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KILN DRYING

INTRODUCTION

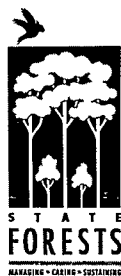
Other than for a few brief periods in its history, Australia has been and remains a nett importer of forest products with a balance of trade deficit in recent years of around \$1.5 billion per annum. The situation in New South Wales is similar to that in the other States with some 30% of our requirements being imported to supplement local production. This situation is gradually being addressed by growers and producers and with modern forest management regimes and improved processing techniques our valuable native hardwood and softwoods forests, supplemented by steadily escalating volumes from pine and hardwood plantations, will see us becoming self-sufficient early in the new century.

CHANGING EXPECTATIONS

A greater expectation among consumers that natural products such as wood should be similar in behaviour to manufactured products has seen a demand for a far greater degree of performance and predictability from decorative and structural timber products than was ever possible in the past. This, coupled with a need to maximise cost recovery at all levels of the supply chain, has led to vastly improved production techniques by sawmillers and other processors. Following sawmilling, the most widely accepted method of ensuring the performance and predictability of timber, and of increasing its inherent value, is the seasoning, or drying, process.

SEASONING

The process of seasoning is simply that of removing moisture from the wood until it reaches equilibrium, or a state of balance, with its surrounding atmosphere. While that atmosphere could, theoretically, range anywhere from 0% upwards, legislation in New South Wales, the Timber Marketing Act (1977), defines the seasoned state as being within a range of 10% to 15% moisture content (m.c.).



In some species, notably certain softwoods, the moisture content can be as high as 150% to 200% in a young standing tree and the removal of such vast quantities of water without causing damage to the wood structure obviously presents certain challenges to the processor.

While seasoning is as described, successful seasoning is another matter entirely. Under normal conditions wood will begin to lose moisture to the atmosphere as soon as it is separated from its natural source, i.e. as soon as the tree is felled. Whether in log form or as sawn timber, the uncontrolled loss of moisture from the wood will create considerable stresses within the wood structure that will result in degrade in the form of cracks, splits and other deformation. The challenge, therefore, is to minimise or eliminate these phenomena.

MOISTURE CONTENT

Moisture content is expressed as a percentage of the oven dried weight of the wood. The expression of moisture content is -

$$\text{m.c.(\%)} = \frac{(\text{initial mass} - \text{oven dry mass})}{\text{oven dry mass}} \times 100$$

Water contained within the wood is stored in two forms: free water is found within the cell voids of the wood and 'bound' or combined water is bound ionically to the cell wall molecules.

During the drying process, water is released from the wood by evaporation, the free water being the first to go. When the stage is reached that only the bound water remains, the wood is said to be at fibre saturation point, usually within the range of 25% to 30% moisture content.

The loss of free water is a relatively straightforward process and while in most timbers there is little shrinkage before timber reaches its fibre saturation point, the phenomenon known as collapse can occur, particularly in mature wood where too severe drying conditions are imposed. Some degree of collapse though can often be

corrected by reconditioning. Where collapse causes internal cracking or checking, however, it is usually impossible to correct the condition by reconditioning. Eucalypts, particularly the ash type species, are susceptible to collapse as are some softwoods typically dried from green in high temperature kilns. As with many other drying defects, the condition can be minimised or eliminated with sound seasoning practices.

Once the free water has evaporated, the water bonded to the cell walls will start to be drawn out and the cell walls will begin to harden and shrinkage will begin to commence. As noted earlier, this will first occur at the surfaces of the timber. From this point on, the loss of moisture will, if not carefully controlled, cause considerable stresses between the inner and outer layers of the wood which will often manifest itself as splitting, checking or warping. The aim, therefore, is to control the rate of moisture loss from the wood by artificially manipulating its environment of wind speed, temperature and humidity.

WHY TIMBER IS DRIED

When the moisture content drops below fibre saturation the wood will begin to shrink. Unless submerged it will eventually dry until it reaches a point of balance with its environment. However, the amount of shrinkage and the time it takes to fully dry will depend on a number of factors such as cross section, surface coatings, density and environment. Artificial drying, therefore, is carried out to pre-condition the timber to its expected environment, minimising many problems that might otherwise occur. Additionally, the strength properties of most species increases with its degree of dryness, while wood with a moisture content maintained below 20% will be immune to decay.

METHODS OF DRYING

Drying is generally carried out by either of two basic methods or, more usually, by a combination of the two:

- Air drying - where the timber is allowed to dry naturally from its 'green' or unseasoned state.
- Kiln drying - where moisture is extracted by artificially controlling its environment under exaggerated conditions.

In theory, there should be no real difference between air dried and kiln dried timber if the process is properly controlled. However, in practice, air drying is a long process particularly once the timber's moisture content

has dropped below fibre saturation point. Kiln drying on the other hand allows relatively predictable results albeit at a cost. The capital costs of establishing a kiln drying operation are substantial no matter what system is chosen.

DRYING

With either method the process of drying is essentially the same. Basically it is controlled by three factors - air flow, relative humidity and temperature.

No matter how low the relative humidity or how high the air temperature, if there is no air flow around the wood, its surrounding air will quickly become saturated to the point that moisture loss to the atmosphere will cease. Simply, as water reaches the surface of the wood the rate or volume of air passing across its surface must be sufficient to carry away the saturated air.

There are two distinct processes in drying - the evaporation of water from the wood surface and the transfer of water from the wood's inner layers to the surface. As the wood's surface dries, water will begin to move to the surface. As this continues, the moisture content difference between the wood surface and its interior will be dependent upon the rate of evaporation versus the rate of water movement through the wood. The difference between the surface and core is known as its moisture content gradient. In an ideal situation, this gradient would be non-existent as the rate of evaporation would exactly equal the rate of moisture movement from the interior to the wood's surface. In practice, this is rarely achievable with straight steep gradients occurring in some high temperature softwood drying operations, while almost exactly the reverse occurs in the case of some high density hardwoods.

If the surface moisture content drops quickly and the rate of evaporation greatly exceeds the rate of water transfer through the wood, a steep gradient occurs. If the wood has a low permeability factor, the gradient may be such that while the outer layers of the wood are trying to shrink they are being restrained by the wet inner parts causing considerable differential stresses to develop between the two. If these stresses exceed the strength of the wood it is likely to crack or check. Where the gradient is less and straight, such as occurs in some of the more permeable softwoods, the wood is far more likely to shrink uniformly with little differential shrinkage occurring between the centre and the surface. In this case there is far less likelihood of excessive stresses developing (see Fig. 1).












Prong when sawn	Prong after room drying		
 <p data-bbox="261 562 464 664">1. Turn out Surface in tension and centre in compression.</p>	 <p data-bbox="564 562 951 766">1A. Turn in Indication of unequal moisture distribution, surface drier than centre. Occurrence: Early stages of drying. Remarks: No need to steam. Raise humidity if checking present.</p>		 <p data-bbox="995 562 1369 818">1B. Do not change Indication of practically equal moisture distribution, surface in tension, centre in compression. Occurrence: After over steaming at low moisture content. Remarks: Steaming treatment has been too severe.</p>
 <p data-bbox="261 1140 474 1242">2. Turn in Surface in compression and centre in tension.</p>	 <p data-bbox="564 1140 914 1374">2A. Pinch tighter Indication of unequal moisture distribution, surface drier than centre. Occurrence: After centre dries below fibre saturation point. Remarks: Advantageous point to relieve stresses by steaming treatment.</p>		  <p data-bbox="976 1140 1350 1374">2B. Become straight or turn out Indication of unequal moisture distribution, centre drier than surface. Occurrence: After steaming but before re-drying. Remarks: Prongs cut after re-drying should remain practically straight.</p>
 <p data-bbox="261 1719 496 1793">3. Straight Timber free from stresses.</p>	 <p data-bbox="564 1719 810 1914">3A. Remain straight Indication of equal moisture distribution and freedom from stresses. Remarks: Correct final condition.</p>	 <p data-bbox="847 1719 1107 1968">3B. Turn in Indication of unequal moisture distribution, surface drier than centre. Remarks: A short steaming treatment to balance moisture content should relieve stresses.</p>	 <p data-bbox="1147 1719 1374 1945">3C. Turn out Indication of unequal moisture distribution, centre drier than surface. Occurrence: During some period of re-drying after steaming.</p>

Figure 1. Tests for detection of stresses.

AIR DRYING

Air drying is just that - allowing timber to season naturally in the air. In practice though, there are many ways of achieving this and a period of air drying before being placed in a kiln is standard in most hardwood drying operations. Generally, although depending on seasonal variations in weather, air drying can be quite effective and relatively quick down as far as the fibre saturation point, after which the process usually slows considerably.

There is little that can be done to control the weather other than to keep the timber under cover, but with the volumes and throughput necessary to run a viable drying operation, 100% air drying is not likely to be a practical solution. However, while the weather is uncontrollable, planning to ensure the efficient circulation of air through and around the timber stacks is essential.

YARD LAYOUT

Air drying is dependent for its success on the efficient circulation of air through and around stacks, therefore, first and foremost, the proposed drying yard should be sited well clear of obstructions such as buildings, trees or other obstacles. Secondly, it would be rather pointless locating a yard in a poorly drained damp area where relative humidity levels are likely to be high. Ideally the yard should be in a high position well drained and spacious to enable all the stacks to be located to take full advantage of prevailing winds.

Other than in cases where there is a deliberate decision to increase drying time because of special considerations, such as with thicker boards, the placing of stripped stacks so that prevailing winds bear at an acute angle to the length of the stack is said to be the most efficient.

STACKING

Sound construction of the stickered timber stacks is the first prime consideration in preparing the timber for drying, no matter whether it is intended only for air drying or later for kiln drying. If not constructed on a sound level base, subsequent difficulties relating to handling and deformation of boards are likely.

The first step in ensuring an efficient drying yard is the construction of sound foundations for the proposed timber stacks. The yard should be levelled and all plant growth in the areas of the stacks removed. It is recommended a minimum clearance between ground level and the lowest boards in the stacks should be around 400 mm. In addition, care must be taken to ensure that the area around and below the stacks is well drained.

The practice of using large concrete bearers to directly support strip stacks is not recommended as they interfere with efficient air circulation. A better practice is to use a grid system of timber or concrete stumps at sufficiently close centres to support timber bearers of lighter size, designed to fully support the proposed stacks without deflection.

STRIPPING

When a sound level bed has been prepared for the timber, the next step is to construct the stacks. Not even the best timber on a level base will perform to expectations if care is not taken during this process. Poor stacking will result in distortion and degrade of a valuable commodity. While there are a few successful automated stripping operations in Australia, the process is generally a labour intensive one and should be supervised closely.

There are many names given to the small pieces of timber used to separate the layers of boards in a stack - strips, fillets, rack sticks and stickers being a few. No matter what they are called though their task is the same, to uniformly separate the layers of boards to allow uniform air circulation throughout the stack. The strips must be accurately sized and generally a thickness of 19 mm is preferred for efficient drying. However, thinner material may be used for species or sizes that are expected to require slower seasoning. Conversely where some species are routinely dried at high temperatures, thicker strips of 25-30 mm are used. The general rule though is that strips are twice as wide as they are thick.

SPACING AND CONSTRUCTION

Widespacing between the strips is generally unacceptable as warping of the boards is likely. 450 mm to 600 mm centres are usually accepted as the norm for boards of up to 25 mm thickness but some species more prone to movement than others, such as brush box (*Tristania conferta*), could benefit from spacings as close as 250 mm-300 mm.

Strips must be placed directly above the support bearers and continue in a direct vertical line or warped timber will be the inevitable result. The strips should also extend beyond the sides of the stack by at least 25 mm to provide adequate support for the outer boards. It is common practice in some operations to provide a wider strip at the ends of rows to provide additional support for the ends of the boards and slightly reduce the drying surface in that area which can also have an effect on incidence of splitting.

The ideal situation in a stack is that only boards of one length be used to ensure flush ends. In practice, this is usually difficult, so the stacks should be built using the full lengths on the outsides of the stack and shorter boards, ideally in exact multiples of the longer ones, on the insides. In any case, the ends of the stack must be boxed, or flush. Where it is impracticable to completely fill all voids within the stack, short strips (the width of the board) should be placed to support the individual ends.

It is extremely important to provide boxed end stacks when kiln drying, not only to ensure efficient utilisation of the space within the kiln but to avoid warping in protruding boards which often transmits itself back along the length of that board for up to 500 mm or more (Fig. 2).

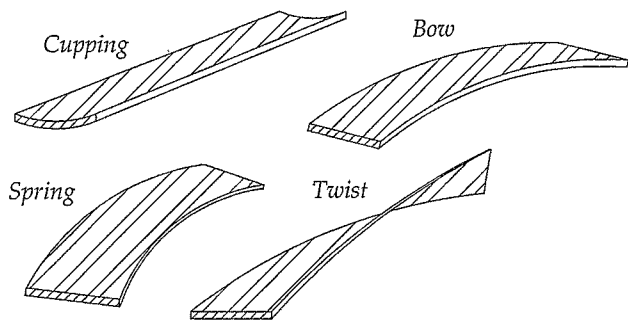


Figure 2. Examples of warping.

EFFECT OF HUMIDITY, TEMPERATURE AND AIR CIRCULATION ON THE DRYING PROCESS

Humidity is the term used to describe the presence of water vapour in the air. There is a limit to the amount of water vapour that air can hold and this limit increases as temperature rises.

Strictly speaking, vapour is an invisible gaseous form of water. The amount of water present in the air is expressed as absolute humidity.

Absolute humidity is defined as the weight of water vapour in a given unit weight of dry air e.g. grams of vapour per kilogram of dry air.

Relative humidity (RH) is a term more widely used in the drying process and it is necessary to understand the effect that temperature has on relative humidity.

Relative humidity is the measure of the amount of water vapour present in the air at a particular temperature expressed as the maximum percentage of water vapour

the air can contain at that temperature. Relative humidity is zero when the air is completely dry and 100 percent when saturated. If a given sample of saturated air is heated and no additional moisture is introduced, its relative humidity will decrease whereas if the same sample is cooled, its relative humidity will increase. In both situations though, its absolute humidity will remain constant.

MEASUREMENT OF RELATIVE HUMIDITY

Relative humidity is normally measured using a wet and dry bulb thermometer, the dry bulb thermometer being a conventional mercury type while the wet bulb differs only because it has a water saturated 'wick' covering the bulb (Fig. 3). The resultant evaporation of water from the wick has a cooling effect. The temperatures taken from both thermometers are applied to established humidity tables which produce a resultant relative humidity reading.

The temperature difference between the two thermometers is known as the wet bulb depression (WBD). The wet bulb depression is greater when the air is both hot and dry than when humidity is high.

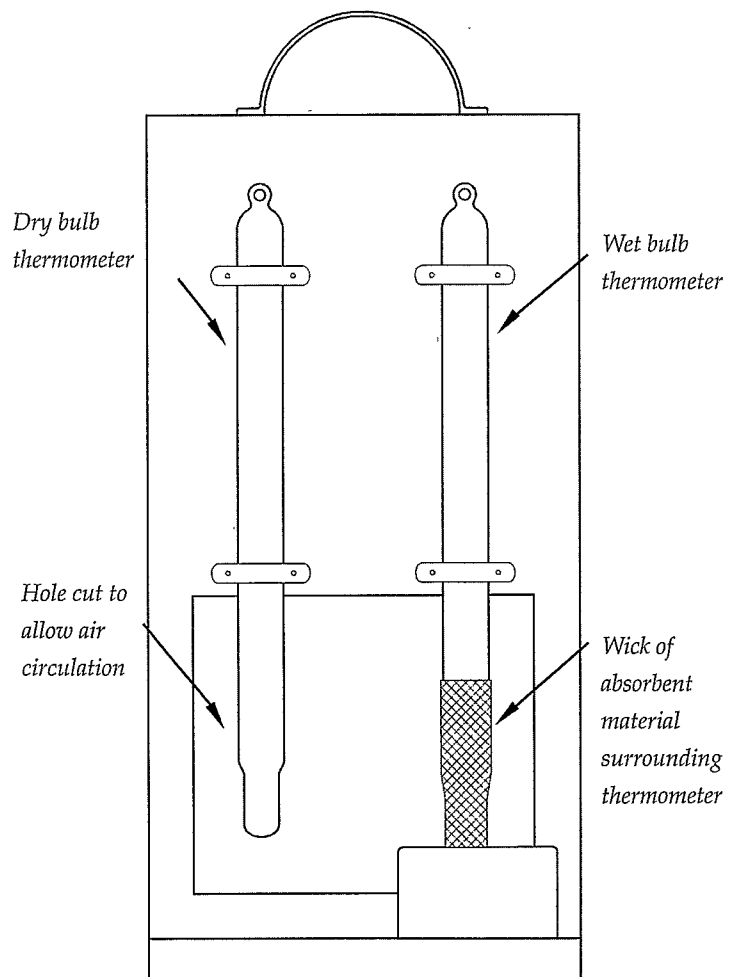


Figure 3. Wet and dry bulb thermometer.

TEMPERATURE

Temperature is a measurement of heat in a substance.

Any increase in temperature of a drying atmosphere will potentially increase the rate of evaporation from the wood because it will decrease relative humidity, resulting in an increase in the moisture carrying capacity of the air and the rate of heat transfer to supply the latent heat necessary for vaporisation.

If the temperature of the timber is raised, the rate of transfusion of moisture from the centre to the surface of the wood will increase because of an increase in vapour pressure on the wood's moisture content.

While it is relatively easy to remove free water from the wood by air drying, some species lose it so rapidly, as mentioned earlier, that collapse can occur, sometimes with resultant cracking and checking that cannot be repaired by reconditioning. Below the fibre saturation point, however, the air drying process becomes noticeably slower as combined water molecules are removed from the wood's cell walls. Using natural methods, it is impossible to season timber below the prevailing equilibrium moisture content (EMC) because, being a hygroscopic material, timber will absorb or lose moisture to the atmosphere depending on relative humidity. Therefore, if faster drying below the fibre saturation point is required, or if it is necessary to dry timber below the prevailing equilibrium moisture content, kiln drying must be used. It is normal practice to kiln dry most hardwoods and some softwoods after a period of initial air seasoning but in the case of our major plantation species, radiata pine, the accepted practice is to kiln dry it directly from the green state.

In conventional kiln drying, the wet bulb temperatures (and therefore the relative humidity) can be controlled so that the time taken to dry the timber may be minimised while still ensuring the degrade is kept to an absolute minimum.

With some softwoods, because of their physical characteristics, drying is able to be carried out quickly at very high temperatures. While species such as radiata can withstand such treatment, care still must be taken to ensure collapse does not occur. In the case of most hardwoods a very careful balance between relative humidity and temperature must be maintained to ensure stresses do not develop within the wood fibre.

In the case of dehumidifying kilns, which operate on the same principle as an air conditioner, the aim is to reduce

the relative humidity within the kiln by condensing water on coils and then directing the resultant water to the outside.

Solar kilns rely on external temperature to heat the inside atmosphere, thereby reducing the relative humidity. The daily increase in temperature also enhances the wood's moisture transfusion process.

AIR CIRCULATION

In any of these types of drying operations, efficient air circulation is a pre-requisite for seasoning. Air is the transfer medium delivering heat to the wood and removing the moisture from it. Generally, and all other things being equal, the greater the flow of air across the surfaces of the wood, the more moisture that can be carried away.

Good exposure to prevailing winds will obviously enhance the air drying process, providing other factors such as stack layout and stripping etc. have been properly planned.

Within a kiln, the higher the temperature the greater the importance of even air flow or circulation throughout the stacks because the rate of evaporation varies linearly with the velocity of air passing through the stripped timber stacks. The speed of this air is measured between the stripping spaces on the leeward (or downwind) side of the stack.

While there are no absolutes relating to wind speeds within kilns because of the variables such as timber density, thickness, initial moisture content, sizes of stacks and kiln charges, some suggestions made in the AFARDI Australian Timber Seasoning Manual are:

- High temperature drying from green 5 to 10 m/s
- High temperature final drying 3 m/s
- Conventional final drying (> 100°C) 2 m/s
- Solar and dehumidifier drying 1 m/s
- Pre-driers and progressive kilns 0.5 m/s
- Curing sheds > 0.2 m/s

DETERMINING MOISTURE CONTENT

There are a number of ways to measure the moisture content in wood, the most common being the use of electrical resistance and dielectric moisture meters, and oven drying. Of these, oven drying is the most widely accepted industry standard where a high degree of accuracy is required. The disadvantages associated with

the oven drying method are that it is time consuming and destructive.

Moisture meters, on the other hand, provide a reasonable degree of accuracy in a 'field' situation and are suitable providing their limitations are recognised.

RESISTANCE METERS

Timber, particularly once it reaches its fibre saturation point, is a good electrical insulator with the relationship between moisture content and electrical resistance being well documented for a wide variety of species.

Resistance meters are the most widely used hand held system within the structural timber industry and are most usually calibrated for Douglas-fir with corrections being supplied for various other species. These meters work by driving two electrodes into the wood and measuring the electrical resistance between them. The result is usually displayed on dial or digital type read out. The pins or blades that are driven into the wood come in two basic types - uninsulated for obtaining surface readings or for testing the maximum moisture content in a given area, and insulated pins that only read at their tips and so are able to deliver more localised readings when driven deep into the timber.

It should be noted that different makes of meters are designed to read resistance either along the grain or across it and if used incorrectly will deliver spurious readings.

DIELECTRIC OR CAPACITANCE METERS

Generally, these meters are more accurate at the very low end of the moisture content range. They are totally non-destructive, measuring the dielectric properties from the wood only.

The most common of the two dielectric meters is the capacitance type that uses a radio frequency isolator to make its measurements. While working well in timbers with similar densities, they are susceptible to changes in density, working best on material below 6% moisture content. Generally, they are not as reliable as resistance meters but in the lower moisture content ranges, commonly associated with veneers and plywood, they are considered superior.

The other type available is known as a microwave meter which uses a microwave generator to supply power to make its measurements. The principal advantage of this type of meter is that it is less affected by variations in timber densities.

PRECAUTIONS TO TAKE WITH MOISTURE METERS

Providing manufacturers' instructions are carefully followed, most recognised brands of moisture meters will provide immediate and satisfactory results in most timbers. However, it must be appreciated that there are external factors that, depending on the type of meter used, will influence its reading. For instance, in the case of resistance meters, they are usually calibrated to a wood temperature of around 20°C with temperatures above and below that point often causing considerable variations to readings (variation for temperature must be applied before species corrections).

Similarly, corrections should also be applied to timbers containing preservatives.

In the case of dielectric meters, the correction data for density must be established before relying on readings. If preservatives, glues etc. are present, results will be of limited reliability as preservative treatments appear to provide unpredictable readings. As noted earlier, microwave meters offer better results in such instances.

OVEN DRY METHOD

While oven drying is the most widely accepted method of accurately determining the moisture content of timber, there are several types of ovens that can be used, each having its own peculiarities. Additionally, infra red lamps are used in certain circumstances.

CONVENTIONAL OVENS

These use natural convection to heat the samples to a constant $103 \pm 2^\circ\text{C}$. Because of the necessity for accuracy, they are normally purchased from scientific suppliers and should be fitted with accurate temperature monitoring equipment.

FAN FORCED OVENS

Rapidly replacing conventional ovens, they must operate within the same temperature range but because of their ability to rapidly circulate the air, they are usually able to dry standard sections in considerably less time than natural convection ovens.

MICROWAVE OVENS

While these have the ability to dry small samples in only 20 to 30 minutes, they require very careful monitoring and extremely sensitive ancillary weighing equipment because of the small sample size required. Considerable care must be taken with this system not to over dry the samples and, as drying time is very dependent upon

moisture levels and species, it is difficult to predict a standard time for arriving at a true oven dry state.

INFRA RED LAMPS

The use of infra red lamps is usually limited to measuring the moisture content of chips or sawdust intended for use as boiler fuel and is not normally employed on solid timber.

EQUIPMENT BALANCES

Accuracy in determining sample weight is critical, therefore a good quality balance that will read to 0.1 gram or less is necessary. The easiest to use are direct reading top pan electronic types which are, however, expensive. An alternative is a standard cripple beam balance that must also read to 0.1 gram.

SAMPLES

Samples should be cut from a point at least 500 mm from the end of the board. The samples should be at least 15 mm in length measured along the board and when dry should provide a mass of at least 50 grams. After preparation of the sample, which must be totally free of any loose or foreign matter that could fall off during the drying process, it should be marked with some form of identification.

WEIGHING AND DRYING TIMES

It is critical that the sample pieces be weighed as soon as they are cut because the timber will begin to lose moisture immediately and unless accurately recorded, a false result will be inevitable. Once weighed it does not matter if there is a delay in commencing the drying process.

In the case of chips or sawdust, they should be weighed in a dry dish marked for identification.

As described previously, drying time will vary depending upon the system used. Generally, a conventional oven may be expected to take in excess of four hours at 105°C while a fan forced oven will provide the same result in half that time. At this point samples should be removed and immediately weighed before they begin to cool and once again take up moisture. They are then returned to the oven for a further two to four hours, depending upon the type used, and re-weighed.

This process is repeated until consecutive measurements are the same, at which time the samples may be considered to be dry.

Chips and sawdust are heated by infra red lamps to within a range of 100° to 105°C for a period of four hours before weighing. They are then heated for a further one to two hours and re-weighed. The same procedure as above is followed to determine the fully dried state, the only difference being that empty dishes must be weighed and the result subtracted from the wet and dry readings to provide a final result.

Where a microwave oven is employed, a moderate heat setting should be used and samples weighed every minute or two until consecutive identical readings are recorded. There are no hard and fast rules that can be applied to the use of microwave ovens other than extreme care must be taken not to over dry the samples or they may begin to loose their extractives and/or char internally, thus providing false readings.

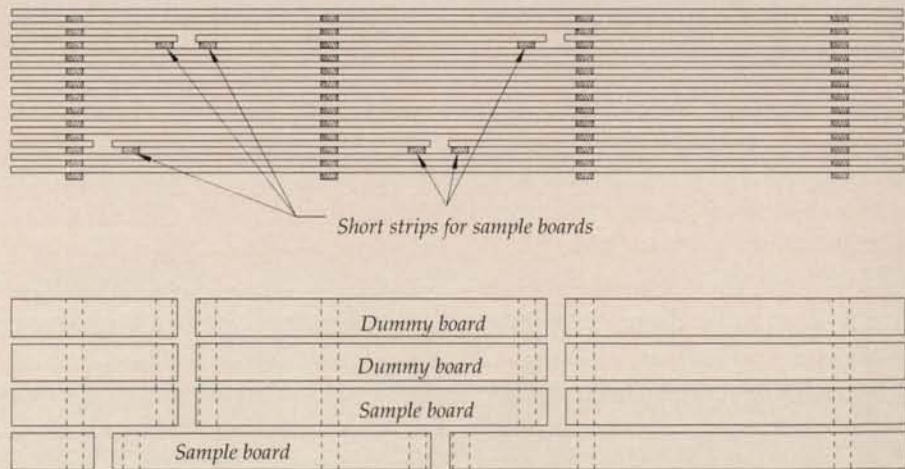


Figure 4. Sample boards (monitoring moisture content).

Throughout the drying process it is important to be able to monitor as accurately as possible the level or amount of moisture within the timber stack or kiln charge. Because there are always so many variables in the drying process this monitoring is vitally important in ensuring uniformity. However, it must be appreciated that with the amount of timber routinely placed in single stacks or in full kiln charges, any indication is only going to be applicable to the piece of timber sampled and that piece will only be a small fraction of a full board which in turn, will represent a minute part of the stack from which it is selected. Therefore, samples should be selected from a number of boards, the usual minimum being six. The statistical accuracy naturally increases with the number of samples selected but they should be as representative of the total parcel as possible.

These samples (or sample boards) are a convenient means of providing the necessary pieces for weighing and/or electronic monitoring throughout the drying process. They should be cut from long lengths commencing at least 450 mm from the end of the board to ensure no end drying effects are transmitted to the samples which should themselves be at least 600 mm long. From each end of the sample a 15 mm moisture content test section should be taken for oven drying to determine the average moisture content of the sample. The long sample, following removal of 15 mm pieces, is then weighed, its result recorded and then end-coated with a proprietary end sealing compound to ensure its rate of moisture loss approximately equals that of the longer boards. The sample piece is then included in the stripped timber stack and supported on strips in the same manner as the rest of the boards as the stack is constructed (Fig. 5).

The dummies and sample boards may all be fixed to their common stickers to facilitate easy removal for monitoring. Sample boards may also be placed in the ends of stacks but once again they should be fixed to and located behind dummy boards (Fig. 6).

MOISTURE MONITORING

There are any number of ways moisture within the stack can be monitored. The sample boards can either be regularly extracted for weighing or electronic monitoring or permanent probes may be inserted in regular production pieces and can provide a useful ongoing indication of the timbers' condition. Additionally, in recent times some producers have been experimenting with load cells that are capable of monitoring the weight of the entire stack.

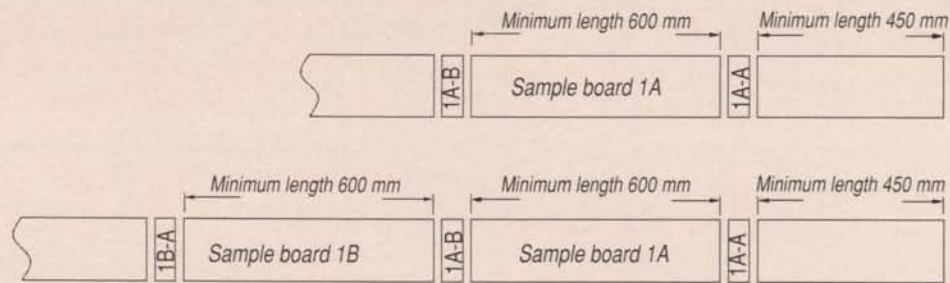


Figure 5. Cutting details for sample pieces.

Because it is intended these boards will provide an indication of the average drying rate throughout the stack they must be placed in representative locations. However, they should be located in such a way that they are accessible throughout the drying process.

With air drying, the process is quite simple and can be accomplished using electronic probes or by extracting and weighing the sample boards. However, when the stack is placed in a kiln, the situation may be slightly different. In conventional low temperature kilns and dehumidifiers, access generally presents no major

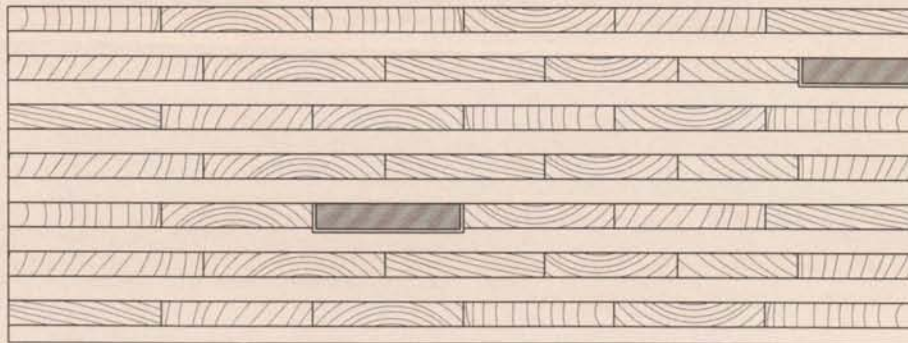


Figure 6. Placement of sample boards.

There would be little point placing all the sample pieces on the top or down one side of the stack as they would then obviously not be representative of the whole stack. Gaps should be provided in the stack so that sample boards can be inserted, supported on strips at least two rows in from the outside and throughout the stack. Dummy boards should then be inserted to close the void.

obstacles and the charge can be monitored in much the same way as it was in the air drying yard. However, with high temperature kilns typically operating at a temperature exceeding 100°C, it is impossible to access the sample boards. In this case, a number of methods have been developed, some of which could also be applied to conventional kiln operations.

- Load cells that continuously and accurately monitor the weight of the entire timber stack throughout its time in the kiln.
- Moisture meter probes located throughout the stack and hard-wired to remote electrical resistance meter.
- Thermocouples to measure the internal rise in temperature of the wood as it dries.
- Temperature variation across the stack. While moisture is evaporating, the temperature on the leeward or downwind side of the stack in the kiln will be lower and will rise as evaporation decreases.
- Equilibrium moisture content measurement devices are available that measure the electrical resistance of a small control sample which is treated to respond to changes in relative humidity.

KILNS

The purpose of any timber seasoning kiln is essentially the same. They are simply chambers in which it is possible to create a controlled artificial environment designed to economically dry timber in the shortest possible time with a minimum of degrade.

PRE-DRYING SHEDS

While not a kiln in the strict sense, pre-drying sheds have been recognised as an economical and effective way to control initial drying conditions while protecting valuable timber from the ravages of the elements. They are used extensively throughout south-east Asia where weather conditions are somewhat more severe than in some parts of Australia. They have also proved valuable in maximising the recovery of some collapse-prone ash species from Victoria and Tasmania and in some hot dry areas of Western Australia. They vary in construction from unwallled sheds to those with louvered walls and forced fan systems.

Designed air speed is typically usually less than 0.2 m/s and if green stacks are replaced regularly, equilibrium moisture content is able to be maintained in the vicinity of 30%. Because of these controlled conditions initial drying stresses are able to be minimised.

PRE-DRYERS

These have traditionally been used in areas of Australia with less predictable climate but with a growing awareness of the cost and value of kiln drying some of

our more unique timber species, interest in pre-dryers is growing in this State. Essentially, they are simply a large kiln capable of containing a number of timber stacks on separate lines in a large single chamber separated by banks of re-heat coils. The main bank of coils is usually located above a false ceiling. Air flow is provided by fans in this ceiling space and is directed by baffles through primary coils in front of the fans and then through secondary coils between the timber stacks. The aim of pre-drying is to simulate accelerated but controlled air drying conditions.

CONVENTIONAL COMPARTMENT KILNS

This type of kiln may be built from any heat and moisture resistant material, the most common being reinforced concrete or concrete blocks. However, the insulating properties of these materials leave something to be desired compared with more recently developed composite materials usually consisting of relatively light weight outer skins filled with various forms of installation material. Polystyrene foam is widely employed as an infill material in low temperature kilns but where temperatures will exceed 80°C, it is unsuitable. 'Isothane' is a suitable infill in high temperature units and is readily available from kiln manufacturers. Conventional kilns are simply sealed chambers into which are placed stripped stacks of timber that are then subjected to various drying regimes that can be anything from low temperature dehumidifiers to the high temperature units commonly used for seasoning radiata pine. No matter what is used though, features in common are a controlled heating and humidifying system, and a means of effective air circulation.

The heating and humidifying process will vary, usually depending on the materials to be dried and the energy source available. Heating can be accomplished in a variety of ways.

INDIRECT HEATING

This system of sealed heat exchangers can use a variety of heat sources from steam, water, heat transfer oil or flue gases. Sealed pipes usually pass the length of the chamber and vary in number and volume depending upon the amount of heat transfer required, i.e. in low temperature kilns, standard 30 mm return steam pipes are common whereas in high temperature softwood units, single return 38 mm finned pipes which are capable of radiating five times the amount of heat are the norm. If flue gas is used, 100 mm stainless pipes are usually used.

DIRECT HEATING

Rather than a sealed system of heat exchanges, in this system the combustion gases from a gas, oil or wood burner are directed through ducts along the length of the kiln and are delivered through a series of ports in the ceiling. Some kilns have been designed to make use of the combustion gases from sawmill waste burners and, while that system has obvious economic benefits, considerable care must be taken with design and maintenance to ensure there is no likelihood of sparks or embers entering the kiln.

HUMIDITY

Where steam is the heat medium, live steam can be introduced into the chamber to control humidity but, where other heat sources are used, atomising water sprays or heated open water troughs are normally employed.

Good sealing is an important but often neglected aspect of kiln operation and maintenance. With the cost of energy, particular care should be taken to maintain the condition of all doors, vents and seals.

DEHUMIDIFYING KILNS

The results obtained with some early dehumidifiers were less than spectacular but more recent examples have proven to give satisfactory results within the limitations of their basic operating system.

The principle of the dehumidifier is that of air conditioning where moisture from the timber is condensed on evaporator coils and then drained away as water. Heat is usually introduced to the system by the heat pump principle which in efficient units can raise internal temperatures to as high as 70°C. Additional heat, if required, can be provided by other conventional means.

Particular care must be taken with dehumidifiers to ensure good sealing is maintained.

TUNNEL KILNS

There are two basic types. The first has usually been referred to simply as a tunnel kiln. Stacks are introduced length ways across the width of the chamber and over a period of time travel the length of the kiln before being removed at the far end. Heat can be generated by most of the methods discussed earlier but a series of fans and baffles direct the air flow straight along the length of the chamber, the hottest air being directed at the driest

timber while material freshly introduced is subjected to the milder conditions of slightly cooler, higher humidity air.

The second type is known as a progressive kiln into which the stacks are introduced length ways along the length of the chamber. With this system the air is introduced back and forth across the chamber by a series of fans and baffles with the hottest air being applied to the driest timber.

SOLAR KILNS

There are a number of solar kilns operating in the more temperate areas of Australia and materials used in their construction vary from UV stabilised plastic sheeting to glass and, more recently, polycarbonates. Solar kilns are relatively inexpensive to build and operate because of their use of light weight materials and natural energy, except for that required to operate the necessary fans, but drying times are usually more than twice that for conventional kilns.

Solar kilns operate on the same principle as a glasshouse where short wave radiation passes through the covering (or glass), is absorbed by the material being dried and retransmitted as longwave radiation that heats the air but cannot pass back out through the glass, typically raising internal temperatures to about 20°C above outside temperatures. Sealing is extremely important with solar kilns because of obvious energy losses during the night.

HIGH HUMIDITY TREATMENT

Typically carried out at the end of the drying process its aim is to reduce stress in stress prone timbers by equalising the moisture content of the timber in the kiln. To accomplish this, steam is introduced to the chamber to increase humidity. While most plantation pines dried from green in high temperature kilns require this process, 'heart in' radiata pine is a particular example of a material that benefits from the process.

AUTOMATIC CONTROLLING INSTRUMENTS

There are any number of options available, from automatic monitoring to fully automated computer control of the seasoning operation.

Instrumentation, however, will always involve, in one form or another, a remote reading wet and dry bulb thermometer (Fig. 7).

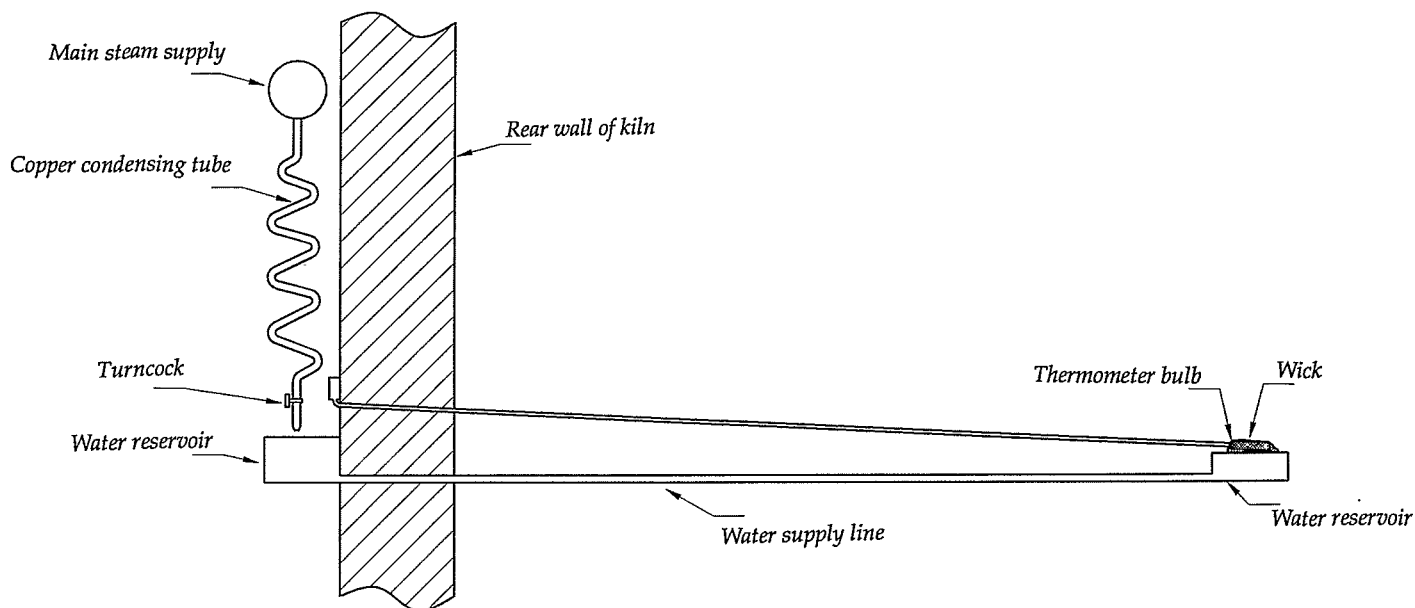


Figure 7. Water supply system used for both automatic instruments and indicating thermometers.

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