# THE PRESERVATION OF EUCALYPTS

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**Abstract** A number of eucalypt species are naturally durable and so do not require preservative treatment. However, as the resource changes, utilisation of faster growing species with lower natural durability and higher proportions of sapwood increase the need for preservation. The relatively thin sapwood band of most eucalypt species can be treated. Heartwood however, will nearly always be poorly treated by conventional vacuum pressure impregnation. For some products, this feature can be an advantage as it avoids over-treatment in areas not in need of protection. Additional heartwood protection is mainly needed for sawn products that are exposed outside, or inside where there is a risk of termite attack. Promising new areas of research into heartwood penetration will be discussed.

## INTRODUCTION

The hardwood industry in Australia has long been able to draw upon a wide range of eucalypt and related species (*Eucalyptus, Corymbia,* and *Syncarpia*) for its various products. Durable species such as river red gum (*E. camaldulensis*), jarrah (*E. marginata*), the ironbarks (*E. sideroxylon* and *paniculata*), and turpentine (*Syncarpia glomulifera*), are used for poles, piles, house stumps, fence posts and bridges. Spotted gum (*C. maculata*) with its relatively wide sapwood band makes an excellent pole timber. Less durable 'Victorian ash' and 'Tasmanian oak' species such as *E. regnans*, *E. delegatensis*, *E. globulus* and *E. obliqua* can be used for scantling and house framing. With such choice of supply, vacuum pressure impregnation plants were not needed in Australia until the late 1950's. However, with the development of plantation forestry, faster growing trees with low durability and high proportions of sapwood ensure greater need for wood preservation.

Eucalypts have two very different zones in need of protection, the sapwood and heartwood. Eucalypts generally have treatable sapwood, and a wide range of commodities can be sold following sapwood treatment alone. However at present, heartwood mostly cannot be treated to the requirements of AS 1604-1997. This difficulty greatly limits the production of sawn timber for exposed conditions. Incising is suitable for sleepers and bridge timbers, but leaves an appearance unacceptable on the domestic market. Therefore, heartwood protection is the main area in need of research today.

## SAPWOOD PROTECTION

### *Protection from lyctids*

A number of eucalypt species are susceptible to attack in the sapwood by lyctid beetles. The larvae feed on starch in the sapwood. Some eucalypt species are naturally resistant to lyctids due to low starch content, or a pore (vessel) diameter too small for the female's ovipositor (Creffield, 1996). However, the majority of eucalypts have some degree of susceptibility. Some species such as *E. delegatensis* have differing susceptibilities depending upon the region in which they were grown (Fairey, 1980). Some loss of sapwood is considered unimportant for scantling (Beesley, 1956). However, even minor damage is unacceptable for the growing market of appearance grade products.

Boron preservatives are used most often in Australia to protect sawn timber from lyctids. The hot and cold bath is the traditional method of boron treatment. It is a relatively simple operation that is cheap to install. However, the industry trend, especially amongst larger producers, is to move towards the vacuum pressure impregnation of unseasoned timber (Cookson et al., 1998). Unlike many softwoods, the simple Bethell treatment of green eucalypt for lyctid protection is possible because the sapwood is generally just 80-90% water saturated. Also, vessels in freshly harvested eucalypts empty rapidly of water (J. Ilic, pers. obs.). Both of these factors increase the void volume in green timber that can be filled with preservative. After treatment, the boron will continue to diffuse to complete more fully the penetration pattern required. This additional diffusion generally occurs within a week of treatment, without the need to wrap the timber. Rubber wood can be treated in a similar manner (Tan, 1991).

*Natural rounds*

The preservatives registered for use for poles, posts and piles are copper-chromium-arsenic (CCA) and creosote. Ammoniacal copper quaternary compound (ACQ) and copper azole can also be considered for in-ground exposure. Nearly all eucalypt creosote treatments in Australia are with pigment emulsified creosote (PEC), predominantly from one plant in NSW. PEC largely overcomes the problem of creosote exudation and emission from the treated product (Greaves et al., 1986). About 130 plants are used to treat pine and hardwood with CCA in Australia. Far fewer use ACQ or copper azole, but their numbers will increase due to environmental pressures on CCA.

Most strength in a post occurs in its outer sapwood perimeter (Tamblyn, 1984). For example, a 125 mm diameter post has 67% of its strength in a 15 mm sapwood band. Therefore, heartwood protection for a post is usually unnecessary. However, a 300 mm diameter pole has just 34% of its total strength in a 15 mm sapwood band. Therefore, heartwood durability or treatment is more important in a pole. Electricity authorities often specify timber species with durable or moderately durable heartwood for preservative treatment. *C. maculata* has both moderately durable heartwood (class 2) and a relatively thick sapwood band of about 30 mm. However, while thick sapwood bands are useful, some results suggest they are not always essential. Tamblyn (1957) found that poles of non-durable species with sapwood thickness of only 12 mm, if heavily treated with preservative oils, could give service lives of 30 years or more under southern Australian conditions. For example, fence posts of gimlet (*E. salubris*) with heavily creosoted sapwood seven mm thick lasted at least 25 years in Western Australia, compared to 3.4 years for untreated controls. Gardner (pers. comm., 1999) also found that CCA and creosote treated blackbutt poles (*E. pilularis*) with mean sapwood thickness of just 16 mm were performing as well as treated *C. maculata* poles in NSW. If the sapwood of poles is not to be treated, it is customary to remove the sapwood with a plane. Otherwise, its presence may accelerate the rate of heartwood decay in eucalypt poles. Pole life can be extended further by maintenance programs that rely on diffusing preservatives applied as rods, pastes or bandages (McCarthy et al., 1993).

Another consideration for eucalypt poles and posts is soft rot. Hardwoods have more variable penetration patterns than softwoods due to their complex and varied anatomy (Greaves, 1974). The penetration of eucalypt sapwood can be considered a two stage process, where liquid most easily flows into vessels, and then more variably, into the surrounding tissues (Rudman, 1965). In fact, the sapwood of some eucalypts of high density may gain preservative retentions after prolonged treatment not much more than the calculated void volume of the vessels, because of minimal movement through the pits (Tamblyn, 1984). For example, the libriform fibres of *C. maculata* are poorly penetrated compared to *E. regnans*, because it has fewer pit connections and a higher incidence of pit occlusion (Rudman, 1966; Greaves, 1974).

The problem of premature failure to soft rot in poles has been largely overcome by treating with higher concentrations of CCA (6-10% CCA salt) so that there is more preservative available to protect the denser wood (Leightley, 1987). Therefore, retentions in AS 1604-1997 are now expressed in terms of % m/m of wood.

Another problem found in some eucalypts is the presence of transition wood, which is sapwood partially converted into heartwood. Normally, the transition zone is very narrow and not noticeable for treatment purposes. However, some species such as *C. maculata* can have a significant transition zone that is difficult to treat (Romero, 1999). The transition zone normally has similar macroscopic appearance to sapwood, because it lacks the extractives needed to change wood colour. However, pits and vessels in transition wood may be clogged with tyloses and gums as in heartwood. Some transition wood may develop in the period after felling, as sapwood cells can remain live for a further four weeks. The loss of humidity and moisture signals those sapwood cells to become heartwood (Romero, 1999). Brennan (1988) also suspected that it was a thin transition zone in jarrah posts (*E. marginata*) that prevented full penetration of 'sapwood' with CCA.

The expanding wine industry in Australia has led to a shortage in the supply of treated *Pinus radiata* vineyard posts. Therefore, eucalypt thinnings from plantations grown on effluent water have been examined for posts (McKimm, 1984). Eucalypts are stronger than *P. radiata*, so should suffer less breakage during mechanical harvesting, if suitable post quality can be produced. Treatment characteristics for posts are essentially the same as for poles. Eucalypt sapwood in posts usually treats well under vacuum pressure impregnation (McKimm, 1984; Nunes and Reimao, 1989). Less effective but still useful are sap replacement for water-borne preservatives (McKimm, 1984) and creosote hot and cold bath treatments (Baonza, 1987; Brennan et al., 1996). The main problem for posts is the development of deep checks and splits that can arise from utilizing fast grown and small diameter trees. These structural effects are mainly seasoning problems, coupled with correct species selection. Slow air drying under cover is usually the best policy for drying posts. However, more research is needed to find the most economical way to season posts obtained from different eucalypt species.

Certain eucalypts also make excellent marine piles, due to their strength and resilience. A relatively thin sapwood band also ensures that the quantity of preservative able to leach from the pile is minimal, compared to most softwood piles (Scown and Cookson, in press). However, the sapwood band should still be of sufficient thickness to withstand abrasion, and the damage caused by marine borer species such as *Sphaeroma*. Creosote treated eucalypts are more resistant than softwood to the creosote tolerant marine borer, *Limnoria tripunctata*, probably due to greater substrate hardness (Barnacle and Cookson, 1990). Unfortunately, treatment of eucalypts with even high retentions of CCA is ineffective in warm temperate to tropical seas. Therefore, most eucalypt marine piles sold commercially in Australia are double treated with CCA and creosote (PEC).

## HEARTWOOD PROTECTION

### *Heartwood penetration*

As for sapwood, heartwood penetration occurs primarily through the vessels, and then into the connecting fibres and rays via pits. The refractory nature of heartwood arises from the formation of tyloses that fully or partially block vessels, and the various gums and deposits that can settle on pits (Rudman, 1965; Greaves, 1974). Eucalypt heartwoods vary greatly in the extent of endgrain penetration possible. Many species such as *C. maculata* and *E. obliqua* often allow just a few mm penetration. However, some ash eucalypts are more easily treated in the end grain. Rudman (1965) states that *E. regnans* is the easiest eucalypt to treat. Some vessels in *E. regnans* will conduct preservatives for a length of two metres, although the penetration pattern achieved at such depth is usually too uneven to provide adequate protection (Cookson and Dougal, 1997). Side grain penetration is usually just 0.5-1.0 mm depth in straight grained samples (Ladu et al., 1995; Cookson and Dougal, 1997).

While limited, the level of treatment achieved in eucalypt heartwood may provide all the protection needed for some commodities such as window joinery (Cookson and Trajstman, 1996), and the above ground components of paling fences (Cookson et al., 1996). In those cases, the treatment would be 'fit for purpose'. Windows tend to fail first in the endgrain, which is the most treatable area for some ash type eucalypts (*E. regnans* and *E. delegatensis*). LOSP treatment targets final form products, so that the limited side grain penetration achieved may also be sufficient if partially protected from the weather by wide eaves and coatings of paint.

## *Improving heartwood penetration*

### *Incising*

Incising to improve penetration is practiced infrequently in Australia, with only 2-3 machines currently in commercial operation. Historically, there was less need to incise the naturally durable hardwoods used for heavy-duty construction in this country. The incision of seasoned eucalypts is sometimes considered cosmetic, because incisions are usually too widely spaced to provide a uniform treatment envelope. The incisions may be more useful as a means of reducing the development of large checks during drying (Henry, 1970; Bergervoet and Page, 1990; Morris et al., 1994). However, there has been renewed interest in incising technology for softwoods. The general trend is towards smaller teeth that will reduce the visual impact of incising (Morris et al., 1994; Winandy et al., 1995). Cosmetically, the prominence of incising is less if it can be done while timber is green (Morris et al., 1994). In this country, close spaced incising for eucalypt commodities such as fencing posts and rails, decking joists and signage posts should be reexamined.

The ability of microorganisms to 'biologically incise' eucalypt heartwood by degrading tyloses and deposits has been shown in a number of studies (Greaves and Barnacle, 1970). The difficulty faced is how to apply the concept consistently and commercially.

### *Presteaming/boiling*

The penetration of refractory *P. radiata* heartwood can be improved greatly by first steaming the timber while green (Bergervoet, 1983). In eucalypts, steam and superheated steam can also improve heartwood penetration, however, the timber usually then suffers from greater checking and collapse (Kohli and Kumar, 1988; Cookson et al., 1996). Therefore, steaming of eucalypts is rarely practiced in Australia (Hawkins, pers. comm., 1999).

Seasoning green heartwood by boiling in oil or creosote while under vacuum (boultonising) improves the treatment of eucalypt heartwood (Tamblyn, 1984). Green incised *E. marginata* and *E. diversicolor* sleepers continue to be treated with furnace oil using this method (Hawkins, pers. comm., 1999). The incisions probably reduce the development of large checks and splits in the sleepers.

### *Pressure variations*

From 1960, high pressures of 7000 kPa were used commercially in Australia to treat eucalypt cross arms and sleepers with preservative oils (Tamblyn, 1984). The high pressures did not appear to damage the more dense eucalypts treated with creosote, if the treating temperature was kept below 75°C. However, high pressure treatments are no longer used because green timber can be treated as easily in the larger standard (1400 kPa) cylinders following incising and boultonising. Kohli and Kumar (1988) used 4000 kPa to treat *E. tereticornis* heartwood with creosote at 4000 kPa, but still obtained an average of just two mm side grain penetration, and a slight degree of collapse.

Tamblyn (1957) found some evidence that penetration in eucalypts can be improved by use of fluctuating pressures to reduce the blocking of pits with debris and air bubbles which seem to be collected and carried along by the preservative. A modified APM (alternating pressure method) also gave slightly higher retentions of white spirit solvent in *E. regnans* heartwood compared to a four hour Bethell schedule (Ladu et al., 1995). However, the improvements obtained generally have not been sufficient to see the commercial introduction of APM schedules for eucalypts in Australia (Hawkins, pers. comm., 1999).

### *Ammoniacal solutions*

Ammoniacal and ethanolamine based preservatives tend to provide improved penetration into seasoned refractory timbers on both a microscopic (Greaves et al., 1982) and macroscopic level. Ammoniacal copper arsenate tended to provide better penetration than CCA in the heartwood of several softwoods (Gjovik, 1983). Lebow and Morrell

(1993) obtained similar results with ammoniacal copper zinc arsenate in Sitka spruce. Romero (1999) found that ACQ penetrated the transition wood of *C. maculata* better than CCA.

### *Diffusion*

While eucalypt heartwood is difficult to treat after seasoning, it is amenable to diffusing preservatives while green. Because diffusing preservatives are generally leachable after treatment, diffusion treatments are most suited to H1-H3 exposure conditions (above-ground exposures). An intact and well maintained paint film can slow leaching rates. However, double diffusion is an alternative way of fixing preservatives into wood (Chin and Ampong, 1985). This process usually involves soaking timber in a first solution of copper sulphate, and a second solution of sodium dichromate (with or without sodium arsenate). The diffusing compounds then undergo fixation reactions when they meet within the wood.

Lignocellulose has a net negative charge. Therefore, it tends to act like an ion exchange column when wet. Diffusing cations react readily with wood to become immobilised, whereas neutral or negatively charged ions should continue to diffuse freely through the heartwood and sapwood (Mamers and McCarthy, 1998). Therefore, copper sulfate ($Cu^{2+}$) could only diffuse through sapwood, not heartwood, in a double diffusion trial (Chin and Ampong, 1985). However, a number of neutral and negatively charged metal chelates diffused through six mm heartwood slabs of *C. maculata* (Mamers and McCarthy, 1998). By selecting and varying the metal and its chelate, the opportunity arises to find a slow fixing preservative that will diffuse through green heartwood in a single treatment. A disadvantage of diffusion treatments for sawn timber is that the product must usually be dried and dressed before sale. This feature can introduce a problem of treated waste shavings disposal.

### *Supercritical fluid treatments*

One of the most promising new techniques for treating refractory wood was described by Morrell et al. (1993). This technology was examined earlier for the explosion pulping of pine in our laboratories (Mamers et al., 1976; Puri and Mamers, 1983). Supercritical fluids combine the solvating power of a liquid with the penetrating properties of a gas. For timber impregnation, carbon dioxide is the best candidate supercritical fluid for a range of organic and organometal preservatives. Although very high pressures of about 15000 kPa are required, the treatment appears not to affect wood structurally because the supercritical fluid penetrates so rapidly that differential crushing pressures do not arise. Potential advantages of the process are fast treatment times, the production of dry treated timber ready for immediate sale, full penetration, use of a non-flammable (though suffocating) gas, absence of volatile organic solvent emissions, and no need for a drip pad. The main drawback for this technology is the high capital cost of the envisaged treatment plants. The process might also be questioned on the basis that some carbon dioxide could escape into the atmosphere and so add to greenhouse problems. However, on a net global basis the carbon dioxide is recycled, because that used in further treatments will be compressed from the atmosphere. The process is generally seen as 'green technology' because it uses a naturally occurring molecule as solvent.

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