AN OVERVIEW OF RESEARCH AND DEVELOPMENT IN WOOD PRESERVATION

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INTRODUCTION

Wood preservation undoubtedly plays a most important role in today's forest products industry. The growing impact of the discipline at national and international levels is clearly witnessed in the numerous research groups and trade bodies, including the International Research Group on Wood Preservation, the Wood Protection Sub-Division of the International Union of Forestry Research Organisations, the Tropical Wood Preservation Group, and the various Associations/Councils, etc. which have been set up by the preservation industries in countries such as America, Australia, Britain, Japan, New Zealand, Scandinavia, and recently, Canada. These Associations/Councils are primarily concerned with legislative aspects like quality control and standards, as well as the dissemination of technical expertise and information. Research and development on the other hand is mainly carried out by Federal and/or State organisations, although in these days of reduced government spending, industries themselves are becoming more involved in research or they are directly supporting government efforts.

The benefits which accrue from effective relationships between government and industry are far wider than the simple issues of laboratory staffing and equipment. For example, a marriage of fundamental and applied attitudes will lead to improved performance all round, measured not only by the bench worker understanding practical problems better and the commercial man appreciating more about research, but also by the consumer ultimately receiving the best available commodity.

In Australia this attitude between government and industry has led to collaborative research programmes in such key areas as pole preservation, improvements in wooden rail sleeper systems, and the development of third generation preservatives. Ruddick (1) has reported a similar collaborative attitude in aspects of preservation research in Canada. In the case of Australia, however, government/industry links have not been formalised to the extent of privatising government laboratories, as has occurred in Canada with the establishment of Forintek in 1979, nor has such a step been seen as necessary. In contrast, in the United Kingdom where industry's involvement in government research has traditionally been absent, particularly in the field of wood preservation, only recently have government researchers been instructed to extend their links with industry in a new cost recovery role. It is hoped that this is not seen as merely an accountancy arrangement. Instead the new links should be approached in the spirit of the Australian and Canadian situations described above which provide the basis for more effective problem solving and some insurance for the future viability of the preservation industry.

A number of topics vital to the preservation industry are receiving attention at the international level. Many of these were raised at the International Research Group/American Wood Preservers' Association Joint Symposium, 'Wood Preservation from Around the World' held in Nashville in 1981. At this, the second annual meeting of the Canadian Wood Preservation Association, some aspects of Australian research and development which have relevance to the international scene, and in particular to Canada, will be discussed. Clearly, there will be differences in emphasis, not the least because the Australian industry is primarily hardwood based. It should also be remembered that in a country as big as Australia the range of hazards (from both climate and biological agencies) is vast, and the diversity of end usage is large.

WOOD POLE RESEARCH

The majority of wood poles presently going into service around the world are produced from non-durable trees. This means that the major strength conferring outer shell has not only to be *effectively* preserved from decay, but also it must offer protection to the inner non-durable heartwood. Adequate penetration and retention is thus essential. In Australia, where well over 90% of our 6 million or so poles are hardwoods, this is presenting difficulties. The same appears to be true for such difficult-to-treat softwoods as the spruces (*Picea* spp.), which are used in Europe, N. America and Canada. A number of techniques for improving the penetrability in such species have been suggested. These range from biological and mechanical incising (2, 3, 4), to pre-treatment steaming (5) as well as modified treatment schedules (6) and novel formulations (7).

We have tried a number of similar approaches with our difficult pole species in Australia and at present our main research efforts are aimed at controlling soft rot in the treated sapwood of eucalypt poles (particularly in Queensland, Tasmania and some parts of New South Wales), preventing centre rots in poles in Victoria, and providing more reliable inspection methods. Emphasis is being placed on formulations and treatment systems, and, at the experimental level in the laboratory, a combination of both. The preservation and pole industries and the State Electricity Commissions are collaborating with government research laboratories on many aspects of this research.

(i) Soft rot in poles

There are many published descriptions of this type of decay from the early descriptive papers by Savory (8, 9) to the more general research accounts, for example Levy (10) and, more recently, Zainal (11). In practical terms the soft rot fungi can cause significant problems in commodities ranging from water cooling towers (12) to shingles, shakes (13) and poles (14, 15). In the latter structures, soft rot is of particular economic importance in countries where hardwood poles predominate, such as S. America, S. Africa, S.E. Asia and Australia. Undoubtedly the fungi also attack softwood poles in the more temperate parts of the world, as reported in Sweden by Friis-Hansen (16), and as may be inferred from the 'shell rot' treatments undertaken by groundline maintenance crews in N. America.

In the case of hardwood treatments, it seems that soft rotting microfungi are able to attack the wood cells because the preservative components are unevenly distributed throughout the timber. Fibres are especially poorly treated (17, 18, 19) and since these cells represent the bulk of the strength conferring tissues effective preservation will probably only occur if the fibres are treated with adequate levels of fungitoxic chemicals. On this basis, formulations capable of opening-up or swelling the wall structure should be more successful than more standard aqueous preservatives such as copper-chrome-arsenic (CCA). This is not to say that copper should not be used in anti-soft rot formulations, and it has been shown that levels of about 0.3-0.4% m/m Cu (depending on wood species) control this form of decay in laboratory tests (20, 21). In the field, however, levels equivalent to 0.6% m/m Cu (24 kg/m^3 CCA Type B or 38 kg/m^3 dry salt in eucalypts of about 640 kg/m^3 density) are not controlling soft rot in poles in parts of Australia and also in Colombia, S. America (22). Our research indicates that the problem comes back to inadequate tissue penetration, and hence we are examining alternative formulations based on wall swelling compounds, such as ethanolamine (23) and various ammoniacal systems (24, 25).

These experimental formulations have so far been copper-based, using fatty acids to form the metal soap, e.g. copper nonanoate. They have been used to treat small sticks of eucalypt, the treated wood being exposed in our accelerated field simulator where soft rot is a major hazard. In addition, treated material has been examined by electron probe microanalysis to ascertain the extent of penetration and distribution in cell walls and wood tissue. The results, which are discussed later in this paper, have been most encouraging and confirm some of the Canadian research, at least on ammoniacal formulations, apropos improved penetration (7, 26).

Concurrent with our programme to develop improved formulations for initial treatment of hardwood poles, we have adopted the N. American and German philosophy of applying bandages as groundline maintenance for the poles already in service and affected by soft rot. However, the commercial bandages available in Australia when the programme commenced were unproven against soft rot, were apparently non-durable, and contained fungicides that did not diffuse well in eucalypt wood.

The CSIRO bandage (27) was developed as a result of screening a wide range of chemicals in the laboratory; the formulations had to diffuse through spotted gum (*Eucalyptus maculata* Hook.) sapwood as well as control a mixed population of soft rotting microfungi. In addition, an effective bandage format was designed (Figure 1a), providing a laminated chemical impregnated inner foam matrix backed by a durable bitumen-coated crosslinked-polyolefin outer cover. The Mark IV bandage (Figure 1b, arrow) is applied by heat shrinking it onto the pole, which provides a high degree of conformity with the pole surface as well as most effective upper and lower margin seals.

Formulations which have so far proved effective in service trials of the bandage include an acidic copper fluoroborate (Basilit BFB), an ammoniacal copper fluoroborate (Blue 7), tri-n-butyl tin oxide plus quaternary ammonium compound (Permapruf T), 2-(thiocyanomethylthio) benzothiazole (as Busan in Busperse 47), and pentachlorophenol in hexylene glycol. In the latter case, the hexylene glycol is proving a most efficient aid for the diffusion of PCP into the pole.

The bandage and its development have been described by Greaves, Chin and McEvoy (28) together with the procedure for assessing the efficacy of its field performance; this is based on a bioassay method performed on cores taken at regular intervals from bandaged poles.

We are investigating the possibility of replenishing the fungitoxic chemicals in the bandage whilst leaving it *in situ* around the pole. We also believe that the bandage is suitable not only for groundline maintenance in hardwood poles, but also for applying to new hardwood poles before they are placed in service. In addition, there is no reason why the CSIRO bandage should not be used in maintenance programmes on softwood poles.

(ii) Centre rots in poles

This type of decay in transmission and telegraph poles is probably as common in softwood poles in the northern hemisphere as it is in Australian eucalypt poles. Furthermore, with the increasing difficulty of adequate (and economic) supplies of the traditional durable pole species, the problem will take on greater significance in the short term.

Although there is much dispute about the onset of decay in the heartwood of non-durable pole species (see for example the paper by Taylor (29), and its accompanying discussion) there can be little doubt about the economic impact on the pole preservation industry of this form of fungal attack. In Australia only limited surveys have been conducted by the utility companies (30), but in N. America and Sweden, for example, it would appear that there is good evidence of the incidence of centre rots in softwood poles. Therefore, it is not surprising that there has been considerable research in countries such as U.S.A. and Canada aimed at controlling this form of basidiomycete decay. The techniques developed, however, may not be entirely suitable for hardwood poles, particularly eucalypts, elsewhere in the world. For example, the success of fumigants as reported by Graham (31), would be minimised in our eucalypts, which frequently develop internal checking leading to the possibility of fairly rapid dissipation of the fungitoxic gases.

Control measures which are showing some potential for hardwood poles, and which equally could be applied to softwood poles, include the introduction of both liquid and fused (solid) diffusion formulations to the heartwood via abaxially drilled holes. Our own tests and trials by the State Electricity Commission of Victoria indicate that multi-salt formulations such as copper fluoroborate work well under these conditions. For example, Murray (32) has shown that in two years both the boron and fluorine in Blue 7 diffuse between 80 and 100 mm horizontally in eucalypt wood when applied via side bored holes to poles in service. The copper component of the formulation diffuses between 40 and 60 mm in the same time.

In recent experiments where boric acid or disodium octaborate (as Timbor) has been mixed with cupric oxide in fused rods (Greaves, McCarthy and Cookson, unpublished data), the copper has been found to be totally unreactive from the diffusion point of view. On the other hand the boron diffused up to 135 mm in the experimental material which consisted of small diameter rounds of messmate (*E. obliqua* L'Herit.). The rounds had been pre-infected with four different centre rots, *Coniophora olivacea* (Fr. ex Pers.) Kart., *Gloephyllum abietinum* (Bull. ex Fr.) Kart., *Fomes lividus* (Kalch.) Sacc., and *Trametes lilacino-gilva* (Berk.) Lloyd. The rods of preservative were introduced into centrally drilled holes in the top and bottom of each round. The treated, infected rounds were incubated in troughs of vermiculite in our accelerated field simulator. The extent to which the fused preservative rods were able to control the spread of these decay fungi is shown in Figure 2.

The incorporation or fusion of biocidal inorganic ions into solid glass-like rods of preservative were recognised by Bechgaard and Dulat (33) in Denmark; the rods were recommended initially for remedial *in situ* treatments of creosoted railway sleepers where basidiomycete decay was considered to be a hazard (34). Our recent results with this form of preservative suggest that its use as a remedial treatment could be extended into pole maintenance programmes.

(iii) Improved inspection methods for pole maintenance

There is no doubt that a reliable and accurate inspection procedure is a vital part of any wood pole maintenance programme. Indeed, research workers in countries as widespread as Australia, Canada, Guyana, Sweden, U.K. and U.S.A. have formed a working sub-group of the International Research Group on Wood Preservation specifically to examine non-destructive testing for the detection of defects in poles. The topic has also been discussed at a recent pole symposium in Australia (35) and provided lively debate at last years AWPA Annual Convention (29, 36).

The debate frequently concerns the relative merits of either different procedures or the equipment being used, which includes instruments utilising sound waves (Pol-tek, Resotest), X-rays, either single or multi-source as in tomography, pulsed electric currents (as in the Shigometer), impact resistance of the timber (e.g. Philodyn), etc. In many cases traditional techniques employing sounding and coring represent the normal inspection procedure, and it is clear that this approach is not entirely accurate in determining (or predicting) a pole's serviceability. Indeed, it has been estimated that poles prematurely removed from service are costing electricity supply bodies in Australia some $20 million annually (37).

Our research indicates that the instrument with greatest economic potential in reducing these costs is the Shigometer. The instrument has been extensively tested in laboratory simulations of progressing decay and moisture content (38, 39). In the field it has been used in cooperation with Telecom, on creosoted telegraph poles (40). The results indicate that the Shigometer can be used to distinguish decaying wood, i.e. active fungal attack, from decayed wood, and that its high sensitivity allows the operator to detect attack in the very early stages. Perrin (pers. comm.) at Forintek has used the Shigometer on softwood utility pole sections and found it to be a valuable aid in predicting actively decaying wood in poles. In addition to these studies more recent work at Forintek has examined the potential of the sound wave technique for detecting internal defects in poles. A system based on this principle was patented in Australia by Shaw (41), and is in field use in Tasmania as well as being examined by electricity suppliers in parts of New South Wales.

A technique based on X-rays is also being examined in New South Wales, where there appears to be some interest in providing ground-line maintenance for poles on a contractural basis, as currently practiced in countries such as U.S.A. (e.g. Osmose) and Sweden (e.g. Cobra). The procedure used involves the operation of a Phillips K140 portable X-ray source, employing special medial plates, 432 X 356 mm, exposed for 7-12 seconds with an energy range of 90-120 kV. Present costs seem rather high when compared with, say, the cost associated with the Shigometer. One radiograph costs $20 and the charge does not include the excavation or back-filling of the pole. The technique has been more fully described by Gardner, Johnstone and Pitt (37) and is claimed to have better than 90% accuracy. The more sophisticated X-ray technique - computerised tomography - recently described by Taylor, Morgan and Ellinger (42) has yet to be examined for Australian hardwood poles, but undoubtedly it seems to have some potential.

Whatever system is adopted by the different utilities around the world, traditional sampling should continue; occasionally, confirmation of a suspected defect should also be obtained. We believe that microscopy rather than the ability to culture decay fungi from the sample core should be the preferred confirmatory technique, and that any method for routine pole inspection should be able to distinguish physical defects from biological ones, active decay or insect attack from dormant or complete attack, should be reasonably quick and inexpensive, and, above all must be reliable.

PROTECTION OF BUILDING MATERIALS

Wood based building materials in Australia are subject to a very wide range of chemical, physical and biological hazards. In addition, the type of material is diverse - in the solid wood sphere alone, some 200 or more native tree species are milled for building purposes and there is a regular supply of imported timber from Europe, U.S.A., Canada, S.E. Asia and many other countries. The shipment of Canadian timber to Australia is of particular relevance to the present meeting.

(i) Some problems with timber imported from Canada

The main supplies of Canadian wood consist of western red cedar and Douglas-fir. In addition, a small quantity of spruce-pine-fir (43) is entering ports in Sydney and Brisbane, causing some concern to the local softwood industry; it is being marketed in direct competition to Australian grown radiata pine, although it has not been subjected to the same grading requirements. In addition, early shipments had an undesirably high moisture content giving rise to both severe discolouration and decay. Poor quality control at the Canadian end has been suggested.*

An interesting feature of the Douglas-fir being imported - representing about 180,000 m^3 per annum on the Australian market - is its notorious impermeability. In studies at CSIRO, Chin (unpublished data, 1980), using a treatment pressure of up to 2100 kPa for 75 minutes, found that Canadian Douglas-fir was twice as refractory from the side grain as Australian and New Zealand grown material, and between 5 and 10 times more difficult to penetrate with CCA from the end grain (roughly the same comparison was found to apply also to Douglas-fir from the U.S.A.). Despite this and its low durability, Australian architects and builders continue to recommend and use Douglas-fir in exposed situations. Research on the problem, for example at Forintek and elsewhere in N. America, could be of immense value to the Australian preservation and building industries; meantime, there needs to be more communication between wood scientist, architect, and builder, and it is refreshing to read that the professional architect agrees (44).

*It is understood that some of the problems have been alleviated and steps are being taken to adjust the Australian standards to cope with this mixed species softwood import, which should overcome much of the early adverse market reaction.

Recently the Council for Forest Industries in British Columbia brought to our attention a particular problem of fungal degradation of western red cedar shakes imported from Canada which had been used on a house roof at Casino, New South Wales. The houseowner was relying on collecting rain run-off as his main supply of water, but after three years the water was of poor quality both for colour and taste (Figure 3a) and the shakes were badly discoloured (Figure 3b).

Our investigations revealed fungal colonisation of the surface of the shakes and to a depth of 0.5 mm, and the same fungi appeared to be growing both on the shakes and in the rainwater butt (Johnson, unpublished data, 1981). Isolations have so far produced a black yeast-like microorganism, a sterile dyaline fungus and two identified dark pigmented fungi, *Curvularia brachyspora* and *Aureobasidium pullulans*. This latter fungus has previously been shown to discolour western red cedar shingles in Florida and Oregon but it is believed not to cause any structural damage to the wood (45). At present we are examining the possibility of preventing further degradation by applying a 2% concentration of benzalkonium chloride in both neutral and acidified solution (46). We understand the problem of fungal discolouration, with subsequent water tainting, has not been encountered before by the Council of Forest Industries of British Columbia, although some 40,000 bundles of western red cedar shakes and shingles are imported each year into Australia.

(ii) Wood-based panel products

In common with other countries, Australia is seeing a dramatic increase in the use of composite wood, or panel products, in the building industry. For example, particleboard production in Australia (which is almost exclusively manufactured from softwood resources) has more than doubled in the last decade, rising from 282,000 m^3 for the year 1970/71 to 622,000 m^3 in 1979/80 (47). A similar trend, world-wide, has been noted by Brazier (48). On the other hand, plywood production in this country has not seen such a dramatic rise, although it is now being used in greater quantities in structural end-uses within the building industry (McCombe, pers. comm., 1981). The trend in N. America, and especially Canada, to use plywood for sheathing has not been widespread in Australia, although in the cyclone prone, northern parts of the country plywood anti-racking panels are employed. In addition, the Australian Standard on timber framing specifies the use of plywood for wall bracing (49) and recently there has been a move to have hardboard also accepted for this purpose.

Clearly, the need for preservation of wood based panel products will depend on the end-use; the plywood anti-racking panels mentioned above may require an insecticide in the glue, since the giant northern termite (*Mastotermes darwiniensis* Froggatt) is a severe hazard in cyclone-prone Australia. Suitable insecticide levels based on the air-dry, total wood volume, include 0.8 $kg/^3$ $As_2 0_3$, 0.48 kg/m^3 dieldrin, or 0.96 kg/m^3 chlordane. On the other hand, soil poisoning is probably preferable to prevent the termites entering the building in the first place.

In Victoria, particleboard is being used commonly for flooring except in wet areas such as bathrooms and laundries. Platform construction is the preferred building technique, where the floor is installed before the walls and roof are built. Thus, the particleboard is often subject to severe weathering. There is a demand therefore for a water repellent-based preservative of the organic solvent type and/or a water-resistant glue.

Actual biodeterioration of the glue is not a common problem in Australia, although recent research has indicated that finger-jointed wall studs made with casein glue are at risk from this point of view. (Finger-jointed wall framing is not uncommon, although the use of casein glue, which offers a number of desirable features, is only at an experimental stage. To combat this a number of preservative chemicals have been screened as glue-line additives, all containing organic molecules as active ingredients. This work (50) has indicated that two formulations based on quaternary ammonium compounds, Tricidal and Permapruf T, have some potential in this rather specialised area of preservation.

(iii) Light organic solvent preservatives for joinery

The use of organic solvent preservatives for the preservation of building timbers was established in Australia only about 15 years ago (these types of preservatives have been in use in Europe and N. America for about 50 years). At that time dipping was the major method of application, but within the last three years a number of treatment plants, employing double vacuum and low pressure Ruping cycles, have come into service, and there are now about 9 plants operating throughout Australia. These plants using preservatives based on tri-n-butyltin oxide (TBTO), and/or pentachlorophenol (PCP) as well as copper naphthenate (Queensland only), are supplying most joinery and some cladding to the building industry. In common with other countries, however, Australia is questioning the use of both TBTO and PCP; in the former case there is some doubt as to the long-term efficacy of the fungicide (see Henshaw *et al.*, (51), regarding the problem in U.K., and the recent studies in Canada by Ruddick, (1)) and we recommend that timber treated with this preservative in light organic solvent should be painted or given some form of secondary protection in end use. With regards PCP, there are a number of handling problems, and in the case of PCP in heavy oil for pole treatment the Electrical Trades Union has strongly opposed its use in Queensland.

Our research on light organic solvent preservatives is thus concentrating on the development of alternative formulations, which involves the screening of potential candidates against a range of basidiomycetes common to Australian buildings; it seems of limited value to pursue the overseas approach of using the standard (i.e. traditional) fungi which dominate the test reports, say, in the European and U.S.A. literature, and which do not even occur in Australia. At present we have examined copper compounds, such as copper naphthenate, copper nonanoate, and copper-8-hydroxyquinolinate, an alkyl ammonium compound, an organotin, and some agricultural chemicals. The results have been rather variable, since effective control of the full range of basidiomycetes tested has been difficult to achieve (although inhibition of 3 or 4 of the fungi at any one time has been possible). This line of research is continuing and at the same time the problem of producing effective penetration in joinery timbers is also being studied.

DEVELOPMENT OF NOVEL FORMULATIONS AS WOOD PRESERVATIVES

Research into the so-called third generation preservatives has intensified over the past few years in government and industrial R & D laboratories. The industry has never before faced such intense questioning of its traditional formulations by both official and 'unofficial' legislative and lobbying bodies. In addition, world-wide fluctuations of basic raw materials (not to mention more direct economic factors) have produced their own pressures on the search for new preservatives.

In Australia a preservative is expected to afford protection over a wide range of hazards, and hence it must have a relatively broad spectrum of activity. Very often this can only be achieved by providing a 'cocktail' in which a fungicide and insecticide are present; it is seldom that any one chemical has activity against both fungi and insects, although some alkyl ammonium compounds are showing possibilities in this respect.

The potential of alkyl ammonium compounds as future wood preservatives has been highlighted by research in New Zealand and Canada (52, 53, 46). The New Zealand work has indicated that dialkydimethyl ammonium compounds perform well in birch and radiata pine in the field and in an accelerated field simulator (or fungal cellar), while tertiary amine salts give relatively poor protection. This is in contrast to results of earlier laboratory tests (Butcher pers. comm., 1981). Variable results have also been obtained with alkyl ammonium compounds by Ruddick at Forintek (1, 54). At CSIRO we have examined selected commercial alkyl ammonium compounds, such as Hyamine 1622 (active ingredient: benzethonium chloride) and Gloquat C (active ingredient: alkylaryl trimethyl ammonium chloride) particularly in reference to *in situ* control of soft rot; both compounds were shown to diffuse through eucalypt sapwood while inhibiting the growth of soft rotting microfungi (55). In addition, formulations in which alkyl dimethyl benzyl ammonium chloride is a major constituent, e.g. Permapruf T, have also shown considerable efficacy against soft rot and basidiomycete fungi. On the other hand, the tertiary amine salt, cocodimethylamine acetate, was found to be ineffective against a range of basidiomycetes when screened as an organic solvent preservative (as an alternative to PCP and/or TBTO).

In addition to the fungicidal potential of alkyl ammonium compounds, the New Zealand researchers have also demonstrated good activity of these compounds against insects (56). In collaboration with the Forest Research Institute in New Zealand we have shown that cocodimethylamine acetate and benzalkonium chloride at levels in excess of 2 kg/m^3 will control *Lyctus* attack of susceptible hardwoods. However, more than 6 kg/m^3 of the amine salt and about 4-5 kg/m^3 of the benzalkonium chloride is required to be effective against the termites *Coptotermes acinaciformis* (Froggatt), *Nasutitermes exitiosus* (Hill) and *M. darwiniensis* (Howick, Creffield, Butcher and Greaves, unpublished data, 1981). We are continuing this research since other alkyl ammonium compounds may have more specific termiticidal efficacy.

Our studies on alternative insecticides have been centred on naturally occurring compounds such as plant and tree extractives, and also a number of synthetic pyrethroids (SP). Similar research is being carried out in the U.S.A. (57) as well as in other laboratories around the world. Much of our research in Melbourne has already been summarised elsewhere (58). Table 1 provides more up-to-date data (abstracted from Howick and Creffield, (59, 60), and indicates the greatest potential of synthetic pyrethroids, particularly for termite control.

It is significant that two of these SPs (permethrin and fenvalerate) have recently been included in the Australian Department of Health's specifications for cargo containers as substitutes for organochlorine insecticides in the sawn timber components of containers entering Australian ports. The minimum retentions recommended are: permethrin 0.12 kg/m^3, fenvalerate 0.18 kg/m^3.

Agricultural chemicals are being screened in many laboratories for their potential as wood preservatives. One of the better candidates emerging from our research in this area is the active ingredient of Busan 30, viz., thiocyanomethylthio benzothiazole. This chemical is presently being incorporated in bandages as a groundline maintenance treatment for controlling soft rot in poles. In

Table 1

A Comparison of Toxic Limits (kg/m^3) of Synthetic Pyrethroids, Aldrin, and Two Arsenicals for Two Australian Termites[1]

Formulation	***Coptotermes acinaciformis***	***Mastotermes darwiniensis***
Experimental SP	<0.05	<0.05
Deltamethrin	<0.002	<0.002
Cypermethrin	0.008 - 0.04	0.04 - 0.20
Fenvalerate	0.08 - 0.12	0.08 - 0.12
Permethrin	0.008 - 0.04	0.04 - 0.08
Aldrin	0.80	<0.80
Arsenic pentoxide	0.06	Not tested
CCA (Tanalith C)	c.1.50	Not tested

[1]Obtained in radiata pine blocks, from different laboratory screenings.

addition the formulation is being studied as a joinery treatment; early results suggested retentions will need to be in excess of 0.3 kg/m^3. Similar good results for Busan 30 have been obtained by Hedley, Preston, Cross and Butcher (61), although these workers indicate that the chemical has little potential as an insecticide.

Other agricultural chemicals, which have shown early promise as base formulations for third generation preservatives, both in Australia and elsewhere, include Skane M-8, Spergon, Nopcocide, Vitavax, Melprex, Tachigaren, Preventol and Captafol. The latter two fungicides are more effective against moulds and sapstain fungi, although in Australia the Radiata Pine Association maintain that sapstain, or bluestain, is not an economical problem to the industry, particularly when compared with the situation in Canada and elsewhere. However, at CSIRO we receive a number of enquiries from sawmillers who are worried about discolouration of their timber, particularly in the spring. In a study involving radiata pine logs from a state forest in New South Wales, Keirle (62) found that winter was the only safe season (mean max. temp. 10°C; mean min. temp. -2°C) in which logs could be left in the forest up to one month without any significant sapstain. In addition to the occasional problems in New South Wales, some difficulties have also been experienced in Queensland with discolouration of softwoods other than pine. Traditional advice, apart from that of suggesting rapid removal of logs from the forest, has been to recommend chemical sprays, such as Santobrite (PCP) and, more recently, Captafol. Also it is possible that quaternary ammonium compounds could be employed to control sapstain, although this is still an experimental situation. The use of agricultural chemicals for sapstain control has not been researched to any extent in Australia, compared with the work undertaken in Canada (63, 1).

Chemicals, not specifically designed for agricultural use, which appear to have some promise as future preservatives include Tricidal, Troysan Polyphase, and a number of metal soaps of fatty acids. As mentioned previously, this latter group of formulations, when used in ammoniacal and/or ethanolamine solutions, offer considerable protection to wood cell walls. Recent research (64, 65, 66) has shown that copper soaps of fatty acids, e.g. copper caprylate, copper nonanoate, in ammoniacal and ethanolamine carriers, penetrate hardwood cell walls much better than the more conventional copper-based CCA. In further experimentation using eucalypt sapwood treated with copper nonanoate in ethanolamine and three other copper soaps of secondary and tertiary synthetic acids in ammoniacal solution, we have demonstrated that there is marked improvement in the degree of protection against soft rot in our accelerated field simulator. This finding tends to confirm the analytical work referred to above, indicating good cell wall penetration for these formulations.

Apart from showing the fungicidal activity of fatty acids, workers in British Columbia studying forest insect pests have recently demonstrated that these compounds have good insecticidal properties too. Clearly, more research on the value of these compounds for the preservation of wood should be undertaken.

Additional treatments, which show some encouraging characteristics as future preservatives particularly for hardwoods (and possibly the more refractory softwoods) in ground contact, are the emulsified creosote preparations (67). Our research in Australia, employing a pigmented emulsified coloured creosote and hardwood pole stubs, was discussed in some detail last year at the AWPA annual meeting (58). In essence, these preparations exhibit a much reduced propensity for bleeding, when compared with ordinary creosote, and the water-phase appears to penetrate the wood cells (68). Thus, selected water-borne fungitoxicants may be incorporated within the creosote preparation to considerably broaden the spectrum of activity. These, and other features of pigmented emulsified coloured creosotes, are being further studied in our current research programme, which involves collaboration between theindustry, consumer and ourselves.

CONCLUDING REMARKS

Clearly, there are many aspects of research and development in the field of wood preservation which have not been mentioned in this presentation. Furthermore, there are areas of work which are unique to a country's particular requirements. On the other hand, it is often the case that research of this type has indirect spin-off value to other countries and end-users. Communication is therefore vital, whether it be at forums such as this, at larger international meetings such as those of the International Research Group on Wood Preservation, or on a person-to-person basis.

Just as vital to the overall forest products industry is the protection of wood in use throughout the world. Thus, to be fully effective, preservation R & D must keep pace with changing needs and technology, particularly in the efficient utilisation of the world's timber resources. Which brings us back to the introductory theme of this paper, namely the importance of collaboration between government and industry to achieve effective research and development in the field of wood preservation. Only then will the discipline continue to make a valuable contribution in today's (and tomorrow's) world.

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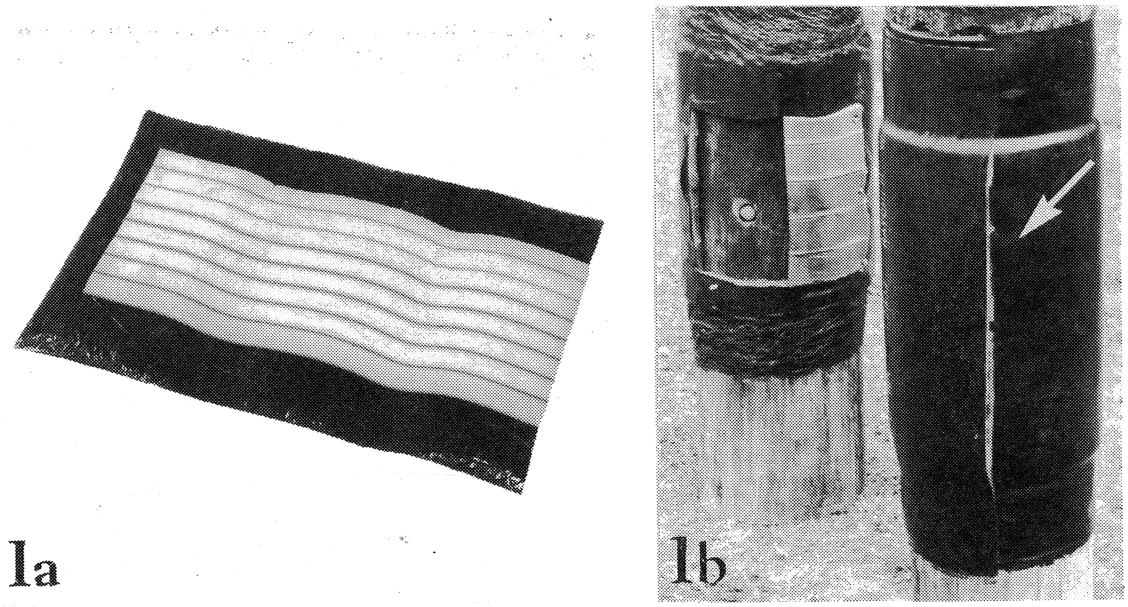

Figure 1. CSIRO pole bandage: (a) general format (b) applied to pole stub. Heat shrink Mark IV model arrowed.

2

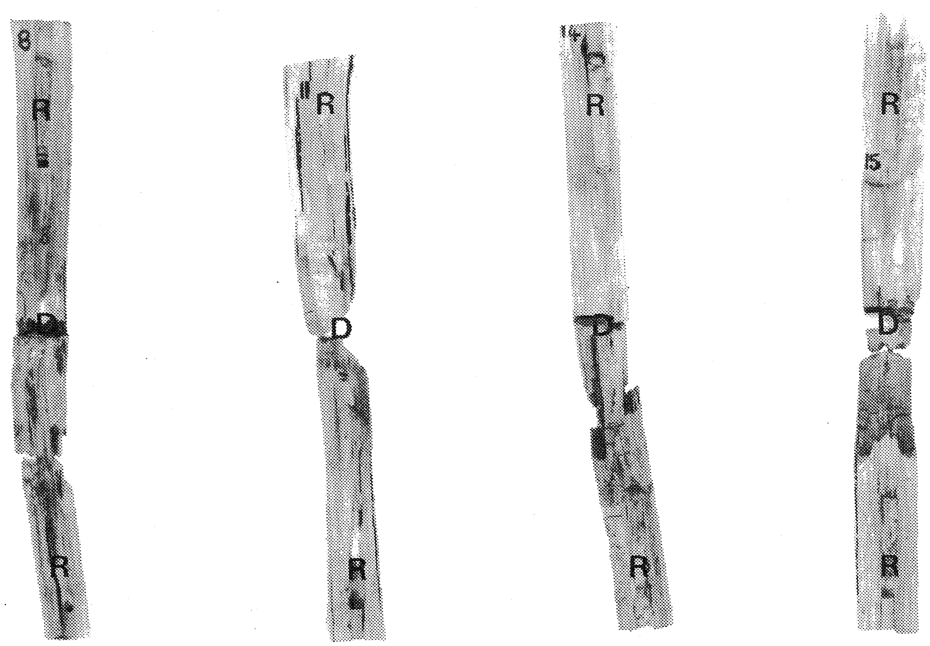

Figure 2. The effect of fused preservative rods (R) on decay (D) in messmate test specimens.

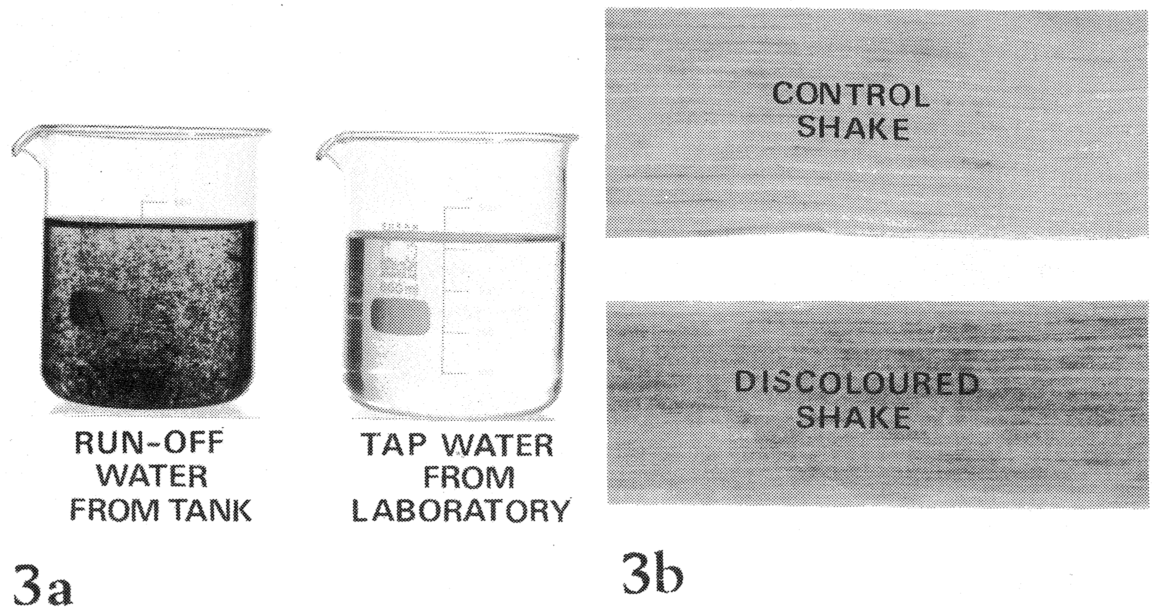

Figure 3. Contamination of run-off water from fungal discoloured western red cedar shakes.