A pole preserved, a tree saved

Power poles, telegraph poles, lamp posts: in profusion they decorate Australian suburbia and countryside. Count them, and you'd arrive at a number close to 7 million.

Each pole is a memorial to a once-living tree — a skeleton stuck in the ground to serve the ends of man.

At one time, when forests were more abundant than now, there was no shortage of prime timber poles. Towering specimens of red and grey ironbark, red bloodwood, white mahogany, and tallow wood could be readily harvested and, strung with wires, could be expected to last a quarter of a century or longer.

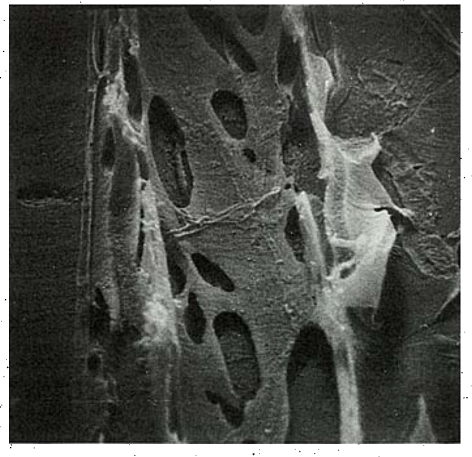
Those times have passed, and now we must use less-durable species. A technological solution has made this enforced choice practical. The idea of impregnating these less-durable timbers with chemical preservatives is to prolong their service life so as to match the long-standing performance of their naturally very durable predecessors.

And so, in the 1960s, a timber preservation industry arose in this country. In long steel chambers loaded with poles, preservative is forced under pressure (typically 1400 kPa for 100 minutes) into the outer parts of the wood. Creosote and copper–chrome–arsenic (CCA) are most commonly used; each year close to 5 million litres of the former and 3500 tonnes of the latter are used in this way.

Keeping poles in service means fewer trees have to be cut down.

Scientists from the CSIRO Division of Chemical and Wood Technology played a prominent role in devising treatments suitable for our unique hardwoods. Their tests verified that treatment was effective, and this influenced the acceptance, and growth, of this now well-established industry.

Today, 45% of in-ground poles have been treated, and the figure is expected to increase. Mr Chris Yule of Koppers Australia Pty Ltd has predicted, from the results of a survey, that the annual requirement for new hardwood poles will rise from the 1981 figure of 153 000 to 165 000 in 1985. During this period, Mr Yule predicts that the proportion of new poles that will be treated will rise to 76% as the availability of durable timbers declines.



The electron microscope shows how soft rot has eaten away the cell walls.

Softwood poles, notably of radiata pine, have also been used. Telecom has been the main user, while three State electricity services have installed several hundred treated pine poles.

Stopping the rot

The Division's conservation and biodegradation program is still very involved in pole preservation studies. The program's leader, Dr Harry Greaves, points to compelling reasons for maximizing the service life of poles.

A good environmental reason is that keeping poles in service as long as possible means fewer trees have to be cut down and, importantly, reduces demand for the harder-to-get durable species.

Another good reason is economic. The price of a common 11-m treated pole is about $130, and so the value of the existing pole population is some $700 million. But to replace each pole costs considerably more — probably between $500 and $1000 after labour and machinery costs are included, giving an Australia-wide replacement cost of $3–7 billion. It therefore pays handsomely to prolong the life of existing poles.

In this context, one of the scientists' major concerns at the moment is how to deal with soft rot — a form of decay that is unexpectedly attacking preservative-treated wood.

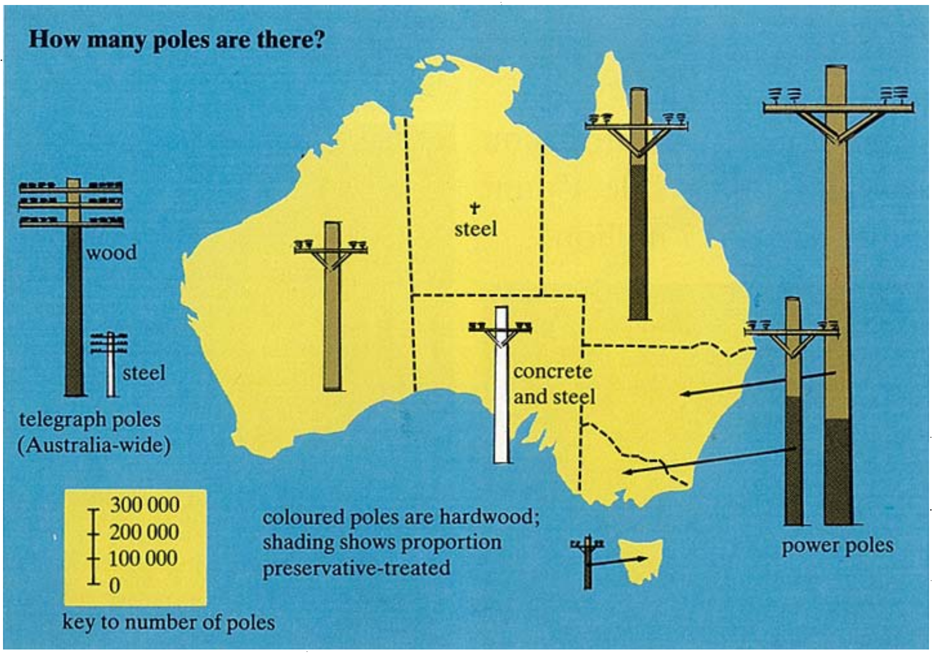
The problem is particularly bad in Queensland, where some half a million CCA-treated transmission poles (more than half of the total) are currently affected to varying degrees. The affected poles are mostly spotted gum, and in all cases hardwoods. In softwoods, normally more resistant to soft rot when untreated, the preservative seems to be doing its job. Failure of CCA protection has also appeared in some areas of New South Wales, Victoria, and Tasmania.

Soft rot attacks the outer sap-wood (where the preservative is), leaving the heartwood open to attack by other organisms.

Soft rot attacks the pole at ground level, starting at the outside in the sapwood and advancing inwards. In severe cases the decay advances at up to 3 or 4 mm a year, consuming all the sapwood (typically 20 or 30 mm) within 8 years. A pole condemned at this age has lost perhaps 75% of its expected service life, although this is an extreme occurrence.

Only a small minority of poles are condemned because of soft rot alone. The fungi responsible attack the sapwood most easily, having a harder time with the heartwood. However, since preservative chemicals reside almost entirely in this outside layer, its destruction leaves the way open for the heartwood to be attacked by other microbes and termites.

A danger is that soft rot damage may not be readily apparent. While soft rot softens



There are more than 6 million poles in Australia. Most are hardwood, and 44% of these are preservative-treated. In addition, softwood poles number more than 60 000 (mostly telegraph), and concrete ones 35 000.

Soft rot is unexpectedly attacking preservative-treated wood.

and chequers the surface of just about any piece of exposed wood, the treated poles suffer a deep form of it that can be overlooked. The wood looks sound, although it may be soft when wet, and when dry it is hard but weak and brittle.

The affected wood may be largely removed with sharp tools, but the problem now is that small pockets of decay will remain some distance in advance of the apparent decay. As time passes, the opportunity for in-service failure of poles due to soft rot has increased, and its incidence now alarms Dr Greaves.

Research by scientists in his group is tackling the problem in several ways.

The fungal soft rot

The first, and most basic, question is: what is allowing the soft rot to gain a foot-hold in what should be protected territory?

Soft rot has been around as long as wood itself, and it occurs in almost all parts of the world. However, the term 'soft rot' was only coined in 1954, and its ability to attack treated hardwood was only discovered in Brisbane in the late 1960s. By 1971, about 10% of the poles in the Cairns region were found to be affected.

Soft rot is caused not by one organism but by a wide range of fungi belonging to the groups known as *Fungi imperfecti* and *Ascomycetes*. These secrete enzymes that can digest parts of wood cells.

Most treated poles that have succumbed to soft rot have been impregnated with CCA, although those subjected to oil-borne treatments, such as creosote, are also susceptible to a lesser degree.

At first scientists suspected that poor treatment methods were to blame — that the loading of the chemicals was not high enough, since hardwoods are relatively impermeable. However, investigation of the stricken poles proved this wrong.

Subsequently, a suggestion was raised that a particularly tolerant fungus may be responsible. Indeed, the CSIRO group's laboratory studies have isolated some micro-organisms that are tolerant of various preservatives, and the scientists have observed microbes detoxifying CCA, but these are exceptional cases. It is impossible to blame these organisms for the present widespread problem.

Dr Greaves has put forward a theory that has received a good degree of acceptance. A combination of various factors may well be involved, including a degree of leaching of the protective chemicals, but he believes the fault lies mainly with an uneven distribution of the chemicals on a microscopic scale.

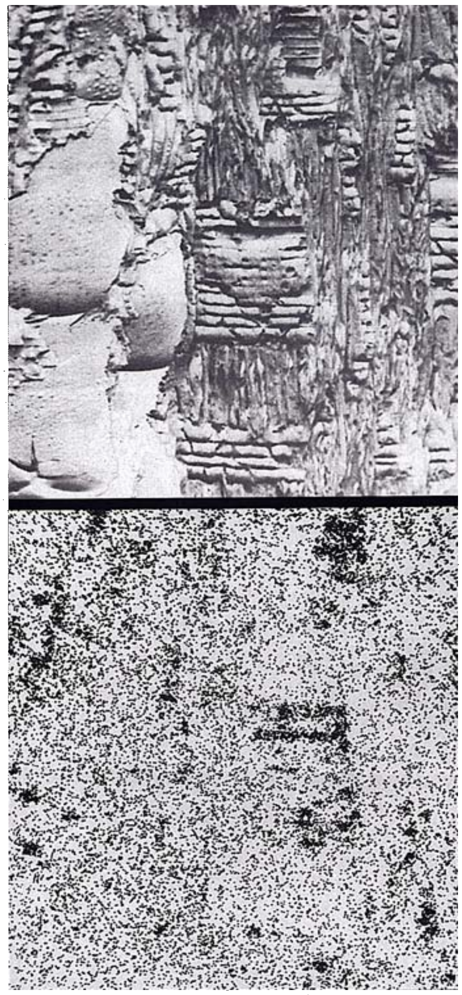
Using an electron microscope and X-ray microanalysis, he has been able to analyse the chemical loading of the wood within cellular dimensions. This has revealed that dense eucalypts are not uniformly penetrated by the CCA. The chemical penetrates this type of timber along rays and vessels, between which large pockets of unprotected fibres remain.

Towards a solution

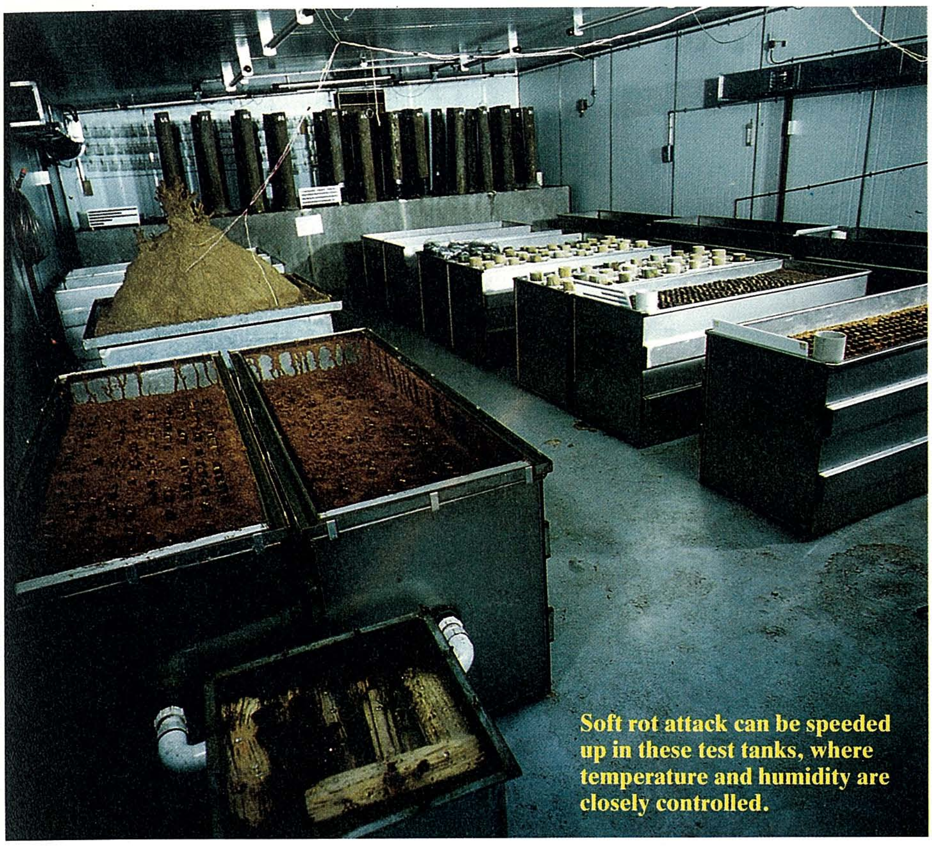
It seems that, if sufficient preservative could be distributed throughout the timber cells, soft-rotting fungi could not establish inroads. Indeed, the reason softwoods are immune from soft rot attack appears to be that their cells are much more permeable to preservative chemicals.

Dr Greaves' group has been looking at novel methods of introducing toxicants into wood, and developing new formulations that permeate more thoroughly. They have screened a large range of potential toxicants, including compounds of copper, fluorine, boron, and arsenic. A number of organic formulations have also been examined.

The screening systems have included petri-dish tests with filter paper and agar, some using a sawdust medium, and others using blocks of solid wood. Loaded with the chemical on test, these dishes have been



A clue as to why CCA preservative doesn't always protect against soft rot. The piece of attacked wood seen under the electron microscope (top) was subjected to X-ray microanalysis: this showed that the chromium was not uniformly distributed (below).


Soft rot attack can be speeded up in these test tanks, where temperature and humidity are closely controlled.

inoculated with pure cultures of fungi and also a blend derived from ground-up fractions of soft-rotted Queensland poles. Equipment for accelerating soft rot attack severalfold has also been built. Large stainless-steel tanks hold various artificial soil profiles that harbour a mixture of fungal strains and even a functioning termite colony (brought by truck from Canberra). Temperature and humidity are closely controlled.

An outcome of the scientists' studies has been the development by Dr Ron Johanson of a new preservative formulation that gives timber short-term protection against soft rot. It is a water-borne complex of copper, fluorine, boron, and ammonia, which has the advantage of penetrating into wood rapidly and, more importantly, evenly. Ammonia causes the cell wall to swell, allowing the fungitoxic copper to penetrate all parts of its structure. Pressure is not needed in its application — it can simply be painted on — and toxicity to humans is low. It is available commercially under the name 'Blue 7'.

However, because it is not fixed into the wood and can be leached out, this product does not give long-term protection to power poles unless special methods of application are used.

Blue 7 can be applied to poles in the form of a bandage (discussed below) that prevents it leaching out, or it can be poured into holes drilled into the heartwood. The Victorian State Electricity Commission and some authorities in New South Wales are using it.

At the Division the search goes on for soft-rot-resistant preservatives for poles,


Heat-shrinking the CSIRO bandage onto the base of a pole afflicted with soft rot.

A meter to detect decay

Inspectors regularly check transmission poles for soundness, but in some cases of soft rot and centre rot the decay is difficult to detect. The outside looks all right, but things aren't so good underneath.

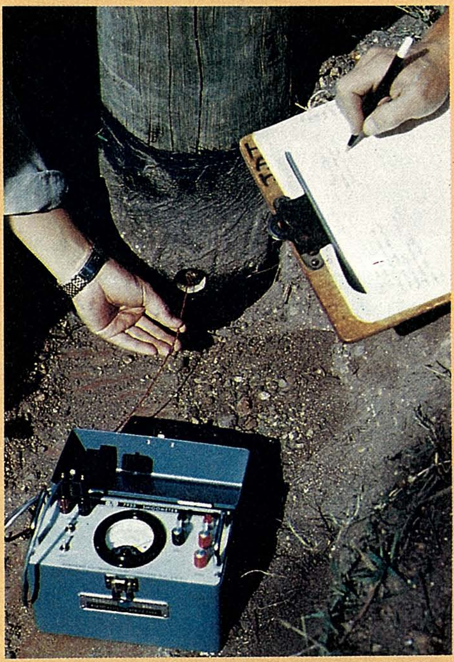
An accurate, non-destructive method for ascertaining the internal condition of wooden poles would be very valuable.

Techniques using X-rays and ultrasound are possible, but these methods are expensive and cannot readily distinguish between internal hollows due to decay and natural checks and splits. Dr John Thornton of the CSIRO Division of Chemical and Wood Technology has done extensive tests with a 'Shigometer', and he believes it can give the inspectors the cheap, accurate tool they are looking for.

The device, developed in America, sends a precise current pulse through a small hole drilled into the pole, and measures its electrical resistance. Originally it was developed to determine the internal condition of living forest trees, but Dr Thornton has confirmed that it is unusually sensitive in detecting the onset of decay, and in determining whether the decay-causing fungi are still active or not.

He believes further field and laboratory studies will prove the reliability of the Shigometer for detecting the presence of decay within standing poles.

Detection of decay in wood using a pulsed-current resistance meter (Shigometer). J.D. Thornton, W.G. Seaman, and M. McKiterick. *Material und Organismen*, 1981, **16**, 119–31.


This meter uses a current pulse to check for decay in standing poles.

Sleepers, too, benefit from treatment

Railway systems are finding it increasingly difficult to obtain naturally durable wood sleepers. As is the case with poles, durable sleepers are in short supply because the tree species required have already been heavily harvested.

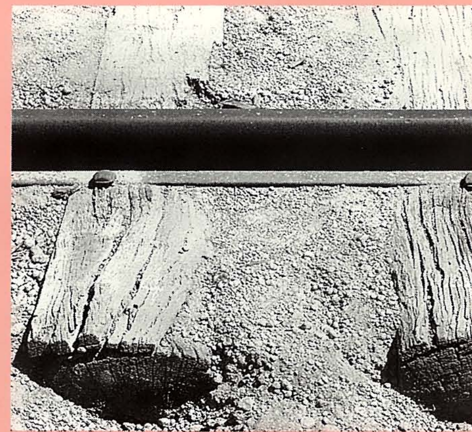
In far-northern Queensland, sleepers of Cooktown ironwood are still in track after more than 80 years' service. But this wood — possibly the toughest, hardest-wearing, and most weather-resistant species in Australia — is so rare that few new sleepers made of it are likely to be laid again.

Jarrah sleepers are world-renowned: they can be found shouldering the rolling stock of London's underground, and their lifetime is typically 25 years or more. Jarrah too is now hard to get. Other hardy, and rare, woods are wandoo and river red gum, species that can also provide a sleeper life of a quarter of a century.

Mr John Barnacle of the CSIRO Division of Chemical and Wood Technology has found that high-pressure preservative treatment of less-durable species can answer the need. He has found that creosote treatment of mountain ash, brush box, and rose gum can extend their service life at least 100% — from an average 11 years to 25 years or more.

Even softwood (radiata pine) can, by preservative treatment, have its service life extended to match that of untreated jarrah. This means an extension of its life from, typically, 4 years to 25 years and more. Preservative treatment can also further extend the long life of jarrah sleepers (and other durable types) by at least 5 years, he has found.

Mr Barnacle's results come from an analysis of the performance of about 8000 sleepers (from 21 wood species) laid between 20 and 28 years ago at 20 sites throughout Australia. The project was initiated by the old CSIRO Division of Forest Products, in co-operation with State and Commonwealth railways and State Forestry Departments. Railways of Australia has provided Mr Barnacle's present Division with funds to follow up and continue the early work.



The jarrah railway sleepers on the left, treated with preservative, are still good after 25 years' service. The ones on the right, from the same location, are the same age but untreated.

The original sleepers were treated with 10 different wood preservatives (or none, as a control), and different concentrations of some of them were tried.

Creosote–oil mixtures and pentachlorophenol–oil mixtures, impregnated at 7000 kPa, were found to perform well. Most of the treated wood types exceeded, or look as if they will exceed, an average life of 25 years.

Mr Barnacle found that water-borne treatments (copper–chrome–arsenic and the like) generally gave a poor performance in the tests. At best, such preservatives could extend service life of hardwood sleepers to 20 years. Only when used on radiata pine could CCA give a service life of 25 years or more. Some oil-treated pine sleepers are still in service after 47 years.

The choice of preservative is more crucial than the natural durability of the wood. An oil-borne preservative will extend the life of many Australian hardwoods, as well as radiata pine, to at least 25 years — a performance better than most untreated durable species.

Indeed, the failure of many of the treated sleepers was not due to rotting and insect attack, but was caused, Mr Barnacle thinks, by mechanical failure of the sleeper in the vicinity of the fastening, usually a simple dog spike. Given a sound sleeper to begin with, he believes that the life of a preservative-treated sleeper could be extended even further — to 30 years and more — if screw spikes or some resilient fastener were used instead.

Another advantage of preservative-treating hardwood sleepers is that it allows the non-durable sapwood to be used (normally only the heartwood is used for sleepers). Preservative easily penetrates into sapwood (just like it does with radiata pine), giving it a service life equal to that of the heartwood. This allows greater utilization of available wood, and even enables smaller trees to be used for sleepers — a desirable move for conservation reasons.

Performance of wood sleepers treated with certain oil-type preservatives in Australian rail tracks. J.E. Barnacle, C.W. Chin, and J.P. Costolloe. *Papers, Fourth International Rail Track and Sleeper Conference, Adelaide 1981.*

and one promising candidate undergoing field tests is a copper salt of a fatty acid. This fungitoxic material is carried by ethanolamine, which swells the cell wall and allows the preservative to penetrate fully.

A number of research groups are presently working on the soft rot problem, and to co-ordinate their research efforts an Australasian Soft Rot Study Group has been formed. It includes researchers from the CSIRO Division of Chemical and Wood Technology, Queensland Forestry Department, Forestry Commission of New South Wales, University of Queensland, University of Tasmania, New Zealand Forest Service, and the Forest Products Research Centre of Papua New Guinea.

An International Research Group on Wood Preservation is also concerned with soft rot: it is undertaking a large-scale experiment to study the performance of treated hardwoods at sites in different countries.

A pole bandage

Until a better preservative can be demonstrated — and field testing takes years — what can be done with the present crop of afflicted poles?

A number of protective techniques have been used but, according to Dr Greaves, most of them leave much to be desired.

Spraying or brushing on a surface coating of fungicide above and below ground level is of questionable value. On intact wood, not enough toxicant gets in to prevent decay; on decayed wood, the fungicide can get in, but not beyond the area of infection. Pockets of fungi ahead of the main site can still keep spreading.

Clean creosote

Everybody knows creosote: it's the smelly material that may occasionally be seen clinging, black and shiny, to the base of wooden poles.

Creosote is made from coke oven tars, and is highly toxic to fungi. It is impregnated into poles using high pressures and elevated temperatures. Railway sleepers, piles, fence posts, outdoor furniture, and paling fences are also often treated with this economical, effective preservative. For domestic use, application by brush, spray, or dip is still quite effective, as the oily liquid tends to inhibit the passage of water into the wood (and dry wood won't rot).

The problem is that creosote is messy to handle, and can easily soil clothes and equipment. In hot weather, particularly, creosote is apt to oxidize and polymerize on the surface of treated wood, forming pitch-like deposits known in the trade as 'crud'.

Environmentalists and some unions have also questioned the safety of creosote, since the material can cause sensitization, irritation, and burning of the skin of some individuals handling the material. In fact, some unions have refused to work with creosote.

In this situation, a clean and dry creosote should find a welcome reception. Called 'pigment emulsified creosote' (PEC), it was originally developed by Koppers Australia Pty Ltd, but an improved ultra-stable emulsion has recently been formulated in collaboration with the CSIRO Division of Chemical and Wood Technology.

The State Electricity Commission of Victoria is involved in evaluation of the new material's effectiveness, and a trial with several thousand treated poles has commenced.

As it uses an iron-based pigment, the new creosote is red, although green or yellow are possible if aesthetic considerations are important. The pigment locks the creosote into the wood structure, and prevents 'bleeding'.

Scientists at the Division have compared the performance of this clean creosote with that of the conventional product. They have established that the toxicities of both materials are similar. In terms of exudation, wetness, surface weathering, cleanliness, and smell, PEC proved superior to ordinary creosote.

The most noticeable differences were those observed immediately after the pressure cylinder was opened. Specimens treated with PEC could be handled straight away — they appeared almost dry — whereas conventionally treated ones were oily and slippery, and fumed profusely.

In the latter case, a yellow vapour was given off, making breathing difficult, and delaying closer inspection for some time. The odour of PEC is not offensive, and not at all like that of ordinary creosote.

One of the most encouraging results was that PEC treatment was just as effective at 60°C as at 90°C, the standard temperature for impregnating creosote. If this result is confirmed in commercial operations, the treatment would allow considerable savings in the industry's energy consumption.

Clean creosote — its development, and comparison with conventional high-temperature creosote. C.W. Chin, J.B. Watkins, and H. Greaves. *Papers, 14th Meeting of the International Research Group on Wood Preservation, Surfers Paradise, May 1983.*

Dressing the pole — using axes or naked flames to remove the visible soft-rotted wood, and then applying preservative — is little better because the troublesome pockets remain.

Sterilization of the wood is an admirable concept; the problem is that its effects are only transitory, and infection returns. Steam, flame, and fumigation with chemicals (or even radiation) have been used, but all present considerable difficulties in handling.

Isolating the pole from the earth with a physical barrier is really only a half measure. Plastic wraps can exclude ground-dwelling organisms, but any already in the wood can survive preservative treatment and flourish when the wrap locks them, and water, in together.

Studies at the Division have shown that a barrier causes a dramatic increase in the moisture content of a pole. Scientists found that after 18 months the average moisture level at ground line in a CCA-treated stub was more than 70%, compared with 25% before it was wrapped. Trials at two locations have shown that sapwood attack can be worse than when no barrier at all is used.

In Dr Greaves' view, the best way of fighting back is to combine the principles of these methods by applying a bandage to the affected pole from about 150 mm above ground line to 500 mm below.

Members of the CSIRO group have developed and patented what they consider to be close to the ideal form of bandage, and it is now undergoing service trials in Queensland, Tasmania, and Papua New Guinea. Commercially available bandages, developed from overseas experience, were not formulated with soft rot in mind.

The new bandage contains a hefty dose of preservative that diffuses into the wood, and it is kept in by a tough plastic backing, which shrinks tightly onto the pole when a blow torch is applied.

The heat also melts an outer layer of bitumen, which flows into cracks and ensures a seal against rain and groundwater. A bandage costs $20 or so, depending on the chemical selected, and it can be applied, after excavation around the pole, in about 20 minutes.

The bandage will last at least 5 years, and the scientists have developed techniques to replenish the chemicals, should this be required, while the bandage is in place.

Andrew Bell

More about the topic

Research and development for the preservation of hardwood poles. H. Greaves. *Papers, Wood Preservation Symposium, National Timber Research Institute, South Africa, March 1983.*

Development of fungitoxic bandages for the groundline maintenance treatment of soft rot in hardwood poles. H. Greaves, C.W. Chin, and C. McEvoy. *Papers, Pole symposium, Electricity Supply Association of Australia, April 1980.*

An illustrated comment on the soft rot problem in Australia and Papua New Guinea. H. Greaves. *Holzforschung*, 1977, **31**, 71–9.

The natural durability of various Australian wood pole species to soft-rotting microfungi. H. Greaves. *International Journal of Wood Preservation*, 1979, **1**, 15–20.

The development and installation of experimental fungitoxic bandages. C.W. Chin, C. McEvoy, and H. Greaves. *International Journal of Wood Preservation*, 1982, **2**, 55–61.