stack are undue sources of drying and moisture. The sun heats and dries the top rows of timber directly and quickly. Occasional wetting by rain and the subsequent fast drying by wind aggravate this and lead to weathering of the timber. In combination, these can lead to losses of affected material, generally the top two or three layers of the stack.

Figure 8. 01. Exposure damage to the top rows of a stack

These losses can be reduced by the use of stack tops. Stack tops serve a variety of functions. They provide some restraint for the top rows and protect them from the worst impacts of the elements, reducing air speed and limiting direct sunlight. Water shedding tops also exclude a high proportion of rain from entering the whole stack. Construction of stack tops is detailed in Section 8.2.2. Another solution is to place a rack of structural material as the top rack in a stack containing appearance racks. This acts as a large stack top to the higher value material.

All stacks should be protected by a stack top or other cover.

Figure 8.02. A lower value rack on the top of the stack protects the higher value material below

Material on the top of stacks may distort significantly as it dries, as the weight of material above it is inadequate to restrain the boards. If losses are noticeable and significant, stack weights may be necessary. These can be of sheet steel or concrete about 100 thick and the same width and length of the rack. Weights should include their own or be placed on bearers to allow drying to occur on the exposed face of the top most layer. If used, stack weights should be applied as soon as practical after racking. While they can reduce cupping and distortion, weighting can increase surface checking on the outer backsawn face of boards.

5. Uniform air flow

Uniform airflow around and through a stack is best achieved by:

- orienting the stacks so that their long sides are generally parallel to the prevailing winds; and
- supporting the racks above the ground.

Racks arranged with their long sides facing the prevailing wind dry more quickly than racks arranged with their long sides parallel to the prevailing wind but the drying in not uniform. The timber on the windward side receives the full attention of the entering air. The temperature of air on the down wind side is usually cooler as it loses heat to supply the energy needed to evaporate moisture from the timber that it has passed through. As a result, the timber on this side dries more slowly. This quick and uneven drying can lead to significant degrade and problems during later production.

Stacks should be built so air can flow under them. As shown in Figure 8.03. without some air movement, relatively cool and moist air can settle between stacks and slow the drying of the lower racks unless it can escape. When the rack is elevated at least 450 mm above the ground, air movement under the stack moves this moisture laden air away and dries the ground. With stacks built close to the ground or where grass and weeds restrict air movement, moisture laden air can be retained around the lower timber of the stack and ground moisture cannot be easily dried away. Studies have shown that adequate ventilation under the stack in an air drying yard can reduce moisture content variation through the stack and speed effective drying considerably.

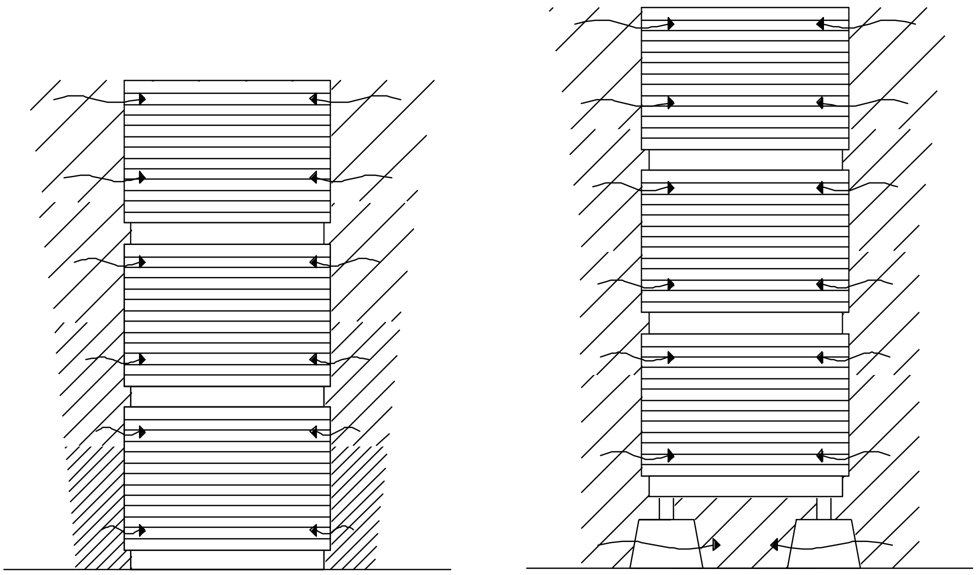


Figure 8.03. Qualitative air movement in stacks

6. Arranging stacks in the yards

The spacing of stacks relative to each other in the drying yard influences the drying rate of the timber significantly. Wide spacing of stacks speeds up the rate of drying while close spacing decrease it. As outlined above, as air flows through a stack and dries the timber, it cools. With increased moisture content, this body of air has less capacity to dry more timber. If this relatively moist air is not removed by ventilation around and under the stack, the rate of drying of this and surrounding stacks is reduced. This can create difficulties when the drying rate of the timber is too slow but can present opportunities for protecting timber that is susceptible to degrade from rapid drying or where drying conditions can be excessively harsh.

6a. Slowing drying

The general drying rate in an air drying yard often needs to be slowed for material that checks and / or collapses very readily (refractory stock), large section timber, and in area with potentially harsh seasonal climates such as parts of NSW, Queensland and West Australia.

As shown in Figure 8.04., rows of stacks placed close together in a block can create their own microclimate. The outer rows shield the inner stacks from wind, reducing airflow in the rest of the block. Evaporation from the wood lowers the temperature and increases relative humidity. These factors combine to slow the drying of the shielded stacks. Buildings and trees create wind and sun shadows that can also be used to establish areas in the yard that have a slower drying rate at particular times of the year.

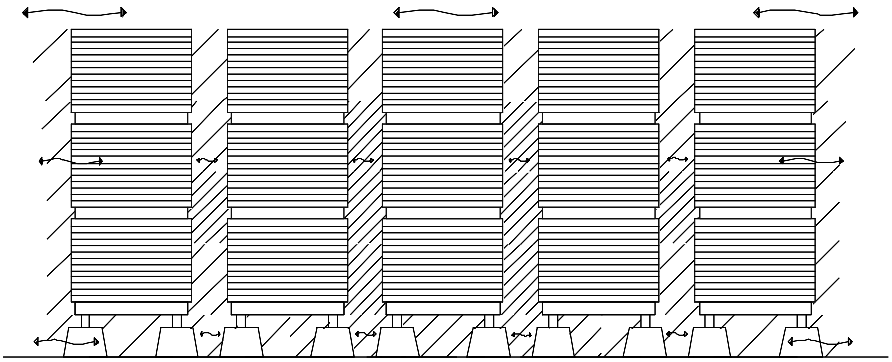


Figure 8.04. Qualitative air movement in blocks of stacks

Figure 8.05. The arrangement of racks can modify ambient conditions

For material that can sustain a higher drying rate without degrade and in the cooler conditions of the southern states, the problem can be in a drying rate that is too slow or uneven. In addition to increasing stock holding costs, this can also lead to grade reduction as the timber may be subject to fungal attack causing mildew, blue stain and other discolouration.

To provide adequate and uniform air circulation in slow drying areas, rows of stacks need to be spaced apart to exploit the prevailing winds, especially in winter. The aisles between rows of stacks must be wide and clear, without obstructions, such as stacks placed across the ends. The space between rows of stacks needs to be sufficient to allow effective air movement. Wind and sun shadows from buildings and trees need to be reduced.

In an air drying yard that is overcrowded, only the outer stacks and the tops of the other stacks receive sufficient air flow to dry at an acceptable rate. As a result, the lower parts of stacks towards the centre of the yard tend to dry slowly and unevenly. Except when the rate of drying needs to be slowed, overstocking a yard may be a false economy.

Figure 8.06. A straight and clean drying yard in a cool temperate climate

7. Sheltering in building or with covers

Stacks are sheltered in buildings to slow initial drying or to moderate extreme drying conditions. Both can improve the recovery of quality dried material. Initial drying can still be quite fast but the moisture gradient between the core and surface of the material can be maintained at a lower level than in an air drying yard. The drying stresses are lower and the timber is less likely to check. Later drying can also be quite fast, compared to air drying in the open as rain, dew and frost are not continuously rewetting the stacks. The stacks can be left in the shed until they are at suitable moisture content for further processing or further yard drying under less controlled conditions. The form of the buildings are outlined in Section 8.2.2

Like arrangements of stacks, the arrangement of buildings can help establish the desired conditions. Fully enclosed buildings or roofed shelters that are surrounded by other buildings have considerably reduced air movement and the rate of drying is slowed. Filled with freshly sawn timber, the temperature in them will be low and the relative humidity high. A temperature drop of 7 - 8 ^{o}C from an ambient of 30^{o}C is common in a large enclosed drying shed.

Roofed shelters in the open can be with or without screens. As they exclude direct sunshine, rain and moderate air movement, the roof and screens reduce adverse conditions that lead to drying degrade.

Covers can also be used to wrap stacks and so slow drying of high quality material. These covers may be plastic, which blocks off almost all air and moisture movement, or open weave fabrics such as hessian or shade cloth. These all moderate the ambient conditions by cooling the air around the timber, increasing its humidity and reducing airflow.

Figure 8.07. Open fronted sheds protect stacks during initial drying

Figure 8.08. Wrapped stack in a shed during initial drying

8. Scheduling of exposure

To provide the timber with the optimal drying conditions, stacks of unseasoned timber can be scheduled to be:

- placed in different locations (and ambient environments) of a site at different stages of their drying; or
- milled at selected times of the year.

This is most important for refractory species of timber or high value and thick material, where slower initial drying rates are required. Thicker, collapse prone timber can be scheduled for milling in autumn so that it has several months of initial drying in the cooler winter air before being exposed to hotter summer conditions. Similarly, this type of material can be placed in a sheltered building for the first few weeks or months to slow initial drying rates and reduce drying induced stresses.

Structural grade material has to be dried to a consistent moisture content but checks are not critical to grade value. This grade of material can be positioned where it will dry quickly and can be used to shelter other more delicate material.

For many sites, air drying is scheduled simplistically on the time the rack has spent in the yard or the shed. The amount of time assumed to be necessary to reach the target moisture content or end of a stage of drying varies considerably between sites and is developed by experience. At most operations, the moisture content of a rack is only measured at the end of the expected air drying period, (when it should have reached the target moisture content). The response to the measurement is either to proceed with or delay further processing.

Scheduling assessment of moisture content is included below.

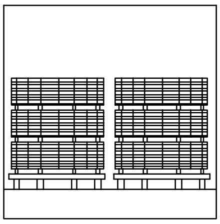
9. Setting out a drying yard

The air drying yard is generally located close to the green mill or the dry mill. An efficient yard layout provides:

- convenient material handling and transport;
- adequate and uniform air circulation, given the local microclimate; and
- good drainage.

A yard laid out to maximise drying potential should be on open, preferably elevated ground with no obstructions to the prevailing winds. Ideally, it would have a slight slope to assist with drainage.

Most yards are laid out on a rectangular plan with the aisles crossing each other at right angles. The aisle need to be wide enough for the loaded rack handling equipment employed on the site to move around. The aisles serve as roads for transporting the timber, as pathways for ventilation and as some protection against the uncontrolled spread of fire. The aisles separate areas for the timber stacks.



The main aisles run parallel to the rows of stack and are for placing material in the stacks. The cross aisles provide access to the main aisles. Generally, the aisles are sized for efficient air movement and easy one way traffic of a forklift loaded with the longest rack used on the site. The cross aisles and any end surrounding aisles also assist with air movement and may be sized for two way traffic.

The yard should be orientated so that the main aisles run parallel to the predominant drying breezes for the site. With this orientation, air can move freely along the aisles. In combination with the space at the ends and sides of the stacks, this movements sets up complex patterns of air velocities and pressure that draws air through the timber in the stacks, from one aisle to the other. If this orientation is roughly north-south, the yard will benefit from good sun access along the rows and aisles. This heats the ground, dries it and improves the evenness of drying generally. If this main aisle orientation is east-west, the width of aisles may need to be increased to ensure some penetration of sun onto the ground in the winter months.

Prevailing winds may vary throughout the year and come from conflicting quarters. In this case, the winds that provide the least harsh drying during summer or the most drying during winter should be favoured in the layout. Whichever of these is dominant depends on the prevailing climate at the site.

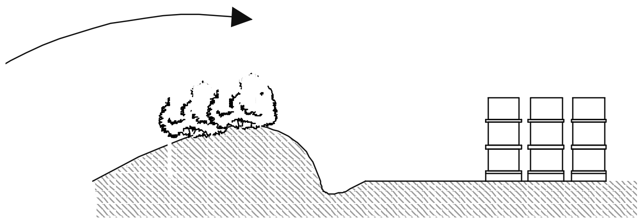


Figure 8.09. Sheltering stacks with a berm

The yard can be arranged in two main ways, as either a:

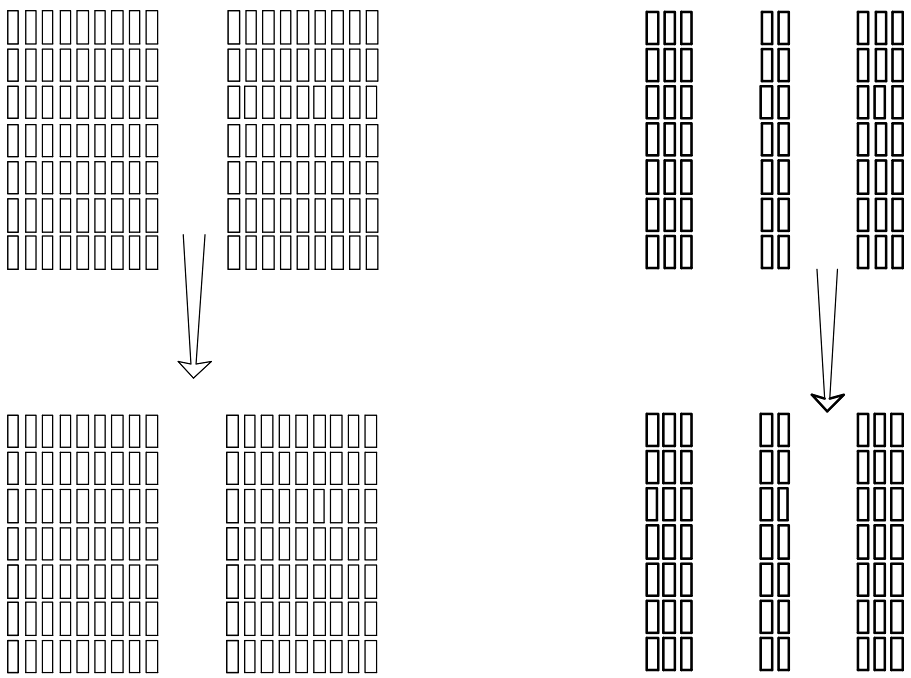
- **line yard.** A line yard is used where the maximum air drying rate afforded by the site is needed to dry the timber efficiently. The rows of stacks are only two or three stacks deep and are separated by aisles. Air only has to flow through this small number of stacks between the aisles. See Figure 8.10.
- **block yard**. A block yard is used where the drying rate of all or some of the material has to be slowed below the natural rate afforded by the site. In it, blocks of stacks are assembled in rows that can be 6 or more stacks deep. These form consolidated blocks and air movement and sun penetration is restricted. This arrangement lowers the temperature and raises the humidity of the air surrounding the timber. See Figure 8.10.

These general arrangements have to be moderated by the specific site conditions and an assessment of the prevailing wind and its effects.

Stacks of structural grade or lower value material, buildings, earth berms or trees may be positioned to protect the yard from the worst effects of the hot, persistent, or stronger winds. Where sites are not flat and there are changes of levels or gullies, complex wind and air flow patterns can result. Often, these can give rise to locations with high drying rates. If moderating these with buildings and windbreaks are difficult, stacks of structural or lower value material can be located in these areas

9a. Stack and aisle spacing

The width of aisles between the rows of timber should be the length of the longest racks assembled on the site plus 4 m. This provides safe and easy access for the longest racks of timber and good air movement along the aisle. Cross and perimeter aisles may need to accommodate two-way traffic and should be about 16-20 wide. The space between the rows of stacks in both line and block stacks should be about 0.6 - 0.75 m. This allows for reasonable air movement between the rows and a space for inspection and maintenance. In a line yard, the space between the ends of racks can be as little as practical as this space does not contribute to air movement. In block yards, a space of about 0.75 to 0.9 m will allow some air movement into the block of stacks.

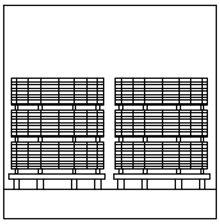


Block Type Yard Dwg 17 Line Type Yard Dwg 18

Figure 8.10. General arrangement of block and line type air drying yard

10. Configuration of the stack

Stacks are generally built to heights between 4.5 - 6 metres in full multiples of racks.



The arrangement of supports in a stack: piers; stringers; bearers and gluts, is governed by the spacing of the rack sticks in the racks that make up the stack. As shown in Figures 8.12 & Figures 8.13, the stack piers, bearers, gluts and rack sticks in all the racks in the stack should align vertically. This ensures that the load being transferred to the ground is carried in simple compression for stick to board to bearer etc. to the ground. Any eccentricity can result in a few boards carrying significant point loads. These bend, deform or indent and then dry in the deformed shape. Also, the integrity and stability of the rack and stack can be compromised. This can complicate further processing as racks that are out of square may not fit in kiln doors or restrict effective baffling in kilns or predryers.

Ideally, stacks should only be assembled of racks of the same width, length and rack stick spacing. While racks may vary in length, only racks of the same width and identical rack stick alignment should be assembled in a stack.

If the rack length varies, shorter racks should be placed above longer racks with the racks sticks aligned vertically. A glut should be placed under the end rack stick line of every rack in the stack and should be repeated vertically below this in any lower racks.

Equipment options for stacks are included in Section 8.2.2.

When using moveable hand placed piers, they should be placed on solid and even ground. A placement gauge or control rod should be used to ensure the pier positions match expected bearer and rack stick positions. The tops of the piers should be leveled to the tolerance in Table 8.02.

	Between any 2 piers	Across all piers (highest to lowest)
Tolerance	5 mm	12 mm

Table 8.02. Levelling tolerance for hand placed stack support piers

Bearer and glut spacing in the stacks should not exceed two rack stick spacings. This limits the maximum spacing of bearers and gluts to 1.2 m. If this spacing leads to noticeable deflection of boards between the bearers or gluts, the spacing should be reduced to one rack stick spacing.

Figure 8.11. A well constructed stack with rack stick, bearers, and piers aligned one over the other

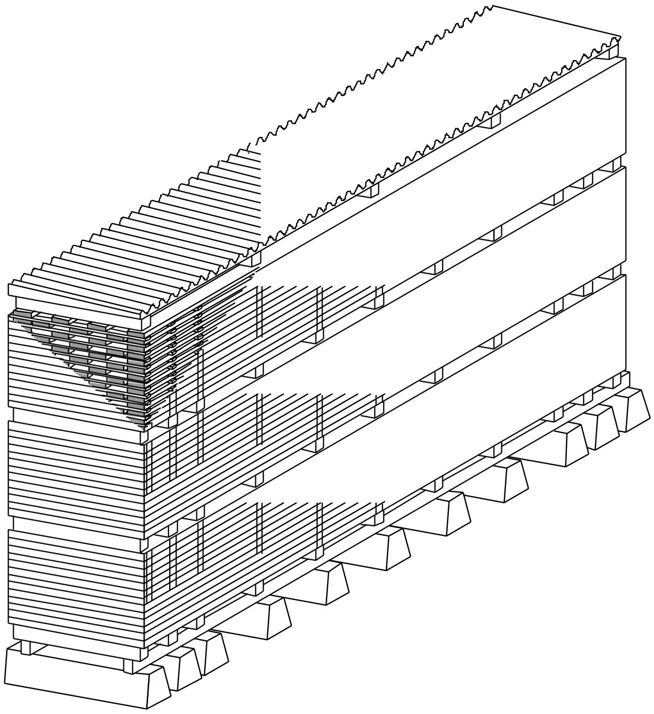


Figure 8.12. General arrangement of a stack

Acceptable
All sticks & gluts positioned within some part of the width of a rack stick.

Unacceptable
Some sticks & gluts positioned wholly outside the width of a rack stick.

Figure 8.13. Rack stick, glut and bearer alignment

Bearers must be positioned as directly as practical under the line of rack sticks.

Figure 8.14. A stack with an unacceptable lean

Stacks have to maintain their structural adequacy. To do this:

- Stacks generally should be no higher than 5 times their width.

- Any stack that develops a lean where the top of the stack is out of line with the bottom of the stack by more than one tenth of the distance between the stringers or support piers should be dismantled and rebuilt. For example, if the stringers are 1.1 m apart, the lean on the rack should be no greater than 110 mm.

These relationships are for sites with some wind protection. If the site is in a high wind area, they should be reduced.

11. MC measurement

Regular, retained and analyzed moisture content measurement of stacks in the air drying yard provides:

- a guide to the drying progress of stacks of timber; and
- information to access the quality and rate of drying in the yard.

11a. Progress measurements

Accurate moisture measurement in the yard of timber above fibre saturation point is only possible through the regular weighing of sample boards. Sample boards can be built into racks as they are assembled and their position marked with paint on the outside of the rack. After their initial preparation and measurement, the sample boards can be weighted during air drying to give an indication of the progress of drying in the stack. Details of using sample boards to measure moisture movement in racks are in Module 16. Moisture Content Monitoring.

Resistance type moisture meters can initially only give a guide to drying in the stack. Resistance meters are not accurate above fibre saturation point. They do indicate that the measured timber is above fibre saturation point and can indicate the rate the moisture content is changing. Regular moisture content readings on racks in the stack will give an increasingly accurate indication of when the measured board are below fibre saturation point. As the rack is being constructed, resistance measurement positions can be set up inside the rack if wire leads are being used, or as nail sets on the outside face. Details of using resistance moisture meters to measure moisture movement in racks are in Module 16. Moisture Content Monitoring.

To assess the drying progress of stacks in the yard, a moisture content reading of the bottom two racks of each stack should be measures to the schedule given in Table 8.03. Only stacks being air dried to a target moisture content below fibre saturation point need to be measured. Only the bottom stacks are measured because it is easier and safer to access them than higher racks and, given all the timber in the stack is the same thickness, the lower racks generally dry more slowly. As air movement is usually greater towards the top of the stack, the top racks usually dry faster.

For readings taken using sample boards, a minimum of one sample board for each of the bottom two racks should be measured. When using resistance moisture meters, three readings should be taken on boards on the outside face of each rack. These should be positioned in the middle of the length of the rack, one each about three rows of boards in from the top and bottom of the rack, and one in the centre of the height of the rack.

Measurements taken with sample boards or resistance moisture meters on the bottom two racks only give an indication of drying of the full stack. This is because only the bottom stacks are measured and the sample boards and resistance moisture meters only measure a few boards that may not be representative. A correlation needs to be developed on each site between the average moisture content of the whole rack and stack, as determined later, and the few reading taken during any progress assessment process.

Expected drying time	**First Reading after placement**	**Subsequent Readings**	**Last month**
6 months	4 month	Each month	Each fortnight.
12 months	9 months	Each 2 months	Each fortnight
18 months	12 months	Each 2 months	Each fortnight
24 months	16 months	Each 2 months	Each fortnight

Table 8.03 Frequency of moisture content readings of stacks

11b. Final yard measurement of racks

Racks should only progress from the air drying yard to further processing after they have reached the target moisture content. This target varies depending on the next production stage. If the timber is progressing to:

- a predryer, usually no definite moisture target is set;
- a reconditioner or elevated temperature kiln, the average moisture content target is below fiber saturation point, usually 18 - 20%; or
- final sizing as an air dried product, the target is either the equilibrium moisture content for the location or a range of moisture contents consistent with the relevant product standard.

Each rack scheduled to progress to the reconditioners or kilns should have the average moisture content assessed. This is to ensure that the centres of all boards are under fibre saturation point. This requires taking a number of readings with a resistance moisture meter on boards selected at random from the outside faces of the rack.

Each rack scheduled to progress to the dry mill or store should have the average moisture content assessed accurately. This requires splitting the rack and taking a number of readings with a resistance moisture meter on boards selected at random from rows in the middle half of rack.

Table 8.04 details the number of readings required for each target range. Table 8.05 details the acceptable range of readings for specific target moisture contents. 90% of readings taken must be within the acceptable range. If more than the acceptable number of readings are outside the acceptable moisture content range, the extra number of readings should be taken.

If more than the acceptable number of all readings are outside the acceptable moisture content range after the extra readings have been taken, the rack should not progress to the next stage.

Next process	Target	Acceptable minimum	Acceptable maximum
reconditioner or kiln	18%	15	21
reconditioner or kiln	20%	17	23
Dry processing	12 %	10	16
Dry processing	14%	11	18
Dry processing	16%	13	21

Table 8.04. Acceptable range of reading for specific target moisture contents

Next process	No. of boards tested	Acceptable no. outside range	No. of extra boards tested	Total acceptable no. outside range
reconditioner or kiln*	5	0	5	1
Dry processing-structural**	5	0	5	1
Dry processing - appearance**	10	1	5	1

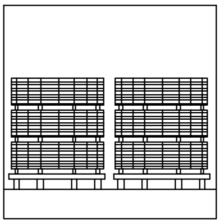
Table 8.05. Number of moisture meter checks for racks leaving the air drying yard

* These readings can be taken on random boards on the outside of the rack.

** These reading should be taken on random boards in the middle half of the rack.

11c. Assessment of the air drying yard

Examination of historic records provides a valuable guide to the likely drying performance of different areas of the yard at different times of the year. In almost every Australian facility, the date that the timber is placed in the yard, the date that it is retrieved, its position in the yard and the final moisture content are known. This information can be assessed to build a picture of the areas that have historically taken longer to dry than others and positions with faster drying, and the times of year when drying has presented problems. If the results of moisture checks showing that the timber was too wet to proceed are retained, these can be used to provide an additional indication of drying speed and effective practice.



12. Problems and rectification

Problems with timber after air drying and possible rectification are detailed in Module 16. Drying Quality Assessment.

8.2.2 Equipment Options

1. Fixed equipment

The fixed equipment in an air drying yard includes drying buildings and shelters; stack foundations; roading and associated drains; and stack tops.

2. Drying building and shelters

The design of buildings used to air dry timber varies considerably with the conditions required to dry the timber adequately and efficiently, and the weather conditions at the mill site: the temperature; humidity; and the prevailing winds.

The form of buildings includes:

- **Complete enclosure with environment control.** Buildings can be completely enclosed, insulated and conditioned. Natural air movement is replaced or significantly augmented by mechanical services. This gives almost complete control of the air drying process. This level of control may be necessary for very high value recovery in benign climates, or high value recovery in aggressive climates;

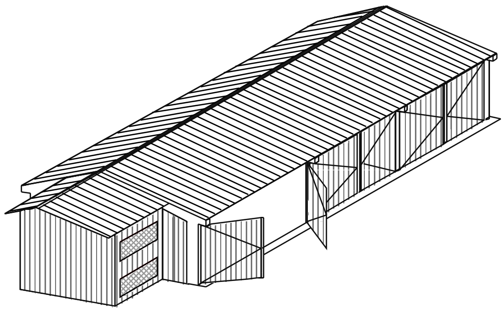
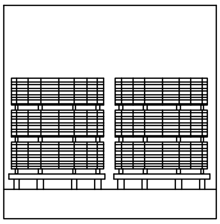


Figure 8.15. Enclosed shed with environmental control

- **Shed with significant enclosure.** Buildings can be structured with a roof and walls with significant openings or screened areas to control exposure to the sun, wind and rain. The local conditions and the nature of the timber being dried determine the position and extent of openings. Often walls will have both high and low level openings in a wall to encourage sufficient air movement under and through the stack. See Figure 8.16;



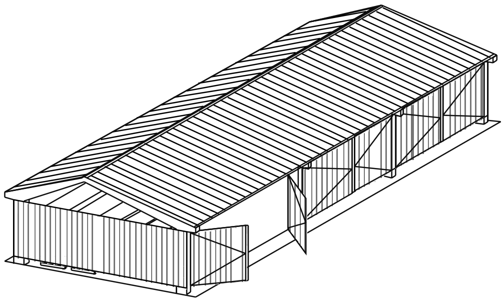


Figure 8.16. Shed with significant enclosure

- **Open shed with local environment control.** The roof shelters the timber from the direct effects of the sun and rain. Additional local environment controls of shade cloth, hessian or plastic covers or curtains protects the timber from the wind. See Figure 8.17; and

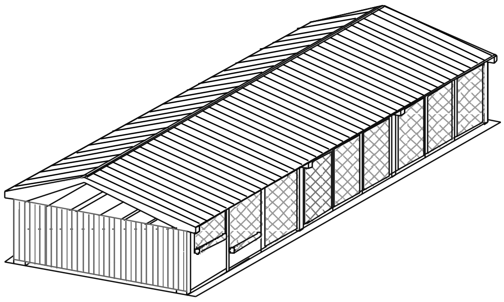


Figure 8.17. Shed with some walls and screens

- **Open shed.** An open shed shelters the timber from sunlight and rain. If surrounded by other buildings it can also reduce airflow through the racks. Sheds can range from simple T-shelters, with rows of timber on either side of central columns, to more conventional sheds that can accommodate several rows of stacks. These sheds typically have low airspeeds (< 0.2 m/s) high relative humidities (>80%) and low temperatures. In summer, they may have a temperature as much as 10^{o} C below ambient conditions. These sheds have an effective EMC of about 30%. See Figure 8.18.

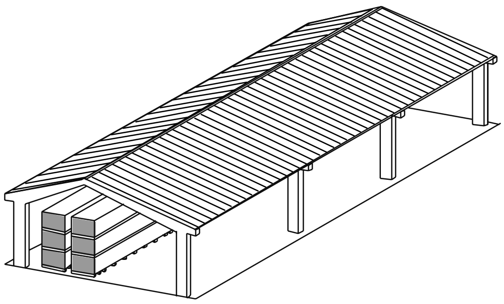


Figure 8.18. Shed sketches

3. Stack foundation and supports

A good foundation is necessary to structurally support the stack. As any irregularity in the base can lead to the deformation of the whole stack, stacks should be assembled on firm, stable, even and compacted ground.

Stack bases support the stack off the foundation and form a key part of the air circulation system. Clearance of at least 400 mm from the ground surface to the bottom layer of boards is needed.

Stack bases comprise several elements; stack piers or stack kerbs, stringers that span between the piers along the length of the stack, and bearers that span between the stringers across the stack (See Figure 8.20).

Occasionally, a single element, a concrete kerb, replaces the stack pier and stringers. (See Figures 8.21 and 8.22.). Stack piers and kerbs can be moveable or fixed.

Moveable piers can be timber or concrete. Timber sections are often large seasoned sections, supported off the ground. Where used, they should be of a durable species or preservative treated. Concrete bases are precast units that taper from the base to the tops. This shape makes for easy casting and reduces the weight of the units so that they can be moved by hand.

Figure 8.19. Precast concrete stack pier. Individual piers can be positioned by hand

Figure 8.20. Precast concrete stack piers, with timber stringers and bearers

Figure 8.21. Fixed concrete kerb with bearers

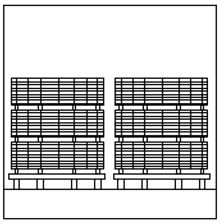


Figure 8.22. Fixed concrete kerb

Fixed supports are often concrete and vary with the arrangement of the yard. When there are only two rows of stacks in a yard line, access to each row is directly from the aisle. In this case, fixed supports can be either a kerb, which allows for differing rack stick spacing, or fixed piers. When there are three or four rows of stacks in the line, an access way for the forklift needs to be provided from the aisles to the centre rows. This can be achieved by having a removable section between the fixed support. Examples of this are shown in Figure 8. 23

The top of any fixed supports should be level.

Figure 8.23. Accommodating more than two rows of stacks on concrete kerbs

Stringers are rack length timbers, placed across the tops of the piers along the length of the stack. All stringers on a site should be a standard size of a minimum 100 x 100 mm nom. They should be of straight sound timber, dry, clean and free from decay and staining fungi. Material that starts to come apart or will not sit flat on the piers should be discarded. It is preferable for stringers to run the full length of the stack. If they must be in more than one piece, no section should be shorter than 2.1 m. long. All parts of a multi section stringer need sound and square ends that will butt neatly together on the pier. The step between the top surfaces of any two sections should not exceed 2 mm.

The required thickness of bearers varies with the different width of racks and therefore the span between the stringers. The size of bottom bearers should be such that there is no noticeable deflection in the bearer when fully loaded.

Gluts or bearers, the timbers used between the racks, should be gauged to a standard depth. Generally, this is about 90 mm. They should be of sound and seasoned timber, dry, clean and free from decay and staining fungi. Material that is not the standard thickness for the site or which start to come apart should be discarded.

4. Roading

Roadways and unloading areas should be safe and trafficable in all weather conditions. Roads and driveways can be concrete, bitumen or compacted gravel. Bare earth is not stable in wet conditions and should not be used. It can lead to safety hazards and environmental damage.

Design recommendations for roadways are available in the Austroad Pavement Design Manual or from consulting civil engineers.

All roadways should drain to suitable swales or drains.

Figure 8.24. Wide main alley in a gravel surfaced drying yard

5. Mobile Equipment

5a. Rack equipment

Almost all rack handling is conducted with forklift trucks. Racks require careful handling. The safe working capacity of the forklift should comfortably accommodate the expected maximum load and placement distance and height. Handling racks on the limit of a machine's working capacity creates a safety hazard for staff and encourages practices that increase rack damage.

Figure 8.25. Fork lift rated for 12 tonnes

5b. Stack tops

An effective stack top is an essential feature of good air drying practice. A roof protects the upper rows of timber from direct sunshine, rain and excessive airflow. Without a cover, the timber in the top rows will weather, warp and check. Stack tops should ideally be a roof that excludes water, but can be an open cover, that allows water through.

Simple stack tops can be made from unseasoned low-grade material into a large pallet to the same or slightly larger width and length of the rack. Nominal 125 – 100 x 25 mm boards are fixed with galvanized nails to nominal 125 x 75 bearers at about 1.5 m spacing. The boards are spaced about 15 mm apart and this allows both air and rain to pass through. These stack tops are simply placed on the racks with a forklift. This type of stack top will weather and will need to be replaced as they start to come apart. While involving some expense, they cost considerably less than the likely 10 -12 rows of timber that they will save directly during their life. If any stack tops are blown by the wind or appear to have moved from their original position boards at any time, all stack tops on the site should be restrained.

Figure 8.26 Simple pallet style rack covers made from low grade boards

More permanent covers designed to shed the water can be constructed from a range of materials in a variety of configurations. All have to have a fall to shed water and ideally, this fall should be away from other stacks towards the aisle. Arrangements can include:

- Corrugated sheet metal on an open frame of roofing purlins and rafters. Corrugated sheet metal has a long life and reasonable quality recycled material is available in many centres;
- Exterior ply on an open frame of roofing purlins and rafters. To ensure a long life, the ply should be coated with a proprietary roofing membrane; and
- Building fabric on pallet frame. House wrapping fabric such as DuPont's Tyvek and similar products from other producers can have a long life exposed to the sun. As they are fabrics, they have to be supported by a pallet like frame and fixed with foil tacks or similar fixings at regular intervals. Most ordinary plastics are not suitable for extended use outside and quickly break down.

As water shedding roofs do not allow air through, all have to be restrained against uplift. Details for this will vary with the construction of the tops.

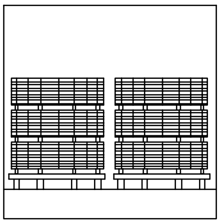
5c. Stack weight

Stack weights restrain the timber that is likely to deform in the top of stacks. These can of any material that will weight down the timber evenly over the top surface of the stack. Generally, they are flat sheet steel or a precast concrete slab.

Precast reinforced concrete slabs should be designed to provide the required weight while being safe to lift on a forklift and use repeatedly.

If a full rack size stack weight is used, it acts as and replaces any other stack top.

Figure 8.27 Stack weight



8.2.3 Air Drying Strategy

1. Placing the rack in the drying yard or sheds

Stack locations should be ordered to standard procedures. To do this:

- Stack location requirement should be readily available and understood;
- The air drying yard and all drying buildings should be mapped with all rows and stack positions located and numbered;
- The drying performance of discrete areas of the yard should be assessed and, where practical, monitored;
- A site drying schedule should be in place that directs racks of different batch characteristics to specific area in the yard or building at specific times of year; and
- A site rack register should be in place that allows the position and drying history of each rack to be recorded, and monitored.

Batch characteristics of rack should be assessed and used to control processing. To do this:

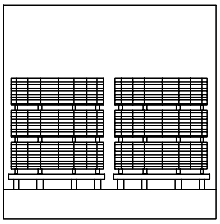
- Product and drying batch / group requirements should be readily available and understood;
- The drying performance of batches in particular locations should be monitored and the results used to refine the drying schedule;
- Racks should be assessed for batch requirements, prior drying history, and probable drying requirements; and
- Assessed racks should be directed for effective drying treatment.

Racks should be adequately and evenly supported and restrained in assembled stacks. To do this:

- Stack assembly requirements should be readily available and understood;
- Stacks should only be assembled from racks with the same width andidentical rack stick alignment;
- Any board that extends more than 100 mm past the last rack stick of any rack being placed in the stack should be cut off and resealed;
- Bearers, gluts and stack piers should be spaced at a maximum distance of two rack stick spacing;
- Bearers, stack piers or supports, and rack sticks should align vertically;
- The front faces of the racks in the stack should align vertically; and
- Where required, stack weights should be placed in position.

Assembled stacks should be stable and even enough so that they do not experience or cause uneven loading on boards, racks or foundations. To do this:

- Stack should be assembled on firm, stable, even and compacted ground;



- Stack piers, kerbs or supports should be standardised elements of the same height and effective bearing and load capacity;
- All gluts, bearers and stringers used in the stack should be sound dry timbers of standardised size;
- Piers, kerbs, gluts, bearers and stringers should be regularly inspected. Elements that are damaged or deteriorated should be repaired or discarded;
- Stack piers, kerbs or supports should be positioned under stacks so that they are even, level and effective;
- Racks should be placed so that their front faces are parallel and in line; and
- If the wind moves any stack top from its initial position, all stack tops should be adequately restrained.

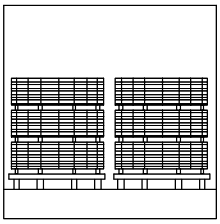
2. Protecting the racks and stacks from physical and drying damage

Stacks should be protected from adverse drying conditions. To do this:

- Climatic conditions, including temperature, humidity and wind patterns should be monitored on the site at least weekly for two years or until a reliable understanding of site weather is developed. This model should be verified at least every five years to maintain its accuracy;
- The air drying yard should be laid out to provide the most effective drying conditions for the material being handled, given the local climate conditions;
- Windbreaks should be positioned to moderate the effects of aggressive drying conditions;
- Stacks should be positioned in specific areas of the yard appropriate to their batch and drying history to minimise adverse drying impacts;
- All stacks should be protected by effective stack tops. At a minimum, these should be a pallet type stack top;
- The surface under and around stacks should drain so that water does not pond for longer than 1 day after rain;
- If stacks are sheltered during the first stage of drying, racks should be moved into the shelter as soon as practical after completion; and
- If stacks are protected with local environment controls during the first stage of drying, racks should be put in place as soon as practical after completion.

The spacing and support of assembled stacks should allow the airflow through each rack in the stack to be as uniform as practical. To do this:

- The aisles and rows of stacks in the yard should be laid out parallel to the predominant drying winds;
- A ventilation area of at least 450 mm should be established and maintained between the surface of the ground and bottom of the lowest layer of timber in the stacks;



- Clear ventilation of at least 600 mm should be established and maintained between the faces of stacks;
- Clear ventilation of at least 600 mm should be established and maintained between the ends of stacks where more than 4 rows occur between aisles; and
- The minimum width of aisles should be the length of the longest racks assembled on the site plus 4 m.

The airflow through arranged stacks should be appropriate for the size, grade, and intended product area of the boards. To do this:

- Segregated batches should be positioned in accordance with the site drying schedule.

Racks stored for further processing or in transport are protected to minimise drying degrade. To do this:

- Rack protection requirements should be available and understood; and
- If being stored between racking and the next stage of production, racks should be stored in a protected location, ideally in an enclosed building.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity. To do this:

- Rack handling requirements should be available and understood;
- If placed in intermediate storage prior to placement in stacks, racks should be adequately supported on bearers placed immediately under a line of rack sticks;
- Racks should only be handled by adequately rated, purpose-designed equipment, operated by staff trained in its use; and
- Roads, loading and unloading areas should be safe, even and trafficable in all weather conditions.

3. Monitoring moisture

When air drying is complete, the moisture content of timber in the racks should be suitable for the next intended production process. To do this:

- Average moisture content targets should be available and understood;
- The moisture content of the rack should be monitored during drying in accordance with Table 8.03; and
- The moisture content of the rack should be assessed before progressing to the next intended production process in accordance with Table 8.04 and Table 8.05.

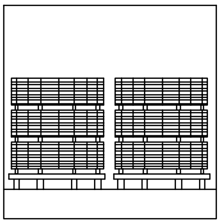
4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively. The requirements for this are included in Section 8.2.5.

8.2.4 Quality Control

Procedures should be established for:

Procedure	General contents
Stack location	Plans of yard and stack location, numbering and identification systems, area drying performance.
Site drying schedule	Schedule of racks to particular location at particular times of year.
Site rack register	Location of each rack and its drying history.
Product specification	Grade, Size, Overcut and Batch requirements for product groups including verification processes.
Drying group	Sorting requirements for products or grades into groups to be dried together
Stack assembly	Stack size, assembly and placement requirements, including stack weighting.
Climate and condition monitoring.	The expected climatic conditions: temperature; humidity; and wind profile of the site and areas in it. This should include monitoring of those conditions in air drying areas and in drying buildings.
Site design parameters.	The decisions made in the layout of the site and their long term maintenance.
Yard up-keep	Control of grass and water, drain, roads and signage maintenance.
Rack storage	Storage provisions including protection of high value racks, shelter of other racks, use of bearers, etc.
Rack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements.
Moisture monitoring	Provision for sample boards, or
Marking and tagging	Identification requirements for grade and sorting
Staff accreditation	Training, Qualifications
Equipment	Maintenance



8.2.5 Information Management

1. Required attributes

Information required for later process control should be collected and passed with the racks effectively. This includes the following:

Required process control information	
Unique rack identification number	Stack location number
Forklift driver	Rack location in stack
Placement / relocation time & date	Staff comment
Stack row number	
Desirable additional information	
Rack cover in place	Moisture monitoring system in place
Store location number	
In store time & date	Out of store time & date
Required moisture control information	
Unique rack identification number	MC measurement position
Staff no.	MC meter reading
Reading time & date	Adjusted MC reading
Monitoring position number	Staff comment
Likely wood temp	

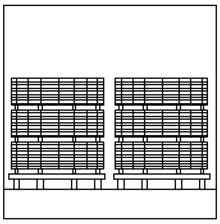
Table 8.06. Attributes required or desirable during air drying

2. Record Collection & Processing

Information required on the rack or the stack location must be legible in normal daylight at least 1.5 meter from the end of the rack or stack.

8.2.6 Equipment Maintenance

The air drying yard needs to be maintained to ensure airflow, adequate drainage and safe material handling. Weeds, scrap timber, and other rubbish accumulating between stacks should be removed regularly. Grass should be cut regularly and signage maintained.



Handling equipment should be maintained so that the expected maximum load and placement distance remains within the safe working capacity of handling equipment at all times.

Road ways should be safe and trafficable in all weather conditions and regularly graded to maintain stability for stacks and forklifts,

8.2.7 OH&S

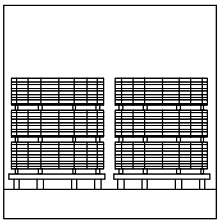
The air drying yard should be inspected regularly and hazards identified and eliminated. This may include.

- unstable stacks of timber;
- dangerous or damaged equipment;
- dangerous equipment use such as speeding in aisles;
- poor procedures for traffic entering and moving between stacks;
- broken stack furniture creating trip or catch hazards;
- boards or rack tops blown off stacks;
- broken fences and gates; and
- poor or no safety signage.

Major OH & S requirements relevant to this section are listed in Table 8.07. This is not a complete list and other relevant codes and regulations may apply.

State	**Major code of practice**
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
QLD	*Sawmilling Industry Health & Safety Guide* – QLD Division of Workplace Health & Safety
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 8.07. Major industry codes of practice



8.3 Operations

8.3.1 Objectives

The objective of air drying is to dry timber in racks in natural conditions to a moisture content suitable for further processing with minimal inappropriate degrade.

8.3.2 Key Drying Factors in Air Drying

Air drying works because air moving through the gaps between the layers of timber in a rack dries moisture from the surfaces of the board. As it does, moisture is drawn from the interior of the board to the surfaces where it is removed from the board. This process continues until the moisture content of the timber is in equilibrium with the prevailing natural conditions. While this happens, the weight of timber in the stack restrains each board and limits deformation.

Air drying can only be cost effective if it does not lead to unacceptable checking, collapse, or deformation of the boards. Generally, these are all grade reducing characteristics and they occurs because the timber is dried too fast.

The key factors in air drying are:

1.The characteristics of the timber batch

These include its species, age, grade and the board thickness. They combine to determine the rate the timber can be dried without loss of grade. Timbers of different species and age dry at different rates. Some can be dried at a fast rate without damage while special care has to be taken with thick material or timber of species that checks easily;

2.The local climate

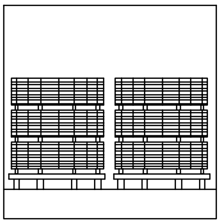
This includes the temperature, humidity and the prevailing winds at the site. Winds particularly affect the rate and uniformity of drying;

3.The exposure of timber in the drying yard

The prevailing natural conditions can be moderated by the arrangement of the yard, sheltering stacks in building, and by grouping stacks together. Some stacks of timber can be dried quickly, while others require gentler conditions; and

4.The scheduling of exposure

This includes the periods racks spend in the various locations in the yard and its progress to the next production process.



8.3.3 Preparation

1. Procedures

Procedures should be in hand for:

Stack location	Site design parameters
Site drying schedule	Yard up-keep
Site rack register	Rack storage
Product specification	Rack transport and handling
Drying group	Moisture monitoring
Stack assembly	Marking and tagging
Climate and condition monitoring.	

2. Equipment

Stack positions should be in good order.

Handling equipment should be maintained and adequate for the expected loads.

All other equipment should be maintained in accordance with the standard procedures.

3. Incoming material

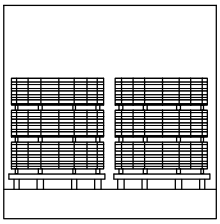
Racks are to be inspected to ensure that:

- Racks are made up of boards of a single batch type;
- Racks are the correct size;
- The faces of the rack are even and vertical;
- The ends of the rack are square, even and vertical;
- No board extends more than 50 mm past the last rack stick;
- High value racks are protected with local environmental controls such as covers;
- Assembled racks are solid and rigid, with no significant areas of missing boards; and
- Moisture monitoring equipment is in place and accessible

8.3.4 Processing & Monitoring

1. Placing the rack in the drying yard or sheds

Stack locations are ordered to standard procedures



- Understand the correct location for racks of particular batches.
- Position racks in the correct location for their batch and stage of drying.

Batch characteristics of rack are assessed and used to control processing.

- Inspect rack batch and history when they enter the yard.
- Segregate racks in accordance with site drying schedule.

Racks are adequately and evenly supported and restrained in assembled stacks.

- Dock off any board that extends more than 50 mm past the last rack stick of any rack and reseal the ends.
- Only assemble stack of racks of the same width and identical rack stick alignment.
- Only place racks shorter or the same length on a lower rack.
- Place a bearer under the end rack stick line of every rack in the stack.

Figure 8.28. Bearer under the end rack stick line

Figure 8.29. Bearer not under the end rack stick line

- Place bearers no wider than every second line of rack sticks in a rack or at a maximum of 1.2 m centres, which ever is smaller.
- Place bearers and gluts at right angles to the side of the rack, directly above the line of rack sticks in the rack below, and directly below the line of the rack sticks in the rack above.
- Repeat all glut or bearer positions between every rack in the stack.

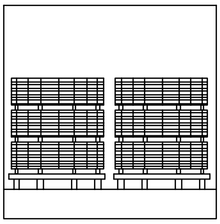


Figure 8.30. Desirable - Repeating the position of bearers and gluts under the upper ones

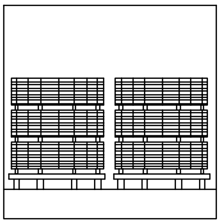
Figure 8.31 Undesirable - Not repeating the position of bearers and gluts under the upper ones

- Replace any bearer or glut displaced as the rack is positioned immediately.

Figure 8.32. Aligning bearers and gluts

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or foundations.

- Ensure the ground under the stack is flat, even and solid
- Check stack base elements: piers; stringers; and bearers. Separate damaged items for repair or disposal.



- Use a placement gauge to position piers under the rack stick locations.
- Level the tops of the piers with packers to the tolerance of 5mm between adjacent piers and 12mm across all piers.

Figure 8.33. top of supports level

- Place stringers on the piers so that they are flat and even.
- Short stringers under long racks must meet on a pier and sit flat and even.
- Position lower bearers over the top of the piers so they are flat and stable on the stringers.

2. Protecting the racks and stacks from physical and drying damage

Stacks are protected from adverse drying conditions

- Position stacks in the yard or drying buildings to the site drying schedule.
- Put required local environment protection in place and secure it
- Fix fabric or other shades and screens in place on drying building and secure.
- Position stack tops on all racks.
- Tie stack tops down.

Figure 8.34. A board blown out of position. If this occurs, stack tops should be tied down securely

The spacing and support of assembled stacks allows the airflow through each rack in the stack to be as uniform as practical.

- Remove weeds, waste or other obstructions under the stacks regularly.

Figure 8.35. Desirable: space under stacks neat and clean

Figure 8.36. Undesirable: weeds under stacks

The airflow through arranged stacks is appropriate for the size, grade, and intended product area of the boards.

Racks stored for further processing or in transport are protected to minimise drying degrade. The timber continues to dry during storage and can be damaged if it is exposed to adverse conditions.

- Protect high value racks from adverse conditions with local environment controls.
- Do not store racks in the sun any longer than absolutely necessary.
- Store racks in an enclosed building out of the sun or in a roofed shelter.

Figure 8.37 Stacks in an enclosed building

- Transfer dried timber for further processing quickly or store under cover.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

- Check rack bearers and gluts are a standard thickness.
- Discard rack bearers and gluts that are not of the standard thickness, are split, broken or show signs of decay.

Figure 8.38. Desirable: Thicknessed rack bearers and gluts

Figure 8.39. Undesirable: Uneven rack bearers and gluts

- Adequately support racks on bearers placed immediately under the line of rack sticks.
- Position bearers at each end and then at a maximum of 1.2 m centres internally, directly under a line of rack sticks.
- Realign or replace any rack sticks that move or fall out during transport.
- Strap the ends of racks for transport if rack sticks keep falling out.
- Only handle racks with adequately rated, purpose designed equipment, operated by staff trained in its use.

Figure 8.40 Forklift damage to a rack

3. Monitoring moisture

When air drying is complete, the moisture content of timber in the racks should be suitable for the next intended production process.

- Measure and record moisture content to standard procedures.
- Confirm the average moisture content of racks to standard procedures.

Figure 8.41 Checking the air dry moisture content

- Separate racks that do not meet the final target moisture content for further drying.
- Progress racks that do meet the final target moisture content to further processing.

8.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the racks effectively.

- Rack tags are in place and legible
- Stack position numbers are in place and legible.
- Complete at least the following records:

Production sheets detailing racks into the yard and their position, and racks out	Rack moisture content measurements
Equipment performance report	Equipment maintenance report
Feedback reports	

8.3.6 Feedback

If noticed regularly, report any of the following to the supervisor:

Problems with processing equipment	Racks exposed to sunlight or other adverse conditions
Boards not end sealed	Racks sides or ends out of line
Rack sticks out of line	Irregular moisture meter readings
Racks, boards or rack tops that have moved or are out of line.	Ponding water

8.3.7. OH&S

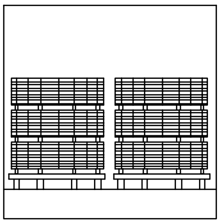
Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational

Keep work areas clean, tidy and clear of trip hazards such as pieces of timber and stack bases.

Inspect the air drying yard regularly. Identify potential hazards and eliminate them. In the air drying yard, this can include:

- unstable roadways;
- blind alleys between racks;
- unstable stacks;
- dangerous equipment use such as speeding in aisles;
- poor procedures for traffic entering and moving between stacks;
- broken stack furniture creating trip or catch hazards;
- boards or rack tops blown off stacks;

- dangerous or damaged handling equipment;
- broken fences, gates or guards; and
- poor or no safety signage.



8.4 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Income racks

	1	2	3	4	5
Racks are made up of boards of a single batch type.					
Racks are the correct size.					
The faces of the rack are even and vertical.					
The rack sticks are in neat and vertical lines.					
The ends of the racks are square, even and vertical.					
No board extends more than 50 mm past the last rack stick.					
Special provisions for high value racks in place.					
Racks are stable for transport and placement in stacks.					
Racks are correctly, clearly and securely tagged.					
Moisture monitoring equipment is in place and accessible.					

2. Stacks

	1	2	3	4	5
Stack supports are even and level.					
Stack stringers and bearers are clean, straight and solid.					
Rack sticks, bearers and piers are in neat, vertical lines.					
Bearer lines are no more than two rack sticks apart.					
The faces to stacks are vertical and even, without a noticeable lean.					
Upon completion, the difference in vertical alignment of the faces of any two racks in the stack is no more than 25 mm.					

Elements knocked out of line during building the stack are realigned.					
Stack tops are in place or lesser value racks are in place as stack top.					
Stack tops are tied down.					
Stack tags are in places.					
Stacks are correctly, clearly and securely tagged.					
Stacks are marked with required information.					
Documentation completed accurately.					

3. Monitoring moisture content

	1	2	3	4	5
The moisture contents of the rack or stack is monitored and recorded regularly.					
Target moisture content confirmed in racks before further processing.					
Inconsistent drying in racks or stacks is recorded and investigated.					

4. Roads and surrounds

	1	2	3	4	5
Roads and stacking areas are even and trafficable.					
Water is not ponding anywhere in the yard more than one day following rain.					
Weeds are kept down and other rubbish is cleaned away.					

5. Racking yard layout

	1	2	3	4	5
The drying characteristics of the yard are recognized.					
The drying characteristics of the timber are recognized.					
Stacks are aligned for prevailing winds.					
Stacks are arranges to moderate adverse drying conditions.					
The value of the product is linked to severity of					

drying exposure.					
High value racks are sheltered from adverse drying conditions.					
High value racks are shed or shelter dried in critical drying period.					
Lower grade lower value racks are place on the top of stacks or shelter higher value racks.					
Micro climate is manipulated to control drying in critical drying periods or times of year.					

8.5 Avoidable Loss

1. Placing the rack

- **Inadequate stack support** – When bearers are out of line and supports are uneven, boards are unevenly loaded and can twist and deform. This reduces grade and recovery. Uneven support also complicates stack assembly. In extreme cases, stack can become dangerously unstable.

Figure 8.42. Poor rack construction and bearer placement leads to unstable stacks and twisted boards

2. Protecting the racks from physical and drying damage

- **Exposing the timber to adverse drying conditions** – If high grade racks are positioned where they dry too rapidly, the timber will check and, grade and recovery will be reduced. Not sheltering thick material from fast initial drying can increase surface and internal checking. Positioning racks so they do not dry quickly enough leads to a direct economic cost due to forgone production and increases the risk of fungal attack and other damage.
- **Inadequate stack conditions** – Poor drainage and ponding water increases fungal, decay and staining problems. Racks close to the ground have poor air flow. Both problems slow drying of the bottom racks. This complicates efficient production and increases the risk of inadequate drying.

Figure 8.43. Poor drainage leaves stacks standing in water. This slows drying, especially in the bottom rack

Figure 8.44. Long grass reduces airflow under racks and promotes decay and uneven drying

- **Inappropriate site layout**. Racks are exposed to uneven drying. If they dry too quickly, they check and grade is lost. If they dry too slowly, production flow is lost.
- **Inadequate stack protection** – If stack tops are not used, most of the top row is completely lost while rows below this are also damaged. If the top of

the rack is no tied down, boards can blow off. In addition to a direct production loss, this is a safety hazard.

- **Rack damage** – Boards subject to mechanical damage due to poor road, lack of capacity in forklifts and poor driving are a direct production loss

Figure 8.45. Poor handling placement knocks bearers out of line in stacks and causes board distortion

- **The racks are stacked too high**. Lower boards are indented and stacks can become unstable.

Figure 8.46. Racks out of line in stacks leads to uneven airflow and concentration of load on some boards

Figure 8.47. Missing bearers cause board distortion

3. Monitoring Moisture

- **Inadequate moisture monitoring** – Wet racks are exposed to further processes that cause damage to the timber. Poorly dried racks often have to be redried and so incur an increased production cost.

8.6 References

Commonwealth Scientific and Industrial Research Organisation 1962, 'Selective Kiln Charging May Cut Your Drying Costs', *CSIRO Forest Products Newsletter*, No. 283.

Commonwealth Scientific and Industrial Research Organisation 1960, 'Can Airdrying Methods be Improved?', *CSIRO Forest Products Newsletter*, No. 261.

Commonwealth Scientific and Industrial Research Organisation 1966, 'Laboratory Studies on Timber Seasoning Yard Design – The Detection of Air Movement', *CSIRO Forest Products Newsletter*, No. 330, pp79-81.

Commonwealth Scientific and Industrial Research Organisation 1964, 'The Effect of Stack Covers on Drying Degrade in Timber', *CSIRO Forest Products Newsletter*, No. 312.

Commonwealth Scientific and Industrial Research Organisation 1964, 'Low Speed Wind Tunnel to Aid Air Seasoning Research', *CSIRO Forest Products Newsletter*, No. 309,

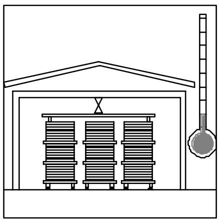
Commonwealth Scientific and Industrial Research Organisation 1972, 'The Effect of Adjacent Buildings on Air Flow Through Seasoning Yards', Reprinted from the *Australian Timber Journal*, October, Vol 38, No 9, 51, 53, DFP Reprint No. 991.

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

9.0: – PREDRYING



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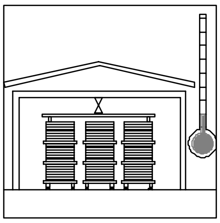
9.0: – PREDRYING



9.1 Objectives

The objective of predrying is to dry timber in racks in controlled low temperature conditions to a moisture content suitable for further processing with minimal inappropriate degrade.

9.1.1 Functions & Performance Requirements

1. Placing the rack in the predryer

Stack locations in the predryer are ordered to standard procedures.

Batch characteristics of rack are assessed and used to control processing.

Racks are adequately and evenly supported and restrained in assembled stacks.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow & duration) in the predryer match the established schedule.

The environmental conditions applied to the arranged stacks are appropriate for the size, grade, and intended product area of the boards.

The spacing and support of assembled stacks and the baffling of the predryer allows the airflow through each rack in the stack to be as uniform as possible.

Racks stored or in transport for further processing are protected to minimise drying degrade.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

3. Monitoring moisture

After predrying, the moisture content of timber in the racks is to be at the target moisture content. Generally this is below fibre saturation point, at 18-20%.

4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively.

5. Identifying & reporting problems for correction

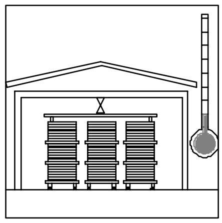
Details of individual and systematic problems are identified and distributed.

Problems are corrected.

6. Management of staff and equipment

Staff and equipment are available to conduct predrying activity safely and efficiently.

9.0: – PREDRYING



9.2 Management

9.0.1 Overview

Activity in predrying is to dry timber in racks in controlled low temperature conditions to a moisture content suitable for further processing with minimal inappropriate degrade.

Predryers are a form of kiln used in a specialist way. Kilns and predryers (and to a certain extent, reconditioners) are enclosed chambers in which the temperature, humidity and circulation (direction and speed) of the drying medium, air, can be controlled to accelerate or retard the drying process.

In this manual, kilns or predryers that are used to dry the timber from green to fibre saturation points or lower moisture contents are included in this section. Kilns that are used for the final drying and treatment of timber are covered in Module 12.00. Reconditioners used for recovery of collapse are covered in Module 11.00

Many of the key factors of operating a predryer are similar to those for operating a kiln. Where there is overlap, the overview section of Module 12.00 contains greater detail.

1. Process overview

Predrying is a parallel process to air drying. It is used to:

- dry the timber from green to below fibre saturation point, when it can then be placed in a reconditioner and/or final drying kiln. The general target for this is below fibre saturation point, about 18-20% moisture content;
- dry timber that has had an initial period of air drying and bring it to below fibre saturation point more quickly than it would in the air drying yard; or
- dry the timber to a final equilibrium moisture content, usually between 10 % & 15%.

In principle, drying the timber in the predryer quickly and evenly, without the level of degrade found in some air drying yards, is straight forward.

A predryer is an enclosed chamber in which the temperature, humidity, and the direction and speed of the air can be fully or partly controlled. In the predryer, air passes across the surfaces of boards in stacked racks, evaporates moisture from the timber and carries it away. The direction of the air may be alternated to even out the exposure of the timber in the stack and the temperature and humidity of the air may be varied as the capacity of the timber changes to sustain increasingly severe conditions without degrade.

In practice, successful predrying requires considerable attention and care. The key aspects are:

- Establishing the series of conditions that the timber can sustain and progressing through them as the timber dries. This series of conditions and the change points for progressing through the conditions are known as a predryer schedule;

- Ensuring that the available equipment maintains the required conditions; and
- Ensuring that boards are subjected to the conditions evenly.

2. Conditions that can be sustained

For most Australian hardwoods, the rate of drying unseasoned timber must be controlled.

When timber begins to dry, moisture is evaporated first from the surface layers. The moisture content at the surface falls more rapidly than that in the centre parts of the board. As the timber dries, it shrinks. So, early in the drying process, the outer parts of the board that have dried more than the inner parts will also have shrunk more. This sets up a zone of tensile stress around the outer parts of the board. The core, or inner part of the board, is subjected to compression as a result. The timber can accommodate this to a point. However, if drying is too rapid, the moisture content gradient in the piece becomes too steep too quickly. In turn, the tensile stress on the perimeter of the board increases above the failure point of the material and surface checking results. Surface checking is one of the main forms of avoidable drying degrade in hardwood.

For predrying to be effective and economic, the rate at which the timber is dried has to be slow enough to keep surface tensile stress below the point where checks will form. However, it should be as fast, as the material can sustain without inappropriate degrade, so that time and energy are not wasted.

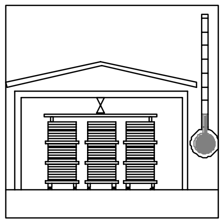
2a. Predryer schedules

A predryer schedule is expressed as a series of temperature and relative humidity conditions (or dry bulb and wet bulb temperatures) or 'set points' to be achieved in the predryer and the change points (time or timber moisture content) for progressing between them. While airflow can also be varied, it is generally set at a constant velocity for a given schedule.

Drying schedules are developed compromises between avoiding drying conditions that cause drying degrade and the need to dry the timber quickly and economically. Schedules are developed by empirical research, modelling programs and by experience.

As the drying behaviour of timber boards changes with diffusivity, thickness, initial moisture content and other timber properties, schedules are optimised for material with generally similar characteristics. Usually these are grouped according to species or species group, its shrinkage and strength properties, and the thickness of the board.

The sophistication of predryer schedules differs with the type and complexity of the unit. With the simplest units, the schedule is a single condition for a particular batch of timber. In progressive predryers, the schedule is a single ideal progression of conditions. The hottest and driest air and driest timber are at the



timber output (and air input) end of the tunnel. The air cools and gains moisture as it moves down the tunnel so that the wettest and colder air and wettest timber are at the timber input end. Air input conditions are only modified when the monitored conditions inside the kiln begin to move outside defined limits.

Other progressive dryers can essentially be a set of conjoined batch kilns. In modern zone and batch predryers, a high level of control is necessary as the timber is very susceptible to drying degrade at this time. With these machines, the predryer schedule is expressed as a series of temperature and relative humidity conditions (or dry bulb and wet bulb temperatures) or 'set points' to be achieved in the predryer and the change points (time or timber moisture content) for progressing between them. Airflow is generally assumed to be constant. Schedules usually conclude when the target moisture content has been reached.

3. Equipment to maintain the conditions

A predryer is an enclosed chamber in which the temperature, humidity, speed and often the air can be controlled. Like the final drying kiln and reconditioner, it is a critical piece of equipment on the site. As the timber needs to be dried to a particular schedule of air temperature and humidity, or within particular limits of temperature and humidity, the predryer must have the capacity to deliver the correct amount of air consistently and uniformly to the entry faces of the stacks in the charge. It must allow conditions of the air and timber to be monitored and controlled efficiently and effectively. This capacity then needs to be maintained.

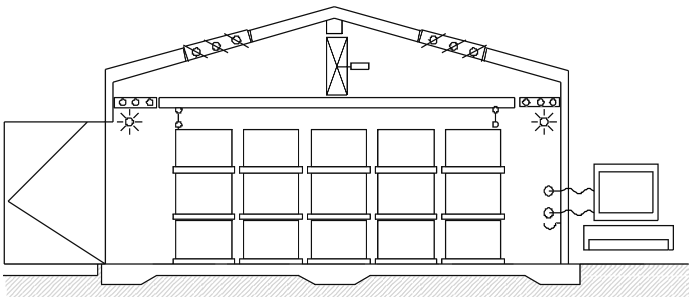


Figure 9.01. Generic layout of conventional predryer

3a. General predryer arrangement

While similar in principle to a final drying kiln, predryers often do not provide the same level of control or flexibility. This is particularly true of older units. Yet, predryers should maintain a high level of control, as the early stage of drying is where degrade is more likely to occur.

The arrangement of a generic batch predryer is shown in Figure 9.01. More detail on each type of predryer is included in Section 9.2.2

The general components of a predryer include:

- **An insulated enclosure.** Ideally, this will be resistant to corrosion, easy to maintain and minimise heat loss. Doors and other openings must be rigid enough to withstand often vigorous handling and be fitted with effective seals and closing mechanisms to prevent air leakages.
- **Fans.** These drive the airflow in the predryer and operate either in a single direction or are reversible.
- **A heat source:** Provided by steam coils, the sun, or other means, heat is required to raise the temperature of the predryer and its contents, overcome the forces holding moisture to the cell walls, and convert the moisture in the timber to vapour.
- **Humidity control mechanism.** This is generally a combination of a humidification source, such as a wet steam supply or water mist system, and vents that allow moist air to be expelled and drier air to enter. In dehumidifier predryers, condenser coils also helps control humidity.
- **A plenum.** This is a space between the fans and the stacks of timber that allows even and controlled air movement through the timber. The action of the fans creates higher air pressure in the plenum on the stack entry face while developing lower air pressure on the exit face. This draws the air between the rows of boards through the stack.
- **A stacking area:** The racks of timber are stacked in a bank that must provide them with even support. This area is either:
  - a flat floor for stacks made up of racks loaded in with a forklift;
  - a series of concrete kerbs for stacks loaded in with a traverser; or
  - a line of low trolleys, which have stacks, loaded onto them with a forklift and then pushed through progressive predryers.
- **Baffles.** Either rigid or flexible, these ensure that airflow is directed through the spaces between the timber and doesn't escape around them.
- **Monitoring equipment.** The condition of the timber and the air need to be monitored to determine the timber's moisture content and the air's temperature, humidity and direction. Knowing these is vital to monitoring and altering predryer conditions to match the required schedule. See Section 9.2.2 for more detail on Monitoring Equipment.
- **Control mechanism.** As the timber dries, the environmental conditions of the air in the kiln have to be maintained or altered in line with the drying schedule. To do this, the components of the kiln have to be controlled. Steam or water spray has to be introduced, temperature raised or vents opened. See Section 9.2.2 for more detail on control mechanisms.

An operational predryer is a sophisticated piece of equipment that must be maintained. This is outlined in Section 9.2.6 Equipment Maintenance and Section 9.4 Checklist.

4. Even drying

The success of applying a particular schedule to a charge of timber in a predryer depends on the regularity of the batch of timber being processed and on the uniformity with which the scheduled conditions can be applied to the timber in the charge. The factors that influence this are:

- The batch characteristics of the timber;
- The uniformity of airflow in the kiln; and
- The timber's arrangement in the rack and stack.

4a. Timber Batch

To make the full use of selected schedules and ensure fast drying with minimum degrade, each charge, line or zone group in the predryer should consist of timber with similar drying characteristics. The rate at which the timber can be dried without loss of grade is determined by:

- its shrinkage, strength, diffusivity and other properties (these are affected by such factors as species and age);
- the thickness and target grade of the board; and
- sawing orientation (backsawn timber dries faster than quarter sawn timber in the same conditions, but generally needs to be dried more slowly to minimise degrade).

As the timber dries, most moisture evaporates from the wide faces, so the thickness of the board is the critical dimension. The thicker the timber, the longer the drying time, and potentially, the more difficult it is to dry without degrade.

Timber with different drying characteristics or different thicknesses cannot be dried in the same predryer charge without slowing overall drying or risking degrade to the material requiring the slowest drying regime.

4b. Airflow in the predryer

Air is the transfer medium in predryers, supplying heat to the timber and removing evaporated moisture from it. Since the rate of drying varies with the velocity of the air, airflow must be both uniform and adequate through all the rows of timber in the predryer.

Achieving this uniformity depends on the design and correct operation of the fans and plenums, the effectiveness of baffling around the racks and the arrangement of racks and stacks in the charge.

Baffling

Correct and effective baffling of the stacks in the predryer is essential in successful predrying.

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Air circulating in the kiln will always try to by-pass racks of timber and go through any large spaces left around the edges or within the stacks. As the air moves through these spaces quickly, less air is available to dry the timber and its movement through the stack is uneven. Also, the greater volume of air going through these spaces dries the surrounding timber more quickly, increasing the likelihood that it will degrade. As a result, drying is inconsistent and energy and time are wasted. These spaces must be kept as small as possible by easy-to-use baffling.

Baffles are rigid or flexible barriers used to direct and control the flow of air. Their positioning varies with the type of predryer but generally, they are positioned on the top and ends of both sides of the stack lines. If the predryer is more than one rack deep, it is often necessary to baffle off the top and/or end gaps between adjacent stacks.

Maintaining the effectiveness of baffles is important. Stacks should be arranged to ensure they operate efficiently. Baffles should be able to be closed and fixed onto the timber to close off air movement, and they need to be well maintained.

Baffling is not restricted to the perimeter of the stacks. The rows of gluts or bearers between racks in a stack also provide a short circuit for air. These can be baffled with boards, or other blocking pieces.

Figure 9.02. A hinged solid baffle with a flexible edge in position in a predryer. Square ended racks are essential for effective baffling

The arrangement of racks

Racks in the predryer are arranged into lines of stacks and it is critical for these to provide an even face to incoming air and easy passage for the air from one side of the predryer charge to the other.

To provide a consistent passage of air through the rows of boards, the stacks need to be the same height, ideally of racks of the same height. The space between high stacks and low ones is difficult to baffle effectively. While there will always be some minor variation in the height of racks and stacks, they should be kept as regular and even as possible.

In batch and zone predryers, racks should be arranged to fill the full length of the predryer. If they cannot, they should not provide an open passage for the circulating air. If possible all racks stacked on each other should be the same length, and the line of stacks should run neatly from the baffles at one end of the predryer to the other.

Generally, lines of stacks should be kept as close together as practically possible. In tall predryers, stacks can move and lean significantly as the timber dries. This can circumvent baffling, or close up necessary airways. In these cases, spacers may be needed on the top of stacks to hold them apart.

Bearers and gluts in the stacks should be the same thickness and placed directly in line with the rack sticks. Differences in bearer or glut thickness can bend and warp boards and raise one rack sufficiently above others so the efficiency of baffling is reduced.

Arrangement of the timber in the rack

In addition to the arrangement of stacks in the predryer, uniformity of airflow over the timber depends on the space between the rows in the rack and the alignment of boards at the side of the rack.

Rack sticks need to be the same thickness. If the sticks between the rows of timber in the rack vary in thickness, more air will flow between the widely spaced rows and these will dry more quickly than closer-spaced rows.

The sides of the rack should be kept as even as possible. If they are uneven, less air will flow through the rows where edges are set back. More air will flow through those rows with edges projecting forward. In both cases, airflow and drying will be uneven in the rack.

5. Monitoring & control equipment

The condition of the timber and the air need to be monitored to determine the timber's moisture content and the air's temperature and humidity. These have to be monitored or controlled in line with the selected schedule or kept within the required limits.

Monitoring and control technologies have changed considerably in the last decade, with the introduction and widespread use of personal computers and electronic sensing devices. For operations not fully computerised, wet and dry bulb thermometers are used to gauge the conditions of the air. These are read from external gauges, or are recorded on charts or with older types of monitoring computers. Vents and heat sources are controlled manually or through relays from a control location. Airflow is not generally measured, except as part of commissioning or calibration tests. Sample boards are used to monitor the moisture in the timber and are tested as often as every two days. One test a week is a minimum requirement.

Alternatively, resistance moisture meter positions are established in the racks and tested at regular intervals. Resistance moisture meters are not accurate at the high moisture contents common in predryers. The resistance reading they provide can an only inform a qualitative understanding of how the timber in a charge is progressing. Their accuracy improves once the timber reaches fibre saturation point.

For modern computerised operations, temperature, humidity and airflow sensors are used in the predryer and resistance moisture probes or electronically weighed sample boards are used in the timber to monitor air and timber conditions. These sensors and probes are connected to computerised control systems, often made up of a programmable logic controller (PLC) and an accompanying computer. These systems perform a range of tasks, including:

- reading and recording the data from the sensors and probes;
- displaying current information on a user interface;
- comparing the readings to previously defined limits; and
- operating equipment and actuators to control predryer conditions. This can occur automatically, or after operator intervention.

The capabilities of these computerised systems vary considerably with the capacity and versatility of the PLC and the sophistication of the software employed.

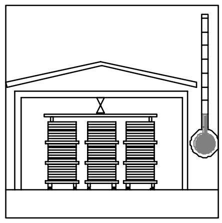
The required number of sensors and probes and quality of monitoring systems will vary with the size of the operation, the size and reliability of the predryer and the intended market for the timber being dried. However, sufficient instruments and controls should be in place in any predryer to:

- determine the temperature and humidity at any time with confidence;
- modify these conditions in line with the required schedule;
- indicate that fans are operating and changing their direction; and
- provide a reasonable indication of the moisture content of the timber.

For new installations, the minimum control requirements are a programmable logic controller (PLC) and a monitoring and recording computer.

5a. Progressing through schedule set points

Predryer schedules are designed to progress between set points when the timber has reached the required moisture content or when a particular period of time has elapsed. There are limitations with both methods.



The limitation with using the timber's moisture content in the predryer as a schedule change point is the difficulty in measuring this accurately and quickly. In practice, the only way to reliably measure the moisture content of timber above fibre saturation point is with sample boards. Unless the sample boards are mounted on scales (or load cells) in or between the racks, they have to be retrieved and weighted by hand. This is time consuming and may be too infrequent to provide sufficient guidance with shorter schedules.

The reliability of time based schedule change points depends on the accuracy of the schedule, the uniformity of the batch being processed and the quality of the predryer and its associated equipment. If the schedule is not accurate and the batch uniform, timber that dries quickly may reach the required moisture content well before the time allocated, in which case, time is lost and energy wasted before the conditions are altered. Also, collapse prone material may be dried to long and suffer more collapse than can be recovered by reconditioning. Similarly, slower drying timber may not have reached the desired conditions when the allocated time has elapsed. If the equipment is not reliable or delivering even drying conditions, the timber may also dry unevenly.

Time based schedules should only be used if regular moisture content readings are taken and confirm the moisture content predicted by the schedule. If the actual reading varies considerably from the expected reading, the schedule will need to be adjusted.

6. Handling and placement

The racks placed in stacks in the predryer must be supported regularly and evenly and concentrations of load on individual boards must be avoided.

Stacks for the predryer are generally built in multiples of a standard rack on a traverser trolley, and then moved into the predryer, or with a forklift to a height just below the upper plenum or the fan deck

When loaded by a traverser trolley, the stacks in the predryer sit on solid generally concrete kerbs positioned on either side of the trolley rails. The spacing of the kerbs determines the number of lines of stacks in the predryer and their spacing. It also determines the depth of the bearers or beams under the stacks. These should be positioned at the same centers as glut in the stacks and be deep enough so that they have no noticeable deflection when fully loaded.

When placed by forklift, stacks are built upon bearers placed on a concrete floor. Stacks should be placed as close to each other as possible, end to end and side to side, and in positions that can be effectively baffled.

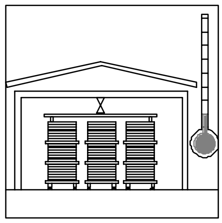


Figure 9.03. A stack of timber being loaded into a large batch predryer on a traverser

Whether positioned either by traverser or forklift, the bearers, gluts and rack sticks in all the racks in the stack, should align vertically. This ensures that the load being transferred to the supports or floor is carried in simple compression for stick to board to bearer, to the ground.

Bearer spacing should not exceed two rack stick spacings. This limits the maximum spacing to 1.2 m.

Material on the top of stacks may distort significantly as it dries if the weight of material above it is inadequate to restrain the boards. If losses are noticeable and significant, stack weights may be necessary. These can be of sheet steel or a piece of concrete about 100 thick and the same width and length of the rack. If used, stack weights should be applied as soon as practical after the stack is assembled. While they can reduce cupping and distortion, weighting can increase surface checking on the outer backsawn face of boards.

7. Determining completion

Predrying is complete when the timber in the charge reaches the required average moisture content. The moisture content can be measured with samples boards or a resistance moisture meter.

The moisture content of sufficient racks should be measured before the predryer is unloaded for the operator to confidently estimate that whole of the charge is within the required moisture content range. The number of racks required to be tested will vary with the size and reliability of the predryer, the regularity of timber's batch and drying characteristics, and the next intended production stage.

These measurements generally only give an indication of drying of the full charge. A correlation needs to be developed for each predryer and each batch of material between the few readings taken and the average moisture content of the whole charge, as determined later.

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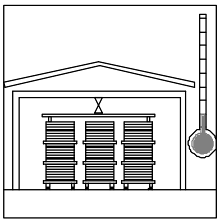


After they are unloaded, each rack scheduled to progress to the reconditioners or kilns should have the average moisture content assessed. This is to ensure that the centres of all boards are under fibre saturation point. This requires taking a number of readings with a resistance moisture meter on boards selected at random from the outside faces of the rack.

Each rack scheduled to progress to the dry mill or store should have the average moisture content assessed accurately. This requires splitting the rack and taking a number of readings with a resistance moisture meter on boards selected at random from rows in the middle half of rack.

Table 9.02 details the number of readings required for each target range. Table 9.01 details the acceptable range of readings for specific target moisture contents. 90% of readings taken must be within the acceptable range. If more than the acceptable number of readings are outside the acceptable moisture content range, the extra number of readings should be taken.

If more than the acceptable number of all readings are outside the acceptable moisture content range after the extra readings have been taken, the rack should not process to the next stage.

Next process	**Target**	**Acceptable minimum**	**Acceptable maximum**
reconditioner or kiln	18%	15	21
reconditioner or kiln	20%	17	23
Dry processing	12%	10	16
Dry processing	14%	11	18
Dry processing	16%	13	21

Table 9.01. Acceptable range of reading for specific target moisture contents

Next process	**No. of boards tested**	**Acceptable no. outside range**	**No. of extra boards tested**	**Total acceptable no. outside range**
Reconditioner or kiln *	5	0	5	1
Dry processing-structural**	5	0	5	1
Dry processing-appearance**	10	1	5	1

Table 9.02. Number of moisture meter checks for racks leaving the predryer

* These readings can be taken on random boards on the outside of the rack.

** These reading should be taken on random boards in the middle half of the rack.

8. Problems and rectification

Problems with timber after predrying and possible rectification are detailed in Module 16. Drying Quality Assessment.

9. Post predryer storage & protection

After predrying, the material should be stored under cover, stacked as for air drying, or transferred directly to the reconditioners or kilns.

16.2 Equipment Options

1. Fixed equipment

The fixed equipment for predrying includes: predryers; monitoring equipment; stack material; and roading and handling equipment.

2. Predryers

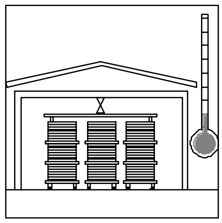
There are a wide variety of predryers in operation or on offer from predryer manufacturers. As described above, all predryers have some similar characteristics. They are enclosed chambers in which the condition of the drying medium, air, can be controlled to varying extents to accelerate or retard the drying process. The detailed design and arrangement of predryers is an extensive area that is not dealt with in this manual.

The major types of predryer are:

- **progressive predryers,** where timber is moved through a chamber, or series of chambers that have variable temperature and humidity conditions;
- **constant condition batch predryers,** where timber is held in one spot and exposed to constant temperature and humidity conditions designed for that batch of timber;
- **conventional batch predryers,** where timber is held in one spot and exposed to temperature and humidity conditions to a particular schedule; and
- **zone predryers,** where timber is held in one spot and exposed to conditions to a particular schedule. Unlike batch predryers, they have a large unpartitioned chamber that maintains different conditions in different parts of the chamber.

2a. Progressive predryers

A typical simple progressive predryer is a tunnel that accommodates usually about seven to nine groups of stacks of timber arranged end to end in a line along its length. Baffles in the plenums on either sides of the tunnel alternate at each stack to force the air through the racks from one side of the tunnel to the other. Warm dry air is introduced at the 'dry' end of the tunnel and it cools and gains moisture from the timber as it moves to the 'wet' end. The air is then



discharged to the outside air or retained in full or in part, heated and recycled to the dry end.

Unseasoned timber is pushed into the ‘wet’ end and progresses along the tunnel with each subsequent push. This is typically at intervals of 4 – 8 days. Thinner or faster drying material is pushed through quickly while thicker or slow drying material is pushed through more slowly. As it moves along the line, the timber is exposed to increasingly warm and dry conditions until it reaches the ‘dry’ end of the predryer. It is then pushed out as a new unseasoned stack is pushed in the ‘wet’ end. At this stage, it should be at the target moisture content.

The general arrangement of a progressive predryer is shown in Figure 9.04

The amount of moist air discharged or retained from the ‘wet’ end of the predryer controls the humidity levels in the tunnel. The less humid inside air is replaced with drier outside air, the higher the internal humidity levels become. Steam passing through a heat exchanger or a similar heat source usually provides temperature control.

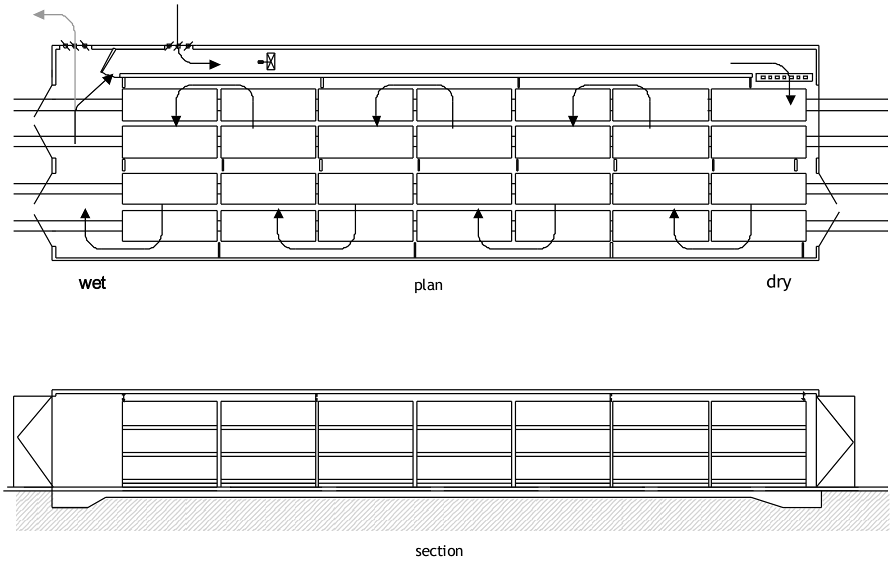


Figure 9.04. Plan and section of a progressive predryer

Temperature and humidity conditions have to be monitored regularly in this type of predryer, as the control processes are not subtle. If the timber entering the line is significantly wetter or dryer than the expected average, the only way to ensure it dries properly is to moderate the conditions for all the racks in the line. This makes batching of material particularly important.

More advanced progressive predryers have solid walls between each batch of timber and the timber progresses between chambers.

Figure 9.05. Stacks ready to be pushed into the wet end of a series of progressive predryers

2b. Constant condition batch predryers

A constant condition batch predryer is an older style predryer that is essentially a large room with some heating and humidity control and fans in an upper plenum. Lines of stacks are placed in the room and are exposed to a constant temperature and humidity regime. Airflow is at a constant speed but alternates direction at regular interval. Timber can be placed in the predryer at any time and in any location. When a line of stacks reaches the target moisture content, usually fibre saturation point, it is replaced with unseasoned material.

Heat exchangers are positioned near the fans and between the lines of stacks to provide temperature control. If the humidity inside the predryer becomes too high, wet air is discharged and replaced by dry outside air. If humidity becomes too low, sprinklers or steam are used to raise it. Baffling is often rudimentary but increases the efficiency of the units.

The general arrangement of a constant condition batch predryer is shown in Figure 9.06.

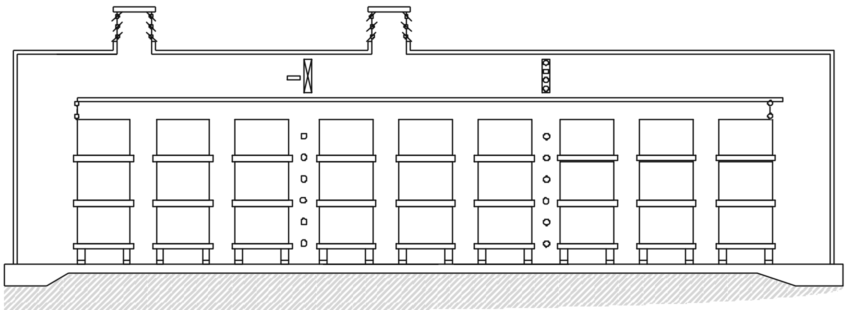


Figure 9.06. Section of a constant condition batch predryer

As the conditions in the predryer are constant, they have to suit the slowest drying material in the unit. Monitoring has to be sufficient so that the required conditions are maintained.

Figure 9.07. Reheating coils in a large constant condition batch predryer

2c. Conventional batch predryer

This type of predryer is used for drying batches of timber either from green to fibre saturation point or from near green to a target equilibrium moisture content. Generally, batch predryers are very similar to final drying kilns. Timber is placed in the predryer and exposed to temperature and humidity conditions to a particular schedule.

There are a number of ways to supply heat or control conditions in this type of predryer: conventional units using steam; solar unit using the sun and possibly a supplementary source; and dehumidifier units.

Conventionally controlled units are built from any heat and moisture resistant material and use steam or a similar medium passing through heat exchangers as the heat source. Steam or water sprays and vents are used to control humidity. Air is circulated by a series of fans. When properly monitored, controlled and maintained, these predryers can have excellent control of internal conditions and reasonable operating costs.

Figure 9.08. An older small conventional batch predryer

Figure 9.09. Fans and baffles in an older small conventional batch predryer

Figure 9.10. A modern batch predryer

Figure 9.11. Bolster and baffles in a modern batch predryer

Solar powered units use the sun's energy to provide the heat to dry the timber. They have a low capital cost compared with conventional kilns, and low operating costs, as the energy is nominally free. The major drawback is that the energy of the sun varies with the time of day, different latitudes and with climate. Season and diurnal changes are also major factors. In the temperate areas of Australia, solar kilns require additional heat to maintain uniform production rates through the year. The basic configurations of solar kilns include:

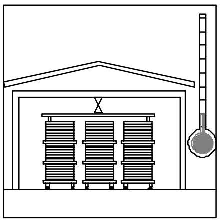
- greenhouse type with walls and roof covered with transparent or translucent skin;
- semi-greenhouse types with roof and some walls glazed and the others insulated to reduce heat loss; and
- external solar collector types that supply heat to an insulated chamber much like a conventional predryer. This type is least subject to variable heat from the sun.

Figure 9.12. Green house type solar kilns used as predryers

Figure 9.13. Small greenhouse type predryer

Figure 9.14. Breeze blocks provide thermal mass and an air diffuser in small greenhouse type unit

Figure 9.15. External solar collector type predryer
Photo courtesy of Solar Dryers Australia



Dehumidifier units use electricity to operate an air-conditioning / heat pump unit located with a kiln chamber. A dehumidifier unit is an air conditioner installed in reverse. Heated dry air is blown over the top of the charge and is drawn back through the timber and into the evaporator coils of the unit. These coils chill the air, which, by the time it reaches them, is at a relatively high humidity. Moisture condenses out of the humid air onto the coils, is collected beneath them, and drains outside the unit. The drier air then passes over the unit's condenser coils where it is heated. The air is then again circulated through the charge. Additional heat is sometimes added to the chamber using electrical or steam heaters.

With this type of predryer, there is nominally no need to vent the predryer air to the outside, because the moisture from the timber condenses as water and drains away. However, some do use vents as they provide an energy saving. These predryers are efficient users of electric energy but, despite this, their operating cost is relatively high. They are also often limited in their operating temperature as the condenser coils can freeze when lower drying temperatures are used.

2d. Zone predryers

Zone predryers are modern units that are similar to a conventional batch predryer except that they have a large unpartitioned chamber that maintains different conditions in different parts of the chamber.

Each zone has separate condition monitoring and control.

Figure 9.16. Inside a large zone predryer

3. Monitoring equipment

Where wet and dry bulb thermometers or electronic temperature and humidity sensor are positioned in a kiln away from the stack face, a calibration check should be carried out against a standard sensor at they stack face. This should be used to either position the operational sensors in a suitable position of develop a correction factor between the regularly measured reading and the actual condition of the air entering the timber.

3a. Dry bulb thermometers

Thermometers, resistance temperature devices (RTDs) and other temperature sensors measure the temperature of the air in the kiln. They measure its actual temperature and are not affected by its water vapour content, or relative humidity. To obtain an accurate reading, the dry bulb sensors must be mounted in the main airflow. To avoid incorrect readings the sensor should not be too close to either the walls, or to steam pipes.

The preferred approach is to have at least two dry and wet bulb sensors placed in the predryer chamber. The sensors are arranged on opposite walls and connected so that the sensor on the warmest side of the predryer (where the air is entering) provides the signal that is sent to the monitoring instrument. When the fans reverse the airflow, the opposite dry bulb obtains the reading.

Temperature sensors that are incorrectly positioned may result in:

- very high temperatures that increase drying losses; or
- very low temperatures that prolong drying time.

Although it is usual to locate one of the dry bulb and wet bulb thermometers close to one another, it is unwise to place the dry bulb sensor below the wet bulb as water may drip off the wet bulb wick onto the dry sensor.

3b. Wet bulb thermometers

A wet bulb thermometers is a temperature measuring device where the sensing element is covered by a smooth, clean, soft, water saturated cloth, or wet-bulb wick. Evaporation from the wick cools the sensor. The difference between dry and wet bulb temperatures, known as the wet-bulb depression, has a known relationship to the relative humidity of the surrounding air, given that the wick receives a standard air velocity of 5m/s over the wick.

Wet bulb thermometers require careful operation.

- The sensor should be located in such a position that the air to be measured can flow freely across the wick. In very low air velocity applications, supplementary airflow may be needed over the wick for the sensor to provide a reliable reading.
- The height of the bulb above the water supply level should be in accordance with the manufacturer’s instructions (normally about 40 mm).
- The feed-rate of the supply water into the trough should be slow so that the water's temperature has time to come to equilibrium with ambient conditions before entering the wick. It is usually a float-controlled drip feed that maintains a constant water level in the trough.
- The wick should completely cover the bulb and every part of the wick should be moist.
- The supply water should be fed to the wick from below the bulb and be drawn up the wick by capillary action.

- The wet bulb wicks must be changed regularly. Wet bulb wicks become contaminated with dust, wood extractive and impurities in the water.

If a wet bulb wick dries out, it should be cleaned in accordance with the wick manufacturer's instructions before replacement, or a new wick should be used.

3c. Electric moisture sensors

Electric moisture sensors are often used to measure equilibrium moisture content or relative humidity (hygrometer) rather than relying on information provided by wet bulb thermometers.

Equilibrium moisture content (EMC) wafers measure the electrical resistance of a small piece of specially treated cellulose pad held by electrodes mounted in the devise. This pad is responsive to changes in relative humidity and the E.M.C. of the surrounding atmosphere. Humidity is calculated from the measured resistance using standard calibrations in the controller. Like the wet-bulb wick, the cellulose wafer or pad becomes dirty and must be changed at specified intervals for the EMC measurements to remain accurate

Relative humidity sensors are capacitance type probes. They measure the varying capacitance of the sensor and the moisture in surrounding air and relate this back to the air's humidity.

Figure 9.17: An EMC wafer used in a predryer

3d. Un-interruptable power supplies

While not a sensor, un-interruptable power supplies (UPS) are important devices that should be kept for protecting and maintaining the operation of controlling and/or monitoring equipment during power failures or surges.

4. Stack material

The depth of any beam spanning between kerbs should be a standardised thickness such that they have no deflection noticeable by eye when fully loaded. They can be of any suitable material. Timber beams should be of straight, sound timber, dry, clean and free from decay and staining fungi. Material that does not meet the standard thickness, or which starts to come apart, should be discarded.

Gluts, the timbers used as spacers between the racks, and other bearers should be gauged to a standard depth. Generally, this is about 90 mm. They should be of sound and seasoned timber, dry, clean and free from decay and staining fungi. Material that will not thickness to the standard size for the site or which start to come apart should be discarded.

Stack weights can be any material that will hold down the timber evenly over the top surface of the stack. Generally, they are flat sheet steel or a precast concrete slab. Precast slabs should be designed to provide the required weight, while being safe to lift on a forklift, and use repeatedly.

5. Roading and handling equipment

Roadways and unloading areas should be safe and trafficable in all weather conditions. See Module 3 Log Yard.

The expected maximum load in the placement range for traversers and forklifts should remains within the equipment's safe working capacity at all times.

9.2.3 Predrying Strategy

1. Placing the rack in the predryer

Stack locations in the predryer should be ordered to standard procedures. To do this:

- Stack assembly requirement should be readily available and understood; and
- The predryers and all stack positions should be mapped and numbered.

Batch characteristics of rack are assessed and used to control processing. To do this:

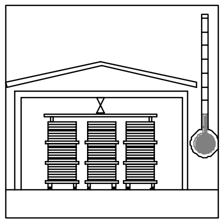
- Product and drying batch / group requirements should be readily available and understood;
- A site rack register should be in place that allows the position and drying history of each rack to be determined and monitored;
- Racks should be assessed for batch, drying history, and probable drying requirements and segregated for effective treatment; and
- Only racks of compatible batches and drying histories should be assembled as a predryer charge, or for part of a predryer line.

Racks should be adequately and evenly supported and restrained in assembled stacks. To do this:

- Stack assembly requirements should be readily available and understood;
- Stacks should only be assembled from racks of the same width and length and where the rack sticks align vertically;
- Any board that extends more than 50 mm past the last rack stick of any rack being placed in the stack should be cut off and resealed;
- Bearers, gluts and other supports should be spaced at a maximum of two rack stick spacings;
- Bearers, gluts, other supports, and rack sticks should align vertically; and
- The front faces of the racks should align vertically.

Assembled stacks should be stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports. To do this:

- Stack kerbs should be standardised elements of the same height and effective bearing and load capacity;
- All stack gluts, bearers and beams should be sound dry timber of standardised size;
- Kerbs, gluts, bearers and beams should be regularly inspected. Elements that are damaged or deteriorated should be repaired or discarded;



- Kerbs, gluts, bearers and beams should be positioned under stacks so that they are even, level and effective;
- Racks should be placed so that their front faces are parallel and in line; and
- Where required, stack weights should be placed in position.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow & duration) in the predryer should match the established schedule. To do this:

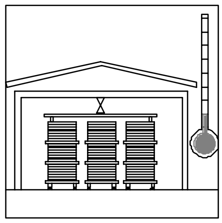
- The predryer schedule or the operational limits of the single condition schedule in operation should be readily available and understood;
- The major components of the predryers should be controlled by safe, easy to use and verifiable means;
- The monitoring equipment installed in the predryer should be sufficient to monitor the schedule conditions with confidence;
- The monitoring equipment should be used to monitor and alter conditions in line with the predryer schedule;
- The operation of the major components of the predryers and the monitoring equipment should be checked during each charge, at an interval equivalent to one full operating cycle; and
- The predryer monitoring and control equipment should be regularly maintained and calibrated.

The environmental conditions applied to the arranged stacks should be appropriate for the size, grade, and intended product area of the boards. To do this:

- The relationship between the timber batch characteristics and the correct predryer schedule for that batch should be readily available and understood;
- The relationship of different timber batches and rack drying histories that may be dried together should be readily available and understood; and
- The correct schedule or conditions should be selected and applied to each charge.

The spacing and support of assembled stacks and the baffling of the predryer allows the airflow through each rack in the stack to be as uniform as possible. To do this:

- Before loading, each rack should be examined to ensure that its physical arrangement is and is likely to remain within acceptable tolerances;
- With each charge, selected racks should fill the predryer to the line of the baffles;
- Racks in each stack should be the same length;



- The stacks should be the same height, ideally of racks of the same height;
- Stacks should be positioned as close as possible to each other end to end and, in zone or conventional batch predryers, side to side;
- Baffles should be positioned to limit airflow around stacks and to direct airflow through them; and
- Baffles should be maintained.

Racks in transport or stored for further processing should be protected to minimise drying degrade. To do this:

- Rack protection requirements should be available and understood; and
- If being stored between predrying and the next stage of production, racks should be stored in a protected location, ideally in a covered building.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity. To do this:

- Rack handling requirements should be available and understood;
- Prior to placement in stacks or storage, racks should be adequately supported on evenly spaced bearers placed immediately under a line of rack sticks;
- Racks should only be handled by adequately rated, purpose-designed equipment, operated by staff trained in its use; and
- Roads, loading and unloading areas should be safe, even and trafficable in all weather conditions.

3. Monitoring moisture

After pre-drying, the moisture content of timber in the racks is to be at the target moisture content. Generally this is below fibre saturation point. To do this:

- Moisture content requirements for each batch should be available and understood;
- Predrying should not conclude until monitoring equipment indicates that the moisture content of the charge is within the required range;
- The moisture content of the racks should be determined in accordance with Table 9.01;
- Any material outside the required tolerances should be separated as a rack for further reprocessing or reprocessed;
- The moisture content tolerances and measured readings of material should be discussed regularly; and
- The cause of repeat occurrence of material outside the required tolerances should be traced.

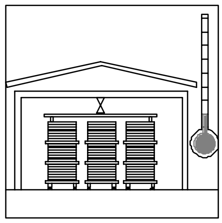
4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively. The requirements for this are included in Section 9.2.5.

9.2.4 Quality Control

Procedures should be established for:

Procedure	General contents
Site rack register	Location of each stack and its drying history.
Product specification	Grade, size, overcut and batch requirements for product groups including verification processes.
Drying group	Sorting requirements for products or grades into groups to be dried together
Predryer schedules	Selected schedules for racks of particular batch, species and thickness.
Stack assembly and baffling	Stack size, assembly and placement requirements.
Predryer condition monitoring	The monitoring processes for conditions inside the predryer.
Predryer maintenance	Routine equipment inspection and reporting processes.
Rack storage	Storage provisions including protection of high value racks, shelter of other racks, use of bearers, etc.
Rack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements.
Moisture monitoring	Provision for sample boards, or resistance meter positions, It should include the type and number of checks to be made when the racks are unloaded, and reporting procedures for non compliant material.
Marking and tagging racks	Identification requirements for grade and sorting.
Staff accreditation	Training, qualifications
Equipment	Maintenance and calibration.



9.2.5 Information Management

1. Required attributes

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Unique rack identification number	Predryer start time and date*
Staff number	Predryer end time and date*
Predryer number	Unique predryer charge record number*
Predryer position number	Staff comment
Time and date loaded	
Desirable additional information	
Store location number	
In store time and date	Out of store time and date

Table 9.03. Attributes required or desirable when loading the predryer

* zone and conventional batch predryers only

Required process control information	
Unique predryer charge record number	Operational humidity and temperature for schedule steps*
Staff number	Operational humidity and temperature for monitoring period**
Predryer number	Each step start time and date*
Intended schedule number	Predryer end time and date*
Predryer start time and date*	Staff comment
Desirable additional information	
Continuous condition monitoring or time and date of reaching operational conditions for each step in schedule	

Table 9.04. Attributes required or desirable for the predryer charge

* zone and conventional batch predryers only

** progressive and constant condition batch predryers only

Required moisture control information	
Unique rack / kd pack identification number	Likely wood temp
Position number (for predryers & predryers)	MC measurement position
Staff number	MC meter reading
Reading time & date	Adjusted MC reading
Production stage	Staff comment
Production location	

Table 9.05. Attributes required or desirable for the moisture content control with resistance type meters.

Required process control information	
Unique sample board number	Sample weight
Staff number	Adjusted MC reading
Reading time & date	Staff comment
Production stage	
Production location	
Desirable additional information.	
Sample location	

Table 9.06. Attributes required or desirable for the moisture content control (with established sample boards)

2. Record collection & processing

Sufficient information should be available at any time in a control room to determine the batch, unique identification number and location of each rack in the predryer, the schedule being employed, the time the charge started, the setting of all major controls, and the current temperature and relative humidity.

9.2.6 Equipment Maintenance/Calibration

The predryer and its associated monitoring equipment need to be maintained so that they operate continually, efficiently and effectively. This requires regular inspection between charges and after specific periods of operation.

Figure 9.18 Leaking water lines

As they are very similar to kilns, predryers have similar maintenance requirements. General requirements are detailed in Module 12.2.6.

Handling equipment should be maintained so that the expected maximum load and placement distance remains within the safe working capacity of handling equipment at all times.

9.2.7 OH&S

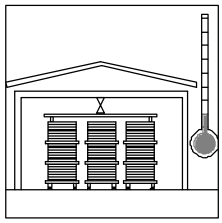
The predryer and surrounding areas should be inspected regularly and hazards identified and eliminated. This may include.

- unstable stacks of boards;
- stacks moving or being pushed through unexpectedly;
- broken rack sticks;
- leaking steam or hot water lines;
- dangerous or damaged handling equipment or trolleys;
- broken or displaced baffles;
- inadequate access and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.

Major OH & S requirements relevant to this section are listed in Table 9.07. This is not a complete list and other relevant codes and regulations may apply.

State	**Major code of practice**
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
QLD	*Sawmilling Industry Health & Safety Guide* – QLD Division of Workplace Health & Safety
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 9.07. Major industry codes of practice



9.3 Operations

9.3.1 Objectives

The objective of predrying is to dry timber in racks in controlled low temperature conditions to a moisture content suitable for further processing with as few drying defects as possible.

This section covers kilns or predryers that are used to dry the timber from green to fibre saturation points or lower moisture contents. Kilns that are used for the final drying and treatment of the material are covered in Module 11. Controlled Final Drying.

9.3.2 Key Drying Factors in Predrying

During predrying, timber is placed in a stream of air that has controlled temperature and humidity. These temperature and humidity conditions may not be constant. They can change as the capacity of the timber to sustain increasingly severe conditions without degrade also changes. This changing series of drying conditions is known as a predryer schedule.

The available equipment needs to maintain the drying schedule.

1. Even drying

For a drying schedule to work effectively, the timber being processed needs to be as regular as possible and the airflow through the timber as uniform as possible. The factors that influence this are:

- The batch of timber;
- The airflow in the predryer; and
- The timber's arrangement in the rack.

2. Correct batching

To make the full use of selected schedules and ensure fast drying with minimum degrade, each charge, line or zone group in the predryer should consist of timber with similar drying characteristics. Timber with different drying characteristics or different thickness cannot be dried in the same predryer charge without slowing overall drying or risking degrade to the material requiring the slowest drying.

3. Uniform airflow

Achieving this uniformity depends on the operation of the fans, the effectiveness of baffling around the racks and the arrangement of racks in the charge.

4. Effective baffling

Correct and effective baffling is essential in successful predrying. Air will always try to by-pass the stacks of timber and enter any larger spaces left around the edges, if baffling is not in place or effective.

5. Rack arrangement

Racks in the predryer are arranged into lines of stacks and it is critical for these to provide an even face to incoming air and easy passage for the air from one side of the predryer charge to the other.

9.3.3 Preparation

1. Procedures

Procedures should be in hand for:

Site rack register	Rack storage
Product specification	Rack transport and handling
Drying group	Moisture monitoring
Predryer schedules	Marking and tagging racks
Stack assembly and baffling	Staff accreditation
Predryer condition monitoring	Equipment
Predryer maintenance	

2. Equipment

Perform routine minor maintenance and housekeeping on and around the predryers.

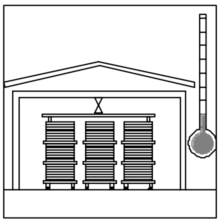
Complete a check of the predryer before loading a charge. Check that:

The floor is clean	There are no leaks in steam or water lines.
Drainage is clear	The fans are operating
Baffles and vents are working	Control sensors are functional
Wet bulb sensors have clean wicks and clean water.	

3. Incoming material

Racks are to be inspected to ensure that:

- Racks are made up of boards of a single batch type;
- The drying history of the racks is consistent;
- Racks are the correct size;
- The faces of the rack are even and vertical;
- The ends of the rack are square, even and vertical;
- No board extends more than 50 mm past the last rack stick;
- Racks are stable for transport and placement in stacks; and
- Moisture monitoring equipment is in place and accessible.



9.3.4 Processing & Monitoring

1. Placing the racks in the predryer

Stack locations in the predryer are ordered to standard procedures.

- Identify and select racks for each charge to maximise use of chamber space.
- Assemble stacks in correct locations.
- Load chamber to maximise chamber space.

Batch characteristics of racks are assessed and used to control processing.

- Inspect rack batch and history when preparing the charge.
- Segregate racks in accordance with the required drying schedule.
- Assemble the charge with materials of consistent drying characteristics.

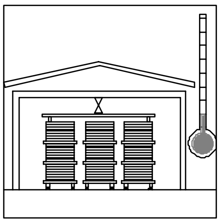
Racks are adequately and evenly supported and restrained in assembled stacks.

- Check racks to be dried for stability, spacing of strips, and support.
- Only assemble stack of racks of the same width, length and rack stick alignment.

Figure 9.19. Same length racks in a predryer

- Place a bearer under the end rack stick line of every rack in the stack.
- Place bearers no wider apart than every second line of rack sticks in a rack or at a maximum of 1.2 m centres which ever is smaller.
- Ensure bearers, beams, other supports, and rack sticks align vertically.
- Immediately replace any bearer or glut displaced as the rack is positioned.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports.



- Maintain stability and integrity of racks during the loading process.
- Keep the floor of the predryer clean and clear of obstructions
- Check bearers and gluts. Separate damaged items for repair or disposal.
- Position supports under racks and stacks so that they are flat, stable and effective.
- Place racks so that their front faces are parallel and align vertically.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow and duration) in the predryer match the established schedule.

- Make sure the predryer schedule in operation is understood.
- Check the operation of the predryer's major components and monitoring equipment regularly.
- Check the temperature, humidity and airflow regularly.
- Establish and maintain the conditions required by the drying schedule.
- Check alarms promptly.

The environmental conditions applied to the arranged stacks are appropriate for the size, grade, and intended product area of the boards.

- Assess timber batch and drying history to determine processing requirements.
- Select and apply the correct schedule to each charge.

The spacing and support of assembled stacks and the baffling of the predryer allows the airflow through each rack in the stack to be as uniform as possible.

- Assemble stacks to the same height and to the line of the baffles.
- Position stacks as closely as possible to each other end to end and, where practical, side to side.
- Position the baffles to direct airflow through the timber stacks.

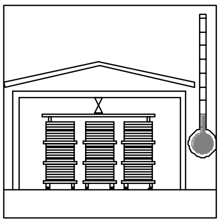
Figure 9.20. Baffles in a progressive predryer

Racks in transport or stored for further processing are protected to minimise drying degrade. The timber continues to dry during storage and can be damaged if it is exposed to adverse conditions.

- Protect high value racks from adverse conditions with local environment controls
- Do not store racks in the sun any longer than absolutely necessary.
- Store racks in an enclosed building out of the sun or in a roofed shelter.

Figure 9.21. Racks in an enclosed building

- Transfer dried timber for further processing quickly or store under cover.



Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

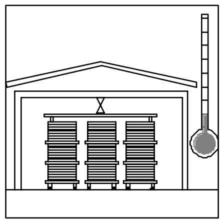
- Check bearers and gluts are a standard thickness.
- Discard rack bearers and gluts that are not of the standard thickness, are split, broken or show signs of decay.
- Position bearers at each end and then at a maximum of 1.2 m centres internally, directly under a line of rack sticks.
- Realign or replace any rack sticks that move or fall out during transport.
- Strap the ends of racks for transport if rack sticks keep falling out.
- Only handle racks with adequately rated, purpose-designed equipment, operated by staff trained in its use.

Figure 9.22. Racks dried to FSP stored undercover before reconditioning

3. Monitoring moisture

After predrying, the moisture content of timber in the racks is to be at the target moisture content. Generally this is below fibre saturation point.

- Establish moisture measuring positions in the timber and check readings.
- Measure and record moisture content in the timber during predrying and compare with anticipated levels.



- Confirm the average moisture content of racks after predrying to standard procedures.
- Separate racks that do not meet the final target moisture content for further drying.
- Progress racks that do meet the final target moisture content to further processing.
- Trace the causes of material repeatedly being outside the required tolerances.

9.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the racks effectively.

- Rack tags are in place and legible
- Complete at least the following records:

Production sheets detailing racks in charge and positions	Charge records detailing schedule, conditions and adjustments.
Equipment performance report	Equipment maintenance report
Rack moisture contents	Feedback reports

9.3.6 Feedback

If noticed regularly, report any of the following to the supervisor:

Problems with processing equipment	Irregular moisture meter readings
Boards not end sealed	Boards in racks that are not the preferred length
Rack sticking out of line	Racks exposed to sunlight or other adverse conditions
Racks sides or ends out of line	Previous damage to incoming timber

9.3.7 OH&S

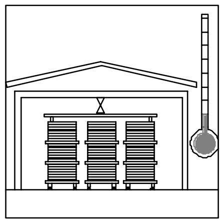
Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational

Keep work areas clean, tidy and clear of trip hazards such as wire and strapping ends, and pieces of timber.

Inspect the area around the predryer regularly. Identify potential hazards and eliminate them. around the predryer, this can include:

- unstable stacks of boards;
- stacks moving or being pushed through unexpectedly;

- broken rack sticks;
- leaking steam or hot water lines;
- dangerous or damaged handling equipment or trolleys;
- broken or displaced baffles;
- inadequate access and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.



9.4 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

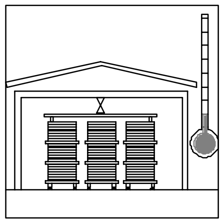
1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Incoming racks

	1	2	3	4	5
Racks are made up of boards of a single batch type.					
Racks are the correct size.					
The faces of the rack are even and vertical.					
The rack sticks are in neat and vertical lines.					
The ends of the racks are square, even and vertical.					
No board extends more than 50 mm past the last rack stick.					
Special provisions for high value racks are in place.					
Racks are stable for transport and placement in stacks.					
Racks are correctly, clearly and securely tagged.					
Moisture monitoring equipment is in place and accessible.					

2. Racks assembled for a charge

	1	2	3	4	5
Racks are selected for similar drying characteristics.					
The drying history of the racks is consistent or compatible.					
The whole charge is the same thickness timber.					
Existing damage to timber noted at the rack level and recorded.					
Rack lengths optimize stack integrity and predryer loading efficiency.					



3. Stacks

	1	2	3	4	5
Stack supports are even and level.					
Stacks are vertical and even, without a noticeable lean.					
Rack sticks, bearers and piers are in all in neat vertical lines.					
Bearer lines are no more than two rack sticks apart.					
Elements knocked out of line during building the stack are realigned.					
Upon completion, the difference in vertical alignment of the faces of any two racks in the stack is no more than 25 mm.					
Baffles are in place and secure.					
Moisture monitoring equipment connected and operational.					
Documentation completed accurately.					

4. Processing the charge

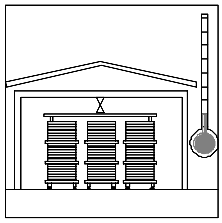
	1	2	3	4	5
The correct predryer schedule is selected for the timber's batch and condition.					
Predryer conditions are monitored and recorded regularly					
Predryer conditions are amended in line with the schedule by processing time or measured moisture content condition of the timber.					
Drying only concludes when the measured moisture content of the charge is within the required tolerances.					
Moisture content gradient sampled at completion of drying.					
Causes for uneven or patchy drying investigated and corrected					
Rack and predryer batch identity maintained					
Equalising and conditioning treatments used correctly and used when needed					

Check for drying stresses using prong test					

3. Monitoring moisture content

	1	2	3	4	5
The moisture contents of the rack or stack is monitored and recorded regularly.					
Proper selection and use of predryer sample boards					
Target moisture content confirmed in racks before further processing.					
Inconsistent drying in racks or stacks is recorded and investigated.					
Racks not meeting specifications are identified and reprocessing options planned.					

The equipment maintenance and inspection checklist for a kiln in Module 12.4 can be used as a base for inspecting a predryer.



9.5 Avoidable Loss

Predrying has higher capital and operating costs than air drying and this has to be recovered through production improvements, including increased grade recovery.

However, predrying introduces risks. Often, the characteristics of the timber may be poorly understood or the operating parameters of the predryer may be inadequate to dry the timber without degrade, even when operating efficiently. These risks may be manageable in a small predryer but are significantly complicated as the predryer increases in size and material of different types and condition are mixed together.

1. Placing the rack in the predryer

- **Inadequate stack support** – When bearers are out of line and supports are uneven, boards are unevenly loaded and can twist and deform. This reduces grade and recovery. Uneven support also complicates stack assembly. In extreme cases, stacks can become dangerously unstable.

2. Protecting the racks and stacks from physical and drying damage

- **Exposing the timber to adverse drying conditions** – If high grade racks are subject to a schedule where they dry too rapidly, the timber will check and, grade and recovery will be lost. Exposing thick material to conditions conducive to fast initial drying can increase surface and internal checking and collapse. This can occur if
  - Inappropriate predrying schedules are used or the equipment is not operating correctly.
  - The predryer design is not mechanically efficient for the material being processed
  - Poor stack arrangement, insufficient baffling, or faulty equipment lead to uneven airflow
- **Rack damage** – Boards subject to mechanical damage due to poor roading, lack of capacity in forklifts and traversers, or poor placement or driving are a direct production loss.
- **The racks are stacked too high**. If the rack sticks are too narrow, or the timber too soft, lower boards can be indented and stacks become unstable.

3. Monitoring moisture

- **Inadequate moisture monitoring** – Wet racks are exposed to further processes that cause damage to the timber. Poorly dried racks often have to be redried and so incur an increased production cost.

4. Maintaining product information

- **Lost information results in inadequate batching**. Mixing material of different species, size, initial moisture content and diffusivity can lead to some timber being subject to conditions that cause degrade while other timber in the charge is not affected. This can lead to a loss in value for the product degraded and increased production cost as the degraded material must be graded out and reprocessed.

9.6 References

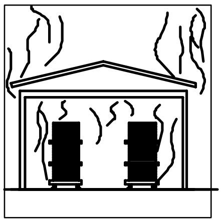
Commonwealth Scientific and Industrial Research Organisation 1960, 'Can Airdrying Methods be Improved?', *CSIRO Forest Products Newsletter*, No. 261.

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

10.0: – RECONDITIONING



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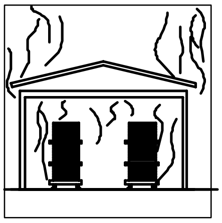
10.0: – RECONDITIONING



10.1 Objectives

The objective of reconditioning is to recover collapse in timber from collapse prone species by treatment in saturated steam.

10.2 Functions & Performance Requirements

1. Placing the rack in the reconditioner

Stack locations in the reconditioner are ordered to standard procedures.

The batch of racks is assessed and used to control processing.

Racks are adequately and evenly supported and restrained in assembled stacks.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity and duration) in the reconditioner match the established schedule.

The environmental conditions applied to the arranged stacks are appropriate for the thickness of the boards.

The arrangement of racks and stacks allows even exposure to the environmental conditions.

Racks in transport or stored for further processing are protected to minimise drying degrade.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

3. Monitoring moisture

Before reconditioning for collapse, the average moisture content of timber in the racks should be about 20%.

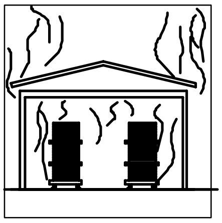
4. Maintaining product information

Information required for later production control is collected and passed with the rack effectively.

5. Identifying & reporting problems for correction

Details of individual and systemic problems are identified and distributed.

Problems are corrected.



6. Management of staff and equipment

Staff and equipment are available to conduct reconditioning activity safely and efficiently.

10.0: – RECONDITIONING

10.2 Management

10.2.1 Overview

Activity during reconditioning is to recover collapse in timber from collapse prone species by treatment in saturated steam before final controlled drying.

Conditioning (also known as reconditioning) after kiln drying is covered in Module 12.00 Controlled Final Drying.

1. Recovering collapse

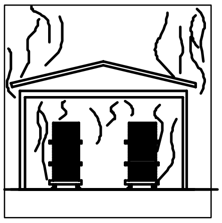
Collapse occurs in some species at moisture contents above fibre saturation point (FSP). On a microscopic level, collapse is the physical collapse of the fibre cells, much like a drinking straw that has been pinched and flattened. On the surface of the board, it is usually seen as a rippling or “wash boarding”, as generally discrete earlywood growth rings will collapse more than latewood rings under common drying conditions. It is generally accepted as being due to tension that occurs in the free water within the wood fibers as the timber dries.

Figure 10.01. Collapse on the end and surface of a board

Reconditioning involves heating the collapsed or collapse prone timber in racks with steam for long enough so that parts of the fibre wall softens with the heat and moisture. The collapsed cells then recover much of their original shape and the board expands. In practice, the whole rack and stack increases in height during reconditioning.

The temperature needed in the wood to recover collapse varies slightly from species to species. Holding temperatures between 95 and 100 C generally provide the best results. Higher temperature can only be attained with superheated steam and this is likely to cause surface checking.

10.0: – RECONDITIONING



Generally, timber from non-collapse prone species or from collapse prone species that has been dried without collapse does not require reconditioned.

Figure 10.02. Collapse in boards before reconditioning

Reconditioning is widely used through industry. While a simple process, reconditioning requires care so that:

the timber is at the correct moisture content when it is reconditioned;

the whole charge is heated to the required temperature and held there for sufficient time; and

The heated charge is protected.

1a. Moisture content

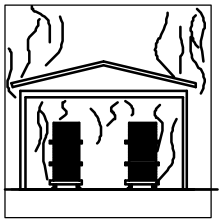
While the general principles of reconditioning are understood, most information about it is based on empirical studies and industry practice.

Reconditioning is most successful when there is no free water in the timber but there is still a reasonable amount of bound water. It appears that a certain level of bound water is necessary for the cells to recover.

So, reconditioning is generally carried out when all parts of the board are below fibre saturation point, typically at an average moisture content for the rack of around 18-20%.

If the moisture content is significantly above this, there may still be free water in some of the cells. Then, reconditioning can damaged the timber, be starting or increasing checking, case hardening and further collapse. Similarly, if the moisture content is significantly below fibre saturation point, the effectiveness of the process is reduced. Assessment of the moisture content of the timber before reconditioning is therefore very important.

Reconditioning generally adds about 1 - 2% to the moisture content of the piece.



1b. Adequate heating

Reconditioning to recover collapse operates to a simple schedule of a single temperature and humidity condition held for period of time. The amount of time has to be sufficient for the timber to heat up all the way through. It varies with species and board thickness.

The target temperature is generally greater than 95 °C and less than 100 °C.

Reconditioning times for major species and board thickness are given in Table 10.01. The treatment times are for the period after the temperature and humidity conditions in the reconditioner have ramped up to the required set points.

Thickness (mm)	Treatment time (hours)
16-19	4
25	5-6
38	6-7
50	7-8

Table 10.01. Reconditioning treatment times

1c. Charge protection

After reconditioning, the timber should be allowed to cool slowly down to ambient conditions or be moved directly into final drying kilns. Care needs to be taken. Degrade can result if cold, dry air is allowed to flood a stack of hot, moist timber.

2. Assessment on completion

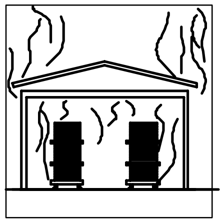
Reconditioning is complete when the cells in the timber have recovered their shape and the boards being treated regained the dimension expected. The treatment period required to achieve this is determined using either of the following:

Experience with the timber being processed. In this case, the timber is treated for a particular time for a given thickness and species; or

Direct measurement. A simple height gauge can monitor the increase in size of a rack in the reconditioner. Again, the expected gain in dimension is determined by experience with the timber being processed. For example, a rack of 23 rows of 25 mm. quarter sawn boards may regain between 35 and 60 mm.

2a. Observed degrade

Reconditioning has historically been held responsible for surface and internal checking of timber, mainly because the first time it is observed in a rack is after it is reconditioned. However, many of these checks result from collapse and uneven drying in the early parts of drying process. As the timber continues to



dry and shrink in later drying, the checks close up. They only reappear again after reconditioning.

3. Process of steaming

Reconditioning involves loading a charge of racks into a special chamber and injecting low-pressure steam. Atmospheric pressure (or wet) steam is used because it is an efficient heat transfer medium that heats the timber without drying it.

Atmospheric pressure (or wet) steam is low temperature steam with 100% humidity. It can be produced by: a low-pressure boiler; bubbling high pressure steam through a water bath; or boiling a water bath with piped steam or hot oil.

Steam directly from the high pressure boiler, or live (superheated) steam, can be significantly hotter than 100 °C and can damage the timber. If used for reconditioning, this type of steam should always be run through a sparge line in a water bath.

As steam is lighter than air, vents at the bottom of the chamber allow cold air to escape as the chamber fills with steam. The vents can be closed when steam starts to escape from them.

4. Arrangement, handling and placement

Racks are arranged in the reconditioner in stacks. Unlike predryers or kilns, air movement is not critical in a reconditioner. However, the timber must be in racks so that the steam can reach each board. Racks must be supported regularly and evenly, and concentrations of load on individual boards as the timber becomes plastic, must be avoided.

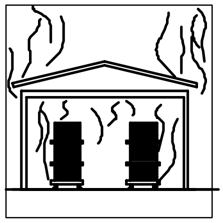
As the heat and steam of a reconditioner plasticises the timber in the rack, the potential for indentation of boards limits the height of stacks. The pressure on lower boards of high stacks or lower stacks with thin rack sticks can exceed their capacity to resist indentation when heated. In practice, reconditioner stacks are limited to two to three racks high.

Racks stacked on each other should be the same length and only racks of identical rack stick spacing should be assembled in a stack.

The beams, gluts and rack sticks in all the racks in a stack should align vertically. This ensures that the load being transferred to the beams, and eventually to the ground, is carried in simple compression from stick to board to bearer

Bearers in the stacks should be the same thickness and placed directly over lines of rack sticks. Differences in bearer thickness can bend and warp the boards. Bearer spacing should not exceed two rack stick spacings. This limits the maximum spacing to 1.2 m.

Stacks for the reconditioner are usually built on a trolley, and then moved in on rails. They then generally sit on solid, normally concrete kerbs positioned on either side of the trolley rails.



The spacing of the kerbs determines the number of lines of stacks in the reconditioner. It also determines the depth of the beams under the stacks. These should be positioned at the same centers as bearers in the stacks and be deep enough so that they have no noticeable deflection when fully loaded.

The spacing of the kerbs determines the number of lines of stacks in the reconditioner. It also determines the depth of the beams under the stacks. These should be positioned at the same centers as bearers in the stacks and be deep enough so that they have no noticeable deflection when fully loaded.

5. Monitoring & control equipment

Sufficient instruments and controls should be in place in any reconditioner to:

determine the temperature at any time with confidence; and

modify the supply of stem in line with the required schedule.

A device to provide a reasonable indication of the dimensional gain of a control stack is optional.

10.2.2 Equipment Options

1. Fixed equipment

The fixed equipment for reconditioning includes: reconditioners; monitoring equipment; stack material; roading and loading equipment.

1a. Reconditioner

There are a wide variety of reconditioners in operation or on offer from reconditioner manufacturers. The general components of a reconditioner include:

An insulated enclosure. This should be resistant to corrosion and high levels of moisture, easy to maintain and well insulated to minimise heat loss. Doors and other openings must be rigid enough to withstand often vigorous handling and be fitted with effective seals and closing mechanisms to prevent unnecessary air leakage;

A steam source: The steam provides the heat required to:

raise the temperature of the reconditioner and its content sufficiently so that the wood fibre will soften; and

maintain the moisture level necessary to eliminate any degrade that drying at a high temperature may cause;

A stacking area: The racks of timber are stacked with even support. This area must also accommodate rack handling mechanisms, usually traverser trolleys;

Monitoring Equipment. The condition of the air needs to be monitored to determine its temperature. This is vital to ensure that the correct treatment is delivered for the correct period of time; and

Control mechanism. Though generally only a single condition is required in the process, a control mechanism must allow this to be achieved and maintained effectively.

The arrangement of a generic reconditioner is shown in Figure 10.03.

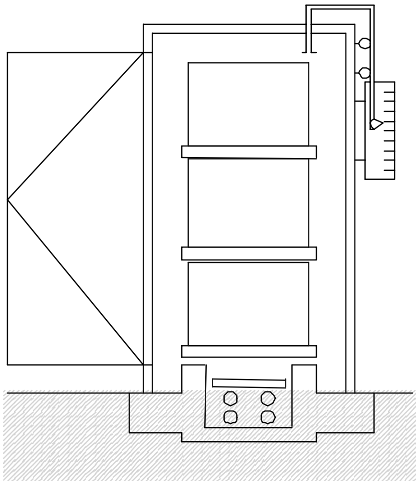


Figure 10.03. Reconditioner generic arrangement

Figure 10.04. Reconditioner in operation

1b. Monitoring equipment

Dry bulb thermometers

Thermometers, resistance temperature devices (RTDs) and other temperature sensors measure the temperature of the air in the reconditioner. They measure its actual temperature and are not affected by its water vapour content, or relative humidity. To obtain an accurate reading, the dry bulb sensors must be mounted in a clear area at the side of the stack. To avoid incorrect readings the sensor should not be too close to either the walls, or to steam pipes. Temperature sensors that are incorrectly positioned may result in very high temperatures that increase drying losses or very low temperatures that do not allow the material to recover fully.

1c. Stack material

The depth of any beam spanning between kerbs should be a standardised thickness such that they have no deflection noticeable by eye when fully loaded. They can be of any suitable material. Timber beams should be of straight sound timber, dry, clean and free from decay and staining fungi. Material that does not thickness to the standard size or which starts to come apart should be discarded.

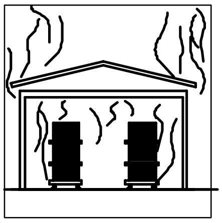
Gluts and other bearers should be gauged to a standard depth. Generally, this is about 90 mm. They should be of sound and seasoned timber, dry, clean and free from decay and staining fungi. Material that will not thickness to the standard size for the site or which start to come apart should be discarded.

5. Roading, traverser and forklifts

Roadways and unloading areas should be safe and trafficable in all weather conditions. See Module 3. Log Yard.

Figure 10.05 Traverser preparing to load a stack for the reconditioner

The expected maximum load in the placement range for traversers and forklifts should remains within the equipment's safe working capacity at all times.



10.2.3 Reconditioning Strategy

1. Placing the rack in the reconditioner

Stack locations in the reconditioner should be ordered to standard procedures. To do this:

Stack assembly requirement should be readily available and understood; and

The reconditioners should be mapped and numbered.

The batch of racks should be assessed and used to control processing. To do this:

Product and drying batch / group requirements should be readily available and understood;

Racks should be assessed for batch requirements, drying history and measured moisture content, and segregated for effective treatment; and

Only racks of compatible batches and drying histories should be assembled as part of a reconditioner charge.

Racks should be adequately and evenly supported and restrained in assembled stacks. To do this:

Stack assembly requirements should be readily available and understood;

Stacks should only be assembled from racks of the same width and length and where the rack sticks align vertically;

Bearers, gluts, other supports and rack sticks should align vertically; and

Bearers, beams and other supports should be spaced at a maximum of two rack stick spacing.

Assembled stacks should be stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports. To do this:

Stack kerbs should be standardised elements of the same height and effective bearing and load capacity;

All stack gluts, bearers and beams should be sound dry timber of standardised size;

Kerbs, gluts, bearers and beams should be regularly inspected. Elements that are damaged or deteriorated should be repaired or discarded; and

Kerbs, gluts, bearers and beams should be positioned under stacks so that they are even, level and effective.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity & duration) in the reconditioner should match the established schedule. To do this:

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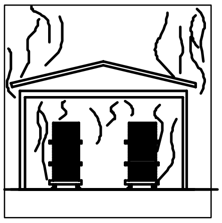


The reconditioner schedule in operation should be readily available and understood;

Conditions in the reconditioner should be monitored during each charge and maintained in line with the schedule;

The monitoring equipment installed in the reconditioner should be sufficient to monitor the schedule conditions with confidence;

The monitoring equipment should be used to monitor and alter conditions in line with the reconditioner schedule;

The components of the reconditioner should be controlled by safe, easy to use and verifiable means;

The operation of the major components of the reconditioner and the monitoring equipment should be checked during each charge; and

The reconditioner monitoring and control equipment should be regularly maintained and calibrated.

The environmental conditions applied to the arranged stacks should be appropriate for the thickness of the boards. To do this:

The correct schedule should be selected and applied to each charge.

The arrangement of racks and stacks should allow even exposure to the environmental conditions. To do this:

Boards should be evenly spaced in racks; and

Before loading, each rack should be examined to ensure that its physical arrangement is and is likely to remain within acceptable tolerances.

Racks in transport or stored for further processing should be protected to minimise drying degrade. To do this:

Rack protection requirements should be available and understood; and

If being stored between reconditioning and the next stage of production, racks should be stored in a protected location, ideally in an enclosed building.

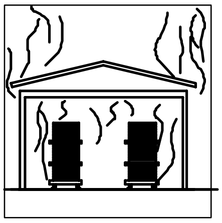
Racks in transport and storage should be handled to minimise physical damage and loss of rack integrity. To do this:

Rack handling requirements should be available and understood;

Prior to placement in stacks or storage, racks should be adequately supported on evenly spaced bearers placed immediately under a line of rack sticks;

Racks should only be handled by adequately rated, purpose-designed equipment, operated by staff trained in its use; and

Roads, loading and unloading areas should be safe, even and trafficable in all weather conditions.



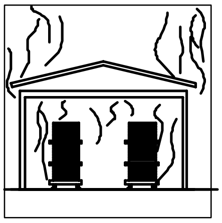
3. Monitoring moisture

Before reconditioning for collapse, the average moisture content of timber in the racks should be about 20%. To do this:

- The moisture content determined at the completion of air or predrying is confirmed.
- The cause of repeat occurrence of material outside the required moisture and recovery tolerances should be traced.

4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively. The requirements for this are included in Section 10.2.5.



10.2.4 Quality Control

Procedures should be established for:

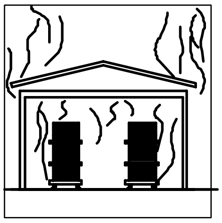
Procedure	General contents
Site rack register	Location of each stack and its drying history.
Drying group	Sorting requirements for products or grades into groups to be dried together
Reconditioner schedules	Selected schedules for racks of particular batch, species and thickness.
Reconditioner stack assembly	Stack size, assembly and placement requirements.
Reconditioner condition monitoring.	The monitoring processes for conditions inside the reconditioner.
Reconditioner maintenance	Routine equipment inspection and reporting processes.
Rack storage	Storage provisions including protection of high value racks, shelter of other racks, use of bearers, etc.
Rack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements.
Marking and tagging racks	Identification requirements for grade and sorting
Staff accreditation	Training, qualifications
Equipment	Operational parameters, maintenance

10.2.3 Information Management

1. Required attributes

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Unique rack identification number	Time and date rack loaded
Staff number	Unique reco charge record no
Reco number	Staff comment
Reco position number	



Desirable additional information	
Store location number	
In store time and date	Out of store time and date

Table 10.02. Attributes required or desirable when loading the reconditioner

Required process control information	
Unique reco charge record number	Reco start time and date
Staff number	Time and date of reaching operational humidity and temperature
Reco number	Reco end time and date
Intended schedule Number	Staff comment
Desirable additional information	
Continuous condition monitoring	

Table 10.03. Attributes required or desirable for the reconditioner charge

2. Record collection & processing

Sufficient information should be available at any time in a control room to determine the batch of timber, unique identification number of each rack in the reconditioner, the time the charge started, the setting of all major controls, and the current temperature.

10.2.6 Equipment Maintenance

The steam and conditioning monitoring equipment needs to be operating efficiently to ensure that the correct conditions are maintained for the required time.

Figure 10.06 Broken door seal releases steam

Detailed maintenance checklists are included in Section 10.4.

10.2.7 OH&S

The reconditioner and surrounding areas should be inspected regularly and hazards identified and eliminated. This may include:

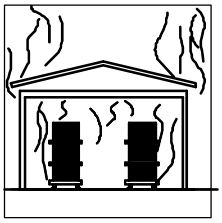
- unstable stacks of boards;
- leaking steam or hot water lines;
- handling or moving hot timber;
- dangerous or damaged handling equipment or trolleys;
- inadequate access and warning procedures; and
- poor or no safety signage.

Major OH & S requirements relevant to this section are listed in Table 10.04. This is not a complete list and other relevant codes and regulations may apply.

State	Major code of practice
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
QLD	*Sawmilling Industry Health & Safety Guide* – QLD

	Division of Workplace Health & Safety
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 10.04. Major industry codes of practice



10.3 Operations

10.3.1 Objective

The objective of reconditioning is to recover collapse in timber from collapse prone species by treatment in saturated steam before final controlled drying.

10.3.2 Key Drying Factors

During reconditioning, timber is placed in a chamber and treated with saturated steam. This allows collapsed cells in the timber to recover their original shape. While a simple process, reconditioning requires care so that:

1. The timber is at the correct moisture content

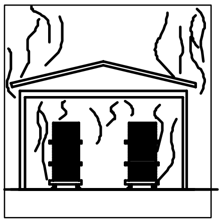
Typically, this is at an average of around 18-20%. If the moisture content is significantly above this, at about 30% anywhere within the board, the timber can be severely damaged. It can check or caseharden. Similarly, if the moisture content is below this at about 14%, the effectiveness of the process is reduced.

2. The treatment is sufficient

The whole charge has to be heated to the required temperature and held there for sufficient time.

3. The heated charge is protected

If cold, dry air is allowed to flood a stack of hot, moist timber, degrade may result.



10.3.3 Preparation

1. Procedures

Procedures should be in hand for:

Site rack register	Rack storage
Drying group	Rack transport and handling
Reconditioner schedules	Marking and tagging racks
Reconditioner stack assembly	Staff accreditation
Reconditioner condition monitoring.	Equipment
Reconditioner maintenance	OH&S

2. Equipment

Perform routine minor maintenance and housekeeping on and around the reconditioner.

Complete a check of the reconditioner before loading a charge. Check:

The water bath and control cocks.	There are no leaks in steam or water lines.
The steam nozzles.	Control sensors are functional.
The recovery gauge.	

3. Incoming material

Racks are to be inspected to ensure that:

The moisture content of the racks is suitable for reconditioning;

Racks are made up of boards of a single batch type;

Racks are the correct size;

Racks are stable for transport and placement in stacks; and

Required tags and marks are in place.

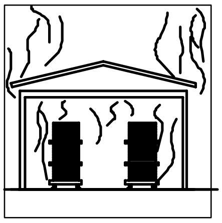
10.3.4 Processing & monitoring

1. Placing the rack in the reconditioner

Stack locations in the reconditioner are ordered to standard procedures.

Identify and select racks for each charge to maximise use of chamber space.

Assemble stacks in correct locations.



Load chamber to maximise chamber space.

Batch characteristics of racks are assessed and used to control processing.

Assemble the charge with materials of consistent drying characteristics.

Racks are adequately and evenly supported and restrained in assembled stacks.

Check racks to be dried for stability, spacing of strips, and support.

Only assemble stack of racks of the same width and identical rack stick alignment.

Only place racks shorter or the same length on a lower rack.

Place a bearer under the end rack stick line of every rack in the stack.

Place bearers no wider apart than every second line of rack sticks in a rack or at a maximum of 1.2 m centres, which ever is smaller.

Ensure bearers, beams, other supports, and rack sticks align vertically.

Replace any bearer or glut displaced as the rack is positioned immediately.

Check bearers and gluts. Separate damaged items for repair or disposal.

Position supports under racks and stacks so that they are flat, stable and effective.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity & duration) in the reconditioner match the established schedule.

Make sure the reconditioner treatment in operation is understood.

Establish and maintain the conditions required by the treatment.

Check the operation of the reconditioner's major components and monitoring equipment regularly.

Check the temperature regularly.

Do not conclude treatment until the required recovery is achieved.

The environmental conditions applied to the arranged stacks are appropriate for the thickness of the boards.

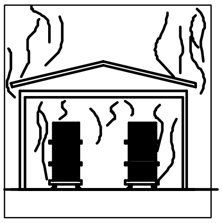
Assess timber batch and drying history to determine processing requirements.

Select and apply the correct schedule to each charge.

The arrangement of racks and stacks allows even exposure to the environmental conditions.

Only load properly racked timber.

Racks in transport or stored for further processing are protected to minimise drying degrade.



Allow the timber to cool slowly in the reconditioner, or move it directly to the kiln.

Do not store racks in the sun any longer than absolutely necessary.

Store racks in an enclosed building out of the sun or in a roofed shelter.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

Check bearers and gluts are a standard thickness.

Discard rack bearers and gluts that are not of the standard thickness, are split, broken or show signs of decay.

Position bearers at each end and then at a maximum of 1.2 m centres internally, directly under a line of rack sticks.

Realign or replace any rack sticks that move or fall out during transport.

Only handle racks with adequately rated, purpose-designed equipment, operated by staff trained in its use.

3. Monitoring moisture

Before reconditioning for collapse, the average moisture content of timber in the racks is about 20%.

Check that the moisture content of the timber was determined at the completion of air or predrying.

Trace the causes of material repeatedly being outside the required tolerances.

10.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the rack effectively.

Rack tags are in place and legible.

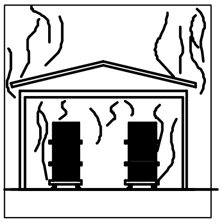
Complete at least the following records:

Production sheets detailing racks in charge	Charge records detailing schedule, conditions and adjustments.
Equipment performance report	Equipment maintenance report
Rack moisture contents	Feedback reports

10.3.6 Feedback

If noticed regularly, report any of the following to the supervisor:

Problems with processing equipment.	Irregular board recovery.



Rack sticks out of line.	Racks sides or ends out of line.
Previous damage to incoming timber.	Racks exposed to sunlight or other adverse conditions or any degrade from this.

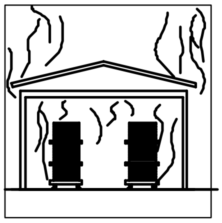
10.3.7 OH&S

Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational

Keep work areas clean, tidy and clear of trip hazards such as wire and strapping ends, and pieces of timber.

Inspect the reconditioner regularly. Identify potential hazards and eliminate them. Around the reconditioner, this can include:

- unstable stacks of boards;
- broken rack sticks;
- short lengths of timber on sorting tables;
- leaking steam or hot water lines;
- dangerous or damaged handling equipment or trolleys;
- broken or displaced baffles;
- inadequate access, cool down and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.



10.4 Checklists

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Income racks

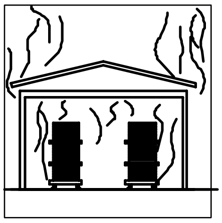
	1	2	3	4	5
The moisture content of the racks is suitable for reconditioning.					
Racks are made up of boards of a single batch type.					
Racks are the correct size.					
The sides of the rack are even and vertical.					
The rack sticks are in neat and vertical lines.					
The ends of the racks are square, even and vertical.					
Racks are stable for transport and placement in stacks.					
Racks are correctly, clearly and securely tagged.					

2. Racks assembled for a charge

	1	2	3	4	5
Racks are selected for similar drying characteristics.					
The drying history of the racks is consistent or compatible.					
The whole charge is the same thickness timber.					
Existing damage to timber noted at the rack level and recorded.					
Rack lengths optimize stack integrity and predryer loading efficiency.					

3. Stacks

	1	2	3	4	5
Stack supports are even and level.					
Stacks are vertical and even, without a noticeable lean.					



Rack sticks, bearers and piers are all in neat vertical lines.					
Bearer lines are no more than two rack sticks apart.					
Documentation completed accurately.					

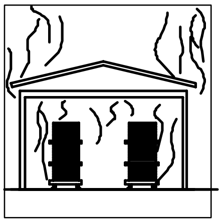
4. Processing the Charge

	1	2	3	4	5
The correct reconditioner schedule is selected for the timber's batch and condition.					
Reconditioner conditions are monitored and recorded regularly.					
Reconditioning treatment concludes when the charge has achieved the required recovery.					
Treated material stored under cover to cool before further processing or moved directly to kiln.					

5. Equipment Maintenance and Inspection

	1	2	3	4	5
Traps checked for proper operation.					
Regular maintenance program for steam valves					
Regular calibration of temperature sensing devices and indicators					

Valves Operate Properly	1	2	3	4	5
Steam heat valves operate properly.					
Gauges are working and legible.					
Heating coils and steam pipe free of steam or water leaks.					
Steam spray uniformly distributed.					
Steam spray free of liquid water.					



10.5 Avoidable Loss

1. Placing the rack in the reconditioner

Reconditioning when the material has the wrong moisture content. If the timber's moisture content is too high, the timber can case harden, or check. If the timber's moisture content is too low, it does not recover its dimension adequately. This leads to more hit and miss in boards during dry milling.

Inadequate stack support – When bearers are out of line and supports are uneven, boards are unevenly loaded and can twist and deform as they soften in the heat and steam of the reconditioner. This reduces grade and recovery. Uneven support also complicates stack assembly. Stacks can become unstable and jam in the reconditioner.

2. Protecting the racks and stacks from physical and drying damage

Inappropriate treatment - If the timber is exposed to superheated, dry steam is can check and case harden. The timber will not recover fully if:

the timber is not brought up to the required temperature;

the timber is not reconditioned for long enough;

the equipment is not operating correctly or is not mechanically efficient for the material being processed; or

the timber is cooled down too fast.

Rack damage – Boards subject to mechanical damage due to poor roading, lack of capacity in forklifts and traversers, or poor placement or driving are a direct production loss.

10.6 References

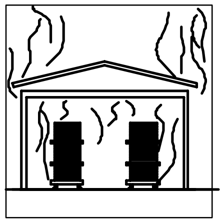
Chafe, S. C., (1995). 'Preheating, 'Drying, Internal Checking and Shrinkage in *Eucalyptus regnans',* Holzforschung, 49.

CSIRO, (1971). 'Control of Seasoning Degrade in Jarrah Joinery Stock', CSIRO Forest Products Newsletter No. 386.

CSIRO, (1964). 'The Control of Surface Checking during Drying Part II', Forest Products Newsletter, No. 314, Australia.

CSIRO, (1960). 'Presteaming Cuts Drying Time of "Ash" Eucalypts', CSIRO Forest Products Newsletter No. 263.

CSIRO, (1959) 'Can Chemical Seasoning help the Timber Industry', CSIRO Forest Products Newsletter No. 257,



Commonwealth Scientific and Industrial Research Organisation 1957, 'Dimension Stabilizing Treatments For Timber', *CSIRO Forest Products Newsletter* No. 230.

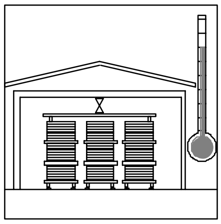
Commonwealth Scientific and Industrial Research Organisation 1938, 'Collapse and its Removal: Some Recent Investigations with *Eucalyptus regnans', CSIRO Division of Forest Products Technical Paper* No. 24.

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

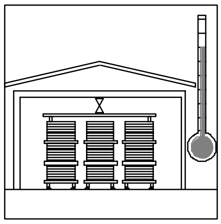
Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

Illic, J. 1995, ' Advantages of prefreezing for reducing shrinkage-related degrade in eucalypts: General considerations and review of the literature', *Wood Science and Technology*, 29.



11.0 CONTENTS

11.0: – Controlled Final Drying



11.1 Objectives

The objective of controlled final drying is to dry the timber in controlled conditions to the final required moisture content and stress condition and pass it on for further processing without inappropriate degrade.

This includes elevated temperature drying, conditioning and equalisation treatments.

11.1.1 Functions & Performance Requirements

1. Placing the rack in the kiln

Stack locations in the kiln are ordered to standard procedures.

Batch characteristics of rack are assessed and used to control processing.

Racks are adequately and evenly supported and restrained in assembled stacks.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow and duration) in the kiln match the established schedule.

The environmental conditions applied to the arranged stacks are appropriate for the size, grade, and intended product area of the boards.

The spacing and support of assembled stacks and the baffling of the kiln allows the airflow through each rack in the stack to be as uniform as possible.

Racks in transport or stored for further processing are protected to minimise drying degrade.

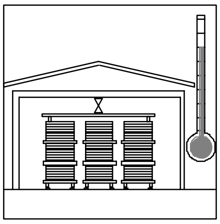
Racks in transport and storage are handled to minimise physical damage and loss of rack integrity.

3. Monitoring moisture

After kiln drying, the moisture content of the timber in the racks is to comply with the relevant standards (AS 2796, AS 2082, AS 4787) or the intended customer specification.

4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively.



5. Identifying & reporting problems for correction

Details of individual and systematic problems are identified and distributed.

Problems are corrected.

6. Management of staff and equipment

Staff and equipment are available to conduct coupe activity safely and efficiently.

11.2 Management

11.2.1 Overview

Activity in controlled final drying is to dry the timber in controlled conditions to the final required moisture content and stress condition and pass it on for further processing without inappropriate degrade. This includes elevated temperature drying, conditioning and equalisation treatments.

In this manual, processes with kilns that are used for the controlled final drying and treatment of material are covered in this module. Kilns or predryers that are used to dry the timber from green or elevated moisture contents to fibre saturation points or lower moisture contents are included in Module 9. Predrying.

1. Process overview

Kiln drying is the final drying and treatment stage for timber. When it is complete, the timber should have achieved the target moisture content, moisture gradient and stress condition. In principle, drying the timber at this stage quickly and uniformly without unacceptable degrade is straightforward.

Racked timber is placed in an even stream of air that has an elevated temperature and controlled humidity. As the rows of boards are separated, the heated air passes across the surfaces of all boards, evaporates moisture from the timber and carries it away. The direction of the air is regularly alternated to even out the exposure of the timber in the stack. As the capacity of the timber to sustain increasingly severe conditions without degrade changes, the temperature and humidity of the air is varied to increase the drying rate. When drying is complete, conditions can be modified again to even out drying stress and moisture gradients generated as the timber dries.

This process occurs in a final drying kiln: an enclosed chamber in which the temperature, humidity, and the direction and velocity of the air can be accurately controlled. The arrangement of a generic kiln is shown in Figure 11.01

In practice, consistent and reliable kiln drying requires considerable attention and care. Its key aspects are:

- Establishing the series of drying conditions (temperature, humidity and air velocity) that the timber can sustain without starting or increasing drying degrade, and progressing through these conditions as the timber dries. This series of conditions is known as a kiln schedule;
- Ensuring that the available equipment maintains the required conditions reliably; and
- Ensuring that boards are subjected to the drying conditions uniformly.

2. Conditions that can be sustained

For many Australian hardwoods, the timber can only sustain relatively moderate conditions without degrade until the centre part of all boards is below fibre saturation point. Once this has been reached, the center sections start to shrink. This decreases the level of tensile stress at the surface and the possibility of starting or increasing surface checking. From this time, drying can proceed much more quickly under more extreme conditions. In practice, boards are dried to below fibre saturation point during air drying or predrying. They progress through the final stages of drying more quickly in the kiln.

Timber does not dry at a linear rate over time. As the moisture content falls and approaches the target moisture content, more energy is needed to remove each additional unit of water. If this is not supplied, the rate of drying tends to decrease rapidly.

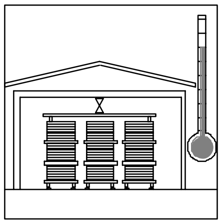
2a. Kiln schedules

A kiln schedule is expressed as a series of temperature and relative humidity conditions (dry bulb and wet bulb temperatures) or 'set points' to be achieved in the kiln and the triggers (time or timber moisture content) for progressing between them. While airflow can also be varied in a kiln, it is generally set at a constant velocity for a given schedule. In addition to drying the timber, schedules for some species include conditioning and equalisation periods at the end of drying to even out moisture gradients and / or decrease residual stresses.

Schedules usually conclude when the target moisture content, moisture gradient and stress condition should or have been reached. This is usually in accordance with the allowable moisture contents for the target product set out in **AS 2796-1999**: Timber - Hardwood - Sawn and milled products, **AS 2082-2000**: Timber - Hardwood - Visually stress-graded for structural purposes or the intended customer specification and **AS/NZS 4787:2001**: Timber - Assessment of drying quality.

Drying schedules are developed compromises between the need to dry the timber as quickly and economically while avoiding drying conditions that degrade the timber and lead to a loss in value. Schedules are developed by empirical research, modelling programs and by experience. As the drying characteristics of timber boards vary with species, age, diffusivity, thickness and initial moisture content, schedules are optimized for material with generally similar drying characteristics. Usually these are grouped according to species or species group, its shrinkage and strength properties, and the board thickness.

As such they are best fit solutions for a particular batch of material, skilled operators frequently use their experience of specific batches of timber and vary the initial schedule. This adds an *expert system* or *art* to the science of dealing with a variable material.



2b. Equalisation and stress relief

As timber is dried in an elevated temperature, drying stress and moisture gradients are generated. In some less dense species, these stresses and gradients are not significant and do not appear to affect the subsequent use of the timber. However, in other, often more dense species, one or both conditions appear to be significant. In these cases, an equalisation treatment is included in the drying schedule to even out moisture gradients and /or a conditioning treatment is included to reduce residual stress. In some cases, the conditioning treatment is carried out in a reconditioner.

When timber is dried in a final drying kiln, a moisture gradient develops from the centre of the board to its surface. While the average or core moisture content of the board may meet the moisture content target, the moisture content of the surface of the board may be outside the required range. In these cases, the timber is subjected to a high humidity equalisation treatment, applied for a period sufficient to bring the surface moisture content to within required limits while leaving the core moisture content relatively unaffected. This increases the product's stability in service.

A conditioning process relieves stress by heating the timber and allowing stresses to relax by creep and other processes.

The timing and conditions for these treatments have been largely based on empirical studies. There is currently no detailed scientific understanding of their mechanism, so it is not possible to confidently provide generic recommendations on them.

3. Equipment to maintain the conditions

A timber drying kiln is an enclosed chamber in which the temperature, humidity, and the direction and speed of the air can be closely controlled. It is a central piece of equipment in any timber drying facility. As the timber needs to be dried to a particular schedule of air temperature and humidity, the kiln must have the capacity to deliver the correct amount of air at the required temperature and humidity consistently and uniformly to the entry faces of the stacks in the charge. It must allow conditions of the air and timber to be monitored and controlled efficiently and effectively. This capacity then needs to be maintained.

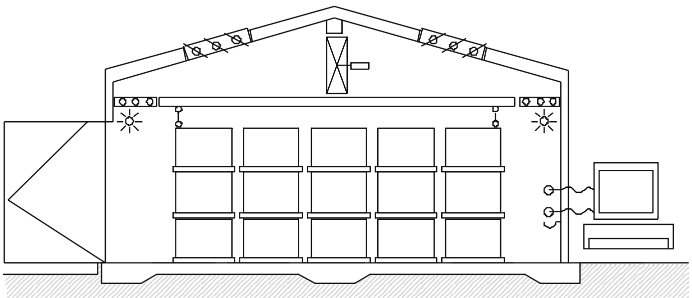
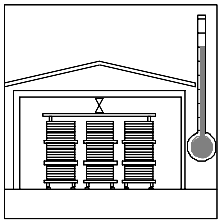


Figure 11.01. Generic layout of conventional drying kiln

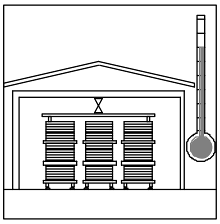


2. General kiln arrangement

The general components of a kiln include:

- **An insulated enclosure.** Ideally, this will be resistant to corrosion, easy to maintain and minimise heat loss. Doors and other openings must be rigid enough to withstand often vigorous handling and be fitted with effective seals and closing mechanisms to prevent air leakages.
- **Fans.** These drive the airflow in the kilns and operate in a single or alternating direction.
- **A heat source.** Provided by steam, the sun, or other means, heat is required to raise the temperature of the kiln and its content, overcome the hydroscopic forces holding moisture to the cell walls of the wood; and change the liquid moisture in timber to moisture vapour.
- **Humidity control mechanism.** In a conventional kiln, this is a combination of a humidification source, such as a wet steam supply or water mist system, and vents that allow moist air to be retained or expelled and drier air to enter. In dehumidifier kilns, the condenser coils help control humidity.
- **A plenum.** This is a space between the fans and the stacks of timber that allows uniform and controlled air movement through the timber. The action of the fans creates higher air pressure in the plenum on the stack entry face while developing lower air pressure on the exit face. This draws the air over the rows of boards through the stack.
- **A stacking area.** The racks of timber are stacked in a bank that must provide them with even support. This area must also accommodate rack handling mechanisms, either forklifts or traverser trolleys.
- **Baffles.** Either rigid or flexible, these ensure that airflow is directed through the timber and doesn’t escape around or over the stacks.
- **Monitoring equipment.** The condition of the timber and the air needs to be monitored to determine the timber’s moisture content and the air’s temperature, humidity and direction. Knowing these is vital to monitoring and altering kiln conditions to match the required schedule and dry the timber efficiently and effectively. See Section 11.10. for more detail on Monitoring Equipment.
- **Control mechanism.** As the timber dries, the environmental conditions of the air in the kiln have to be maintained or altered in line with the drying schedule. To do this, the components of the kiln have to be controlled. Steam has to be introduced, temperature raised or vents opened. See Section 11.10. for more detail on control mechanisms.

An operational kiln is a sophisticated piece of equipment that must be maintained. This is outlined in Section 11.2.6 Equipment Maintenance and Section 11.4 Checklists. The design and arrangement of kilns is a detailed area that is not dealt with in this manual.



3. Consistent and uniform drying

The success of applying a particular schedule to a charge of timber in a kiln depends on the regularity of the batch of timber being processed and on the uniformity with which the scheduled conditions can be applied to the timber in the charge. The factors that influence this are:

- The batch characteristics of the timber;
- The uniformity of airflow in the kiln; and
- The timber's arrangement in the rack and stack.

3a. Timber batch

To make the optimal use of selected schedules and ensure fast drying with minimum degrade, each kiln charge should consist of timber with similar drying characteristics. The rate the timber can be dried without loss of grade is determined by:

- its shrinkage, strength, diffusivity and other properties. Such things as species and age affect these.
- the thickness and target grade of the board.
- sawing orientation. Backsawn timber dries faster than quarter sawn timber in the same conditions, but generally needs to be dried slower to minimise degrade.

As the timber dries, most moisture evaporates from the wide faces, so the thickness of the board is the critical dimension. The thicker the timber, the longer the drying time and potentially the more difficult it is to dry without degrade.

Timber with different drying characteristics or different thicknesses cannot be dried to completion in the same kiln charge without slowing overall drying or risking degrade to the material requiring the slowest drying regime.

3b. Airflow in the kiln

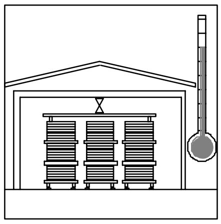
Air is the transfer medium in kilns, supplying heat to the timber and removing evaporated moisture from it. Since the rate of drying varies with the velocity of the air, airflow must be both uniform and adequate through all the rows of timber in the kiln.

Achieving this uniformity depends on the design and correct operation of the fans and plenums, the effectiveness of baffling around the racks and the arrangement of racks and stacks in the charge.

Baffling

Correct and effective baffling of the stacks is essential in successful kiln drying.

Air circulating in the kiln will try to by-pass the stacks of timber to go through any larger spaces left around the edges or within the stacks. As the air moves



through these spaces quickly, less air is available to dry the timber and its movement through the stack is uneven. As a result, drying is inconsistent and energy and time are wasted. These spaces must be kept as small as possible by easy-to-use baffling

Baffles are rigid and / or flexible barriers used to direct and control the flow of air though the stack. They are positioned on the top and ends of both sides of the stack and should be attached in a way that allows them to be easily closed when air movement needs to be closed off. Maintaining the effectiveness of baffles is important. Stacks should be arranged to ensure they operate efficiently. They also need to be well maintained.

Baffling is not restricted to the perimeter of the stacks. The rows of gluts and bearers between and under racks in a stack also provide a short circuit for air across stacks and the ends of these can be baffled also.

The arrangement of racks

Racks in the kiln are arranged into lines of stacks and it is critical for these to provide an even face to incoming air and easy passage for the air from one side of the kiln charge to the other, ideally through aligned rows of boards.

To provide a consistent passage of air through the rows of boards, the stacks need to be the same height, ideally of racks of the same height. While there will always be some minor variation in the height of racks and stacks, they should be kept as regular and even as practical. The space between higher stacks and low ones is difficult to baffle effectively.

Racks should be arranged to fill the full length of the kiln. If they cannot, they should be effectively baffled. If practical all racks stacked on each other should be the same length, and the line of stacks should run neatly from the baffles at one end of the kiln to the other.

Generally, lines of stacks should be kept as close together as practically possible.

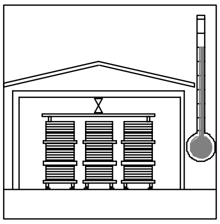
Bearers and gluts in the stacks should be the same thickness and placed directly over lines of rack sticks. Differences in bearer and glut thickness can bend and warp the boards and raise one rack sufficiently above others so the efficiency of baffling is reduced.

3c. Arrangement of the timber in the rack

In addition to the arrangement of stacks in the kiln, uniformity of airflow over the timber depends on the space between the rows in the rack and the alignment of boards at the side of the rack.

Rack sticks need to be the same thickness. If the sticks between the rows of timber in the rack vary in thickness, more air will flow between the widely spaced rows and these will dry more quickly than closer spaced rows.

The sides of the rack should be kept as even as practical. If they are uneven, less air will flow through those rows whose edges are set back. More air will flow through those rows with edges projecting forward. In both cases, airflow and drying will be uneven in the rack.



The ends of racks and stacks need to be square and regular. Rows where all the boards stop short of the end of the rack provide a gap for air to move through easily and circumvent the baffles. This reduces the volume of air moving through the racks and wastes time and energy.

4. Monitoring & control equipment

The condition of the timber and the air need to be monitored to determine the timber's moisture content and the air's temperature and humidity. These have to be monitored or controlled in line with the selected schedule or kept within the required limits.

Monitoring and control technologies have changed considerably in the last decade, with the introduction and widespread use of personal computers and digital sensing systems. For operations not computerised, sample boards are used to monitor the moisture in the timber and are tested as often as once a day. Alternatively, resistance moisture meter positions are established in the racks and wired back to a common monitoring and recording point. The moisture content of each position is then read with a meter or digital gauge. Wet and dry bulb thermometers or electronic sensors are used to gauge the conditions of the air and are read from external gauges or recorded on charts or monitoring computers. Vents and heat sources are controlled manually or through relays from a control location. Airflow is not generally measured, except as parts of commissioning or calibration tests.

Figure 11.02. Moisture probe and a rotary switch used with a portable moisture meter. The board is connected to probes in each rack in the kiln

For modern computerised operations, temperature, humidity and airflow sensors are used in the kiln to measure the conditions of the air and resistance moisture meter probes are used in the timber to monitor its moisture content. These sensors and probes are connected back to computerised control systems, often made up of a programmable logic controller (PLC) and an accompanying computer. These systems perform a range of tasks, including:

- reading and recording the data from the sensors and probes;
- displaying current information on a user interface;
- comparing the readings to previously defined limits; and
- operating equipment and actuators to control the kiln conditions. This can occur automatically, or by operator intervention.

The capabilities of these computerised systems vary considerably with the capacity and versatility of the PLC and the sophistication of the software employed. Some control the separate functions as individual systems with little or no process optimisation. Others control the kiln and the drying behaviour of the timber in an integrated manner. They can compare the options available and modify several aspects of the kiln's operation to optimise performance.

The required number of sensors and probes and quality of monitoring systems will vary with the size of the operation, the size and reliability of the kiln and the intended market for the timber being dried.

However, sufficient instruments and controls should be in place in any final dryer to:

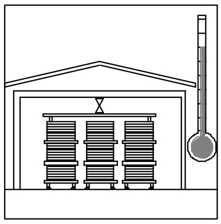
- determine the temperature and humidity at any time with confidence;
- modify these conditions in line with the required schedule.
- indicate that fans are operating and reversing; and
- provide a reasonable indication of the moisture content of the timber.

For new installations, the minimum control requirements are a programmable logic controller (PLC) and a monitoring & recording computer.

4a. Progressing through schedule set points.

Kiln schedules are designed to progress between set points when the timber has reached the required moisture content rather than when a particular period of time has elapsed. While schedules can be run successfully using time as the schedule change point, this is not as effective or efficient as using the timber's measured moisture content. Timber that dries rapidly may reach the required moisture content well before the time allocated, in which case, time is lost and energy wasted before the conditions are altered. If this occurs in the final stage of the schedule, the timber can be over dried. Similarly, slower drying timber may not have reached the desired conditions when the allocated time has elapsed. Changing to harsher conditions at this time risks damage to timber.

However, using the timber’s moisture content as the trigger between set points is only possible when that moisture content can be measured regularly and effectively at any time. In practice, this is only possible with directly wired resistance moisture metering positions. The form, location and safety issues of monitoring sample boards in a kiln limit their practical use for regular measurement.



5. Handling and placement

The racks placed in stacks in the kiln must be supported regularly and evenly and concentrations of load on individual boards must be avoided.

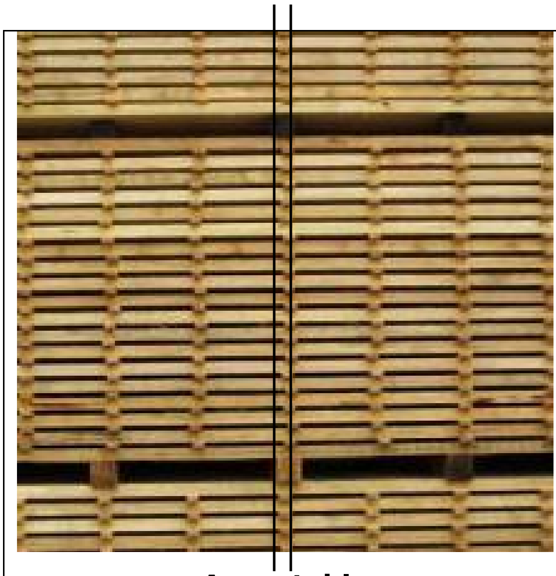
Stacks for the kiln are generally built on a traverser trolley and then moved into the kiln or are assembled in the kiln with a forklift to a height just below the upper plenum or roof of the kiln, in multiples of a standard rack.

When loaded by traverser trolley, the stacks in the kiln sit on solid, generally concrete kerbs positioned on either side of the traverser trolley rails. The spacing of the kerbs determines the number of lines of stacks in the kiln and their spacing. The spacing of the kerbs also determines the depth of the beams under the stacks. These should be positioned at the same centers as the gluts in the stacks and be deep enough so that they have no noticeable deflection when fully loaded.

Figure 11.03. Concrete hobs and rails for use with a traverser trolley. Beams spanning between the kerbs should have no noticeable deflection

When placed by forklift, stacks are built up on bearers placed on a concrete floor. Stacks should be placed as close to each other as possible, end to end and side to side, or in positions that can be effectively baffled.

Whether positioned either by traverser or forklift, the bearers and rack sticks in all the racks in the stack should align vertically. This ensures that the load being transferred to the supports or floor is carried in simple compression for stick to board to bearer etc. to the ground. Any eccentricity means that a few boards can carry significant point loads, bend and then dry in the bent shape. Also, the integrity of the rack and stack can be compromised. This can complicate further processing as the out of square racks may not fit out of kiln doors or restrict effective baffling.



Acceptable
All sticks & gluts positioned within some part of the width of a rack stick

Unacceptable
Some sticks or gluts positioned wholly outside the width of a rack stick

Figure 11.04. Rack stick, glut and bearer alignment

Bearer spacing should not exceed two rack stick spacings. This limits the maximum spacing to 1.2 m. If this spacing leads to noticeable deflection of boards between the bearers, the spacing should be reduced to one rack stick spacing. Bearers must be positioned directly under the line of rack sticks.

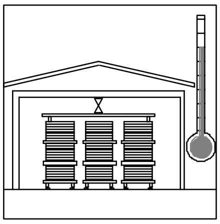
6. Determining completion

Kiln drying is complete when the timber in the charge has reached the target moisture content, moisture gradient and stress condition. Moisture gradients and stress conditions cannot be usefully measured while the timber is in racks in the kiln. However, the moisture content of the boards can be measured with resistance moisture meter positions and, with difficulty, sample boards.

The moisture content from a sufficient number of boards and racks should be measured before the kiln is unloaded for the operator to confidently estimate that whole of the charge has reached the required moisture content. The number of racks that need to be tested will vary with the size and reliability of the kiln, the regularity of timber's batch and drying characteristics, and the intended market for the timber being dried.

These measurements generally only give an indication of drying of the full charge. A correlation needs to be developed for each kiln and each batch of material between the few readings taken and the average moisture content of the whole charge, as determined later.

Each rack needs to have its average moisture content accurately assessed after controlled final drying and before dry milling. Accurate assessment means



splitting the rack and taking readings with a resistance moisture meter on boards selected at random from rows in the middle half of the rack. This assessment can occur:

- **At the kiln area.** The requirements of this are detailed below.
- **At the dry mill**. The requirements for accurate moisture content assessment at the dry mill are detailed in Module 12. Drymilling.

Accurate moisture content assessment at the kiln area requires splitting each rack, usually with fork lift tynes, and taking readings with a resistance moisture meter on boards selected at random from rows in the middle half of it. Table 11. 01 details the number of readings required for each product range. Table 11.02 details the acceptable range of readings for specific target moisture contents.

90% of readings taken must be within the acceptable range. If more than the acceptable number of readings is outside the acceptable moisture content range, the extra number of readings should be taken.

As the racks may be hot after final drying, the correct temperature corrections need to be made to the reading.

If more than the acceptable number of all readings are outside the acceptable moisture content range after the extra readings have been taken, the rack should not progress to the next stage.

Intended product area	No. of boards tested	Acceptable no. outside range	No. of extra boards tested	Total acceptable no. outside range
Structural products	5	0	5	1
Appearance products	10	1	5	1

Table 11.01. Number of moisture meter checks for accurately assessing racks leaving the kiln

Target	Acceptable minimum	Acceptable maximum
10%	8	13
12%	10	16
14%	11	18
16%	13	21

Table 11. 02. Acceptable range of reading for specific target moisture contents

Racks being dispatched to the dry mill after assessment should be accompanied with a full record of the moisture readings taken or an effective link to them.

7. Problems and rectification

Problems with timber quality after final drying and possible rectification are detailed in Module 15. Drying Quality Assessment.

8. Post kiln storage & protection

After final drying, the material should be stored under cover, to cool and equalise. When cool, it should be transported to the dry mill or stored for further processing.

11.2.2 Equipment Options

1. Fixed equipment

The fixed equipment for final controlled drying includes: kilns; monitoring equipment; storage shelters; stack material; and roading and handling equipment.

2. Kilns

There are a wide variety of kilns in operation or on offer from kiln manufacturing organisations. As described above, all kilns however, have similar characteristics. They are enclosed chambers in which the condition of the drying medium, air, can be controlled in terms of temperature, humidity and circulation to accelerate or retard the drying process as required.

The major kiln types are:

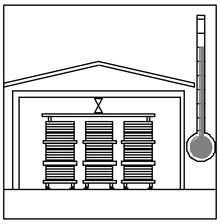
1a. Conventional batch kiln

This type of kiln is used for drying batches of timber either from green or for final controlled drying from fibre saturation point to dry. Generally, batch kilns are set up and maintained either for final drying or are used as predryers.

Kilns can be built from any material or material combination that provides good heat and moisture resistance and high thermal insulation. Timber clad with fibre cement or aluminium, concrete or aluminium and insulation sandwich panel fixed to an aluminium frame have all been used.

Conventional kilns generally use steam, hot water, heat transfer oil, or flue gas as the heat source. Heat is usually introduced through heat exchanger coils. However, gas fired kilns may heat directly. The quality of heat distribution is vital to successful final drying. The heat source and air distribution system must provide and maintain an even temperature distribution across the full face of the stack entry face. Localised hot or cold spots in the kiln almost certainly result in uneven drying in the charge.

Humidity is raised by generating steam from open heated water baths, injecting wet steam or misting water sprays. Humidity is reduced by discharging humid



inside air and introducing dry outside air through outlet and inlet vents usually in the roof.

Air is circulated by a series of fans, plenums, and baffles designed to deliver a sufficient volume of air evenly over the stack face.

When properly monitored, controlled and maintained, these kilns can have

- Effective and efficient control of the kiln conditions.
- Reasonable operating costs.

Figure 11.05. A bank of kilns built from masonry

Figure 11.06. Modern final drying kiln built of aluminium clad insulated panels

Figure 11.07. Modern precast concrete final drying kiln

1b. Dehumidifier kilns

These kilns use electricity to operate an air-conditioning / heat pump unit located within a kiln chamber. A dehumidifier unit is an air conditioner installed in reverse. Heated dry air is blown over the top of the charge and is drawn back through the timber and into the evaporator coils of the unit. These coils chill the air, which, by the time it reaches them is at relatively high humidity. Moisture condenses from the air onto the coils with the loss of temperature, flows down the coils and drains outside the unit. The drier air then passes over the unit's condenser coils. Here it is heated to a slightly higher temperature than it was before it entered first set of coils. The air is then again circulated through the charge. Additional heat is sometimes added to the chamber using electrical or steam heaters.

With this type of kiln, there is no need to vent humid kiln air as the moisture evaporating from the timber condenses as water on the condenser coils and drains away. These kilns are efficient users of electric energy but, despite this, their operating cost is relatively high. As the capital cost is relatively low, this type of kiln may be attractive for small installations. Their shortcoming is that they are limited in operating at higher temperatures and this reduces their efficiency considerably as the timber approaches a lower moisture content.

1c. Solar kilns

Solar kilns use the sun's energy to provide the heat to dry timber either from green or an elevated moisture content to fibre saturation point, or for final controlled drying from below fibre saturation point to a target moisture content. Solar kilns are particularly useful for drying small quantities of appearance grade hardwood species. Other advantages are the low capital cost compared with conventional kilns, generally low energy consumption and cost of operation, ease of construction with some types, and ease of operation.

The major drawback of some types is that they rely on the energy of the sun for heating and that varies with the time of day, the season, latitude and climate.

There may be some benefit in the diurnal (day and night) variation in drying conditions in some solar kilns as drying stresses and moisture gradients in timber can relax at night. There is currently no detailed scientific understanding of this, so it is not possible to confidently provide generic recommendations on it.

In the temperate areas of Australia, solar kilns often require supplementary heating to maintain uniform production rates through the year. Basic configurations of solar kilns include:

- greenhouse type with double skin walls and roof covered with a transparent or translucent skin;
- semi-greenhouse kilns with roof and some walls glazed and the others insulated to reduce heat loss; and
- Kilns with a separate insulated kiln chamber connected to solar collectors. These collectors may heat air or water that is then circulated to heat the kiln chamber directly or indirectly This type is least subject to variable heat from the sun.

2. Monitoring equipment

2a. Dry bulb thermometers

Thermometers, resistance temperature devices (RTDs) and other temperature sensors measure and control the kiln temperature on the side of the kiln where the air enters. They measure the actual temperature of the air and are not affected by its water vapour content, or relative humidity. To obtain an accurate reading, the dry bulb sensors must be mounted in the main airstream flow. To avoid incorrect readings the sensor should not be too close to either the wall, the timber racks, or to steam pipes.

The most common approach is to have at least 2 dry bulb sensors and one wet bulb sensor placed in the kiln chamber. The dry bulb sensors are arranged on opposite walls and connected so that the bulb on the warmest side of the kiln (where the air is entering) provides the signal that is sent to the monitoring instrument. When the fans reverse the airflow, the opposite dry bulb obtains the reading. Dry bulbs that are incorrectly positioned may result in;

- very high temperatures that increase drying losses
- very low temperatures that prolong drying time.

Although it is usual to locate one of the dry bulb and wet bulb thermometers close to one another, it is unwise to place the dry bulb sensor below the wet bulb.

2b. Wet bulb thermometers

A wet bulb thermometers is a temperature measuring device where the sensing element is covered by a smooth, clean, soft, water saturated cloth, or wet-bulb wick. Evaporation from the wick cools the sensor in direct proportion to the relative humidity of the surrounding air given it receives a standard air velocity of 5m/s over the wick.

Wet bulb thermometers require careful operation.

- The sensor should be located in such a position that the air to be measured can flow freely across the wick.
- The height of the bulb above the water supply level should be in accordance with the manufacturer's instructions (normally about 40 mm).
- The feed-rate of the supply water into the trough should be slow so the water's temperature has time to come to equilibrium with ambient conditions before entering the wick. It is usually a float controlled drip feed that maintains a constant water level in the trough.
- The wick should completely cover the bulb and every part of the wick should be moist.
- The supply water should be fed to the wick from below the bulb and be drawn up the wick by capillary action; and
- The wet bulb wicks must be changed regularly. Wet bulb wicks become contaminated with dust and wood extractive.

If a wet bulb wick dries out, it should be cleaned before replacement, or a new wick should be used.

2c. Electric moisture sensors

Electric moisture sensors are used to monitor the moisture condition of the air and the timber in the kiln.

Sensors monitoring the air measure either the equilibrium moisture content or relative humidity. Equilibrium moisture content (EMC) wafers determine the EMC of a wafer of organic material by resistance, so the humidity of the air can be calculated using standard calibrations in the controller. Relative humidity sensors are capacitance type probes. They measure the varying capacitance of the sensor and the moisture in surrounding air and relate this back to the air's humidity.

Sensors monitoring the timber are generally resistance type systems that measure the resistance between two pins inserted into a board. The probes are often nailed onto the side or in the middle of the racks. These are connected to permanent cabling in the kiln as the charge is loaded and are monitored with either a fixed or portable resistance moisture meter.

Since resistance moisture meters rely on a reading the difference in a small electrical charge, it is important to ensure that all cable connections are clean and effective and that cable runs are kept to a minimum.

Figure 11.08. The monitoring unit for resistance moisture sensors connected to each stack in the kiln

3. Drying building and shelters

The buildings needed to shelter kiln dried timber vary with the characteristics of the timber and the prevailing weather conditions at the mill site: the temperature, humidity and the prevailing winds. The form of buildings includes:

- **Complete enclosure with environment control.** Buildings can be completely enclosed, insulated and conditioned. Natural air movement is replaced or significantly augmented by mechanical services. This gives almost complete control of the ambient conditions. This level of control may be necessary for very high value recovery in normal climates, high value recovery in aggressive climates, or for material dried to specific moisture contents for special orders.
- **Shed with significant enclosure.** Buildings can be structured with a roof and walls with significant openings screened to exclude exposure to the sun, wind and rain.
- **Open shed.** An open shed protects the timber from sunlight and rain. If surrounded by other buildings it can also reduce airflow

Figure 11.09. An open dry storage shed for kiln dried material awaiting transport to the dry mill

4. Stack material

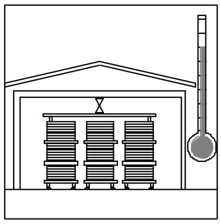
The depth of any bearer spanning between kerbs should be a standardised thickness such that they have no deflection noticeable by eye when fully loaded. They can be of any suitable material. Timber beams should be of straight sound timber, dry, clean and free from decay and staining fungi. Material that does not thickness to the standard size or which starts to come apart should be discarded.

Gluts should be a standardised thickness. They should also be of straight sound timber, dry, clean and free from decay and staining fungi. Material that does not thickness evenly or which starts to come apart should be discarded.

5. Roading and handling equipment

Roadways and unloading areas should be safe and trafficable in all weather conditions. See Module 03 Log Yard.

The expected maximum load in the placement range for traversers and forklifts should remain within the equipment's safe working capacity at all times.



11.12 Kiln Strategy

1. Placing the rack in the kiln

Stack locations in the kiln should be ordered to standard procedures. To do this:

- Stack assembly requirements should be readily available and understood;
- The kilns and all stack positions should be mapped and numbered;

Batch characteristics of rack should be assessed and used to control processing. To do this:

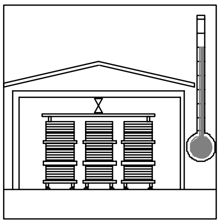
- Product and drying batch / group requirements should be readily available and understood;
- A site rack register should be in place that allows the position and drying history of each rack to be determined and monitored.
- Racks should be assessed for batch, drying history, and probable drying requirements and segregated for effective treatment.
- Only racks of compatible batches and drying histories should be assembled as part of a kiln charge.

Racks should be adequately and evenly supported and restrained in assembled stacks. To do this:

- Stack assembly requirements should be readily available and understood;
- Stacks should only be assembled from racks of the same width and where the rack sticks align vertically;
- Any board that extends more than 100 mm past the last rack stick of any rack being placed in the stack should be cut off and resealed;
- Bearers, gluts and other supports should be spaced at a maximum of two rack stick spacings;
- Bearers, gluts, other supports, and rack sticks should align vertically; and
- The front faces of the racks should align vertically.

Assembled stacks should be stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports. To do this:

- Stack kerbs should be standardised elements of the same height and effective bearing and load capacity.
- All stack gluts, bearers and beams should be sound dry timber of standardised size.
- Kerbs, bearers and beams should be regularly inspected. Elements that are damaged or deteriorated should be repaired or discarded.
- Kerbs, bearers and beams should be positioned under stacks so that they are even, level and effective.



- Racks should be placed so that their front faces are parallel and in line.

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow & duration) in the kiln should match the established schedule. To do this:

- The kiln schedule in operation should be readily available and understood;
- The major components of the kiln should be controlled by safe, easy to use and verifiable means.
- The monitoring equipment should be used to monitor and alter conditions in line with the kiln schedule.
- The operation of the major components of the kilns and the monitoring equipment should be checked during each charge.
- The kiln monitoring and control equipment should be regularly maintained and calibrated.

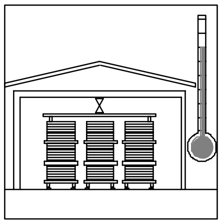
The environmental conditions applied to the arranged stacks should be appropriate for the size, grade, and intended product area of the boards. To do this:

- The relationship between the timber batch characteristics and the correct kiln schedule for that batch should be readily available and understood;
- The relationship of different timber batches and rack drying histories that may be dried together should be readily available and understood.
- The correct schedule should be selected and applied to each charge.

The spacing and support of assembled stacks and the baffling of the kiln should allow the airflow through each rack in the stack to be as uniform as possible. To do this:

- Before loading, each rack should be examined to ensure that its physical arrangement is and is likely to remain within acceptable tolerances.
- With each charge, selected racks should fill the kiln to the line of the baffles.
- Racks in each stack should be the same length;
- The stacks should be the same height, ideally of racks of the same height;
- Stacks should be positioned as close as possible to each other end to end and side to side;
- Baffles should be positioned to limit airflow around and to direct airflow through the timber stacks; and
- Baffles should be maintained.

Racks in transport or stored for further processing should be protected to minimise drying degrade. To do this:



- Rack protection requirements should be available and understood;
- If being stored between kiln drying and the next stage of production, racks should be stored in a protected location, ideally in an enclosed building.

Racks in transport and storage should be handled to minimise physical damage and loss of rack integrity. To do this:

- Rack handling requirements should be available and understood;
- Prior to placement in stacks or storage, racks should be adequately supported on evenly spaced bearers placed immediately under a line of rack sticks.
- Racks should only be handled by adequately rated, purpose-designed equipment, operated by staff trained in its use.
- Roads, loading and unloading areas should be safe, even and trafficable in all weather conditions.

3. Monitoring moisture

After kiln drying, the moisture content of the timber in the racks is to comply with the relevant standards (AS 2796, AS 2082, AS 4787) or the intended customer specification. To do this:

- Moisture content requirements for each batch should be available and understood;
- Final drying should not conclude until monitoring equipment indicates that the moisture content of the charge is within the required tolerances.
- The final moisture content of the racks should be determined in accordance with Tables 11.01 and 11.02.
- Any material outside the required tolerances should be separated as a rack for future reprocessing or reprocessed.
- The measured moisture content tolerances and measured readings of material should be discussed regularly
- The cause of repeat occurrence of material outside the required tolerances should be traced.

4. Maintaining product information

Information required for later production control is collected and passed with the racks effectively. The requirements for this are included in section 11.2.5.

11.2.4 Quality Control

Procedures should be established for:

Procedure	General contents
Site rack register	Location of each stack and its drying history
Product specification	Grade, size, overcut and batch requirements for product groups including verification processes
Drying group	Sorting requirements for products or grades into groups to be dried together
Kiln schedules	Selected schedules for racks of particular batch, species and thickness
Kin stack assembly and baffling	Stack size, assembly and placement requirements
Kiln condition monitoring.	The monitoring processes for conditions inside the kiln
Kiln maintenance	Routine equipment inspection and reporting processes
Rack storage	Storage provisions including protection of high value racks, shelter of other racks, use of bearers, etc
Rack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements
Moisture monitoring	Provision for sample boards, or resistance meter positions, It should include the type and number of checks to be made when the racks are unloaded, and reporting procedures for non compliant material,
Marking and tagging racks and charges	Identification requirements for grade and sorting
Staff accreditation	Training, Qualifications
Equipment	Maintenance

11.2.5 Information Management

1. Required attributes

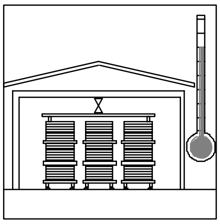
Information required for later process control should be collected and passed with the racks effectively. This includes the following:

Required process control information	
Unique rack identification number	Kiln start time & date
Staff number	Kiln end time & date
kiln number	Unique kiln charge record number
Kiln position number	Staff comment
Time & date loaded	
Desirable additional information	
Store location number	Out of store time & date
In store time & date	

Table 11.03. Attributes required or desirable when loading the kiln

Required process control information	
Unique charge record number	Operational humidity & temperature for each step in Schedule
Staff number	Each step start time & date
Kiln number	Kiln end time & date
Intended schedule number	Staff comment
Kiln start time & date	
Desirable additional information	
Continuous condition monitoring or time & date of reaching operational conditions for each step in schedule	

Table 11.04. Attributes required or desirable for the kiln charge



Required moisture control information	
Unique rack identification number	Likely wood temp
Position number (for kilns & predryers)	MC measurement position
Staff number	MC meter reading
Reading time & date	Adjusted MC reading
Production stage	Staff comment
Production location	

Table 11.05. Attributes required or desirable for the moisture content control with resistance type meters

Required process control information	
Unique sample board number	Production location
Staff number	Sample weight
Reading time & date	Adjusted MC reading
Production stage	Staff comment
Desirable additional information.	
Sample location	

Table 11.06. Attributes required or desirable for the moisture content control with established sample boards.

2. Record collection & processing

Sufficient information should be available at any time in a control room to determine the batch, unique identification number and location of each rack in the kiln, the schedule being employed, the time the charge started, the setting of all major controls, and the current temperature and relative humidity.

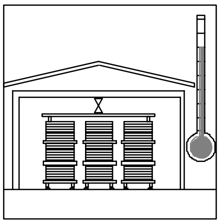
Figure 11.10. Kiln and predryer control equipment

11.2.6 Equipment Maintenance/Calibration

The kiln and its associated monitoring equipment need to be maintained so that they operate continuously, and in an efficient and effective manner. This requires regular inspection between charges and after specific periods of operation.

Aspects usually covered in kiln inspections and periodic testing are:

- **Air circulation** Fans must be checked to see that they are reversing as required and that they rotate in the same direction. Airflow should be measured as part of regular maintenance or immediately when moisture variability problems occur with the finished timber. This will help identify obstruction and equipment problems. Using an anemometer (a device for measuring air speed) the airflow should be measured on the grid of positions on the air entry side of the stack. This can be at every 3rd or 4th rack stick spacing down the stack, at intervals of about 2 metres along the stack. This should be done with the airflow in each direction and the baffles in place. The kiln doors must be closed while the airflow readings are being taken. This can only be done when the kiln is cool.
- **Temperature and humidity** Calibrated control resistance temperature devices (RTDs) and humidity sensors attached to a suitable recorder should be used to check and calibrate dry bulb, wet bulb and other sensors in the kiln as part of a regular sensor calibration program. If the calibrations are conducted in-house, the calibrating sensors should, at a minimum, be placed at both ends of the kiln, in the centre and where the dry and wet bulb sensors are positioned when the kiln is operational. They should be conducted as regularly as recommended by the kiln sensor manufacturer or annually if no recommendation is available. If the calibrations are conducted by an external organisation, the calibration period should be established after discussion. In addition to calibrating the kiln's sensors, these tests can indicate whether there is any difference in temperature (hot or cold spots) from one end of the kiln to the other.



- **Moisture content** If recurrent problems are occurring with a kiln, the drying progress of a complete kiln charge through the full schedule should be monitored using a number of sample boards or preferably, a series of moisture probes. Ideally, several positions on each rack should be monitored, and core and case reading taken in some racks.
- **Equipment above the fan deck** Fans, motor, bearings and other equipment should be visually inspected regularly or whenever airflow or moisture variability problems occur. The equipment should be serviced in line with manufacturer's recommendations. If manufacturer's recommendations are not available, seek specialist advice on the correct service period.

Additional maintenance checks are included in Section 11.4 Checklists.

Figure 11.11. Kilns seals need to be inspected regularly and repaired as required

11.2.7 OH&S

The kiln and racking handling area should be regularly inspected and hazards identified and eliminated. This may include:

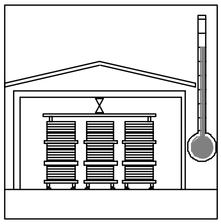
- unstable stacks of boards;
- broken rack sticks;
- leaking steam or hot water lines;
- dangerous or damaged handling equipment or trolleys;

- broken or displaced baffles;
- inadequate access and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.

Major OH & S requirements relevant to this section are listed in Table 11.07. This is not a complete list and other relevant codes and regulations may apply.

State	Major code of practice
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
QLD	*Sawmilling Industry Health & Safety Guide* – QLD Division of Workplace Health & Safety
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 11.07: Major industry codes of practice



11.3 Operations

11.3.1 Objective

The objective of controlled final drying is to dry the timber in controlled conditions to the final required moisture content and stress condition and pass it on for further processing without inappropriate degrade.

This includes elevated temperature drying, conditioning and equalisation treatments.

During controlled final drying, timber is placed in an even stream of air that has an elevated temperature and controlled humidity. As the timber is in racks, the heated air passes across the surfaces of all boards, evaporates moisture from the timber and carries it away. The direction of the air alternates to even out the exposure of the timber in the stack. Also, the air's temperature and humidity is varied as the capacity of the timber to sustain increasingly severe conditions without degrade changes or to even out drying stress.

This varying series of drying conditions is known as a kiln schedule.

The available equipment needs to maintain the drying schedule.

1. Even drying

For a drying schedule to work effectively, the timber being processed needs to be arranged as regularly as possible and the airflow through the timber as uniform as possible. The factors that influence this are**:**

- The batch of timber;
- The airflow in the kiln;
- The timber’s arrangement in the rack;

2. Correct batching

To make the full use of selected schedules and ensure fast drying with minimum degrade, each charge, line or zone group in the kiln should consist of timber with similar drying characteristics. Timber with different drying characteristics or different thickness cannot be dried in the same kiln charge without slowing overall drying or risking degrade to the material requiring the slowest drying.

3. Uniform airflow

Achieving this uniformity depends on the operation of the fans, the effectiveness of baffling around the racks and the arrangement of racks in the charge.

4. Effective baffling

Correct and effective baffling is essential for successful final drying. Air will always try to by-pass the stacks of timber, to go through any larger spaces left around the edges, if baffling is not in place or effective.

5. Rack arrangement

Racks in the kiln are arranged into lines of stacks and it is critical for these to provide an even face to incoming air and easy passage for the air from one side of the kiln charge to the other.

11.3.3 Preparation

1. Procedures

Procedures should be in hand for:

Site rack register	Rack storage
Product specification	Rack transport and handling
Drying group	Moisture monitoring
Kiln schedules	Marking and tagging racks and charges
Kin stack assembly and baffling	Staff accreditation
Kiln condition monitoring.	Equipment
Kiln maintenance	

2. Equipment

Perform routine minor maintenance and housekeeping on and around the kilns.

Complete a check of the kiln before loading a charge. Check that:

The floor is clean	There are no leaks in steam or water lines
Drainage is clear	The fans are operating
Baffles and vents are working	Control sensors are functional
Wet bulb sensors have clean wicks and clean water	

4. Incoming material

Racks are to be inspected to ensure that:

- The boards in the rack do not have existing drying degrade, such as excessive collapse, or case hardening;
- Racks are made up of boards of a single batch type;
- The drying history of the racks is consistent;
- The moisture content of the racks is suitable for kiln drying;
- Racks are the correct size;
- The faces of the rack are even and vertical;
- The ends of the racks are square, even and vertical;
- No board extends more than 100 mm past the last rack stick;
- Racks are stable for transport and placement in stacks;

- Moisture monitoring equipment is in place and accessible; and
- Required tags and marks are in place.

11.3.4 Processing & Monitoring

1. Placing the rack in the kiln

Stack locations in the kiln are ordered to standard procedures

- Identify and select racks for each charge to maximise use of chamber space.
- Assemble stacks in correct locations.
- Load chamber to maximise chamber space.

Batch characteristics of rack are assessed and used to control processing

- Inspect rack batch and history when preparing the charge.
- Segregate racks in accordance with the required drying schedule.
- Assemble the charge with materials of consistent drying characteristics.
- Segregate racks with significant existing drying degrade.

Racks are adequately and evenly supported and restrained in assembled stacks

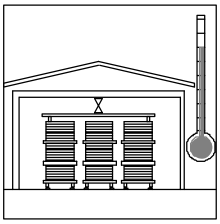
- Check racks to be dried for stability, spacing of strips, and support.
- Only assemble stack of racks of the same width and identical rack stick alignment.
- Place a bearer under the end rack stick line of every rack in the stack.
- Place bearers no wider apart than every second line of rack sticks in a rack or at a maximum of 1.2 m centres, whichever is smaller.
- Ensure bearers, beams, other supports, and rack sticks align vertically.

Assembled stacks are stable and even enough so that they do not experience or cause uneven loading on boards, racks or supports

- Maintain stability and integrity of racks during the loading process.
- Check stack kerbs.
- Check bearers and gluts. Separate damaged items for repair or disposal.
- Position supports under racks and stacks so that they are flat, stable and effective.
- Place racks so that their front faces are parallel and align vertically

2. Protecting the racks and stacks from physical and drying damage

The environmental conditions (temperature, humidity, airflow & duration) in the kiln match the established schedule:



- Make sure the kiln schedule in operation is understood;
- Check the operation of the kiln's major components and monitoring equipment regularly;
- Check the temperature, humidity and airflow regularly;
- Establish and maintain the conditions required by the drying schedule.
- Check alarms promptly;
- Investigate and report any problems with processing equipment.

The environmental conditions applied to the arranged stacks are appropriate for the size, grade, and intended product area of the boards:

- Assess timber batch and drying history to determine processing requirements;
- Select and apply the correct schedule to each charge.

The spacing and support of assembled stacks and the baffling of the kiln allows the airflow through each rack in the stack to be as uniform as possible:

- Assemble stacks to the same height and to the line of the baffles;
- Position stacks as close as possible to each other end to end and, where practical, side to side;
- Position the baffles to direct airflow through the timber stacks.

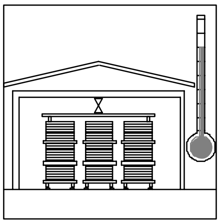
Figure 11.12. Desirable: Baffles correctly placed

Figure 11.13. Undesirable: Baffling incorrect

- Repair and report damage or problems with the baffles.

Racks in transport or stored for further processing are protected to minimise drying degrade; The timber continues to dry during storage and can be damaged if it is exposed to adverse conditions:

- Protect high value racks from adverse conditions with local environment controls;



- Do not store racks in the sun any longer than absolutely necessary.

Figure 11.14. Racks positioned under cover

- Store racks in an enclosed building out of the sun or in a roofed shelter;
- Transfer dried timber for further processing or store under cover.

Racks in transport and storage are handled to minimise physical damage and loss of rack integrity:

- Check bearers and gluts are a standard thickness;
- Discard rack bearers and gluts that are not of the standard thickness, are split, broken or show signs of decay;
- Position bearers at each end and then at a maximum of 1.2 m centres internally, directly under a line of rack sticks;
- Realign or replace any rack sticks that move or fall out during transport;
- Strap the ends of racks for transport if rack sticks keep falling out;
- Only handle racks with by adequately rated, purpose-designed equipment, operated by staff trained in its use.

3. Monitoring moisture

After kiln drying, the moisture content of the timber in the racks is to comply with the relevant standards (AS 2796, AS 2082) or the intended customer specification:

- Make sure moisture content requirements for each batch are understood;
- Establish moisture measurement positions in the timber and check readings;
- Measure and record moisture content in the timber during drying and compare with anticipated levels;

- Do not conclude final drying until the measured moisture content of the charge is within the required tolerances;
- Confirm the average moisture content of racks after kiln drying to standard procedures;
- Separate racks that do not meet the final target moisture content for further drying;
- Progress racks that do meet the final target moisture content and condition to further processing;
- Trace the causes of material repeatedly being outside the required tolerances.

11.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the racks effectively:

- Processed racks are tagged or marked;
- Complete at least the following records:

Production sheets detailing racks in charge	Charge records detailing schedule, conditions and adjustments.
Equipment performance report	Equipment maintenance report
Rack moisture contents	Feedback reports
Previous damage to incoming timber	

11.3.6 Feedback

If noticed regularly, report any of the following to the supervisor:

Problems with processing equipment	Irregular moisture meter readings
Racks sides or ends out of line	Racks exposed to sunlight or other adverse conditions

11.2.7 OH&S

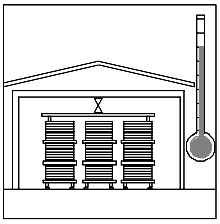
Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational;

Keep work areas clean, tidy and clear of trip hazards such as wire and strapping ends, and pieces of timber;

Inspect the kiln and rack handling area regularly. Identify potential hazards and eliminate them. In the kiln and rack handling area area, this can include:

- unstable stacks of boards;
- broken rack sticks;

- leaking steam or hot water lines;
- dangerous or damaged handling equipment or trolleys;
- broken or displaced baffles;
- inadequate access and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.



11.4 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Incoming Racks

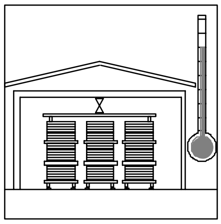
	1	2	3	4	5
Racks are made up of boards of a single batch type.					
Racks are the correct size.					
The sides of the rack are even and vertical.					
The rack sticks are in neat and vertical lines.					
The ends of the racks are square, even and vertical.					
No board extends more than 50 mm past the last rack stick.					
Racks are stable for transport and placement in stacks.					
Racks are correctly, clearly and securely tagged.					
Moisture monitoring equipment is in place and accessible.					

2. Racks assembled for a charge

	1	2	3	4	5
Racks are selected for similar drying characteristics.					
The drying history of the racks is consistent or compatible.					
The whole charge is the same thickness timber.					
The moisture content of the racks is suitable for kiln drying.					
Existing damage to timber noted at the rack level.					
Rack lengths optimize stack integrity and kiln loading efficiency.					

3. Stacks assembled for the kiln

	1	2	3	4	5



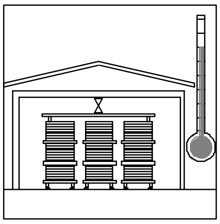
Stack supports are even and level.					
Stacks are vertical and even, without a noticeable lean.					
The faces and ends of the stack are vertical and in the same plane.					
Rack sticks, gluts and bearers are in all in neat vertical lines.					
The ends of gluts on the stack faces are baffled.					
Bearer and glut lines are no more than two rack sticks apart.					
Baffles are in place and secure.					
Documentation of the kiln load is complete.					

4. Processing the charge

	1	2	3	4	5
The correct kiln schedule is selected for the timber's batch and condition.					
Kiln conditions are monitored and recorded regularly.					
Kiln conditions change in line with the schedule, either by processing time or measured moisture content of the timber.					
Final drying only concludes when the measured moisture content of the charge is within the required tolerances.					
Causes for uneven or patchy drying investigated and corrected.					
Dried material stored under cover to equalise before further processing.					
Rack and kiln batch identity maintained.					
Equalising and conditioning treatments used correctly and used when needed.					

5. Monitoring moisture content

	1	2	3	4	5
The moisture contents of the rack or stack is monitored and recorded regularly.					



Proper selection and use of kiln sample boards.					
Target moisture content confirmed in racks before further processing.					
Inconsistent drying in racks or stacks is recorded and investigated.					
Racks not meeting specifications are identified and reprocessing options planned.					
Moisture content gradient sampled at completion of drying.					
Check for drying stresses regularly.					

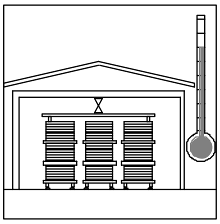
6. Initial and kiln operational checks

	1	2	3	4	5
Kiln can achieve and maintain schedule set points within acceptable limits.					
Control sensors are functioning.					
Wet bulb sensors have clean wicks and water.					
Adequate airflow across wet bulb.					
Heating coils and steam pipes free of leaks.					
Steam spray free of liquid water.					
Steam spray uniformly distributed.					
Traps are clear and functioning.					
Baffles and vents are working.					
Doors, walls, and roof are free of leaks.					
Fan are operating and reversing.					

7. Equipment maintenance and inspection

	1	2	3	4	5
Equipment above fan floor inspected regularly.					
Air velocity checks made regularly.					
Traps checked for proper operation and plumbed for checking.					
Air supply to control instruments and operating valves checked at regular intervals.					
Regular maintenance program for steam valves.					

11.0: – Controlled Final Drying



Regular calibration of temperature sensing devices and indicators.					
Wet bulb wicks changed on a regular schedule.					
EMC wafers changed on a regular schedule.					
Regular maintenance program for dehumidification kilns.					

Valves Operate Properly	**1**	**2**	**3**	**4**	**5**
Steam heat valves operate properly.					
Steam spray valve fully opens and closes.					
Gauges are working and legible.					

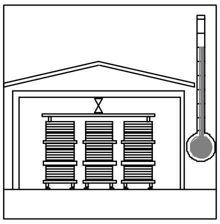
Controls Operate Properly	**1**	**2**	**3**	**4**	**5**
Vents and spray are not on together.					
Recent control charts show fan reversals occur.					
Recent charts show set point changes are made according to the					
Correct instrument charts are used.					

Fans	**1**	**2**	**3**	**4**	**5**
Fans and shrouds are well maintained.					
Fans turning for proper airflow.					
Fan deck (fan floor) in good repair.					
Easy access to fan deck and roof vents.					

Heat Distribution System	**1**	**2**	**3**	**4**	**5**
Heating coils clean and free of dust and debris.					

Vents	**1**	**2**	**3**	**4**	**5**
Vent lids open and close fully.					
Vent actuators and linkages operate properly.					

11.0: – Controlled Final Drying



Inside a Cold Kiln	**1**	**2**	**3**	**4**	**5**
Damaging condensation or other water inside kiln.					
Drainage from kiln floor.					
Proper wet-bulb wick is used.					
Adequate water flowing to wet-bulb.					

11.5 Avoidable Loss

1. Placing the rack in the kiln

- **Inadequate stack support** – When bearers are out of line and supports are uneven, boards are unevenly loaded and can twist and deform. This reduces grade and recovery. Uneven support also complicates stack assembly. In extreme cases, stacks can become dangerously unstable.

2. Protecting the racks and stacks from physical and drying damage

- **Exposing the timber to adverse drying conditions** – If racks are subject to a schedule where they dry too rapidly, the timber may surface check or develop unacceptable moisture or stress gradients. If racks are subject to uneven conditions, drying is not uniform and material with a moisture content out of specification has to be dried or conditioned again. This can occur if
    - Inappropriate kiln schedules are used or the equipment is not operating correctly;
    - The kiln design is not mechanically efficient for the material being processed;
    - Equipment is not maintained or ceases operating; and
    - poor stack arrangement, insufficient baffling, or faulty equipment leading to an uneven air flow.
- **Rack damage** – Boards subject to mechanical damage due to poor roading, lack of capacity in forklifts and traversers, or poor placement or driving are a direct production loss.

3. Monitoring Moisture

- **Inadequate moisture monitoring** – Wet racks or parts of racks are exposed to further processes that can damage to the timber. Poorly dried racks often have to be redried and so incur an increased production cost. Over dried timber can be processed and marketed. This can be out of specification and cause problems in applications such as furniture and flooring.

4. Maintaining product information

- **Lost information results in inadequate batching**. Mixing species, sizes, initial moisture content and diffusivity leads to some of the timber being subject to conditions that cause grade and value degrade while not affecting other timber in the charge. This leads to the loss of the product degraded and increased production cost as this material must be graded out and reprocessed.

11.6 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

12.0: – DRY MILLING

12.0 CONTENTS

12.0: – DRY MILLING

12.1 Objectives

The objective in dry milling is to convert dry timber into the required profiles without unacceptable variation to the required moisture content and stress condition.

12.1.1 Functions & Performance Requirements

1. Grading the boards

Drying degrade that leads to a reduction in grade is identified and recorded.

2. Protecting the boards, racks and packs from drying and transport damage

Boards are handled in the mill to minimise exposure to adverse drying conditions.

Racks and packs being assembled, in transport or stored for further processing are protected to minimise exposure to adverse drying conditions.

3. Monitoring moisture

Before dry milling, the moisture content of the timber in the racks is to be at the level required by the relevant standards or the intended customer.

4. Maintaining product information

Information required for later production control is collected and passed with the KD pack effectively.

5. Identifying & reporting problems for correction

Details of individual and systemic problems are identified and distributed.

Problems are corrected.

6. Management of staff and equipment

Staff and equipment are available to conduct dry milling activity safely and efficiently.

12.0: – DRY MILLING

12.2 Management

12.2.1 Overview

Drying activity in dry milling is to convert dry timber into the required profiles without unacceptable variation to the required moisture content and stress condition.

The drying process is not complete when the timber reaches the dry mill. Action in the dry mill is needed to:

confirm that the timber is dry and stable before processing;

maintain the timber in this state through the milling process; and

identify drying problems with the timber so that it is redirected and the causes of the problems rectified.

1. Confirming moisture content and board condition

Dry milling adds significant production cost to boards and this cost can be wasted if the timber is not properly dry when it is milled. Therefore, at the beginning of dry milling, the timber should be stable, with the correct moisture content, an even moisture profile and minimal residual stress.

Each rack should have its average moisture content accurately assessed before dry milling. Accurate assessment means splitting the rack and taking readings with a resistance moisture meter on boards selected at random from rows in the middle half of the rack. This assessment can occur:

At the kiln area. The requirements for accurate moisture content assessment at the kiln are detailed in Module 11. Controlled Final Drying. Racks arriving at the dry mill whose moisture content has been accurately assessed at the kiln area must be accompanied by a full record of the moisture readings or an effective link to it. This should include all readings and reading dates.

At the dry mill. The requirements of this are detailed below.

The moisture content of any rack arriving at the dry mill from:

the kiln area or other sites without a full record of the moisture readings;

storage; or

another company;

should be accurately assessed at the dry mill before further processing. Similarly, KD packs brought from storage should also be assessed before subsequent milling operations.

The moisture content of the racks and packs should be within the range established by the company for the target product. Table 12.01 details the number of readings required for each product type. Table 12.02 details the acceptable range of readings for specific target moisture contents.

Figure 12.01. Moisture meter and record sheet for assessing incoming racks

90% of readings taken must be within the acceptable range. If more than the acceptable number of readings is outside the acceptable moisture content range, the extra number of readings should be taken.

If more than the acceptable number of all readings is outside the acceptable moisture content range after the extra readings have been taken, the rack or pack should be redirected.

Intended product area	No. of boards tested	Acceptable no. outside range	No. of extra boards tested	Total acceptable no. outside range
Structural products	5	0	5	1
Appearance products	10	1	5	1

Table 12.01. Number of moisture meter checks for racks entering the dry mill

Target	Acceptable minimum	Acceptable maximum
10%	8	13
12%	10	16
14%	11	18
16%	13	21

Table 12.02. Acceptable range of reading for specific target moisture contents

The readings should be made immediately before the rack is broken down and processed. If they are made as the boards are being processed, wet boards may enter production.

The readings should be made with a hand held resistance moisture meter. Capacitance meters can also be used but only for additional spot checks. While not as accurate as resistance moisture meters, they can provide a useful indication of problems that can then be investigated further with a resistance meter.

Figure 12.02. Checking moisture with a resistance meter

2. Maintaining the moisture content

The moisture content of timber changes after final drying to remain in equilibrium with the surrounding environment. It must be protected from adverse conditions such as:

High temperature, from sunlight, hot walls of metal storage buildings, boiler buildings and kilns;

Uncontrolled humidity, from rain, standing water, broken down pipes and drains, condensation from sheet metal roofs and steam discharges; and

Wind, from external storage areas and significant drafts through factory doors.

KD packs need to be wrapped in plastic unless they are remaining in the dry mill or being moved into a fully enclosed and dry storage area. The plastic should run over all vertical sides plus the top and be secured with tapes or straps.

Any wrap that is torn or punctured should be replaced

Figure 12.03. Wrapping a kiln dried pack of timber

3. Identifying and eliminating problems

Any degrade from the drying process becomes apparent when timber is dimensioned, moulded and graded in the dry mill. These problems need to be:

Identified. The affected timber can then be taken out of production.

Traced to their cause. Other material can be checked to see if it is similarly affected and the cause of the problem identified. This protects future production.

3a. Identifying drying problems and degrade

Table 12.03 lists the major types of drying degrade encountered and their probable cause. A more complete and detailed list is included in Module 16: Drying Quality Assessment.

Surface checking

(p12-09)

Characteristics: Split along the grain of the timber visible on any face of the board.

Probable Causes: Drying the boards too quickly, especially during the initial stages.

Internal checking

(p12-10)

Characteristics: Split along the fibres inside the piece of timber, often visible on the end of a freshly docked board.

Probable Causes: Collapse can cause internal checking. The amount of internal check may also be related to the temperature of drying, as this affects collapse.

End splitting and checks

(p12-11)

Characteristics: Splits and checks at either end of the board.

Probable Causes: Fast end drying and/or growth stresses in the wood. Not end sealing the boards.

Other splitting

(p12-12)

Characteristics: Splits and shakes either obvious on the surface or hidden inside the piece.

Probable Causes: A heavy load or impact, such as being dropped, fractures the timber in the tree, log, flitch or piece.

Collapse

(P12-13)

Characteristics: Abnormal and irregular shrinkage usually seen in quarter-sawn boards as rippling or "washboarding" on the surface.

Probable Causes: The fibre of the cells collapses, much like a drinking straw that has been pinched and flattened. Drying too fast or at high temperatures exacerbates it. It mostly recovers during reconditioning but can lead to internal checking.

Case hardening

Characteristics: A heavy board with a distinct dark area visible around the board when viewed from the end.

Probable Causes: Drying the board too quickly or at too high a temperature in early stages.

Sapstain and mould growth

Characteristics: A bluish or greyish discolouration in the sapwood indicates sapstain. Other moulds and mildew stain the timber various colours.

Probable Causes: Fungus and mould grows on the wood and discolours it. This happens with poor air circulation and very slow drying in the air drying yard. It can also occur if the storage time between green packing and racking is too long.

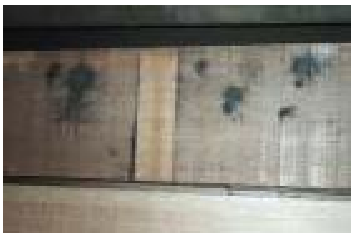
Sticker Mark

(P12-16)

Characteristics: Light or dark stripes across milled boards corresponding to rack stick positions. They can appear as a shadow of the rack stick.

Probable Causes: Differences in the rate of oxidation of the timber; migration of extractives; or fungal contamination from wet, dirty or old rack sticks. Slow initial drying, such as green boards being subject to lengthy rain periods after initial racking.

Indentation



(P12-17)

Characteristics: An indentation in the timber directly under the rack stick.

Probable Causes: The load through the rack stick is too great because the stacks are too high or the rack sticks are out of alignment or are not wide enough.

Insect attack

(P12-18)

Characteristics: A series of small holes and piles of fine dust in the sapwood of susceptible species.

Probable Causes: Attack of susceptible timber by the lyctus borer; inadequate or no preservative treatment.

Uneven drying

Characteristics: Some parts of the board are dry while others are not, or some boards are dry and others not.

Probable Causes: Poor racking; improper stack placement during air drying; too much variation in the air conditions or velocity from one part of the predryer or kiln to another.

Distortion – All forms

(P12-20)

Characteristics: The board is not straight, but bows, cups, warps or springs.

Probable Causes: Differential shrinkage in any of the directions of the board; improper racking or stacking; or growth stress.

Hit & miss or undersize

(P12-21)

Characteristics: Part of the board will not dress or mould to standard dimensions.

Probable Causes: Excessive shrinkage; local grain distortion; inadequate overcut; poor sawing control.

Table 12.03. Types of drying degrade

Drying degrade needs to be identified by:

Standard production checks. Unusual occurrences should be noted as part of regular grading and moisture content checks and passed on as feedback to senior staff for investigation and remedy. To ensure consistency in their task, graders need consistent light, regular rotation between tasks, and a routine for discussing what they observe. Formal and effective feedback mechanisms need to be in place. This is described in greater detail in Module 14 Information Management and Module 15 Drying Quality Assessment.

Production audits. Audits are regular and systematic evaluations of random samples of production. They are conducted to quantify the types and level of degrade occurring and provide a benchmark for 'usual' and 'unusual' levels of recovery and loss given the available resource and equipment. Audits are described in greater detail in Module 15 Drying Quality Assessment.

3b. Tracing the cause

To identify where drying degrade is likely to have occurred, the production history and state of the affected rack has to be examined and compared to the performance of other racks of the same batch exposed to the same conditions, or that contain similar timber. Anomalies in handling, placement, treatment, schedules and readings have to be investigated. While these will narrow the possible causes, further experimentation may be needed to pinpoint the cause.

While labour intensive, this is an essential process as the unresolved production problems can continue to degrade material and cause considerable loss. Naturally, the ease of locating problems is directly related to the quality of production information collected and the ease with which it can be examined.

Figure 12.04. Dry rack being broken down in the dry mill

4. Pack arrangement & support

After boards are broken down from racks and processed, they are assembled in a kiln dried (KD) pack. As the timber is dry and stable, KD packs are block stacked, without rack sticks.

Timber of any grade in KD packs is very valuable and any loss to mechanical damage needs to be avoided by:

Building solid and stable packs. Any unstable stack should be rebuilt. KD packs should be strapped regularly enough to maintain their shape.

Supporting the pack regularly. KD packs are often assembled on a trolley so they can be moved between milling operations easily. When they are stacked, they should be supported regularly enough on clean dry gluts or bearers so that there is no noticeable deflection in the boards.

Protecting the bottom surfaces and edges of packs. Forklift tynes can damage the bottom layer of boards. If this happens repeatedly or packs are of high value timber, low value boards can be used as a protective or sacrificial layer. Sheet metal, cardboard, or timber protectors should be used on the corners of KD packs underneath the straps. This eliminates 'strap-bite' indentations on the corner boards.

Figure 12.05. KD Packs strapped and stored in the dry mill

Figure 12.06 Plastic strap & cardboard corner protector

12.2.2 Equipment Options

The equipment relevant to drying during dry milling includes the dry mill building; stack material; roading and handling equipment; and moisture meters. Acceptable building types are included in Module 13 Storage. Moisture meters are described in detail in Module 16 Moisture Content Monitoring.

1. Stack material

Gluts and bearers should be a standardised thickness. They should be of straight sound timber, dry, clean and free from decay and staining fungi. Material that does not thickness evenly or which starts to come apart should be discarded.

2. Roading and handling equipment

Road ways and handling areas should be safe and trafficable in all weather conditions. See Module 03 Log Yard.

The expected maximum load in the forklifts' placement range should remain within the equipment's safe working capacity at all times.

Figure 12.07. A large dry mill building

12.2.3 Dry Milling Strategy

1. Grading the boards

Drying degrade that leads to a reduction in grade should be identified and recorded. To do this:

Product grade requirements should be readily available and understood;

Boards that do not meet grade requirements through drying degrade should be separated for future regrading or regraded;

Drying degrade characteristics of the species handled by the mill should be discussed and understood;

Graders and de-rackers should discuss and review observed characteristics regularly;

Drying degrade that results in a loss of grade should be noted in regular feedback;

Drying degrade that results in a loss of grade should be audited regularly.

2. Protecting the boards, racks and packs from drying and transport damage

Boards are handled in the mill to minimise exposure to adverse drying conditions. To do this:

Racks should only be broken down and boards milled in an enclosed building, out of the sun and the wind and clear of any sources of moisture.

Racks and packs being assembled, in transport or stored for further processing should be protected to minimise exposure to adverse drying conditions. To do this:

Rack and pack protection requirements should be available and understood;

Packs should be assembled in an enclosed building, out of the sun and the wind and clear of any sources of moisture;

If only protected by a roof, all packs and packing stations should be out of the sun for at least 80% of the time and local environmental controls should be used to protect high value racks;

If being stored between packing and the next stage of production, packs should be stored in a protected location, ideally in an enclosed and weatherproof building;

Racks and packs should only be transported between sites in taut liners or under covers such as plastic wrapping or tarpaulins.

3. Monitoring moisture

Before dry milling, the moisture content of the timber in the racks should be at the level required by the relevant standards (AS 2796, AS 2082) or the intended customer. To do this:

- Moisture content requirements for each batch or product group should be available and understood;
- The moisture content of the racks should be determined in accordance with Table 12.01 and Table 12.02 respectively;
- Any material outside the required tolerances should be separated as a rack for future reprocessing or reprocessed;
- Material outside the required tolerance should be noted in regular feedback;
- The cause of repeat occurrence of material outside the required tolerances should be traced.

4. Maintaining product information

Information required for later production control should be collected and passed with the KD pack effectively. The requirements for this are included in Section 12.2.5.

12.2.4 Quality Control

Procedures should be established for:

Procedure	General contents
Product specification	Grade, size, overcut and batch requirements for product groups including verification processes
KD pack storage & protection	Storage provisions including protection of high value packs, shelter of other packs, use of bearers, strapping etc
KD pack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements, covering
Moisture monitoring	The type and number of checks to be made when the packs are unloaded or prepared for dispatch, and reporting procedures for non complying material
Marking and tagging	Identification requirements for grade and sorting
Staff accreditation	Training, qualifications
Equipment	Maintenance

12.2.5 Information Management

1. Required attributes

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Unique rack identification number	Break down time & date
Staff number	Staff comments
Break down position.	

Table 12.04. Attributes required or desirable when breaking down racks.

Required Information on KD Pack	
Unique KD pack identification number	Board width
Batch type	Board thickness
Date KD pack completed	Board length
Grade	

Board profile	
Required process control information	
Unique KD pack identification number	Board width
Staff number	Board thickness
Batch type	Board length
KD pack arrival / complete time & date	KD pack tally number
Grade	Staff comments
Board profile	
Desirable additional information.	
Packer	Pack started time & date
Packing location	

Table 12.05. Attributes required or desirable when assembling KD packs

Required moisture control information	
Unique rack / KD pack identification number	Likely wood temperature
Staff number	MC measurement position
Reading time & date	MC meter reading
Production stage / location	Adjusted MC reading
Staff comment	

Table 12.06. Attributes required or desirable for the moisture content control with resistance type meters

2. Marking & tagging

Information required on the KD pack must be legible in normal daylight at least 1.5 meters from the end of the pack.

Pack tags should be of resilient and weather resistant material securely fixed to the pack. Ideally, they should be colour coded by grade, species or product group. Pens used to mark the tags should use permanent ink. Stamps or paint should be permanent and not be readily obscured by dust.

All tagging systems have to be able to survive any transshipment stage with less than a 0.5% loss rate.

12.2.6 Equipment Maintenance

The dry mill building needs to protect the timber and handling equipment from all adverse climatic conditions. It should be completely enclosed with well-maintained gutters and drains and have a sloped or draining floor and paved surrounds. Any instance of leaking or standing water should be investigated and the cause fixed. There should be enough ventilation or insulation in the building to maintain a relatively stable temperature. Metal clad walls facing west should be insulated or shaded. Shade trees may be suitable for this.

The maintenance and calibration of moisture meters is included in Module 17 Moisture Content Monitoring.

12.2.7 OH&S

Workers should not be required to work in strong sunshine and they will not be able to work effectively in the rain. To grade and mill effectively, workers and especially graders need consistent light, protection from wind and large temperature changes and regular rotation between tasks.

The dry milling area should be regularly inspected and hazards identified and eliminated. This may include:

- unstable stacks of boards;
- broken rack sticks;
- dangerous or damaged handling equipment or trolleys;
- inadequate access and warning procedures;
- broken fences, gates or guards; and
- poor or no safety signage.

Major OH & S requirements relevant to this section are listed in Table 12.07. This is not a complete list and other relevant codes and regulations may apply.

State	**Major code of practice**
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
QLD	*Sawmilling Industry Health & Safety Guide* – QLD Division of Workplace Health & Safety
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 12.07. Major industry codes of practice

12.3 Operations

12.3.1 Objective

Drying activity during dry milling is to convert the timber into the required profiles without unacceptable variation to the required moisture content and stress condition. However, the drying process is not over once the timber reaches the dry mill.

12.3.2 Key Drying Factors in Dry Milling

Action in the dry mill is needed to:

1. Confirm that the timber is suitably dry before processing

Dry milling adds significant cost to processing boards and this cost can be for nothing if the timber is not properly dry. The moisture content of every rack should be checked as it is being broken down. The same applies to KD packs coming out of storage.

2. Maintain the timber in this state through the milling process

The moisture content changes after final drying to remain in equilibrium with the surrounding environment. It must be protected from high temperatures (sunshine and hot walls), humidity, (rain or standing water) and wind. Timber that is stored anywhere except in an enclosed building should be wrapped in plastic.

3. Identify drying problems with the timber

This is done so that the identified timber can be redirected and the causes of the problems rectified. Descriptions and photos of drying problems are included in Table 12.03.

Before and after dry milling, the timber should be stable, with the correct moisture content for the target product; an even moisture profile and minimal residual drying stress.

12.3.3 Preparation

1. Standards

AS 2796-1999: Timber - Hardwood - Sawn and milled products

AS 2082-2000: Timber - Hardwood - Visually stress-graded for structural purposes

AS/NZS 4787:2001: Timber - Assessment of drying quality.

Company or customer product specification.

2. Procedures

Procedures should be in hand for:

Product specification	Moisture monitoring
KD pack storage & protection	Marking and tagging
KD pack transport and handling	Staff accreditation

3. Equipment

Routine maintenance is regularly carried out on and around the packing stations and other equipment in accordance with standard procedures.

KD pack marking and tagging equipment and measuring gear (moisture meters, tapes and callipers) should be in hand and operational.

4. Incoming material

Racks are to be inspected to ensure that they:

are made up of boards of a single batch type;

have required identification tags and marks in place; and

are marked as dry and ready for processing.

12.3.4 Processing & Monitoring

1. Grading the boards

Drying degrade that leads to a reduction in grade is identified and recorded:

Inspect all sides of the board;

Grade boards to relevant standards;

Separate boards that do not meet grade requirements and size;

Note drying degrade to loss of grade in feedback.

Figure 12.08. Grading boards

Figure 12.09. Checking the dimensions of a dressed board in the dry mill

2. Protecting the boards, racks and packs from drying and transport damage

Boards are handled in the mill to minimise exposure to adverse drying conditions:

Do not leave boards in the sun;

Move boards out of hot or windy places as soon as possible;

Maintain covers, roofs, or humidity control.

Racks and packs being assembled, in transport or stored for further processing are protected to minimise exposure to adverse drying conditions:

Protect high value racks from adverse conditions with local environment controls;

Do not store packs in the sun any longer than absolutely necessary;

Store racks in an enclosed building out of the sun and wind or in a roofed shelter;

Only transfer dried timber for further processing or store under cover.

3. Monitoring moisture

Before dry milling, the moisture content of the timber in the racks is to be at the level required by the relevant standards (AS 2796, AS 2082) or the intended customer:

Figure 12.10. Assessing the moisture content of incoming timber with a capacitance moisture meter at a deracker

Make sure moisture content requirements for each product are understood;

Measure and record moisture content in the timber to standard procedures;

Figure 12.11. Confirming the final moisture content

Separate racks that do not meet target moisture content range;

Note material outside the target moisture content range in feedback;

Figure 12.12. Moisture meter and record sheet for assessing incoming racks

Trace the causes of material repeatedly outside the target moisture content.

12.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the KD pack effectively:

Identify finished KD packs with marks or completed tags that include:

Unique KD pack identification number	Board width
Batch type	Board thickness
Date KD pack completed	Board length
Grade	Board profile

Complete at least the following records:

Production sheets detailing racks broken down & KD packs assembled	Rack moisture contents
KD pack tally	Feedback reports
Equipment performance report	Equipment maintenance report

12.3.6 Feedback

If noticed regularly, report any of the following to the supervisor:

Problems with processing equipment	Irregular moisture meter readings
Racks exposed to sunlight or other adverse conditions	Drying degrade that leads to a loss of grade

12.3.7 OH&S

Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational.

Keep work areas clean, tidy and clear of trip hazards such as wire and strapping ends, and pieces of timber.

Inspect the dry milling area regularly. Identify potential hazards and eliminate them. In the racking area, this can include:

unstable stacks of boards;

broken rack sticks;

short lengths of timber on grading tables;

dangerous or damaged handling equipment or trolleys;

broken fences, gates or guards; and

poor or no safety signage.

12.4 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Grading the boards

	1	2	3	4	5
Boards meet grade and size specification.					
Non conforming boards separated for other processing.					
Boards are handled carefully.					
Loss to drying degrade is noted.					
Drying degrade is audited regularly.					

2. Protecting the boards, racks and packs from drying damage

2a. Timber care during packing

	1	2	3	4	5
KD packs are assembled in a protected position.					
Packing and grading staff are protected from wind and direct sunlight.					
Boards are placed in the pack, not dropped.					

2b. Assessing the completed packs

	1	2	3	4	5
The sides of KD packs are even and vertical.					
KD packs are stable for transport and storage.					
KD packs are correctly, clearly and securely tagged					
KD packs are marked with required information.					
Tags are legible 1 meter from end of pack.					
Documentation completed accurately.					

2c. KD pack protection

	1	2	3	4	5
High value racks and packs are protected with local environmental controls.					

KD packs are stored out of the sun.					
KD packs are supported evenly and adequately.					
KD packs are covered or fully enclosed during transportation.					
KD packs are handled with adequately rated equipment.					

3. Monitoring moisture content

	1	**2**	**3**	**4**	**5**
The moisture content of the rack is measured and recorded.					
Racks not meeting the moisture target are identified and redirected.					
Material outside the moisture target is noted.					
Moisture content and profile is audited regularly.					
The causes of material repeatedly outside the target moisture content are traced.					

12.5 Avoidable Loss

1. Grading the boards

Poor identification of production induced degrade - Unsatisfactory performance in production is not apparent or identified and material continues to be damaged or not properly dried. This can lead to reduced recovery and increased claims from customers for poorly performing product.

Inadequate auditing of product - Lack of auditing leads to damaging practices being continued with a resultant loss of material, grade and value. Production costs increase as non-conforming product continues along the production chain.

Confused lines of communication and areas of responsibility - Error, anomaly and bad practice is allowed to go undetected and uncorrected.

Inefficient feedback mechanisms - While unsatisfactory performance is uncovered, the action necessary to remedy it is not taken at all levels. Again, material is damaged or not properly dried.

2. Protecting the boards, racks and packs from drying and transport damage

Exposing the timber to adverse moisture conditions – If racks are positioned where they will get wet before destacking, or after milling, the timber may fail in service, or be rejected as not meeting standard. Timber left in the sun will discolour.

Rack damage – Boards subject to mechanical damage due to poor roading, lack of capacity in forklifts and traversers, or poor placement by forklifts and traversers are a direct production loss.

Figure 12.13. Forklift damage to a KD pack

3. Monitoring moisture

Inadequate moisture monitoring – Wet racks or parts of racks are exposed to further processes that can cause damage to the timber. Wet material can be dispatched and fail in service, leading to a loss of customers and claims by customers against the company. This is particularly important for flooring products.

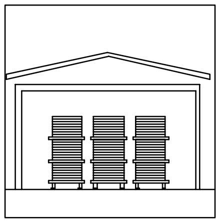
12.6 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

13.0: – STORAGE



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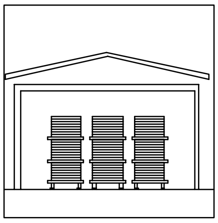
13.0: – STORAGE



13.1 Objectives

The objective during storage and transport is to protect the timber from unacceptable variation from the required moisture content.

13.1.1 Functions & Performance Requirements

1. Protecting the KD packs from drying damage

KD packs in transport or storage are protected to minimise exposure to adverse drying conditions.

2. Monitoring moisture

After receipt into store or directly before dispatch, the moisture content of the timber in the KD packs is at the level required by the relevant standards or the intended customer.

3. Maintaining product information

Information required for later production control is collected and passed with the KD pack effectively.

4. Identifying & reporting problems for correction

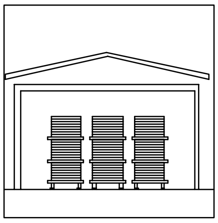
Details of individual and systematic problems are identified and distributed.

Problems are corrected.

5. Management of staff and equipment

Staff and equipment are available to conduct storage activity safely and efficiently.

13.0: – STORAGE



13.0 Management

13.2.1 Overview

Activity during storage and transport is to protect the timber from unacceptable variation from the required moisture content.

At the beginning of storage, the timber should be grouped in batches, graded, straight, clean and stable in ordered KD packs with a known and appropriate moisture content. In storage, action is required to:

maintain the timber in this state while it is stored;

ensure that the moisture content is appropriate when it is received or dispatched; and

protect it during transport.

1. Maintaining the moisture content

Dry and milled timber in store represents a considerable investment. The company has borne the cost of production and hopes to generate income once the material is sold into the target market.

However, the moisture content of timber changes in store (after final drying and milling) to remain in equilibrium with the ambient conditions of the surrounding environment. The ambient conditions (especially sunlight) can also change the surface quality of the boards.

If these conditions alter the moisture content or condition of the boards so that income is reduced, or the timber becomes unsuitable for the intended market, they need to be controlled and the timber protected.

Generally, the harsher the local climate (very hot, sunny and dry or very wet and damp), the more exacting the market, and the greater the loss in potential value, the higher the level of control and protection is warranted.

All forms of protection aim to moderate temperature, exclude direct sunlight, reduce air speed and control humidity or exposure to moisture. They include protecting the timber with:

Complete enclosure with environment control. The storage area is completely enclosed in an insulated building that has temperature and humidity control. These are necessary for facilities seeking to provide consistent, high quality products in areas with harsh climates;

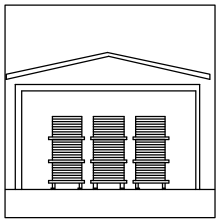
Complete enclosure. The storage area is completely enclosed in a building. This minimises air movement and eliminates uncontrolled sources of moisture. The reduction in temperature extremes varies with the nature of the local climate and the amount of insulation in the building;

Figure 13.01. Dry wrapped material in a fully enclosed store before dispatch

Partial enclosure. The storage area is partially enclosed by a shelter with a roof, floor and ideally some walls. The level of protection varies with the detailed arrangement of the shelter and the effectiveness of the roof, floors and gutters in excluding rain and ponding water. All packs stored in a partial enclosure should be plastic wrapped;

Figure 13.02. Fully wrapped bundles stored in an open sided shed

Wrapping. Plastic wrapping individual KD packs only provides short-term protection to external conditions and should only be relied on when packs are being stacked ready for transport. Moisture can enter through any unwrapped surface or the timber sweats when exposed to sunlight. Also, the plastic breaks down relatively quickly and holds any entering moisture close to the timber. Any wrap that is torn or punctured should be replaced.



Dry material should not be stored in the open without wrapping, as it degrades quickly.

2. Moisture content on receipt and at dispatch

The moisture content of every pack should be determined when it arrives in store. If the pack has been delivered directly from an adjacent dry mill or another site, it must be accompanied by a full record of the moisture readings taken there or an effective link to it.

The moisture content of a pack should be accurately assessed in accordance with Tables 13.01 and 13.02 if they are:

received into store from the dry mill or another site without a full record of the moisture readings; or

being prepared for dispatch from the store after a specified period of storage. The length of this period depends on the species of timber, storage conditions, time of year and other factors. It should be established from experience informed by comparisons of readings for material stored on the site previously or from a series of test measurements.

Table 13.01 details the number of readings required for each product type. Table 13.02 details the acceptable range of readings for specific target moisture contents.

The initial number of readings should be made on boards selected at random from several rows of the KD pack. 90% of readings taken must be within the acceptable range. If more than the acceptable number of readings is outside the acceptable moisture content range, the extra number of readings should be taken.

If more than the acceptable number of all readings is outside the acceptable moisture content range after the extra readings have been taken, the rack or pack should be redirected.

Intended product area	No. of boards tested	Acceptable no. outside range	No. of extra boards tested	Total acceptable no. outside range
Structural products	5	0	5	1
Appearance products	10	1	5	1

Table 13.01 Number of moisture meter checks for KD packs.

Target	Acceptable minimum	Acceptable maximum
10%	8	13
12%	10	16
14%	11	18

16%	13	21

Table 13.02. Acceptable range of reading for specific target moisture contents.

The readings should be made with a hand held resistance moisture meter. Capacitance meters should only be used for additional spot checks.

The moisture readings should be recorded and provided with the KD pack to the customer.

3. Protection during transport

Dry timber should ideally be transported undercover.

For local delivery, all appearance grade material should be in packs wrapped in plastic. For any distance further than local delivery, appearance timber should be in packs wrapped in plastic and all timber should be covered by tarpaulins or enclosed in a taut liner. For these deliveries, the plastic should run over all vertical sides plus the top and be secured with tapes or straps.

When sent by ship, packs should be fully wrapped (on all four sides) and then packed in a container or assembled on a container base and wrapped in heat sealed plastic.

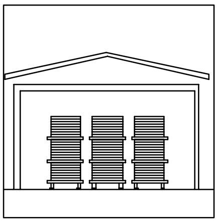
Specific care is needed with timber being exported into or across the tropics.

Figure 13.03. Fully wrapped material on a bolster ready for shipment

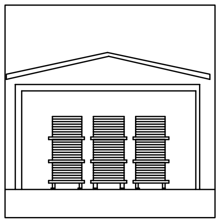
13.2.2 Equipment Options

1. Fixed equipment

The equipment relevant to drying during storage includes the storage building and moisture meters. Acceptable building types are included in Module 13.2.1



Storage. Moisture meters are described in detail in Module 17 Moisture Content Monitoring.



13.2.3 Storage Strategy

1. Protecting the KD packs from drying damage

KD packs in transport or storage should be protected to minimise exposure to adverse drying conditions. To do this:

KD pack protection requirements should be available and understood;

KD packs should be stored in a building with a level of enclosure and environmental control adequate to maintain the packed timber at the moisture content required for its target market;

Storage areas should be inspected regularly to ensure that required conditions are being maintained;

KD packs of appearance grade material being exposed to external conditions for longer than an hour should be wrapped in plastic;

KD packs of structural material being exposed to external conditions for longer than half a day or likely to be exposed to rain should be wrapped in plastic; and

KD packs should only be transported between sites or to customers outside the local area in taut liners or under covers such as tarpaulins.

2. Monitoring moisture

After receipt into store or directly before dispatch, the moisture content of the timber in the KD packs should be at the level required by the relevant standards (AS 2796, AS 2082) or the intended customer. To do this:

Moisture content requirements for each batch or product group should be available and understood;

The moisture content of the KD packs on receipt from another site or on dispatch should be determined in accordance with Table 13.01;

The measured moisture content should be provided to the customer;

Any material outside the required tolerances should be separated for future reprocessing or reprocessed;

Material outside the required tolerance should be noted in regular feedback; and

The cause of repeat occurrence of material outside the required tolerances should be traced.

3. Maintaining product information

Information required for later production control should be collected and passed with the KD pack effectively. The requirements for this are included in Section 13.2.5.

13.2.4 Quality Control

Procedures should be established for:

Procedure	General contents
Product specification	Grade, size, overcut and batch requirements for product groups including verification processes
KD pack storage & protection	Storage provisions including protection of high value packs, shelter of other packs, use of bearers, strapping etc.
KD pack transport and handling	Allowable truck configuration, use of tarpaulins, forklift requirements, covering
Moisture monitoring	The type and number of checks to be made when the KD packs are unloaded, or being prepared for dispatch, and reporting procedures for non complying material
Marking and tagging	Identification requirements for grade and sorting
Staff accreditation	Training and qualifications
Equipment	Maintenance

13.2.5 Information Management

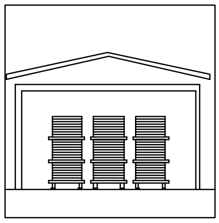
1. Required attributes

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Unique KD pack identification number	Out of store time & date
Staff number	Staff comments
In store time & date	Store location

Table 13.03. Attributes required or desirable when accepting or dispatching KD packs that have not been broken down since the dry mill

Required Information on KD Pack	



Unique KD pack identification number	Board width
Batch type (species)	Board thickness
Date KD pack completed	Board length
Grade	
Board profile	
Required process control information	
Unique KD pack identification number	Board width
Staff number	Board thickness
Batch type	Board length
KD pack arrival / complete time & date	KD pack tally number
Grade	Staff comments
Board profile	
Desirable additional information.	
Packer	Pack started time & date
Packing location	

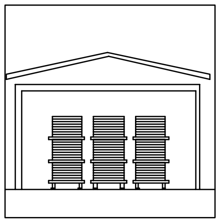
Table 13.04. Attributes required or desirable when assembling new KD packs

Required moisture control information	
Unique KD pack identification number	Likely wood temp
Staff number	MC measurement position
Reading time & date	MC meter reading
Production location	Adjusted MC reading
	Staff comment

Table 13.05. Attributes required for moisture content control with resistance type meters

2. Marking & tagging

Information required on the KD pack must be legible in normal daylight at least 1.5 metres from the end of the pack.



Pack tags should be of resilient and weather resistant material securely fixed to the pack. Ideally, they should be colour coded by grade, species or product group. Permanent pens should be used to mark the tags. Stamps or paint should also be permanent ink and not be readily obscured by dust.

All tagging systems have to be able to survive any transshipment stage with less than a 0.5% loss rate.

13.2.6 Equipment Maintenance

The store building needs to protect the timber from adverse climatic conditions. The required conditions of the building should be maintained. Buildings and storage area should be inspected for:

uncontrolled moisture resulting from leaking or overflowing gutters, leaking roofs, broken downpipes, blocked drains, standing water, depressions in floors or roadways, dampness in slabs or adjacent cladding, windblown rain, or leaking or broken pipes;

high temperatures resulting from strong sun on especially on western walls, steam lines, or adjacent equipment; or

strong airflow resulting from breaks in the building fabric, or winds funnelled between buildings.

The maintenance and calibration of moisture meters is included in Module 17 Moisture Content Monitoring.

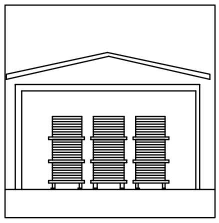
13.2.7 OH&S

The storage area should be regularly inspected and hazards identified and eliminated.

Major OH & S requirements relevant to this section are listed in Table 13.06. This is not a complete list and other relevant codes and regulations may apply.

State	Major code of practice
NSW	*Codes of Practice for the Sawmilling Industry* – Workcover Authority
Victoria	Victorian Workcover Authority
QLD	*Sawmilling Industry Health & Safety Guide* – QLD Division of Workplace Health & Safety
Tasmania	*Code of Practice for Sawmill Operation* – Tasmanian Forest Industries & Workplace Standards Tasmania
WA	*Timber Milling and Processing Occupational Safety & Health Code*- FIFWA

Table 13.06. Major industry codes of practice



13.3 Operations

13.3.1 Objective

Activity during storage and transport is to protect the timber from unacceptable variation from the required moisture content.

At the beginning of storage, the timber should be grouped in batches, graded, straight, clean and stable in ordered KD packs with a determined and appropriate moisture content.

13.3.2 Key Drying Factors in Storage

1. Maintain the timber in this state while it is stored

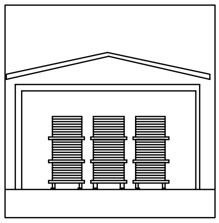
The moisture content changes after final drying to remain in equilibrium with the surrounding environment. It must be protected from conditions that will cause it to move outside a moisture content suitable for its grade and intended purpose. Timber that is stored anywhere except in an enclosed building should be wrapped in plastic.

2. Ensure that the moisture content is appropriate when it is dispatched

The moisture content of every pack should be determined when it arrives in store. If the pack has been delivered directly from an adjacent dry mill, the moisture content readings taken there should be available. If the pack has been received from another site or readings are not available, the moisture content should be checked. The moisture content of every pack stored for a specified time should be checked as it is being prepared for dispatch. In all cases, the moisture content should be within the range established for the target product by the company, and

3. Protect timber during transport

The moisture content of the KD packs should, at all times, be within the range established for the target product by the company.



13.3.3 Preparation

1. Standards

AS 2796-1999: Timber - Hardwood - Sawn and milled products

AS 2082-2000: Timber - Hardwood - Visually stress-graded for structural purposes

AS/NZS 4787:2001: Timber - Assessment of drying quality

Company or Customer Product Specification

2. Procedures

Procedures should be in hand for:

Product specification	Marking and tagging
KD pack storage & protection	Staff accreditation
KD pack transport and handling	Equipment
Moisture monitoring	

3. Equipment

Routine maintenance is regularly carried out on and around the store in accordance with standard procedures.

Pack marking and tagging equipment and measuring gear (moisture meters, tapes and calipers) should be in hand and operational.

4. Incoming material

KD packs are to be inspected to ensure that:

Required identification tags and marks are in place;

KD packs are protected with plastic and ready for storage; and

The measured moisture content readings are available if they are from the site.

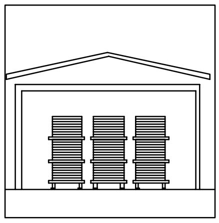
13.3.4 Processing & Monitoring

1. Protecting the boards, KD packs and packs from drying damage

KD packs in transport or storage are protected to minimise exposure to adverse drying conditions:

Identify the grade and product type of each KD pack upon receipt;

Store the pack in a building or shelter to standard procedures for that product;



Do not store packs in the sun any longer than absolutely necessary;

Do not expose appearance material to external conditions unless wrapped in plastic;

Do not expose structural material to external conditions for longer than half a day unless wrapped in plastic;

Only transfer dried timber between sites or to customers under cover outside the local area.

2. Monitoring moisture

After receipt into store or directly before dispatch, the moisture content of the timber in the KD packs is to be at the level required by the relevant standards (AS 2796, AS 2082) or the intended customer:

Make sure moisture content requirements for each product are understood;

Measure and record the moisture content of any pack arriving from another site or for dispatch;

Separate racks that do not meet target moisture content range;

Note material outside the target moisture content range in feedback;

Trace the causes of material repeatedly outside the target moisture content.

13.3.5 Marks, Tags & Records

Information required for later production control is collected and passed with the KD pack effectively:

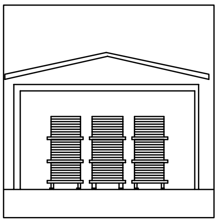
Identify KD packs for customer with marks or completed tags that include:

Unique KD Pack identification number	Board width
Batch Type	Board thickness
Date KD pack completed	Board length
Grade	Average recorded moisture content
Board Profile	Date of moisture readings

Complete at least the following records:

Production sheets detailing including KD packs received and dispatched	Location KD packs stored
Pack moisture content	Feedback reports
Equipment performance report	Equipment maintenance report

Include measured moisture content records with customer documentation.



13.3.6 Feedback

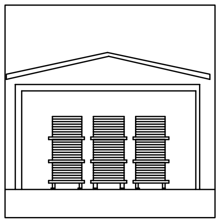
If noticed regularly, report any of the following to the supervisor:

Any standing water or dampness in storage building	Irregular moisture meter readings
Packs exposed to sunlight or other adverse conditions	Drying degrade that leads to a loss of grade

13.3.7 OH&S

Maintain and wear all required safety gear. Ensure all protective guards and warning devices are operational.

Keep work areas clean, tidy and clear of trip hazards such as wire and strapping ends, and pieces of timber.



13.4 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

1. Protecting the KD packs from drying damage

1a. KD packs received into store and prepared for dispatch

	1	2	3	4	5
The sides of KD packs are even and vertical.					
KD packs are wrapped adequately for the intended storage areas.					
KD packs are stable for transport and storage.					
KD packs are correctly, clearly and securely tagged.					
KD packs are marked with required information.					
Tags are legible 1 meter from end of pack.					
Documentation completed accurately.					

1b. KD pack protection in storage

	1	2	3	4	5
High value packs are fully protected from adverse conditions.					
KD packs are stored in a building fully protected from water or abnormal sources of moisture.					
KD packs are stored out of the sun at all times.					
KD packs are supported evenly and adequately.					
KD packs are handled with adequately rated equipment.					

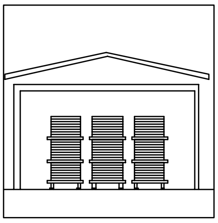
1c. KD pack protection in transport

	1	2	3	4	5
High value packs are fully protected from adverse conditions during transportation.					
Appearance grade KD packs are covered or fully enclosed during transportation.					

Other KD packs are wrapped adequately for the intended distance and means of transport.					

3. Monitoring moisture content

	1	2	3	4	5
The moisture content of the incoming KD pack from the same mill is confirmed.					
The moisture content of the incoming KD pack from the other sites is measured and recorded.					
KD packs not meeting the moisture target are identified and redirected.					
KD packs not meeting the moisture target are not dispatched.					
Material outside the moisture target is noted.					
The causes of material repeatedly outside the target moisture content are traced.					



13.5 Avoidable Loss

1. Protecting the KD packs from drying damage

Exposing the timber to adverse moisture conditions – If packs are:

stored before dispatch where they get wet;

transported where they are exposed to the wind, rain or sun; or

stored on receipt where they are influenced by moisture;

the moisture content or conditions of the timber may make it unsuitable for use. It may fail in service, such as when hardwood flooring shrinks or distorts unacceptably when laid, or it may be rejected as not meeting the required standard. Timber left in the sun discolours quickly.

Figure 13.04. Material stored in the weather may be exposed to moisture variation

Figure 13.05. Plastic wrapping damaged after prolonged storage outside. The longer material is stored in the open, the greater the chance of significant moisture damage

Pack damage – Boards subject to mechanical damage due to:

poor roading;

lack of capacity in forklifts and other handling equipment;

inadequate or inappropriate support or packaging;

bad driving or handling by forklift operators are a direct production loss

2. Monitoring moisture

Inadequate moisture monitoring – Wet packs are stored, incurring a further cost to the company. Wet material can be dispatched and fail in service, leading to a loss of customers and claims by customers against the company. This is particularly important for flooring products.

13.6 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

14.0: – INFORMATION MANAGEMENT

14.0 CONTENTS

14.0: – INFORMATION MANAGEMENT

14.1 Objectives

The purpose of information assessment is to manage the collection, retention and display of production information and use it to monitor, manage and improve the drying process.

14.1.1 Functions & Performance Requirements

1. Maintaining production information

Information required for effective process control is collected, held and displayed effectively.

2. Identifying & reporting problems for correction

Effective information analysis processes are maintained in place.

Workable feedback mechanisms are maintained in place to identify and distribute details of individual and systemic problems.

3. Management of staff and equipment

Staff and equipment are available to conduct coupe activity safely and efficiently.

14.2 Management

14.2.1 Overview

Activity in information assessment is to manage the collection, retention and display of production information and use it to monitor, manage and improve the drying process.

Information about the bundles of timber, logs, packs, racks and KD packs, is collected and managed for:

Immediate process control.
This information is normally displayed on the bundle as a mark or a tag, or is retained on a card or spreadsheet near the main working areas. It is collected by the operational staff and they use it to monitor and guide processing;

Verification of process quality.
This information is normally collected on a paper form by operational staff and processed in an office for management to guide processing or to verify the quality of the bundle to the customer;

Process improvement.
Critical summary information is developed from the detailed analysis of operational information, such as process control and quality records, supplemented by the results of equipment and production audits. It forms part of the feedback mechanism that allows management to identify systemic problems with production or characteristics of the resource that affects volume and grade recovery.

While these currently focus on process and cost control, chain of custody requirements for product environmental certification will soon demand additional information processes.

While the collection of information is conducted throughout a company, establishing the processes and ensuring that they are carried out is exclusively a management function.

1. The information to collect

Significant amounts of information can be collected while drying timber. However, not all of it is essential to control the process or ensure quality. There is little point collecting information if it is not necessary. As collecting and processing each additional piece of information adds cost and complexity to the process, it is important to establish efficient:

information structures;

collection processes; and

processing systems.

It is then critical to identify the information that needs to be collected to successfully pursue the chosen product and production strategy.

14.0: – INFORMATION MANAGEMENT

1a. Information structures

Information collected during the production process needs to be ordered into a structure that allows efficient and effective planning and management. This structure should then be mapped in a flow chart listing the key attributes to be collected at each production stage and showing the connection between attributes in different production stages.

Generally, a relational approach underpins the most efficient information structures, whether they are maintained in a paper or computer system.

A relational approach is based upon providing unique identifiers to items, such as kilns or racks, and then relating them to each other from the different information sources by using those unique identifiers.

For example, if Rack No. 1557 is placed in and taken out of Kiln 2 at particular times and Kiln 2 runs Schedule 24K between those times, it is possible to work out that Rack No. 1557 was subject to Schedule 24K. This is even though that information was not directly noted on any single piece of paper.

An identifier can be a number, such as Kiln ***2***, or a consistent name, such as ***select*** (or standard or high feature) grade.

For timber drying, unique bundles of timber should have unique identifiers. This includes:

log numbers, for the individual log produced in the forest and transported to the log yard. The minimum details that should be collected about the log are listed in Module 3 Log yard;

pack numbers, for the collection of unseasoned boards assembled in the green mill for treatment at this site or transported to another site. The minimum details that should be collected with the pack are listed in Module 5 Green Pack;

rack numbers, for the stickered rack of board, assembled in the green mill or the drying yard. The material remains in the rack until it comes out of the kiln. This rack number is used as the key identifier for all subsequent movement, moisture and kiln details. The minimum details that should be collected with the rack are listed in Module 7 Rack Timber; and

KD pack numbers for the pack of dry and graded material. This is used as a key for moisture checks and for storage purposes. The minimum details that should be collected with the KD pack are listed in Module 12 Dry Milling.

Maintaining a relationship between the bundles as one is broken down and assembled into the next is important but not easy. It is usually not practical for one bundle to flow completely into another bundle. At these times, information is amalgamated as coming from one group of bundles to another group of bundles. For example, all the logs milled on one day can be associated with the racks of timber produced during that day.

Other items or equipment that can be given a unique identifier include:

Board	**Predryer**
Board batch type	Predryer charge record number
Board grade	Predryer number
Dry Mill	Predryer position number
Dry milling breakdown location	Predryer schedule number
Dry milling moulding location	**Rack**
Green Mill	Rack supplier
Green mill saw line number	Racking bay number
Kiln	**Reconditioner**
Kiln charge record number	Reco charge record number
Kiln number	Reco number
Kiln position number	**Stack**
Kiln schedule number	Stack location in Stack
MC items	Stack location number
MC measurement position	Stack row number
MC production stage	**Staff**
MC sample board location	Staff number
MC sample board number	**Store**
Pack	Store location number
Pack supplier	Store number
Packing bay number	**Tally**
	Tally number

Table 14.01 Unique identifiers for key equipment and stages

Figure 14.01: Rack tag with its unique identification number and key product information

1b. Collection and processing

There are currently three ways of collecting information: by hand on a form, by machine or gauge on a form or chart, or direct into a stationary computer. Systems that use hand held portable computers are being developed but are not currently commercially available. Only generic systems are available for them.

The simplest method is filling out a printed form by hand. Generally set out as a simple table with headings, these are used to collect repetitive information at a particular work location, such as the moisture reading taken off racks at a destacker. While easy to use and produce, the forms have to be collected and stored after they are used. If the information is transcribed into a computer database, it can be reformatted for analysis and related to other information collected about the same rack or item. If it is not, it is very hard to analyse and if it is retained, it is only useful to prove product quality at a later date. Also, every time information is transcribed there is the potential for errors to occur.

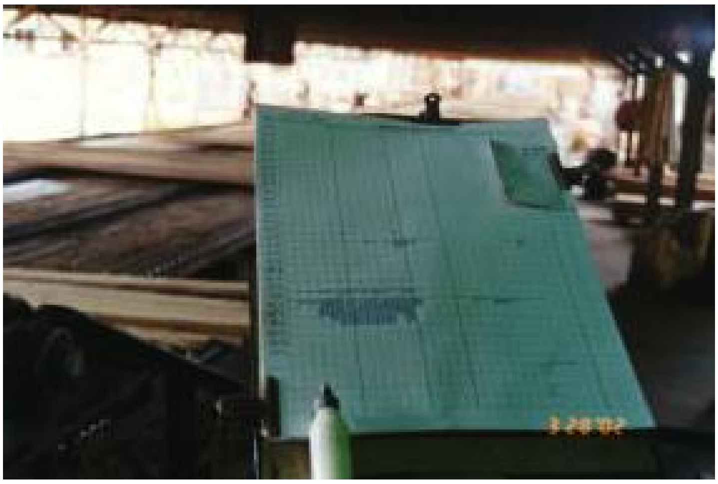


Figure 14.02. Paper tally form on a green chain

Figure 14.03. Paper record of moisture readings

Charts from gauges are similar. While they are completed automatically, they must be interpreted before they can be used or related to other information.

Figure 14.04. Rack cards stored in pigeon holes that correspond with positions in predryers

Computer systems have the potential to store information easily and bring the information from a number of different processes together so they can be inspected or compared quickly and efficiently. If data is entered directly into a computer at the work location, there is no need for it to be transcribed and entries outside of acceptable bounds can be identified quickly. These both reduce the number and impact of errors and the cost of handling data.

However, there are several significant limits on the use of computer systems:

systems on a site must have compatible data output.
This means that information collected at one machine or piece of equipment can be compared efficiently to the information collected at another. For example, if a measuring machine uses one data format, while the stock tallying machine another, their information can only be compared once it has been put through a purpose designed program that 'lines' up matching information. Developing this program is time consuming and the resulting data may be prone to error. All equipment suppliers should be required to ensure output data is in the required format;

they must be maintained.
Computer systems can become obsolete very quickly as either company requirements change or as key software is upgraded, or worse, no longer supported.

Though hardwood drying is essentially a very similar process in many companies, there are currently no commercial integrated information systems available for it. Some older proprietary systems are still in use but are no longer supported. These systems usually focus on sales and stock control.

Generally, companies maintain individually designed process control systems, either as databases or spreadsheets.

1c. Analysis

Collected information needs to be analysed regularly. This allows:

the operation's performance to be monitored against key indicators for each stage of production; and

improved process controls and skills to be developed and implemented effectively.

This analysis is a management function and is closely allied to production auditing, detailed in Module 15 Drying Quality Assessment.

Analysis does not necessarily require the collection of additional information. However, without structured analysis of the information that is collected, very useful process improvement can be lost. This is best illustrated by example.

Company A used their air drying yard in the same way for fifteen years. During that time, they always measured the moisture content of the racks in the yard after a set period to see if they were dry enough for further processing.

It didn't matter if it was summer or spring, the 25 mm racks were checked after 9 months, the 38 mm after 12 months and the 50 mm after 15 months. If the racks were found to be too wet, they were left for another period and tested again. If they had reached the target moisture content, they went for further processing.

In doing this, the company recorded and kept: the rack number, the rack's major characteristics (species, thickness, etc); the date the racks were placed in the yard; their position in the yard; and the date and reading every time the moisture content of the racks were tested.

All this information was only used to show that the racks were at the correct moisture content when they progressed for further processing.

However, if this information had been fully analysed, it could reveal:

The areas of the yard that dried quickly and those that dried more slowly;

The effect of the time of year on drying time;

The rate of drying relative to the position in the stack; &

The rate of drying relative to board thickness and species.

By comparing this and other process information, a connection could have been made between final drying quality and location in the yard.

These are all useful understandings that can make the timber production process more efficient and cost effective, reducing production time and loss to drying degrade.

Analysis processes should be in place to determine:

Recovery	Gross recovery from Log to rack or pack, and Rack to KD pack by species and grade.
Grade loss	Loss of recovery and loss of grade caused by production induced defects by species and size. This is in addition to gross recovery and should show the reasons why material is lost.
Moisture Content and moisture change.	The moisture content at the end of each stage of production and the change from the end of the previous stage for each rack, batch of material, and major item of equipment, including the air drying yard. This should include flagging readings that are outside the acceptable range.

2. What needs to be collected

The amount of information that needs to be collected depends on the production and product strategy of the company. The list of attributes included in Section 2.5 of each module are designed for companies pursuing either a *Quality* or *High Quality* production strategy.

They are structured on a relational basis, with equipment and repetitive items given a number or a fixed range of values. They also include additional attributes that allow links to be made across processes.

It is possible to collect both more and less than the number of attributes listed.

However, the list should only be expanded with care. Some quality systems pursue a 'collect everything' approach. Staff end up managing so much paper, it is forgotten that they are really managing a production process. This can mask a process's success or failure as effectively as collecting too little information.

Certain attributes can be excluded from the lists. While this will restrict some interrelationship, it will remain effective so long as enough information is collected so that the drying history of a particular piece or bundle of timber can be traced back to the pack received from an external supplier or a rack assembled on a particular day.

2a. Retaining the information

Information should be retained as long as it is remains useful. The retention period should be chosen with care.

Certain attributes, such as staff names, are only useful as long as that staff member is employed or responsible for an action. Attributes relating to a bundle's processing remain relevant for at least the period of claim against that bundle, often several years.

Other attributes, such as a successful drying schedule, or information that is used to monitor the performance of processes and equipment over time can remain useful for the life of that piece of equipment. For a kiln, this can be more than 20 years and for an air drying yard more than 50 years.

Paper records should be catalogued and archived for the required period in a cool, dark and dry storeroom, preferably off site.

Figure 14.05. Paper records can be damaged easily. These records are only 8 years old

Computer records should be catalogued and archived on CD's. They should not be stored on floppy disks as these degrade with time. Given the ease of copying CDs, at least two copies of all computerised records should be retained. At least one set should be stored off site.

14.2.2 Equipment Options

The equipment relevant to information management includes tagging systems, and forms.

There is a broad range of computer and mechanical recording systems both in use and available from a wide range of producers. It is beyond the scope of this manual to detail them here.

1. Tagging equipment

Tags for logs, packs and racks can be anything from a piece of wood with details written on it, to numbered cow tags, to a proprietary product. However, all tagging systems have similar requirements. They must be:

Legible at an effective distance.
Logs and racks are stacked on each other so tags are often some distance away from a safe and easy working position. They need to be large enough to read easily. Ideally, they should be colour coded by grade, species or product group as this can be read easily and quickly from a distance

Resilient and weather resistant.
Tags have to survive storage in the yard and processing in a kiln.

Cheap and easy to use.

Compatible with other processes.
If waste timber is chipped, the tag should not be able to contaminate it easily.

Widely used in the pine industry, the main types of proprietary tags are:

Solid plastic.
These have small teeth and are fixed to the wood with a proprietary hammer. While effective on the ends of logs, they do not work well on racks or packs.

Figure 14.06. A solid plastic log tag

Plasticised fabric.
These are economical, rugged and can be fixed with a nail or stapled. They can be coloured, numbered or include a bar code. They can also have spaces for information to be written on with an indelible pen.

Durable paper.
Also fixed with a nail or staple, these tags can be pulped so they will not contaminate wood chips. As the tags are not as durable as the plasticised fabric, they sometimes have several layers, each with the same number.

Preprinted plastic stickers.
These stickers are used on plastic sheet. They are durable, cheap and easy to both produce and use. They can include pre-numbered bar codes if required.

Figure 14.07. A preprinted sticker

14.2.3 Info Management Strategy

1. Maintaining production information

Information required for effective process control should be collected, held and displayed effectively. To do this:

The information to be collected at each stage of production should be readily available and understood;

The information to be collected at each stage of production should be documented and reviewed at least annually;

Key production items and characteristics should be numbered or given a unique value from a restricted list;

The use, collection and retention of computer or mechanised records should be documented and reviewed at least annually;

The use, collection and retention of forms and tags should be documented and reviewed at least annually;

Forms and tags should be prepared to a style manual to ensure that they are clearly titled, labelled, have sufficient space to write easily, and form a coherent set;

The use and layout of forms, computerised information systems and tags should be discussed regularly;

Failures to collect information or repetitive errors in the information should be identified and corrected.

2. Identifying & reporting problems for correction

Effective information analysis processes are maintained in place. To do this:

Key production indicators are to be established, documented and reviewed at least annually;

Production should be systematically assessed against these indicators at least every three months.

Workable feedback mechanisms are instigated and maintained to identify and distribute details of individual and systemic problems. To do this:

An effective feedback mechanism should be introduced and maintained The results of production assessments should be discussed among senior drying, production and management staff regularly;

The results of the assessments should be used to correct drying practice.

14.2.4 Quality Control

Procedures should be established for:

Procedure	**General contents**
Information structure	The information to be collected at each stage and the numbers and values to be used for key items
Information collection	The completion of forms or other data collection processes, their processing, copying or backup, and retention
Production indicators	The key indicators that indicate success or failure of particular processes, such as prime grade recovery, prime board downgrade and causes of board downgrade
Feedback mechanism	The process for passing information about production to others influenced by it
Style manual	The style, layout and size of forms and tags

14.3 Avoidable Loss

1. Maintaining product information

Insufficient monitoring of process - Unsatisfactory performance in production is not apparent and material is damaged or not properly dried. This can lead to reduced recovery and increased claims from customers for poorly performing product.

Records are not retained in a useable form – The same mistakes are made again and again and potential for process improvement is lost.

2. Identifying & reporting problems for correction

Insufficient monitoring or analysis of product - Unsatisfactory performance remains undiscovered and material is damaged or not properly dried.

Inefficient feedback mechanisms - While unsatisfactory performance is uncovered, the action necessary to remedy it is not taken at all levels. Again, material is damaged or not properly dried.

Unwarranted reliance on recording processes that mask key indicators. For example, prime grade recovery figures do show the value of production but do not identify the causes of avoidable downgrade.

14.4 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

15.0: – DRYING QUALITY ASSESSMENT

15.0 CONTENTS

15.0: – DRYING QUALITY ASSESSMENT

15.1 Objectives

The objective during drying quality assessment is to identify, quantify and eliminate inappropriate drying quality and degrade.

15.1.1 Functions & Performance Requirements

1. Monitoring drying quality & degrade

Drying degrade in products is identified.

Drying degrade in production is quantified.

Drying quality is assessed regularly.

2. Identifying & reporting problems for correction

Workable feedback mechanisms are maintained in place to identify and distribute details of individual and systemic problems.

Problems are corrected.

3. Management of staff and equipment

Staff and equipment are available to conduct drying quality assessment activity safely and efficiently.

15.0: – DRYING QUALITY ASSESSMENT

15.2 Management

15.2.1 Overview

Activity during drying quality assessment is to identify, quantify and eliminate inappropriate drying quality and degrade.

At the end of final drying, quality timber should have:

- the moisture content and profile within the target ranges for the intended product;
- minimal residual stress. It should be flat and stable, even if milled to another size or shape; and
- few or no grade reducing characteristics that are due to drying.

To ensure that this is the case, these attributes need to be checked as a normal part of production and by regular product audits.

1. Moisture content & moisture profile

Standardised methods of determining the moisture content of the timber are detailed in Module 16 Moisture Content Monitoring. The type and number of tests that should be performed at each production stage are included in the relevant Module.

Standardised methods for assessing drying quality are established in **AS/NZS 4787:2001**: Timber - Assessment of drying quality. This Standard sets down procedures for customers to specify the moisture content and other drying quality criteria of seasoned timber products. The standard lists five moisture content quality classes from A to E with progressively increasing tolerance on moisture content variation.

Under this Standard, the target average moisture content must be specified as well as the quality class. In addition, other drying quality criteria may be specified, such as residual stress and moisture gradient.

One important aspect of this standard is that it is not called up by any other standard. This means that its provisions only come into force if the producer or the customer specifically references them.

The other relevant Australian Standards are:

- **AS 2796-1999**: Timber - Hardwood - Sawn and milled products; and
- **AS 2082-2000**: Timber - Hardwood - Visually stress-graded for structural purposes.

AS 2796-1999 specifies the target moisture content for the major product groups. These are set out in Table 15.01. These moisture contents apply to all grades.

Product	Required moisture content
Parquet, and Sawn or dressed furniture components	8 to 13 %
Strip flooring, Overlay strip flooring, Lining Boards, Dressed boards, Joinery Stock, Mouldings and sawn boards for Feedstock	9 to 14 %
Light decking, cladding, fascia and barge boards	10 to 18%

Table 15.01. AS 2796 Target moisture content for the major product groups

AS 2082 requires that 90% of the pieces being graded have a moisture content not more than 15% with no piece having a moisture content of more than 18%.

Producers and customers can agree their own specification for products while other moisture content ranges are required by international standards.

2. Residual stress

A piece of seasoned timber may be stable in a regular shape and still contain various residual but balanced stresses. These stresses may result from drying or may remain in the timber from the growth of the tree. However, if the piece is resawn or moulded, the balance of stress may be disturbed. As the opposing stresses are no longer balanced, they distort the board until they come into balance again.

One way of measuring residual drying stress is by cutting through the cross-section of a piece and placing the halves together. As shown in Figure 15.01, if any residual stresses are present, the pieces will cup. While exposing residual stress is simple, quantifying it is difficult due to variability in the timber, the size of the piece, and other factors. For example, the distribution of stress can vary considerably with the sawing orientation of the section, such as backsawn or quartersawn.

The method recommended in **AS/NZS 4787**, the 'ripping test' method, has been designed to minimise measurement error by minimising cutting, and provides a practical reference to potential behaviour in processing after drying.

Many references detail the use of prong tests to determine residual stress. However, the measurement error with this type of test can be considerable and it has not been included in the Standard.

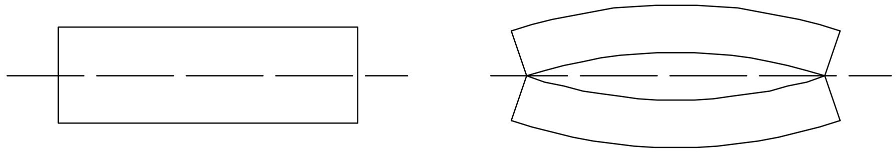


Figure 15.01. The rip test shows the result of stress relief

3. Grade reducing characteristics

Grade reducing characteristics are those that make a piece of timber unsuitable for the target grade and size, and force it to be regraded into a less valuable grade or a smaller size. For example, unacceptable surface checking can force what is potentially a select appearance grade piece into a structural grade piece.

Grade reducing characteristics can be either natural features from the log or induced in the piece by its treatment during production. While natural characteristics cannot be avoided without varying the resource, drying induced characteristics can be eliminated or significantly reduced by improving drying practice.

Many grade reducing characteristics induced during drying result from poor drying practice. Recognising them is important to improving that practice. Most of the common grade reducing characteristics, their causes and ways of preventing them are listed below.

Surface checking

Surface checking

This is a split along the grain of timber visible on any face of the board. Surface checks do not extend through the piece from face to face.

Major surface checks are obvious and easy to see in dry milled timber. Smaller checks are not obvious in rough sawn material and may close up completely during the later stages of drying.

Causes

Checks usually result from stresses that build up when the surface of the board dries quickly and shrinks while the centre of the board has not. If the stresses are high enough, the timber splits and a check forms. As surface stress is higher on the wider and backsawn faces of boards, these tend to check more readily than narrow or quarter sawn faces.

Surface checks can also result from collapse near the surface.

Prevention/reduction

Slow the rate of drying and stress in the surface of the board, especially during initial drying by:

quarter sawing rather than back sawing;

protecting the timber before it is racked;

sheltering racks in the air drying yard to reduce temperature and airflow, and increase humidity;

use higher relative humidities or lower temperatures in the early stages of drying in a predryer; and

ensure temperature and humidity monitoring equipment in the predryer is accurate and control equipment is delivering the correct conditions.

If checks are open during air drying, they can trap dirt and water. This stains the timber and can indicate when the checks formed.

Possible remedies

There is no remedy for surface checks once they have formed except milling them out. Surface checks may close when the wood is dried to uniform moisture content. However, they remain in the wood and can reappear after milling or during use.

Internal checking

Internal checking

This is a split along the fibres inside the piece of timber. The check runs along the board and generally at right angles to the growth rings. It almost always begins at the junction of an earlywood and latewood band.

Internal checking is particularly hard to detect. The checks are normally not visible on the surfaces and may not be visible on a cut section. They may have closed up during reconditioning or only occurred in a part of the length of the board. They are often not obvious until the timber is undergoing final finishing when they present as persistent localised furring, small surface bubbles or flaking edges on moulded or sanded pieces.

Regrowth collapse prone timber, especially from "ash" group eucalypts, is particularly susceptible to internal checking.

Causes

Collapse (described below) can lead to internal checking. This is probably due to the differential shrinkage between growth rings that do collapse, and adjacent ones that don't.

The amount of internal check may also be related to the temperature of drying, as this affects collapse.

Prevention/reduction

Slow the speed of drying, especially initial drying by:

- protecting the timber before it is racked;
- sheltering and protecting racks in the air drying yard or in drying buildings. This lowers both the temperature and drying rate; and
- using lower temperature and higher relative humidity in the early stages of predrying.

Avoid using material prone to internal checking in deep moulded profiles.

Possible remedies

There is no remedy to internal checking.

Internal checks can close when the wood is fully dried. However, they remain in the wood and reappear after milling and finishing.

End Checks & Splits

End checks & splits

End checks are separation of fibres on the end of the board. End splits are cracks in the end of the board that extend through the piece from face to face. Both are obvious on the end of the board and can extend some way along the board.

Causes

End checks and splits can result from a combination of:

- fast end drying. Water transfers much more quickly along the board than across it so the ends dry more quickly than the rest of the board. If the stresses that result exceed the strength of the timber, it splits and an end check or split forms; and
- growth stresses in the wood. These result from the growth of the tree and remain in the board when it is cut from the log. They cause the wood fibres at the end of the board to separate and form splits.

The extent of end checks and splits are exacerbated by:

- poor pack and rack protection.
- the ends of board overhanging the rack.
- too much air circulating around the ends of stacks.
- species, age, and sawing characteristics. Backsawn regrowth collapse prone material checks and splits readily.

Prevention/reduction

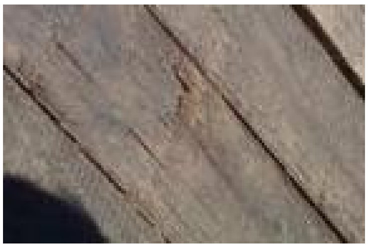
Slow the rate of end drying and restrict splitting by:

- sealing the end of boards or logs, ideally immediately after felling and any cross cutting;
- stacking the timber with rack sticks near the end of rows of boards; and
- ensuring uniform air flow through stacks by correct stacking, and the proper use of baffles.

End splits from growth stresses cannot be completely prevented without relieving the stress. There is currently no accepted method for this. Sawing pattern selection may minimise the effect, but the growth stresses then often express as distortion.

Possible remedies

There is no remedy for end checks and splits. The affected timber needs to be docked off.



Other splitting

Other splitting

Other splits and shakes can be found in the board. Some are obvious on the surface but others are more difficult to detect as much of the splitting is inside the piece.

These splits only become apparent when the board is moulded or put under a load. They appear as furred edges on the surface when moulded and the affected boards can break without warning.

Causes

Shakes and splits are fractures or deviations in the grain of a tree or a piece caused by the stresses that result from a heavy load or impact. These include:

- wind on the standing tree;
- bending or impacts during felling of the tree;
- gripping and mishandling of the log on the coupe, in transport or in the log yard;
- gripping and mishandling the flitch in the sawmill; or
- mishandling boards during racking and subsequent drying.

Prevention/reduction

Handle the logs, flitches and timber with care, without concentrated loads or severe bending.

Possible remedies

There is no remedy for shakes and splits. The affected timber is docked out or discarded.

Collapse

Collapse

This is abnormal and often irregular shrinkage occurring above fibre saturation point. It is usually seen in quarter sawn boards as a rippling or "washboarding" at the surface. In back sawn material it shows as excessive and irregular shrinkage.

Collapse is particularly pronounced in many south-eastern Australian eucalypt species.

Causes

Collapse results from the physical collapse of the fibre cells, much like a drinking straw that has been pinched and flattened. This occurs at moisture contents above FSP and is generally accepted as being due to water tension within the wood fibres that arises as a result of drying.

Its occurrence increases with high temperatures and fast drying.

Prevention/reduction

Collapse can be reduced by slowing drying and maintaining a lower temperature.

Possible remedies

Collapse can generally be largely recovered by reconditioning with saturated atmospheric pressure steam at close to 100°C when the average moisture content of the wood is about 20%. See Module 11: Reconditioning.

Unfortunately, collapse is often associated with internal checking in the board and this cannot be unrecovered.

Case hardening

This is characterised by compression stresses in the outer zone of a piece, the case, and tension stresses in the core.

It displays as a board that may be unusually heavy due to high internal moisture content. With severe case hardening, there may be distinct colour variation on the cut ends. This often appears as a white boundary around a glassy blue/green/ purple core. With less severe case hardening, this colour variation may not occur.

It is very difficult to satisfactorily dry the centre of case hardened boards. However, while case hardened boards often have high internal moisture contents, this is not always the case.

Apart from the likelihood of cupping when it is re-sawn, case hardened timber is difficult to machine and to nail.

Causes

Casehardening results from drying the timber too quickly and at too high a temperature, usually in the early stages. This causes permanent set (or stretching) of the outer zone, initially, that reverse in final drying to compression stresses in the outer zone and tensile stresses in the core.

Prevention/reduction

Slow the rate of drying by lowering the initial temperature and ensuring higher relative humidity early in the process.

Batch material as consistently as practicable so that all material is treated in the correct way.

Possible remedies

It is very difficult to recover any material that is case hardened. At the end of the kiln schedule, a long conditioning period may be partially successful.

Sapstain and mould growth strain

This is discolouration in wood caused by fungus and moulds that infect and stain the timber as it dries.

Sapstain presents as a bluish or greyish discolouration in the sapwood, while other moulds and mildew will stain the timber various colours.

Causes

Fungi & moulds will grow anywhere that there is sufficient moisture, air and a food supply. In drying timber, this is either the timber itself or organic material in the dirt caught on the surface of the wood.

If timber is dried very slowly on sites with a moderate climate or the storage time between green packing and racking is too long, fungi and moulds may establish on the wood, especially during damper months. Once a site is infected with fungi or mould, new racks of timber can be contaminated quickly.

Prevention/reduction

The conditions that lead to mould and fungus growth can be reduced by:

- during air drying, spacing the stacks of timber further apart, ensuring good airflow beneath the stacks and orienting them correctly. This will increase the airflow around the timber and it will dry more quickly;
- during predrying, increasing either airflow or temperature to increase drying;
- increasing the airflow in the drying shed, particularly beneath the stacks;
- keeping the timber clean, away from dirt and rain;
- racking promptly; and
- keeping the yard, predryers and kilns clean and free of accumulated wood dust.

Alternatively, the timber can be dipped in an anti-sapstain solution. This kills the fungus as it attempts to establish itself in the wood.

Possible remedies

Once stained, the affected timber must be planed off or the material regraded to a structural product.

Sticker mark

Sticker mark

These are light or dark stripes across boards that correspond with the position of rack sticks. They can occasionally appear like a shadow of the rack stick, with darker strips either side of a lighter strip.

While there are regularly sticker marks on dry rough sawn material, this is often due to weathering of the exposed surfaces and planes out easily. The timber under the stick does not weather and so is paler.

Causes

Sticker mark may be caused by:

differences in the rate of oxidation of the timber under the rack sticks relative to the adjacent wood. Oxidation is a chemical reaction in the wet area of board;

Slow initial drying, such as fresh air drying racks being subject to lengthy rain periods. Water can then pool under rack sticks, increasing the likelihood of staining;

migration of extractives in the board and the rack stick to under the rack stick; and

fungal contamination from wet, dirty or old rack sticks.

Prevention/reduction

Use only clean dry rack sticks and ensure adequate airflow through the rack. Do not use unseasoned rack sticks.

Possible remedies

None. The affected timber has to be planed off. However, sticker marks can exhibit all the way through the board.

15.0: – DRYING QUALITY ASSESSMENT

Indentation

Indentation

This is an indentation or compression in the timber that forms directly under the rack stick.

Causes

This occurs when the load being transmitted through the rack stick is too great for the timber under it and it compresses. It is caused by:

- stacks being too high or by poor stack arrangement where rack sticks are out of vertical alignment
- poor racking. Extreme local loads can develop in an uneven rack, bending the rack sticks and compressing the boards

Lower density and lower hardness species are particularly prone to indentation.

Prevention/reduction

- Build stacks correctly. Rack sticks, bearers and supports should align vertically. Bearers should be positioned under every second rack stick and under the end rack sticks.
- Build racks correctly. Support and load transfer from in the rack should be even. Avoid large empty spaces in the rack.

Possible remedies

Indentation cannot be recovered. Affected timber must be dressed out or regraded.

Insect attack

Insect attack

The most common form of insect attack in drying timber is lyctus borer. Infestation presents as a series of small holes and piles of fine dust in sapwood of timber of susceptible species.

Lyctus attack can cause significant damage to timber in air drying yards and in service. The sale of timber that contains lyctus susceptible sapwood is restricted by Australian Standards and by legislation in NSW and Queensland.

Causes

Lyctus beetles infect the starch rich sapwood of some timber as it dries. The larva eats through the timber as it grows and leaves the piece through an exit hole.

Kiln drying does not reduce lyctus susceptibility and susceptible sapwood can be attacked after years in service.

Prevention/reduction

Lyctus infestation is common in most parts of Australia. It is prevented by treating all timber that contains lyctus susceptible sapwood to at least Hazard Level 1 as defined in **AS 1604-1997**: Timber - Preservative-treated - Sawn and round.

Possible remedies

There is no remedy for infected timber except chemical treatment to prevent future infestation.

Uneven drying between boards and within boards

Uneven drying between boards displays as an unacceptable range of moisture contents of boards in a rack or charge.

Uneven drying in the board appears as unacceptable moisture content variation throughout the board. This can be from the middle to the outside (core to case) or from one part of the board to another.

Both are detected by regular moisture content checks of the case and core along the boards.

Unevenly or inappropriately dried boards can shrink, expand, or distort during service. They are the source of a significant proportion of claims by customers against producers.

Causes

Uneven drying results because timber:

- with different drying characteristics is dried together. This occurs when timber is not effectively separated into batches of like material. This can occur from combining timber of:
    - incompatible species;
    - different thickness;
    - different sawing orientation - quarter and back sawn dried together; or
    - in some cases, significantly different initial moisture content;
- is dried in a kiln or a predryer under an inappropriate drying schedule. This results in unacceptable final moisture content gradients; or
- has not been given an appropriate or efficient equalisation treatment after final drying; or
- in a rack is exposed to uneven drying conditions. This can occur during any production stage from racking to final drying. These are listed in Table 15.02

Racks
Racks that are poorly built and have uneven airflow through the boards. This can be due to racks having uneven sides or ends, or uneven board lengths.
Air drying
Excess moisture and insufficient air movement at the bottom of racks and stacks.
Poor rack orientation.
Poor yard layout.
Predryers & Kilns
Too much variation from one part of the predryer or kiln to another due to: poor stacking and baffling; insufficient control of temperature, humidity and airflow; a breakdown of equipment; inadequate or poorly operating equipment; or leaks in the doors or building fabric.

Table 15.02 Causes of uneven drying in racks.

Prevention/reduction

Uneven drying can be reduced by batching boards of like drying characteristics together as much as practically possible and by exposing racks and stacks to as regular a drying regime as practicable.

This requires:

- good racking, air drying and subsequent final drying practice; and
- effective maintenance and control of adequately rated equipment throughout the drying process.

Possible remedies

There is no accepted way to remedy uneven drying. The timber first has to be identified.

An additional drying process at the end of final drying may lower or even out the moisture content in the material. This process may include an equalisation period to even out moisture gradients or a reconditioning period.

Distortion - Rack buckle

Distortion – All forms

These are changes in the shape of a piece of timber. Distortion degrade includes, cup, bow, twist, spring and diamonding, or a combination of some or all of these.

Causes

Timber distorts due to:

differential shrinkage in the timber. Timber has different shrinkage rates in the radial, tangential and longitudinal directions. These tend to distort the boards. Best drying practice in handling and racking the boards aims at controlling these distortions;

poor sawing practice. This can concentrate the effects of differential shrinkage & unbalanced stress;

irregular grain. Local distortions such as grain around knots and branches, reaction wood and spiral and wavy grain lead to an uneven pattern of shrinkage in the effected area;

growth stresses. These are stresses in the wood inherent from its growth. They find relief during sawing by distorting the board; and

inappropriate processing, especially poor racking. If the timber is not restrained or is subjected to uneven loads during drying, it will distort. It can also distort with overdrying.

Prevention/reduction

All forms of distortion can be minimised by:

improved sawing practice;

racking carefully. This includes placing rack sticks at required intervals in vertical alignment;

using stack weights to hold the timber flat as it dries; and

reducing board overhang at the end and centre of the racks. This is achieved by only including boards of the same length in a rack, or push-pull racking.

Possible remedies

Consider slab sawing and drying to reduce spring.

Apply a further reconditioning treatment as for collapse. If the timber is incorrectly stacked, dismantle and re-stack it properly before treatment.

Distortion: Cupping

Distortion: Cup

Cup is a curvature across the grain or width of a piece of timber. It is obvious and easy to see.

Causes

Differential shrinkage across the grain in tangential and radial directions.

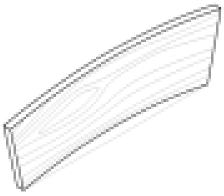
Prevention/reduction

Cupping is reduced by weighting the boards in a rack or stack as it dries. If it is occurring in the top of the stacks, stack weights may be needed. However, these can lead to surface checking as the stresses that cause cupping may check the surface if restrained.

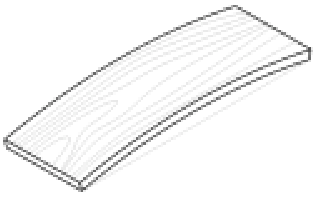
Possible remedies

Cupping tends to be recovered during reconditioning. Any that doesn't recover has to be milled out.

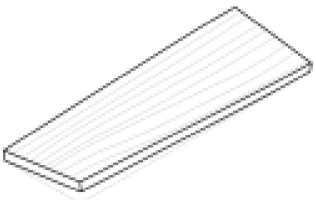
15.0: – DRYING QUALITY ASSESSMENT



Spring



Bow



Twist

Distortion: Spring, bow and twist

Spring is a curvature along the edge of the board causing it to move away from a straight line from end to end. It does not affect the face.

Bow is a curvature along the face of the board causing the wide face to move away from a flat plane.

Twist is a winding of the board, so that the four corners of any face are no longer in the same plane.

All are obvious and easy to see.

Causes

These result from:

- differential shrinkage along the grain owing to irregular or curved grain or reaction wood; or
- growth stresses in the board. In quarter-sawn boards, they cause spring. In back sawn boards, they cause bow.

Prevention/reduction

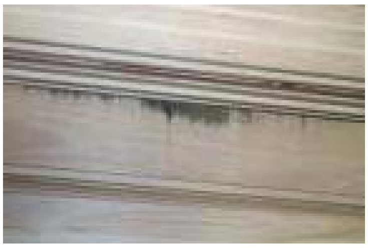
All can be reduced by weighting the boards in a rack or stack as it dries. However, much of the bow and spring is evident straight off the saw. Spring can be reduced by slab sawing and drying. The dry material is then straight edge sawn to the required sizes. Irregularly grained material can also be excluded or directed to other product lines.

Possible remedies

Material with spring can be straight edge sawn to a smaller size.

Increasing restraint of the board can reduce bow and twist. Susceptible material can be placed on the bottom racks of the stack or stack weights can be used during drying and conditioning.

Hit and Miss / Skip



Hit and Miss / Skip

This is unevenness in the thickness or width of the boards. It displays as areas on dressed or moulded boards that are not machined fully.

Causes

Hit & miss results from:

- excessive shrinkage. This is usually related to unrecovered collapse;
- localised grain distortion;
- poor sawing practice, where the board ends up at different thicknesses along its length or there is variation in thickness between boards. This can occur when the flitch distorts as it is sawn; or
- inadequate overcut allowed for shrinkage.

Prevention/reduction

Hit & miss is reduced by:

- improving sawing consistency and the overcut allowance; and
- minimising drying practice that can result in excess shrinkage and collapse.

Possible remedies

There is no remedy for hit & miss except regrading the board or milling it to a smaller size.

15.0: – DRYING QUALITY ASSESSMENT

Monitoring drying quality and degrade

Identifying grade reducing characteristics caused by poor drying is important to improving drying practice, isolating equipment problems and reducing further loss. They are monitored in four ways:

- standard production checks;
- regular quality checks and analysis of results;
- quality audits; and
- effective feedback.

All can occur at any time after the timber is first batched into the rack or pack, but they occur most regularly during dry milling, when the rack is broken down and each board is individually examined as it is graded.

Standard production checks

Before Dry Milling

Production checks before dry milling usually involve the visual assessment of the pack or rack and measuring its moisture content. They can indicate gross failures in the drying process. For example, it is easy to see if the timber in a pack is severely surface and end checked when it has been left out in the summer sun, or if a rack coming out of the kiln contains significant collapse.

Avoiding these gross failures requires:

- experienced staff who can identify the failure, and understand its cause and its consequences;
- effective checking and feedback mechanisms. This is discussed more fully below; and
- responsive management, who act to correct the cause of the failure once reported.

All three of these requirements are necessary for production checks to work effectively and eliminate occasional and systemic problems. Of the three, responsive management is most important. For example, if a severely checked pack is found and reported but no action is taken to provide better shelter for other packs, reports of further checked packs soon cease. Operational staff learn very quickly that certain problems and practices leading to loss are regarded as acceptable or too hard to fix and so have management's tacit 'approval'.

During Dry Milling

Production checks during dry milling ensure that the product is fit for purpose and complies with the required grade. They usually involve an accredited grader examining each piece and giving it an appearance or structural grade, the sorting of the timber by grade and sampling the moisture content of a number of pieces in each rack. With structural material, there may also be proof or stress testing.

The results of the moisture sampling and structural testing are recorded. As they are a simple number and there are relatively few of them, they can be assessed immediately and values that are outside an acceptable range easily identified. A group of unacceptable values can signal a drying problem quickly.

The characteristics that lead to a single grading decision are not recorded as this is difficult and onerous. With only a short time to spend on each board, the grader can only discern the pattern of characteristics in the material as it flows past. As a combination of many characteristics can contribute to a grade decision, there is no number to record or assess easily. Subtle indications of drying problems can easily be missed.

Identifying drying problems at this stage can only occur through:

observations by the graders.
The graders notice and report an uncommonly regular occurrence of a particular drying degrade characteristic. This can be while they are grading or while reviewing the KD packs as they are assembled. This is a qualitative assessment and can be highly variable. Different graders notice different things depending on their training, mood, the quality of light, the time of day, etc. They may not notice subtle changes consistently. To encourage consistent reporting, graders need comfortable working conditions, consistent light, regular rotation through tasks, and a routine of discussing and reporting problems; and

comparison of grade recovery.
A comparison is made between the grade recovery of racks coming into the mill on a given shift and historical recovery from the same type of racks. For example, three racks of appearance grade boards coming into the mill may usually result in 7 KD packs of select, 2 of standard and one of high feature. However, if three racks coming in result in 3 KD packs of select, 4 of standard and three of high feature, there is likely to be a problem. This is a very broad measure and a problem may only become apparent when production figures are tallied. This may be some time after the event.

Regular quality checks

Not all characteristics are assessed as part of normal grading. Regular quality checks can be made of:

moisture content and sample size.
This is the analysis of the readings taken during standard production checks to determine their regularity over time, the spread of results within the acceptable range and the number of readings outside the acceptable range. This data helps build up an understanding of species and can indicate systemic or emerging drying problems; and

drying stress and moisture profile.
Boards selected at random from racks being broken down in production are tested for drying stress and moisture profile in accordance with **AS/NZS 4787** for the target product quality. This standard establishes the number of samples to be taken for each class of drying and the methodology for testing.

The kiln or drying manager is usually responsible for supervising and analysing the result of these tests. Unacceptable variations in the readings should be reported to the other senior production staff and the causes traced and corrected.

Production samples should ideally be retained for at least two years. This is the stabilisation period currently being used when assessing timber floors. If they cannot be retained, the number, accurate size, moisture content and source of the sample should be recorded and retained.

Quality Audits

A quality audit is a regular and systematic assessment of drying induced characteristics in the timber that result in a loss of grade.

They are usually conducted once the timber is dry and milled. This is when most drying degrade is apparent. They can be carried out at any time during production if drying degrade is visible. The aim of quality audits is to identify poor drying practice and performance by:

- determining the type and quantity of drying induced grade reducing characteristics in production;
- providing a benchmark of drying quality over time; and
- building up a detailed understanding of the timber being handled and the equipment available to process it.

They complement ongoing product assessment during production and do not replace it.

Quality audits involve:

- **selecting a random batch of boards from production.**
  These should be selected so that they mirror the whole population of downgraded boards produced in a given period. Assuming normal grading processes are rigorous, only boards graded below ***Select*** should be examined. The sample should be large enough so that at least 20 boards with drying induced features are included. If more than one species or species group is being processed at the site, 15 boards of each major species or species group is needed. A smaller number of boards may be adequate for a minor species group;
- **examining the batch in detail.**
  Each board should be examined to identify the features that led to loss of grade. All drying induced, grade reducing characteristics listed above are important. The length of board affected by each type of characteristic should be noted on a standardised form;
- **analysing the results.**
  This is to determine the proportion of boards affected by drying induced characteristics and the type and regularity of those characteristics. Analysis should at least determine the proportion of clear board and board affected by end check, surface check and hit & miss;
- **determining the causes of these characteristics**.
  If the audit is the first on the site, this may require an investigation of production records for each step of the process. If the results differ

significantly from previous audits, the cause of the variation should be traced; and

Eliminating these causes where possible.

In the first audits on a site, the process may be both time-consuming and intense. They should be conducted by senior drying or production management staff or by external consultants working in cooperation with company staff.

As drying problems are eliminated, and species and equipment specific behaviour is more clearly understood, audits can be simpler, and analysis more routine.

Effective feedback

Effective feedback is necessary to maintain an adequate level of drying quality. The minimum required in drying is:

A formal internal feedback process. This would include:

checking procedures for all production stages;

a process for passing non conformance reports to responsible staff members;

a mechanism for withdrawing non conforming material from production; and

regular discussion between timber graders, drying staff and management.

15.2.2 Equipment Options

The fixed equipment for drying quality assessment is the same as for moisture assessment and is detailed in Module 17: Moisture Monitoring.

15.0: – DRYING QUALITY ASSESSMENT

15.2.3 Drying Quality Assessment Strategy

Monitoring Drying Quality and Degrade;

Drying degrade in products should be identified. To do this:

Drying induced, grade reducing characteristics and their causes should be recognised and understood;

Boards should be graded in accordance with the relevant product standard;

Grade reducing characteristics should be discussed regularly.

Drying degrade in production is quantified. To do this:

Stock monitoring procedures should be available and understood;

Stock monitoring should be capable of identifying broad grade recovery from a defined input or period within a week;

Quality audits should be conducted at least every month on a representative sample of production.

Drying quality should be assessed regularly. To do this:

Drying quality testing procedures should be available and understood;

Drying quality tests should be conducted on a representative sample of production.

Identifying & reporting problems for correction

Workable feedback mechanisms are maintained in place to identify and distribute details of individual and systemic problems. To do this:

An effective feedback mechanism should be maintained between operational staff in different production stages and between operational staff and management;

The results of drying quality tests, stock monitoring and the quality audits should be discussed among senior drying, production and management staff regularly;

These results should be used to correct drying practice.

15.2.4 Quality Control

Procedures should be established for:

Procedure	**General contents**
Register of grade reducing characteristics	Descriptions and images of common grade reducing characteristics on the site
Stock monitoring	Monitoring of grade recovery output against material input
Quality auditing	Regularity of audit, auditing process and reporting
Drying quality testing	Regularity of testing, testing process and reporting
Feedback mechanism	The process for passing information about production to others influenced by it
Staff accreditation	Training, qualifications & responsibilities
Equipment	Maintenance

15.2.5 Information Management

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Staff no.	Time & date
Unique rack identification no.	Board grade
Unique board identification no.	

Table 15.03 Attributes required or desirable when collecting samples for quality audits.

Required process control information	
Staff no.	Time & date
Unique board identification no.	Clear length
Board side (A or B)	Length per drying characteristic (repeats for each characteristic)
Moisture content	

Table 15.04 Attributes required or desirable when conducting quality audits.

15.2.6 Equipment Maintenance

The equipment maintenance requirement for drying quality assessment is the same as for moisture assessment and is detailed in Module 17: Moisture Monitoring.

15.0: – DRYING QUALITY ASSESSMENT

15.3 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

	1	2	3	4	5
Production and management staff understand the fundamentals of timber drying and the production process followed at the site.					
Graders and operators can recognise drying induced defects and their causes.					
Operators understand potential remedies for the recognised defects.					
Graders are rotated through tasks regularly.					
Checklists for each production stage are completed at least every three months.					
Feedback mechanisms are clear and effective.					
Regular feedback sessions are held between production and management staff.					
Drying quality tests are conducted on a representative sample of production.					
Samples are retained or documented in detail.					
Non conforming product is identified before each production stage.					
Non conforming product is removed from production for further treatment.					
Thorough quality audits are conducted at least every month.					

15.0: – DRYING QUALITY ASSESSMENT

15.4 Avoidable Loss

1. Monitoring Drying Quality and Degrade

Poor identification of production induced degrade - Unsatisfactory performance in production is not apparent or identified and material continues to be damaged or not properly dried. This can lead to reduced recovery and increased claims from customers for a poorly performing product.

Inadequate assessment of final drying quality - Finished timber may have an average moisture content within specification but unacceptable moisture content gradient across the thickness of the board. This timber will not perform adequately. Similarly, the board may have an unacceptable level of residual stress.

2. Identifying & reporting problems for correction

Inadequate auditing of product - Lack of auditing leads to damaging practices being continued with a resultant loss of material, grade and value. Production costs increase as non-conforming product continues along the production chain.

Confused lines of communication and areas of responsibility - Error, anomaly and bad practice is allowed to go undetected and uncorrected.

Inefficient feedback mechanisms - While unsatisfactory performance is uncovered, the action necessary to remedy it is not taken at all levels. Again, material is degraded or not properly dried.

16.5 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australasian Furnishing Research & Development Institute Limited, 3rd ed.

16.0: – MC MONITORING

16.0 CONTENTS

16.0: – MC MONITORING

16.1 Objectives

The objective during moisture content monitoring is to establish regular procedures to monitor the moisture content of the timber during the production process and use this to guide and improve the drying process.

16.1.1 Functions & Performance Requirements:

1. MC monitoring processes

Processes necessary for efficient, effective and economic MC monitoring are established and maintained.

2. Identifying & reporting problems for correction

Workable feedback mechanisms are maintained to identify individual and systemic moisture content problems.

3. Management of staff and equipment

Staff and equipment are available to conduct moisture content assessment activity safely and efficiently.

16.2 Management

16.2.1 Overview

Activity during moisture content monitoring is to establish regular procedures to monitor the moisture content of the timber during the production process and use this to guide and improve the drying process.

Drying timber is defined as removing moisture from a sawn piece to improve its serviceability in use. Drying occurs from the time the tree is converted into a log and continues until the milled boards cut from the log achieve moisture content equilibrium with the final service environment.

During production, the process of drying hardwood is broken into distinct stages: drying to FSP, and final drying to EMC. The main indicator that determines the rate the timber can move through or between these stages is its moisture content.

1. When to test for moisture content

Once boards or slabs have been racked, their moisture content needs to be monitored and shown to be at the target moisture content before the timber moves from one production stage to another. No additional processing cost should be added to the timber unless it is shown to be at the correct moisture content.

The stages for sampling the moisture content are included in Table 16.01,

Methods that can usefully sample moisture at these stages are included in Table 16.02.

Sampling stage	Reason for sampling
9.0. Air drying	
As drying progresses	To determine the rate of drying and probable date of advance to the next stage
Drying to a target moisture content	To determine that the timber has the correct moisture content to: ▪ load it into a predryer. Often, no definite average moisture target is set for this; ▪ load it into a reconditioner or final drying kiln. The general target moisture content for this is below fibre saturation point, about 18-20% average moisture content; or ▪ dispatch to a customer. The general target for this is at a final equilibrium moisture content, usually between 10 & 15%, or to a customer specification

10.0. Pre drying	
As drying progresses	To determine the rate of drying and time to advance to the next step of the schedule or predryer chamber
Drying to target moisture content	To determine that the timber has the correct average moisture content to be placed in a reconditioner or final drying kiln. The general target for this is below fibre saturation point, about 18-20% moisture content
12.0. Controlled Final Drying	
As drying progresses	To determine the rate of drying and time to advance to the next step of the schedule
Drying to target moisture content	To determine that the timber has the correct average moisture content and moisture gradient for equalisation treatment, final milling or dispatch to a customer. The general target for this is final equilibrium moisture content, usually between 9 & 14% or to a customer specification
13.0. Dry Milling	
At break down of the racks or remilling of packs taken from storage	To determine that the timber has the correct average moisture content and moisture gradient for milling or dispatch to a customer
14.0. Storage	
On receipt into store directly from the dry mill.	To determine that the timber has the correct average moisture content and moisture gradient for storage. These tests may not be necessary if the timber in the KD pack has come to the store directly from the dry mill
On receipt into store from other sites or stores.	To determine that the timber has the correct average moisture content and moisture gradient for storage or dispatch to a customer
On dispatch to customer	To determine that the timber has the correct average moisture content and moisture gradient for dispatch to a customer
16.0. Drying Quality Assessment	
During production audits	To determine that the timber in the audit sample has the correct average moisture content and moisture gradient and to indicate drying problems

Table 16.02. Sampling stages in each module

Sampling stage	Resistance Meters	Sample boards	Oven drying	Capacitance Meters
9.0. Air drying				
As drying progresses - general indicate of rate	Limited	Yes	Yes	
Drying to target moisture content	Yes	Yes	Yes	Yes
10.0. Pre drying				
As drying progresses - determining schedule set points	Limited	Yes	Yes	
Drying to target moisture content	Yes	Yes	Yes	Yes
11.0. Controlled Final Drying				
As drying progresses - determining schedule set points	Yes	Yes	Yes	Yes
Drying to target moisture content	Yes	Yes	Yes	Yes
12.0. Dry Milling				
At break down of the racks or remilling of packs taken from storage	Yes		Yes	Yes
13.0. Storage				
On receipt into store directly from the dry mill.	Yes		Yes	Yes
On receipt into store from other sites or stores	Yes		Yes	Yes
On dispatch to customer	Yes		Yes	Yes
13.0. Drying Quality Assessment				
During quality audits.	Yes		Yes	

Table 16.03. Useful measurement methods for each sampling stage

2. Moisture content and its measurement

The moisture content of timber is the weight of water contained in the wood. It is expressed as a percentage of the weight of the wood when it is oven dry.

This can be expressed mathematically as:

Formula 1: M.C.% = (Weight of water in the sample / Oven dry weight of the sample) x 100

A range of methods can be used to measure the moisture content of a piece of timber. They include:

- **Direct methods:**
  Oven testing; and
- **Indirect methods:**
  Electrical resistance measurement; Electrical capacitance measurement; and Sample Boards

Each method has advantages and limitations. These are discussed in detail below.

All methods have the limitation that they only measure generally the average moisture content of the section of timber involved. This sample is usually only a very small fraction of a board. In turn, this board may be only a small fraction of a pack or consignment of timber. As timber properties vary naturally from piece to piece, a single reading is an unreliable indication of the moisture content for a whole bundle of timber. The reliability increases with the number of samples taken from that bundle.

The number of samples required during each production stage is detailed in the relevant module.

Pieces taken for moisture content measurement should be either a:

- **representative sample** of the bundle being tested and taken from boards across the whole profile of the rack; or a
- **specifically selected sample** of the bundle representing a group having particular characteristics.

Representative sampling provides the most reliable results, as boards are taken at random from all parts of the bundle. However, for a rack, this means splitting the rack and testing boards in the centre rows of boards. This can be a time consuming and labour intensive process.

Specifically selected sampling is when an identified group of boards are sampled and their moisture content is used as an indicator for a representative sample. For example, slower drying quartersawn boards may be used for sample boards in a mill because experience has shown that when these boards are at the required moisture content, the rest of the rack is at least at this required moisture content or probably below it. While not as statistically reliable as representative sampling, selected sampling can provide a useful result.

With on-site testing, a useful correlation can be developed between the moisture sample of a specifically selected sample and the likely moisture content of a representative sample. For example, boards on the outside of the rack are probably drier than boards in the centre of the rack but they are much easier to access and sample regularly. After a short testing process, it is probably possible to develop a correlation between the average moisture content readings for the boards on the outside of a rack to boards taken at random from all parts of it.

Though this correlation may need to be established for the major seasons (winter, summer, wet, or dry), developing it may significantly simplify moisture measurement and provide greater confidence in the measured readings.

3. Oven drying

Oven drying is a direct and the standard reference method for determining the moisture content of a test sample. It is also the most reliable and accurate method. The process of performing an oven dry test is detailed in **AS 1080.1: 1997** Timber Methods of test – Moisture Content.

It involves taking a test sample about 30mm long from a board, weighing it and placing it into an oven at 103±2°C. It is then periodically reweighed until it reaches a constant mass. This is its oven dry weight. The difference between the initial weight and oven dry weight is the weight of water that was originally in the sample. The moisture content is then calculated as:

Formula 2: M.C.% = (Initial weight of the sample- Oven dry weight of the sample)/ Oven dry weight of the sample x 100.

For using a calculator, this formula is the same as:

Formula 3: M.C.% = (Initial weight of the sample/Oven dry weight of the sample-1) x 100.

For example, if the initial weight of the sample is 154.4 g and the oven dry weight is 95.6g, then using Formula 2:

M.C.% = (154.4 - 95.6) / 95.6 x 100 = 58.8 / 95.6 x 100 = 61.5%

Using Formula 3:

M.C.% = **<**(154.4 / 95.6) – 1> x 100 = (1.615 - 1) x 100 = 61.5%

Oven dry testing can also be used to determine the moisture profile of the sample. Smaller samples are cut from the edges of the initial sample to an established pattern. These smaller samples are then weighed and dried and the moisture content calculated. The simplest pattern of these detailed in **AS 1080.1: 1997** is shown in Figure 16.1. Normally, the sample is about 35 mm long taken at least 400 mm from the end of a board.

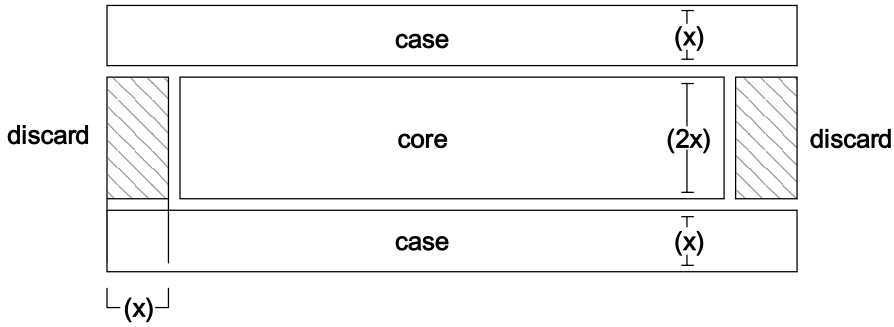


Figure 16.01. Cutting samples to establish a moisture gradient

The two outside or case pieces can be weighed together to give a heavier sample, or separately to compare the moisture contents of each face of the board.

While generally very accurate, the disadvantages of oven dry sampling are that it is relatively time consuming, samples take up to a day (or longer) to dry in the oven, and sampling is destructive.

The accuracy of oven dry testing is dependent on the control accuracy of the oven, the accuracy of the equipment used to weigh the samples, and the mass of the sample. The smaller the mass of the sample or the less accurate the equipment, the more uncertain the result.

The following example shows that an error of one percent in measuring the oven dry weigh results in a difference of at least one percent in the calculated moisture content.

Initial Weight	Oven dry weight	Calculated moisture content
33.3 grams	29.7 grams	12.8%
	30.0 grams	11.7%
	30.3 grams	10.7%

Table 16.04. Error from inaccurate weighing of samples.

3a. Preparing oven dry samples

Oven dry samples should be cut from timber that is sound and relatively free of gum veins, resin pockets and knots. To provide a conservative result, they should be selected from what is probably the slowest drying timber in the rack.

Sample boards are cut and prepared as follows:

- Cut the sample at least 500 mm from the end of the board. This avoids the possibility that rapid end drying may have occurred. The sample should be at least 30 mm long and not weigh less than 50 grams when dry;
- Scrape or sand off all loose splinters and sawdust. Any bits falling off during subsequent measurement will result in a higher moisture content reading;

- Immediately weigh the sample. This is particularly important in warm and dry conditions. If the sample can't be weighed immediately, it should be sealed in a dry plastic bag until it can be weighed;
- Mark the sample with a unique identification number. This is often the number of the rack or combined with it;
- Place the samples in an oven controlled at 103° ± 2°C. Conventional ovens will take at least 24 hours to dry samples. Fan forced ovens may take about 12 hours;
- Remove the samples from the ovens after the expected drying time. Weigh the samples immediately, as the timber will pick up moisture very quickly. If the timber must be held for some time before weighing, it should be stored in a desiccator, a sealed chamber containing silica gel, which absorbs all of the moisture out of the air in the chamber;
- Record the weight and the identifying number;
- Return the samples to the oven. After 2 to 5 hours, reweigh the samples. A sample is considered to be dry if the second weight is within 0.2 % of the first;
- With samples placed in a dish, weigh the empty dishes and subtract these weights from the wet and dry weights to give the sample weights;
- Record the weights, identifying numbers and calculations progressively;
- Through all the steps, ensure that dust, debris, or sawdust does not contaminate the scales or samples.

4. Electrical Resistance moisture meters

Electrical resistance moisture meters are an indirect method of measuring moisture content and their use is also detailed in **AS 1080.1: 1997** Timber Methods of test – Moisture Content.

As the name suggests, electrical resistance moisture meters measure the electrical resistance of the wood which directly relates to the wood's moisture content if the piece is below FSP. Oven dry wood is a very good electrical insulator and has a very high resistance. However, water has low resistance. So, the high resistance of timber falls as the amount of water in the timber increases. This relationship continues at known (but non-linear) rates until the timber is at fibre saturation point. Above fibre saturation point, the resistance change with a change in moisture content is relatively small and the relationship inconsistent.

Measurements are taken by placing two or more electrodes into the wood and reading the resistance between them. If the electrodes are insulated except at the tip, the reading is for the path of least resistance in the wood between the tips of the electrodes. If the electrodes are not insulated, the reading is for the path of least resistance in the wood anywhere it makes contact with the electrodes. Generally, for uninsulated electrodes (eg. nails) the resistance will be measured at the wettest point between the electrodes.

In either case, the resistance is then converted to a moisture content and displayed on a dial or digital display.

The accuracy of resistance moisture meters is highest at lower moisture contents and decreases as the actual moisture contents approaches fibre saturation point, generally about 30% moisture content. They are inaccurate above that figure, though a correctly configured meter may still be useful in assessing drying trends.

At lower moisture levels, resistance meters are sufficiently accurate and easy to use so that quick readings can be taken at many locations.

4a. Correction of resistance moisture meter readings

The relationship between moisture content and resistance changes with the species of the timber and with its temperature. Meters are generally calibrated for Douglas Fir at 20 °C. Readings have to be corrected first for temperature and then species.

Corrections factors are listed in **AS 1080.1: 1997** Timber Methods of test – Moisture Content.

4b. Electrode type

Resistance moisture meter electrodes come in a variety of types. The most common being the blade, uninsulated pin and insulated pin types.

- Blade type electrodes are fast to use and still commonly used in production areas. These electrodes are strong and durable and do the minimum of visible damage to the timber tested.
- Uninsulated pin electrodes are commonly used as uninsulated pins in a slide hammer assembly or as a pair of nails hammered in a piece of timber. If nails are used then the meter is connected to them with either a nail contactor or alligator clips.
- Insulated pin electrodes only expose the tip of the pin to the wood. The body of the pin is insulated. This allow the meter to measure an indication of the moisture gradient as the pins are hammered into the wood.

The resistance of the wood also changes with the direction of the grain. Most moisture meters are calibrated for reading from a pair of pins positioned parallel to the grain of the wood. However, always follow the manufacturer's recommendations.

Figure 16.02 Blade electrodes

Figure 16.03. Nail (pin) contactor for a resistance meter

4c. Using resistance meters

Resistance moisture meters assess the moisture content of the timber as:

- Portable units used on random boards during production. Usually a particular number of boards are tested to provide a close approximation of the average moisture content of a rack after air or predrying, or as it is broken down.
- Portable units used at fixed locations in a rack. This assesses the rack during air or predrying, or in some kilns. The locations are often:
  - several pairs of nails driven into the side of racks and used as constant measurement positions or
  - nail assemblies placed in the racks as they are being built. Wire tails are left hanging out of the side of the rack and the moisture meter is connected to them with alligator clips.

- Fixed units used at fixed locations in a rack. These are used to assess the rack during predrying, or kiln drying. In advanced systems, these are coupled directly into computerised kiln controls.

Figure 16.04. Row of testing points for a resistance moisture meter

Figure 16.05. Sampling the testing points

4d. Testing Procedures

A workable test procedure for using a resistance meters is:

- Ensure that the batteries in the meter have sufficient charge. Most meters are equipped with a battery test phase;
- Choose the right pins for the meter, either blade, uninsulated or insulated. Insulated pins are not affected by a wet timber surface;
- Choose the location for the measurement. It should be at least 400mm from the end of the board and in clear timber;
- The distance between the pins must be to the meter manufacturer's recommendations;
- Drive the pins into the timber parallel to the grain (unless otherwise specified by meter manufacturer);
- Drive insulated pins to a depth of one fifth of the timber's thickness to get an indication of the average moisture content;
- Correct the moisture content reading for temperature;
- Correct the temperature-adjusted reading for species;
- Take care to avoid getting the meter, cable or electrodes wet;
- Meters must be regularly calibrated using a standard resistance block.

4e. Considerations and limitations

There are several major considerations when using resistance moisture meters.

- **Moisture distribution:**
  Resistance moisture meters will always register the moisture content at the wettest point between the bare parts of the electrodes. If uninsulated nail electrodes are driven into the centre of a piece of timber, they will read the moisture content of the centre of the board during fine weather but only the surface reading if the timber has been recently wet.
- **Thickness of specimen:**
  The length and penetration of electrodes must be taken into account. For example, blade type electrodes are usually only 10-15 mm long and so are only useful in determining the core moisture content on thin stock. Longer nail or pin type electrodes will penetrate further into thick stock.
- **Estimating wood temperature:**
  As discussed above, resistance moisture meters are normally calibrated for testing timber at 20 °C so the reading has to be corrected for the temperature of the wood. Wood is a good insulator and its temperature changes slowly unless temperature variations are high. It tends to even out from day to night. So, the wood temperature should not be assumed to be that of the air or even the temperature of the kiln. It should be estimated from the average likely temperature.
- **Contact:**
  There needs to be firm contact between electrodes and the wood. Poor electrical contacts increase the resistance and may result in lower readings.

- **Calibration:**
  Electrical equipment in a production environment should be checked to an established procedure regularly to ensure it is functioning properly. The accuracy of meter readings should be confirmed by occasional oven dry testing.
- **Preservatives, glues and additives:**
  Glues and preservatives such as CCA affect the resistance of timber significantly. Preservative treatment appears to affect readings in sometimes unpredictable ways. Resistance readings taken on treated material should be regarded as having limited reliability.

5. Electric capacitance moisture meters

Electrical capacitance moisture meters are another indirect method of measuring moisture content.

These meters measure the varying capacitance of wood with changing moisture content. They use a radio frequency oscillator to supply the power to make their measurements and measure the amount of water per unit volume in the wood. As the moisture content is proportional to the amount of water per unit weight, the relationship between weight and volume or density therefore affects the readings. The relations between the dielectric properties and moisture content are not as reliable as for resistance type meters because of their sensitivity to density variations in the timber.

They may be used over painted or polished surfaces without error and without damaging the surface. The lack of electrodes requiring physical contact with the wood being tested makes these units well suited to continuous monitoring on production lines. They can also be used with an extension to take moisture readings inside a rack. Capacitance meters are much less sensitive to temperature than resistance meters and will function at temperatures up to 150^{0}C

The readings of capacitance meters must be corrected for the density of the timber being tested. However, these corrections only account for the average density of the material and do not account for variations in density within and between boards. Species corrections are not applicable to dielectric meters.

It is important to consider:

- **Density:**
  Correction data for density are required when using capacitance type meters. Before using any moisture meter, the availability and reliability of the correction data applicable should be established and calibrated against oven dried samples.
- **Moisture Distribution:**
  It is not possible to measure a moisture gradient using a dielectric meter. The actual moisture content measured on a board with a moisture gradient may vary from instrument manufacturer to manufacturer.

- **Thickness of the board**:
  The penetration of these units varies with the design. Reference to the instructions should be made on this matter.
- **Contact:**
  Some meters require firm contact between electrodes and wood, others do not require contact. Follow the manufacture's recommendations.
- **Preservatives, Glues etc:**
  Any meter readings taken on treated material should be regarded as having limited reliability. Preservative treatment appears to affect readings in sometimes unpredictable ways.

6. Sample boards

Sample boards are used to gauge the moisture content of a rack of timber outside the ranges of reliable readings from resistance and capacitance moisture meters.

A sample board is a length of the timber about 500 mm long taken from one of the unseasoned boards in a rack. The moisture content of the sample board is determined initially by cutting a small piece from the board and determining its moisture content by oven drying. The moisture content of this small sample is then assumed to be the average moisture content of the sample board.

The ends of the sample board are then sealed immediately after cutting to reduce end drying and the sample board is weighed. With this weight and the moisture content calculated from the small section, the estimated oven dry weight of the sample board can be calculated.

Formula 3 used for oven drying can be re-expressed as:

Formula 4: Oven dry weight = Initial <wet> weight of the sample / (M.C.% +100) x 100

For example, if the initial weight of sample board is 3kg and the moisture content is 61%, the calculated oven dry weight is:

Oven dry weight = 3.0 x 100 / (61+100) = 300 / 161= 1.863kg

When the oven dry weight of the sample board is known, it is then possible to calculate the moisture content at any subsequent time by weighing the board again. The amount of weight lost relative to the initial reading is used to calculate the new moisture content of the sample board and by inference, of the timber in the rack.

For example, suppose that the weight of the sample board dropped from 3.0 to 2.61 kg after a period of air drying.

Applying Formula 3, the moisture content = (2.61 / 1.863 - 1) x 100= 40.1%

Sample boards are prepared when the rack is being built, end sealed and placed so that they can be removed at any time for weighing and be returned to the rack. As they are to be used to gauge the average rate of drying throughout the rack, they also need to be placed in representative positions. Generally, they are placed at least two rows in from the edge of each rack about half way up.

Figure 16.06. Sample board with two outside cover boards

Once established, sample boards can be a convenient means of determining the progress of drying and estimating the moisture content of the rack. They work reasonably accurately at any moisture content and so can be used in airdrying, predrying or in the kiln. They can also be used to test the uniformity of drying within a kiln or the different rates of drying in stacks in an air drying yard.

Sample boards have their limitations. They are a short piece of timber that may dry more quickly than a larger piece. They take longer to make a reading than a resistance moisture meter and only provide one reading that is assumed to represent a much larger group. They may also not be readily available, such as in a kiln. Usually, the sample board reading is confirmed by additional moisture meter or moisture probe readings and these meters are used where samples boards are inappropriate, such as in a hot kiln and the dry mill.

6a. Preparation of sample boards

The boards from which sample boards are cut should be sound and sufficiently free from gum veins, resin pockets and knots to allow the samples themselves to be comparatively clear. They should be selected from the slowest drying timber in the rack. This would generally be the densest, quarter sawn timber, as this generally dries more slowly than less dense, back sawn material.

If more than one sample board is used, each should be cut from a separate board.

Sample boards are cut and prepared as follows:

- After selecting a suitable board, dock at least 500 mm from the end. This avoids the possibility that rapid end drying may have already occurred;

- Cut the sample to length so that it will fit between the rack sticks of an intended rack;
- As soon as the sample board has been cut, cut smaller moisture samples from each end. These smaller moisture samples should be at least 15mm long and not weigh less than 50 grams when dry;
- Scrape or sand all loose splinters and sawdust off the samples. Any loose bits falling off during drying will cause a higher moisture content result;
- Coat both ends of the sample board with either three coats of end sealer, three coats of good quality acrylic exterior grade paint or a coat of medium bituminous paint;
- Immediately weigh the sample board and the two smaller moisture content samples. This is particularly important in warm and dry conditions;
- If the smaller moisture content samples cannot be weighed immediately, they should be sealed in an airtight bag until they are weighed;
- Mark the sample board and the moisture content samples with the same unique identification number. This is often the number of the rack;
- Return the sample board to the rack;
- Obtain the moisture contents of the smaller moisture samples using the oven dry method, described above;
- The average of the moisture contents for the two smaller moisture sections is taken as the moisture content of the sample board;
- Record all the weights and calculations as the process progresses.

6b. Placing sample boards in the stack

Sample boards must be positioned so that they experience the same air circulation and conditions as the rest of the timber in the rack. Their supports should not impede or encourage air movement across or around the board.

Sample boards should be placed into the rack where practicable while still allowing them to be removed and replaced. They should not be placed on the outside of layer of the rack as they may then dry more rapidly than the rest of the stack. They can be positioned on the side or end of the rack, usually on additional short rack sticks. The location for the sample board should be marked on the rack with paint, and relevant identification numbers marked on the timber near by.

The sample board itself should not be painted, except at the ends, as this will change the rate it dries.

For production purposes, it is necessary to have at least one sample board for each rack in a stack. More samples are necessary if the accuracy of the sample board moisture content does not adequately reflect the average moisture content of the rack.

Figure 16.07. Building a test sample into the rack as it is assembled

Figure 16.08. Test sample is removed and prepared after air drying

Figure 16.09. Test sample built into the end of a rack so that it can be accessed from the kiln door

Figure 16.10. Weighing the test sample with balance scales

6c. Sample boards & load cells

Sample boards can also be combined with or positioned on load cells that weigh the sample continuously to provide continual and remote moisture monitoring.

Load cells simplify the use of sample boards considerably and allow them to be positioned throughout a charge. Small, low load cells can be used inside a rack and support the sample board, or between stacks or in the air plenum of predryers and kilns. When they are used outside the rack, the sample board can be suspended from a single load cell, or be supported on a single or several cells. Inside or outside the rack, the load cells are cabled back to the control room where the weight of the sample is converted to a moisture content.

When the sample boards are used outside the racks, they may dry at a different rate than material inside the racks. A correlation needs to be developed between the moisture content measurement at each sample board location and the average moisture content of the adjacent racks or stacks. This correlation needs to be developed across the required moisture content range and applied to the sample board readings.

The only practical way to develop this correlation above fibre saturation point is by drying a test charge that has 2 -3 sample boards in each rack of the outside stacks of the charge.

8. Systems comparison

The two major methods for measuring moisture content during production are sample boards and resistance moisture meters. Other methods are usually restricted to specialist or limited applications.

The two major systems of measurement used in industry are:

- Sample boards as the primary measure, supported by resistance measurement between stages; &
- Resistance measurement only with a combination of fixed sample positions and random measurement.

Both systems have their advantages and disadvantages. These include:

Issue	**Sample board**	**Resistance meter**
Precision of the individual reading	Determined as an average of oven dry weights, the reading is a direct measure of moisture in the piece and should be accurate at all moisture contents.	Measuring a surrogate for moisture content, electrical resistance, the precision of the reading is influenced by factors that affect resistance such as the grain direction, the positioning of the pins in the piece, the presence of any surface moisture and the absolute moisture content. Resistance readings are most accurate at lower moisture contents above 6% and are not reliable over FSP (about 30% moisture content). Correction factors for temperature and species must also be applied to the reading. If they are used in a kiln, accuracy is increased if cabling lengths are kept to a minimum or wireless transmission units are used.
Reliability of the reading as an indicator of the moisture content of the bundle	Even through it is end-sealed, the sample board is a single short piece of timber that probably dries faster than a full length board.	Many samples can be measured quickly, increasing the reliability of the result if the timber is within the meter accurate working range. In practice, this is a comparison between a small number of accurate oven readings to a larger number of less accurate resistance readings.
Ease of use	Require skill to establish the sample and both skill and care to retrieve and weigh	Very easy to use but racks have to be split so that

	samples.	central boards can be tested.
Time involved	Not extensive but requires samples to be collected, taken to a weighing station and returned.	Individual sampling is quick but more samples are needed.
Versatility	Access to the sample boards in a kiln or predryer can be difficult. There are also safety concerns if the kilns are at a high temperature.	They can be used anywhere and can be wired so that they can sense remotely. While they may give a useful indication of the change in moisture content over 30%, the moisture content must be below this before readings are reliable.
Computerisation	Can only be collected digitally and continually if load cells are incorporated into the system.	Can be connected directly to a data acquisition system for continuous monitoring and recording.

Table 16.05. Comparison of moisture measurement methods

The more effective method for any given site will vary with the product and production strategy pursued and the skill of the staff.

16.2.2 Equipment Options

The equipment for moisture monitoring includes moisture meters, ovens, scales, and saws.

1. Resistance moisture meters

A resistance moisture meter is an electronic device that measures the electrical resistance of timber at the points of contact between the timber and the pins of the meter. Algorithms built into the meter then convert the resistance measured into a reading of the timber's moisture content. The meters are usually calibrated for Douglas Fir and the readings must then be corrected for temperature and species.

The quality, accuracy and reliability of moisture meters vary considerable, often with their price. Only reliable, good quality meters should be used where the moisture content readings are used to make production decisions.

Figure 16.11 Resistance meter with blade electrodes

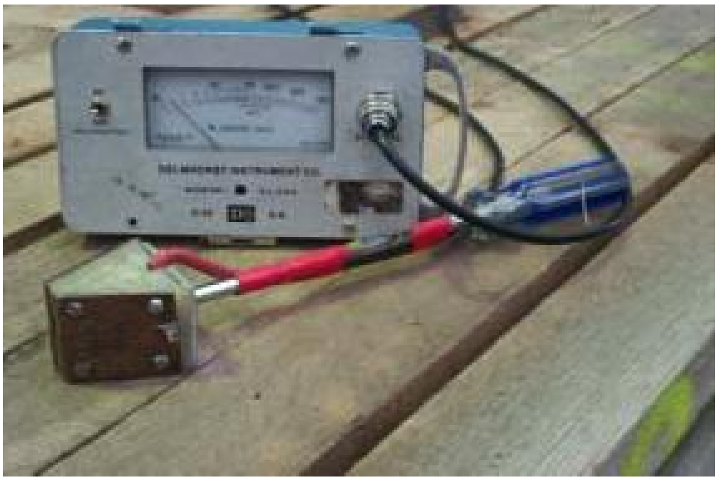


Figure 16.12 Resistance meter with nail connector

2. Capacitance moisture meters

An electrical capacitance moisture meters is an electronic device that measure the varying capacitance of wood with changing moisture content. Algorithms built into the meter convert the capacitance measured into a reading of the timber's moisture content. They use a radio frequency oscillator to supply the power to make their measurements and measure the amount of water per unit volume in the wood. As the moisture content is proportional to the amount of water per unit weight, the relationship between weight and volume or density therefore affects the readings.

If used extensively, correction factors for local species can be developed in a mill by comparing a significant number of oven dry readings with capacitance meter readings.

Like resistance meters, the quality, accuracy and reliability of capacitance moisture meters vary considerable, often with their price.

3. Ovens

Both conventional and fan forced ovens can be used to give a conventional oven dry result.

3a. Conventional ovens

The standard operational temperature of these ovens is 103 + /-2 °C. These ovens use natural convection to circulate the air inside the oven. If the temperature is below 100 °C then the samples may not dry out completely and if above 106 °C they may start to char or evaporate the extractives.

They should be fitted with a high precision thermostat and thermometer so that temperature can be accurately maintained and checked.

3b. Forced draught or fan forced ovens

The standard operational temperature of these ovens is also 103 + /-2 °C. These ovens use a small fan to circulate the air. They are usually able to dry sections in less than 24 hours. They are rapidly taking over from normal convection ovens, as they will produce the same result with less delay.

They should also be fitted with a high precision thermostat and thermometer so that temperature can be accurately maintained and checked.

3c. Microwave oven

Microwave ovens can be used instead of conventional ovens to obtain oven dry weight in about 20 minutes. However, microwave ovens have severe limitations because:

- thin test sections must be used and a very sensitive scale is required;
- the drying time is dependent on species and the moisture content level, making it difficult to arrive at a safe standard time for achieving the true oven dry condition;
- their use is tedious and time consuming. Samples have weighing repeated;
- only one or two samples can be dried at a time, whereas 50 or more can be dried at once in a conventional oven;
- over drying is a problem leading to incorrect moisture content results.

For these reasons, drying samples in a microwave does not comply with **AS 1080.1: 1997** Timber Methods of test – Moisture Content.

4. Scale

Any accurate balance that reads to 0.1g or smaller accurately and reliably is suitable. Most commonly used today are electronic, direct-reading, top pan balances. These units are quick and accurate. They are ideal in a large operation where a number of M.C. sections have to be weighed every day.

5. Saws

Hand, circular or band saws can be used to cut samples. It is important that the saw is sharp and that the cutting rate is not too fast in order to avoid errors caused by heating of the sample and subsequent partial drying.

Figure 16.13. Testing Station with oven and electric scales

Figure 16.14. Preparation station with docking and band saws for cutting test samples

16.2.3 MC Monitoring Strategy

1. MC monitoring processes

Processes necessary for an efficient, effective and economic MC monitoring should be established and maintained. To do this:

- Moisture sampling stages should be available and understood;
- Moisture content should be sampled at the stages detailed in Table 16.05;
- Moisture content sampling procedures should be available and understood;
- Moisture content sampling procedures should detail;
  - the sampling method used and the number of samples taken at each sampling stage;
  - Detailed procedures for selecting the samples and conducting the tests in each sampling method;
  - The marking and documentation requirements for each method.
- Moisture sampling should be conducted on representative samples of production;
- Analysis of moisture sample should be discussed among senior drying and production staff regularly;
- The results of the analysis should be used to correct drying practice; and
- An effective feedback mechanism is maintained.

16.2.4 Quality Control

Procedures should be established for:

Procedure	**General contents**
Moisture sampling stages	The stages of production that require sampling and the method to be used
Moisture sampling processes	The sampling method to be used at each stage, the number of samples taken, analysis of results
Moisture measurement methods	Procedures for taking moisture measurements for the selected methods
Feedback mechanism	Forms and reporting process
Staff accreditation	Training, Qualifications & responsibilities
Equipment	Maintenance & Calibration

16.2.5 Information Management

Information required for later process control should be collected and passed with the packs effectively. This includes the following:

Required process control information	
Unique Rack / KD pack identification number	Likely wood temp
Position number (for kilns & predryers)	
Staff number	MC measurement position
Reading time & date	MC meter reading
Production stage	Adjusted MC reading
Production location	Staff Comment

Table 16.06. Attributes required or desirable for moisture content control with resistance type meters

Required process control information	
Unique sample boards number	Sample weight
Staff number	Adjusted MC reading
Reading time & date	Staff Comment
Production stage	
Production location	
Desirable additional information.	
Sample location	

Table 16.07. Attributes required or desirable for moisture content control with established sample boards

Required process control information	
Unique rack / KD pack identification number	Initial sample board weight
Unique sample board number	Initial MC reading
Staff number	Staff comment
Reading time & date	

Production stage	
Desirable additional information.	
Sample location	

Table 16.08. Attributes required or desirable for establishing sample boards

1. Marking &tagging

Identification number on sample boards or resistance meter sample positions should be weather resistant and easy to see. Pens used to mark the samples should be permanent. Stamps or paint should be permanent and not be readily obscured by dust.

All tagging systems have to be able to survive any processing stage with less than a 0.5% loss rate.

2. Record collection & processing

Sufficient information should be available during any moisture content reading to determine the batch, unique identification number and location of each rack being tested.

Moisture content records should be recorded automatically, or on a standardised recording sheet.

16.2.6 Equipment Maintenance

The equipment used to monitor the timber's moisture content needs to provide an accurate reading so it must be regularly calibrated.

Test equipment, such as scales, should be calibrated by an external agency at least every two years. They should be checked against a local measure, such as a test weight on a scale, at least every month.

Resistance moisture meters are calibrated against a resistance test block to the manufacturer's recommendations. A relatively simple process, resistance meters should be calibrated daily. They should be calibrated against a reading determined by the oven dry method at least every three months.

Other calibration processes should be in accordance with the manufacturer's instructions.

16.3 Checklist

Use this checklist to monitor key aspects of your operation. Mark each item on the following scale:

1	2	3	4	5
Very bad, never	Bad, rarely	Satisfactory, usually	Good, almost always	Very good, always

	1	2	3	4	5
The production stages, sampling rate and methodology for moisture content measurement are established in procedures.					
The moisture content measurement procedures are followed.					
All measuring and test equipment is calibrated at set intervals or following prescribed events.					
The readings from all moisture measurement methods are periodically calibrated against the oven dry method.					

16.4 Avoidable Loss

Avoidable loss from inadequate moisture monitoring occurs in all production stages after the timber is racked. This is detailed in the relevant modules.

Avoidable loss also results from ineffective moisture content monitoring procedure and processes

1. MC monitoring processes

- **Insufficient or incorrect monitoring** – If there are not enough moisture content readings or they provide incorrect readings, many production processes will begin, change or end at inappropriate times. This exposes the timber to conditions that can cause drying damage, wastes time and / or resources, and can allow material onto the market that is not fit for purpose.

2. Identifying & reporting problems for correction

- **Identified problems are not corrected** - Cost, not value, is added to products. Indirect losses are incurred in inefficient production. Direct losses usually follows as damaged material is re-mould to a smaller section or downgraded. Litigation or user claims can then occur due to the material not being fit for purpose.

16.5 References

Denig, J. Wengert, E.M. & Simpson, W.T. 2000, *Drying Hardwood Lumber*, Gen. Tech. Report. FPL-GTR-118, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA.

Peck, E.C. 1999, *Air Drying of Lumber*, Gen. Tech. Rep, FPL-GTR-117, U.S Department of Agriculture, Forest Service, Forest Products Laboratory, WI, USA

Waterson, G.C. 1997, *Australian Timber Seasoning Manual*, Australian Furnishing Research & Development Institute Limited, 3rd ed.

17.0: Glossary

This glossary lists terms that occur in the text or are useful in drying and handling timber.

Terms are generally listed alphabetically. Terms that include several words are usually listed under the key concept in the term. For example, the term *initial moisture content* is listed under the more general term *moisture content.*

Term	Explanation
Air Dried	The condition of timber allowed to dry and equilibrate in the prevailing natural conditions, usually 10% to 20% moisture content.
Air Drying	The process of drying green timber or other wood products in the prevailing natural conditions. **Yard** - a site where stacks of timber are positioned in the open or in partially enclosed buildings. The stacks may be arranged in the yard to moderate or enhance the prevailing natural conditions.
Air Velocity	The velocity of air in the passages between rows of boards in a rack.
Anemometer	Instrument for measuring velocity of airflow.
Anti-stain Chemical	A chemical applied to timber to prevent or retard chemical or fungal stain development.
Attribute	A characteristic of an action or production stage in information processing, such as a kiln number or a log grade.
Back sawn	Timbers sawn so that the growth rings are inclined at less than 45 degrees to the wide face.
Baffle	A rigid or flexible barrier used to direct and control the flow of air.
Batch	In drying, a group of timber with similar drying and product characteristics.
Bearer, Bolster	A section of wood or other material, generally about 100 x 75 mm, placed between or under racks to provide space for fork lift tynes. Synonymous with 2.
Board	A piece of sawn, hewn, or dressed timber of greater width than thickness.
Botanical	**Classification** - An internationally accepted system of scientific classification and naming of plants. It subdivides similar plants into subdivisions, classes, orders, families, genera, and individual species. For example, messmate (Eucalyptus obliqua): Species: obliqua Genus: Eucalyptus Family: Myrtaceae

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Term	Explanation
	Order: Myrtales Class: Dicotledonae Subdivision: Angiospermae **Name** - The botanical names of species and their relationship to trade names are defined in AS/NZS 1148: 2001 Timber – Nomenclature – Australian, New Zealand and imported species.
Bound Water	Water molecules bound into the cell wall of timber. They are weakly bound chemically to the molecules of the cell wall and energy is required to break them free
Bow	A curvature in the longitudinal direction of a board causing the wide face to move away from a flat plane.
Burl	1. A hard, woody outgrowth on a tree, more or less rounded in form, usually resulting from the entwined growth of a cluster of buds. Burls are often the source of the highly figured veneers used for appearance purposes. 2. In timber or veneer, a localised severe distortion of the grain generally rounded in outline.
Cambium	A thin layer of tissue between the bark and wood that repeatedly subdivides to form new wood and bark cells.
Case Hardening	A drying defect characterised by the presence of compression stresses in the outer zone and tensile stresses in the core. It occurs when rapid drying has caused permanent set or stretching of the outer zones of a piece of wood.
Cell	In wood anatomy, a general term for the minute units of wood structure that have distinct walls and cavities, including wood fibres, vessel segments, and other elements of diverse structure and function. In dense hardwoods, the fibre cells are thick walled and make up the major part of whole zones of wood. These fibrous zones dry slowly.
Cellulose	The carbohydrate that is the principal constituent of wood and forms the framework of wood cells.
Check	**Surface** - A separation of fibres along the grain forming a fissure, but not extending through the piece from face to face. Checks commonly result from stresses built up during seasoning. They tend to run radially, across the growth rings. **Internal** - In timber, separation of the fibres in the interior of the piece, usually in the radial direction. The checks are often not visible on the surfaces and may not be visible on a cut section. **End** - A failure, usually radial on the end of a log, timber, or board resulting from stresses caused by too rapid or

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Term	Explanation
	excessive end drying.
Collapse	Abnormal and often irregular shrinkage occurring above fibre saturation point. Shrinkage due to collapse is distinguished from normal shrinkage by the fibres changing their shape (or collapsing) during drying. Collapse is visible in quartersawn boards as a ribbed 'wash board' appearance. In back-sawn material it shows as excessive shrinkage.
Compression	A state or condition of being pushed or shortened by a force. **Failure** - Deformation or fracture of wood fibres across the grain resulting from excessive compression along the grain.
Conditioning	In kiln drying, a process for relieving the stresses and reducing moisture content variations present in the wood at the end of drying. Generally achieved by applying a comparatively high temperature and high humidity treatment near the end of kiln drying.
Correction	**Species** - An adjustment of the readings of the resistance-type electrical moisture meter to compensate for different species of wood. Corrections are tabulated in AS/NZS 1080.1:1997. **Temperature** - An adjustment of the readings of the resistance-type electrical moisture meter to compensate for changes in the temperature of the wood. Corrections are tabulated in AS/NZS 1080 1:1997
Coupe	A defined area of forest, usually with consistent characteristics.
Creep	Increase in deformation following prolonged loading.
Cup	A curvature across the grain or width of a piece of timber.
Decay	The softening, weakening, or total decomposition of wood substance by fungi.
Degrade	In timber and other forest products, the result of any process that lowers the value of the wood.
Density	As applied to timber, density is the mass of wood substance and moisture enclosed within a piece divided by its volume. As the mass will vary depending on the amount of moisture in the piece, density is often expressed at a specified moisture content, usually 12%. **Air Dry** - Density at an air dry moisture content, usually 12%. **Basic** - The ratio of the oven dry mass of a wood sample to its green volume. **Exceptionally Low** - Pieces abnormally low in density for the

Term	Explanation
	particular species, ie below 75 percent of the average density for that species at 12 percent moisture content or some other designated minimum. **Green** - Density based on mass and volume in the green condition. **Nominal** - Density based on mass and volume at the time of testing. **Oven-dry** - density based on oven-dry mass and oven-dry volume.
Depression	The difference between dry and wet bulb temperatures. It is a measure of humidity.
Dew Point	The temperature at which the relative humidity of a body of air is 100 per cent. Further cooling causes vapour in the air to condense as water droplets.
Diamonding	The change of a square or rectangular section timber to a diamond shape during drying. Diamonding occurs where the growth rings pass through diagonal corners of the section of the piece and is caused by the difference between tangential and radial shrinkage. It is a form of distortion.
Diffusion	Movement of water through wood from points of high moisture content to points of low moisture content by molecular diffusion.
Diffusivity	A measure of the rate of moisture movement through wood by diffusion as a result of differences in moisture content
Dimension	**Sawn** - The nominal dimension of the board plus the overcut to allow for shrinkage. **Nominal** - The general intended size of the dry rough sawn board. **Machined** - The actual size of a machined or moulded board
Dimensional Change	Changes in the size of a piece of dry timber as its moisture content changes to be in equilibrium with the surrounding atmospheric conditions.
Dipping	Submerging timber in a dipping vat containing fungicides or other chemicals to prevent stain or decay.
Discoloration	Change in the colour of wood caused by fungal or chemical stains, weathering, or heat treatment.
Distortion (Warp)	Change in the shape of a piece of timber due to drying or other sources of stress. Distortion may take the form of cup, bow, twist, spring or diamonding.

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Term	Explanation
Dryer	A chamber or apparatus used for drying or conditioning timber or veneer in which the temperature, humidity and velocity of the circulating air are usually controlled.
Drying	The process of removing moisture from timber to improve its serviceability in use. Also see Seasoning. **Defect** - An imperfection developing during drying that decreases the value of a piece of timber. **Degrade** - A reduction in timber grade and volume as a result of drying defects **High Temperature** - In kiln-drying wood, use of dry-bulb temperatures of 100 C (212 F) or more. **Loss** - The reduction in volume and grade quality that can be attributed to the drying process. **Pre-treatment** - Special process taken before drying or early in the drying process to accelerate drying rate, modify colour, or prevent checks and other drying defects. **Rate** - The loss of moisture from timber or other wood products per unit of time. Drying rate is generally expressed in percentage of moisture content lost per hour or day **Record** - A daily or weekly entry of dryer or kiln operation information, which for example can include sample weight, moisture content, and temperature readings or recorder-controller charts. **Schedule** - A sequence of controlled air velocity, temperature and humidity conditions in a kiln or predryer that result in a gradual decrease in moisture content of the wood. **Shed** - An unheated building for drying timber and other wood products. The building may be open on all sides or closed **Stress** - The force per unit area that occurs in some zones of drying wood. It results from the uneven shrinkage that occurs with normal moisture gradients and from the set that develops in wood.
Durability	1. The natural resistance of timber to biodeterioration caused by fungi, insects and mechanical break down (e.g. weathering, checking and splitting). 2. In building, the efficacy of assemblies in preserving or protecting the fabric of the building from decay or deterioration.
Electrodes.	Pins or blades on electric moisture meters, usually made of steel, used to penetrate and contact the wood. **Insulated** - Electrodes that are coated with an insulating

Term	Explanation
	material to limit or control the point of contact between the electrode and the wood.
End Coating.	A coating of moisture-resistant material applied to the end grain of green logs or sawn boards to slow end drying.
Equalisation	In kiln drying, a high humidity treatment in the final stages of drying intended to reduce the moisture content range between pieces of timber and the moisture gradient within pieces of timber. Also known as Equalising.
Extractives	Substances such as tannin in wood that are not an integral part of the cellular structure and can be removed in solution by solvents, such hot or cold water, that do not react chemically with wood substances.
Feature	Any irregularity or imperfection in a tree, log, board, or other wood product. Feature may result from knots and other growth conditions and abnormalities, insect or fungus attack, or during timber processing.
Fibre	Small diameter, thick walled cells in hardwoods. Fibres dominate the structural behaviour of hardwoods.
Fibre Saturation Point (FSP)	The stage in the drying of wood at which the cell walls are saturated with bound water but the cell cavities are free of water. It is usually considered to be approximately 30% moisture content.
Fiddleback	A form of figure in timber or veneer produced by small, regular undulations in the grain.
Figure	The pattern produced on the cut surface of wood by annual growth rings, rays, knots, deviations from regular grain such as interlocked and wavy grain, and irregular coloration.
Flitch	A large piece of log that is usually sawn on at least two surfaces and is intended for further cutting.
Fungus (Fungi)	A plant that feeds on wood fibre. Fungi primarily consist of microscopic threads (hyphae) that traverse wood in all directions, dissolving materials out of the cell walls.
Grade	The designation of the quality or capacity of a log, piece of timber or other manufactured wood products in accordance with standard rules.
Grain	1. The general direction of the fibres or wood elements relative to the main axis of the piece. 2. The direction, size, arrangement, appearance, or quality of the fibres in wood or timber **Across the Grain** - The direction parallel with the length of the fibres and other longitudinal elements of the wood.

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Term	Explanation
	Along the Grain - The direction at right angles to the length of the fibres and other longitudinal elements of the wood. **Coarse** - Timber with wide conspicuous growth rings in which there is considerable difference between earlywood and latewood. The term is sometimes used to designate wood with large vessels, but in this sense the term "coarse textured" is more often used **Closed** - Timber with narrow, inconspicuous growth rings. The term is sometimes used to designate wood having small and closely spaced vessels, but in this sense the term "fine textured" is more often used. **Cross** - Timber in which the fibres deviate from a line parallel to the sides of the piece. Cross grain may be either diagonal or spiral grain or a combination of the two. **Diagonal** - Timber in which the annual rings are at an angle with the axis of a piece as a result of sawing at an angle with the bark of the log. A form of cross grain. **End** - The grain of the ends of logs or timber on a cross cut surface. **Interlocked** - Timber in which fibres are inclined in one direction in a number of rings of annual or seasonal growth, then reverse and are inclined in an opposite direction in succeeding growth rings. **Irregular** - Grain where the fibres contort and twist around knots, butts, curls and so on. Also called wild grain **Open** - Common classification for woods with large vessels in the grain. Also known as coarse textured or coarse grained. **Raised** - Roughened surface of timber and other wood products, particularly softwood, after planing, caused by the projection of earlywood or latewood above the surface. **Slope of** - In timber and other wood products, the ratio of deviation of the grain from the long axis of a piece to the distance along the edge that this deviation occurs. **Spiral** - A form of cross grain in timber in which the fibres take a spiral course about the trunk of a tree instead of the normal vertical course. The spiral may extend in a right handed or left-handed direction around the tree trunk **Straight** - Timber in which the fibres and other longitudinal elements run parallel to the axis of a piece
Green	Freshly sawn or unseasoned wood. See also Moisture Content. **Volume** - Cubic content of green wood

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Term	Explanation
Growth Rings	Rings of earlywood and latewood on the transverse section of a trunk or branch marking cycles of growth.
Gum	A natural exudation, also called kino, produced in trees as a result of fire or mechanical damage. **Vein** - A ribbon of gum between growth rings, which may be bridged radially by wood tissue at intervals. Also known as a kino vein.
Hardness	A property of wood that enables it to resist indentation. It is often determined by the Janka hardness test.
Hardwood	1. A general term for broad leafed trees classified botanically as Angiosperm. 2. The wood and timber produced by these trees. The term is not related to the actual hardness of the wood.
Heart	The wood adjacent to and including the pith that is within 50 mm of the centre of the pith.
Heartwood	The wood making up the centre part of the tree, beneath the sapwood. Cells of heartwood no longer participate in the life processes of the tree. Heartwood may contain phenolic compounds, gums, resins, and other materials that usually make it darker and more decay resistant than sapwood.
Hit and Miss	Areas on dressed or moulded boards that that are not fully machined. It results form unacceptable unevenness in the thickness or width of the boards. It is also called skip
Hobnail	A pattern of irregular marks in timber that result from the cambium layer being attacked by the scribbler beetle. On a back sawn face, the marks appear like a simple scribble. On the quarter sawn face, they appear like a series of small dark triangles in a line.
Humidistat	A device for automatically regulating the relative humidity of air.
Humidity	A general term for the presence of water vapour in air. There is a known limit to the amount of water vapour that air can hold at any particular temperature. **Absolute** - The amount of moisture in air. It is usually expressed as the weight of water vapour in a unit weight of dry air **Relative** - At a given temperature, this is the amount of moisture in air as a percentage of the maximum moisture carrying capacity of the air.
Hygrometer	An instrument for measuring the humidity of air.
Hygroscopic	A hygroscopic material, such as wood, is one that readily

Term	Explanation
	absorbs water.
Hygrostat	A device for automatically regulating the equilibrium moisture content of the air. See also Humidistat.
Hysteresis	As applied to timber's moisture content, the tendency of dried wood to reach equilibrium with any specified temperature and relative humidity at a lower moisture content when absorbing moisture from a drier state than when losing moisture from a wetter state.
Infection	The invasion of timber by fungi or other microorganisms.
Infestation	The establishment of insects or other animals in timber.
Kiln	A room, chamber, or tunnel in which conditions such as temperature, relative humidity and air speed can be controlled to govern drying conditions. **Charge** - In kiln drying, the total amount of timber or wood items to be dried in the kiln at one time. **Dried** - Timber or other wood items that have been dried in a kiln. **Drying** - The process of drying timber in a kiln. **Leakage** - The undesirable loss of heat and vapour from a kiln through and around doors and ventilators or through cracks in the walls and roof. **Operator** - The supervisor of kiln drying. **Dehumidifier** - A kiln that works on the heat pump principle. Moisture evaporated from the timber by a flow of warm air is condensed on the evaporator coils of a refrigeration unit and drained from the chamber. The refrigerant is compressed and passed through condenser coils, re-heating the air stream. **Low Temperature (Predryer)** - A kiln that often operates at milder drying conditions, usually between 20 C and 50 C (85 F and 120 F), that is often used during the beginning of a drying phase. **Progressive** - A kiln whereby the timber progressively moves through the dryer from the entering (wet) end to the exit (dry) end. The kiln is designed and operated so that the drying conditions are milder at the entering end than at the exit end. **Solar (Solar Dryer)** - A low-temperature kiln that uses solar energy for heating. Other heat sources may be used to augment solar heat in temperate areas.
Knot	That portion of a branch or limb that has been surrounded by subsequent growth of the stem. The shape of the knot as it appears on a cut surface depends on the angle of the cut

Term	Explanation
	relative to the long axis of the knot.
Latent Heat	Energy required to vaporise liquid water without increasing its temperature.
Latewood	The portion of the growth ring that is formed after the earlywood formation has ceased. Latewood is usually denser than earlywood. Synonymous with Summerwood.
Layout	Within an air-drying yard, layout refers to the arrangement of timber stacks in the yard.
Lumen	In wood anatomy, the cell cavity.
Meter	**Electric Resistance Moisture** - A meter that measures the electrical resistance of timber, which is converted to a reading of timber moisture content. They are usually calibrated for Douglas Fir. The reading must then be corrected for temperature and species. **Capacitance Moisture** - A meter that measures the varying capacitance of wood with changing moisture content using a radio frequency oscillator. They measure the amount of water per unit volume in the wood.
Microwave Heating	Heating of a material by electromagnetic energy alternating at a frequency from 915 to 22,125 MHz.
Mildew	A fungal growth that does not cause deep discoloration of the wood. Associated with mould, it usually appears as tiny black spots that cover the timber surface.
Mill	A building or site that accommodates a manufacturing process **Green** - A site for sawing, packing and racking unseasoned timber. **Dry** - A site for processing and storing seasoned timber.
Moisture Content	The amount of moisture contained in wood, usually expressed as a percentage of the oven dry mass. **Average** - Moisture content of a single section representative of a larger piece of wood, the average of all measurements taken from timber or other wood products, or the average of measurements taken from a lot of timber or other wood products. **Core** - Average moisture content of the centre section of a piece of timber or moisture section. **Equilibrium (EMC)** - The moisture content of timber that has equalised with the prevailing atmospheric conditions. The EMC will change with changes in humidity and temperature. **Final** - Average moisture content of timber or other wood

Term	Explanation
	product at the end of the drying process. **Initial** - The moisture content of the wood at the beginning of the drying process. **Range** - Difference in moisture content between driest and wettest timber in a rack, lot, or kiln charge or between representative samples of the lot. **Shell (Case)** - Average moisture content of the outer part of a piece of timber or moisture section.
Moisture Content Class	Classification of timber by moisture content. **Green, Green off Saw** —Freshly sawn timber or timber that has received essentially no formal drying. **Air Dried** - Timber that has been air or shed dried to an average of 25% moisture content or lower, with no material having more than 30% moisture content. **Predried** - Timber that has been air dried or dried in a predryer to FSP. **Kiln Dried** - Timber dried in a kiln or by some other refined method, to an average specified moisture content, typically 8% to 14%, or to a moisture content understood to be suitable for a certain application.
Moisture Gradient	The distribution of moisture content within the wood. During drying, distribution varies from the low moisture content of the relatively dry surface layers and the higher moisture content at the centre of the piece.
Moisture Movement	The transfer of moisture from one point to another within wood or other materials.
Mould	A fungal growth on timber or other wood products at or near the surface and, therefore, not typically resulting in deep discoloration. Mould is usually ash green to deep green, although black and yellow are also common. See also Mildew.
Movement	The extent of expansion and contraction that occurs with dried wood as its moisture content responds to changes of climate in service.
Oven Dry	A term used to describe wood that has been dried in a ventilated oven at 102 C to 105 C until there is no additional loss in weight. **Weight** - The weight of wood when all the water has been driven off by heating the wood in an oven.
Overcut	An allowance added to the nominal dimension of an unseasoned board to compensate for shrinkage during drying.

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Term	Explanation
Overhang.	The end of timber that is unsupported by rack sticks and extends beyond the ends of most pieces in an air drying stack, rack, pack, or unit of timber.
Pack	A unit of timber boards
Permeability	The ease with which a fluid flows through a porous material (wood) in response to pressure.
Pith	The central core of a stem mainly consisting of parenchyma or soft tissue. Pith is more obvious in softwoods.
Plain Sawn Timber	Timber converted so that the growth rings meet the face in any part at an angle of less than 45 degrees. Also called backsawn timber.
Pocket	A patch of bark or gum (kino) completely or partially enclosed in the wood.
Polyethylene Glycol	A chemical pretreating agent used to improve the drying behaviour of timber.
Predryer	A structure similar to a kiln that is sometimes used in the initial stages of drying.
Predrying	A wood drying process carried out in a predryer before kiln drying.
Presurfacing	Surfacing of both broad faces of green rough sawn timber intended to permit drying by a schedule more severe than the prescribed schedule for rough sawn timber, achieving faster drying and fewer drying defects.
Pretreatment - Steaming	A process sometimes carried out before commencing a drying schedule. The timber is subjected to atmospheric pressure steam. It is often carried out to fix or enhance colour.
Psychrometric Charts	A psychrometric chart or psychrometric table relates dry bulb temperature, wet bulb depression and humidity.
Push - pull racking	A method for building racks where alternative boards in alternative layers are kept flush with alternate ends. This gives a checkerboard arrangement at the ends of the rack. It is also called topping & tailing.
Quarter Sawn	Timber in which the average inclination of the growth rings to the wide face is not less than 45 degrees.
Rack	A unit of timber where each layer is separated and spaced for drying with rack sticks.
Rack Stick	A strip of wood or another material that is placed between rows of timber or other wood products in a rack. Rack sticks are placed at right angles to the long axis of the timber to permit air to circulate between the layers. . Also referred to as “sticker” or “stripper”.

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Term	Explanation
Racking Frame	A combination of guides and supports that help produce good stick alignment and square sides and ends in hand built racks.
Radial	Coincident with a radius from the central axis of the tree or log to the circumference.
Radially Sawn	Timber sawn on the radius from the central axis of the tree or log to the circumference, perpendicular to the growth rings. The resulting pieces are generally triangular in shape.
Rays	Consisting mainly of parenchyma cells, rays extend radially from the inner bark to the center of the tree (pith) and provide a method of movement and storage of plant food. Large rays in some species produce a distinctive fleck on the quartersawn surface.
Reconditioner	A chamber into which wet steam (not more than 100°C) is injected for several hours to recondition timber.
Reconditioning	The process of using a steaming treatment for the recovery of collapse and thereby reduce the volume of timber lost to shrinkage. It can also relieve drying stress and minimise moisture gradients.
Recorder - Controller	An instrument that continuously records dry- and wet-bulb temperatures of circulated air in a dryer or kiln and regulates these conditions by activating automatic heat and humidification systems.
Redry	In kiln or veneer drying, a process whereby dried material found to have a moisture content level higher than desired is returned to the dryer for additional drying.
Refractory	A term that implies difficulty in processing or manufacturing by ordinary methods, resistance to the penetration of preservatives, difficulty in drying, or difficulty in working.
Resins	A class of amorphous vegetable substances secreted by certain plants or trees.
Rot	Synonymous with decay, the softening, weakening, or total decomposition of wood substance by fungi. **Brown** - In wood, any decay caused by fungi that attack cellulose rather than lignin, producing a light to dark brown friable residue. **Dry** - A term loosely applied to any dry, crumbly rot but especially to rot that, when in an advanced stage, permits the wood to be crushed easily to a dry powder. The term is actually a misnomer for any decay, since all fungi require considerable moisture for growth. **White** - In wood, any decay caused by fungi that attack both

Term	Explanation
	cellulose and lignin, producing a generally whitish residue that may be spongy or stringy or occur in pockets.
Rough Sawn	Surface condition of wood as it leaves the saw, i.e. not dressed or final sawn.
Sample Board	A representative piece of timber of a known moisture content that is placed in a stack, or a predryer or kiln charge, so that it may be removed for comparative examination, weighing, or testing during the drying process.
Sap	The fluid in green wood that contains nutrients and other chemicals in solution.
Sapwood	The outer layers of the stem that contain living cells and reserve materials such as starch. The sapwood is generally lighter in color than the heartwood
Season	To dry timber and other wood items to the final moisture content and stress condition desirable for the intended use.
Seasoning Stresses	Stresses in timber caused by drying.
Cross Section	A section of a board or log taken at right angles to its longitudinal axis.
Set	Permanent deformation in wood that occurs during drying when the tensile and compressive stress exceeds its elastic limit. Set prevents normal shrinkage of the timber and can lead to more obvious defects such as casehardening. **Compression** - Set that occurs during compression, which tends to give the wood a smaller than normal dimension after drying. Compression set is usually found in the inner layers of wood during the later stages of drying, but sometimes occurs in the outer layers after extended conditioning or rewetting. **Tension** - Set that occurs during tension, which tends to increase the dimensions of the wood after drying. Tension set usually occurs in the outer layers of wood during drying.
Shake	Separation or breakage of the wood fibres caused by stresses in the standing tree or by felling and handling of the log. It is not caused by shrinkage during drying. **Ring** - Separation or breakage of the wood fibres along the grain and parallel to the growth rings.
Shrinkage	The contraction of wood fibres caused by drying. Shrinkage is usually expressed as a percentage of the dimension of the wood when green. **Longitudinal** - Shrinkage along the grain. **Radial** - Shrinkage across the grain, in a radial direction.

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Term	Explanation
	Tangential - Shrinkage across the grain, in a tangential direction. **Unconfined** - Shrinkage measured on thin slices assumed free of stresses. This is in contrast to shrinkage of a whole board cross-section. **Volumetric** - Shrinkage in volume.
Sling	A unit of timber. Synonymous with pack
Softwood	1. A general term for trees that, in most cases, have needle or scale-like leaves, classified botanically as gymnosperms. It includes all conifers. 2. The wood produced by these trees. The term softwood is not related to the actual hardness of the wood.
Sorting	Segregation of sawn wood items into groups that have similar characteristics, such as thickness, species, grades, and grain patterns, and into classes for stacking or racking, such as width and length.
Species	A subdivion of a genus in the classification of plants. Species of plants are distinguished by the characteristics of fruits, flowers, leaves, bark and wood.
Specific Gravity	The ratio of the density of wood to the density of water at 4 C. Specific gravity of wood is usually based on green volume and oven-dry weight, in which case it is known as basic specific gravity. See also basic density.
Split	A defect that occurs when tensile stresses cause the wood fibres to separate and form cracks. Splits are cracks that extend through a piece from surface to surface. **End** - A split at the end of a log or board
Sparge line	A steam pipe that has a series of holes in it.
Spring	A form of warp in which a board deviates edgewise from a straight line from end to end, not affecting the face. Also called "crook".
Stack	A number or racks positioned one above the other and separated by bearers or gluts. **Top** - Any cover that protects or restrains the top rows of boards of a stack **Weight** - A stack top that significantly restrains the timber in the top racks of the stack. They are often a piece of flat steel or a pre-cast concrete slab the same width and length as the rack.
Stain	A discoloration in wood that may be caused by microorganisms, metal, or chemicals. The term also applies

Term	Explanation
	to materials used to impart colors to wood. **Blue** –A bluish or grayish discoloration in the sapwood caused by the growth of certain dark-colored fungi. **Sap** - A discoloration in the sapwood caused by the growth of fungi. Sapstain is often blue but can also be red, purple and other colours.
Steam	The gaseous form of water at or above the boiling point. **Saturated** - Steam at 100°C and atmospheric pressure.
Steaming	Subjecting of wood to saturated steam at or close to 100°C.
Sticker	Synonymous with rack stick. **Alignment** - The placement of rack sticks in a rack of timber or other wood products so that they form vertical tiers. **Mark** - Indentation or compression of the timber or other wood product by the rack stick when the load above is too great for the bearing area. Sticker marks or sticker stain also refers to light areas under the rack stick that form as the rest of the timber darkens.
Super Heat	The heat in steam in excess of the amount of heat in saturated steam at a given pressure.
Swelling	An increase in the dimensions of wood resulting from an increase in moisture content. Swelling occurs tangentially, radially, and, to a lesser extent, longitudinally.
Tangential	Coincident with a tangent at the circumference of a tree or log, or parallel to such a tangent. In practice, it often means roughly coincident with a growth ring.
Temperature	**Dry-bulb** - Temperature of air as indicated by a standard thermometer. **Wet-Bulb** - Temperature indicated by any temperature-measuring device, the sensitive element of which is covered by a smooth, clean, soft, water saturated cloth (wet-bulb wick).
Tension	A state or condition of being pulled or stretched by a force. **Failure** - The pulling apart or rupturing of wood fibres as a result of tensile stresses.
Texture	The direction, size, arrangement, appearance, or quality of the fibres in wood or timber; often used interchangeably with grain. Usually described as fine, medium or coarse and uniform or even.

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Term	Explanation
Timber	A general term for natural or sawn wood in a form suitable for building or structural purposes. **Dressed** - Timber finished to a smooth surface on one or more surfaces. **Sawn** - Timber sawn to pre-determined sizes.
Tracheid	The elongated cells that constitute the greater part of the structure of the softwoods; also present but uncommon in some hardwoods.
Transverse	The direction at right angles to the wood fibres or across the grain. A transverse section is a section taken through a tree or timber at right angles to the pith.
Transitional sawn	Timbers sawn so that there are both back sawn and quarter sawn sections in the piece.
Twist	A form of warp; a distortion caused by the turning or winding of the edges of a board, so that the four corners of any face are no longer in the same plane.
Vapour Barrier	In kiln drying, a material with high resistance to vapour movement that is applied to the surfaces of a dry kiln to prevent moisture migration.
Vent	In kiln drying, an opening in the kiln roof or wall that can be opened and closed to control the humidity in the kiln.
Vessels	Tube-like structure of indeterminate length in hardwoods which carry water and nutrients from the roots.
Volume, Green	The volume of wood determined from measurements made while the entire piece of wood is above the fibre saturation point, about 30% moisture content
Wane	The absence of wood on any face or edge of a piece of timber, leaving exposed the original underbark surface with or without bark.
Want	The absence of wood, other than wane, from any face or edge of a piece of timber.
Warp	The distortion in timber and other wood products that causes the material to depart from its original plane. Warp includes cup, bow, crook, twist, kinks, and diamonding, or any combination of these.
Warp Restraint	In drying timber and other wood products, the application of external loads to a rack, stack or pack to prevent or reduce warp.
Water	**Bound** - The water weakly chemically bound in the cell walls of wood.

Term	Explanation
	Free - The water within cavities or lumens, in the cells of wood. **Vapour -** The invisible, gaseous form of water. The amount of vapour present in a body of air is expressed either in terms of absolute humidity or relative humidity.
Weathering	The mechanical or chemical disintegration and discoloration of the surface of timber due to exposure to light, the action of dust and sand carried by winds, and the alternate shrinking and swelling of the surface fibres with continual variation in moisture content brought by changes in the weather. Weathering does not include decay.
Wood	The tissues of the stem, branches, and roots of a woody plant lying between the pith and cambium, serving for water conduction, mechanical strength, and food storage, and characterised by the presence of tracheids or vessels **Compression** - Abnormal wood (reaction wood) formed on the lower side of branches and inclined trunks of softwood trees. As seen on the cross-section surfaces of a branch or stem, it appears as relatively wide, eccentric growth rings with little or no demarcation between earlywood and latewood and more than normal amounts of latewood. Compression wood shrinks more longitudinally than does normal wood. **Early –** Wood formed during the early period of annual growth, usually less dense than wood formed later. **Juvenile** - The wood formed near the pith of the tree. Juvenile wood has significantly different properties to mature wood. Also known as 'heart'. **Late** – Wood formed during the later period of annual growth, usually denser than wood formed earlier. **Tension** - Abnormal wood (reaction wood) found in leaning trees of some hardwood species and characterised by the presence of gelatinous fibres and excessive longitudinal shrinkage. The machined surface tends to be fibrous or woolly, especially when green. **Reaction** - Wood with more or less distinctive anatomical characteristics, formed typically in parts of leaning or crooked stems and branches. In hardwoods, reaction wood is called tension wood (see tension wood) and in softwoods, compression wood (see compression wood).