RECORD
of the
1990 ANNUAL CONVENTION
of the
BRITISH WOOD PRESERVING
and DAMP-PROOFING ASSOCIATION

Cambridge
July 3rd-6th, 1990

Issued by the
BRITISH WOOD PRESERVING AND DAMP-PROOFING ASSOCIATION
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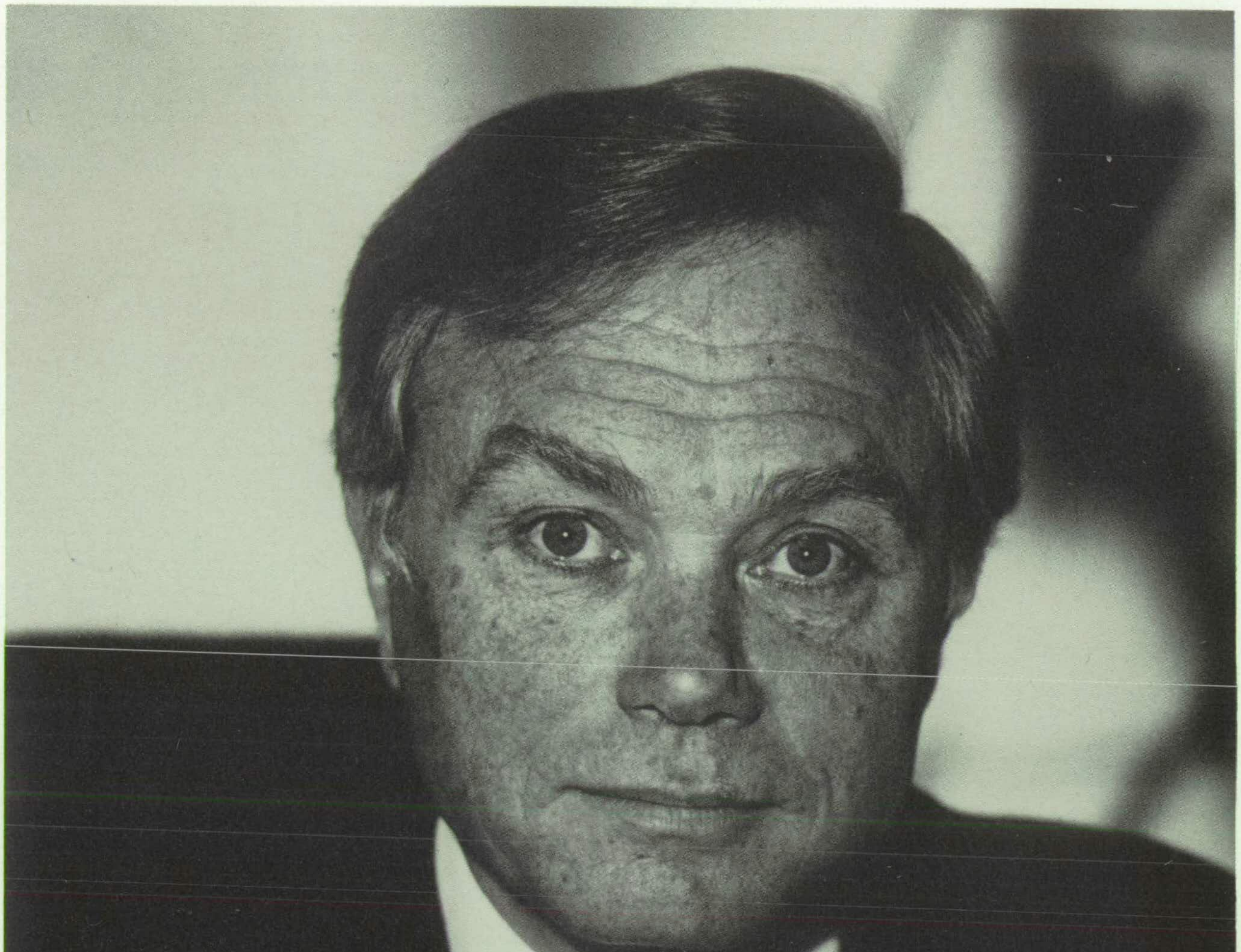

P. D. North
President of the British Wood Preserving and Damp-Proofing Association

THE BRITISH WOOD PRESERVING AND DAMP-PROOFING ASSOCIATION

BUILDING NO. 6, THE OFFICE VILLAGE, 4 ROMFORD ROAD,
STRATFORD, LONDON E15 4EA

BRITISH WOOD PRESERVING AND DAMP-PROOFING ASSOCIATION

The British Wood Preserving and Damp-Proofing Association is a scientific and advisory association.

It is a body which collects information on the preservation and fireproofing of timber and the methods of applying preservatives and fire retardants plus techniques for damp-proofing buildings. It sponsors scientific research into the use of preservatives and fire retardants plus damp-proofing materials and makes available to all enquirers the results of its researches by the publication of leaflets, a technical advice service and specialist lectures. It is completely impartial in its outlook and in the advice it gives. Among other objects it aims at making known the advantages of using preserved timber in the interests of the consumer and the national economy.

MEMBERSHIP: Amongst the members are

Learned societies and research bodies at home and overseas.
Architects, surveyors, builders, etc.
Manufacturers of all types of preservatives plus fire retardant and damp-proofing materials.
Users of timber.
Firms operating all forms of treating plant.
Specialists in the remedial and curative treatment of timber in-situ, plus damp-proofing buildings.
Manufacturers of plant.

COMMITTEES

In the working of its committees close liaison is maintained with Government Departments, as well as with the principal consuming industries.

On the Council there are representatives of learned societies, scientific bodies, principal consumers, architects and consultants, as well as manufacturers and those who specialise in preservative treatment of timber and damp-proofing buildings.

Other Committees deal with technical matters, finance, membership and environmental problems.

On several of these Committees there are representatives of the nationalised industries, consuming industries, and organisations such as the Building Research Establishment, T.R.A.D.A., T.T.F., B.B.A. and the Health & Safety Executive.

SERVICES

It offers a free advisory service on all problems connected with timber preservation and damp-proofing.
It publishes a technical manual, issues leaflets dealing with practical problems and the latest developments in research.
It holds an Annual Convention at which specialist papers are presented by experts from all over the world.
It publishes in book form a Record of the Annual Convention containing copies of the papers, etc.
It issues free of charge to all members a News Sheet.
It maintains a panel of lecturers whose services are available on request.
It organises exhibitions to show the value of preservation and damp-proofing treatments.
It arranges visits to the works of manufacturers and treaters.
It represents the industry on a number of international committees connected with timber preservation and damp-proofing.

FINANCES

It should be appreciated that the Association depends entirely on subscriptions and special contributions from its members. This, of course, enables it to remain completely independent and at the same time to maintain its impartial and scientific approach to all problems.

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PRESIDENT'S OPENING ADDRESS – 1st B.W.P.D.A. CONVENTION – CAMBRIDGE, JULY 1990

The year since the close of the 1989 Convention, the last of the B.W.P.A., has been enlivened by change, National and International, on a scale and at a pace that few could have dreamed of.

However, even developments in Eastern Europe, and the Community Charge at home, must take subsidiary place in our minds today to the amalgamation at the beginning of the year of the B.W.P.A. and the B.C.D.A. It is this factor that will be the central preoccupation for the next two days.

At the last Convention, Austin Hilditch urged this industry to strengthen its research and development and I believe that in addition to that we must sharpen our reflexes in order to react to the many changes that affect us, some of which cannot be foreseen and provided for. However, some things need not change.

This Convention has always been an indicator of the mental processes of the industry and its importance was never greater. We have in prospect a rich variety of subjects for discussion with papers from England, Scotland, Wales and Denmark. Once again many of them have not been received by the Associations staff in time for circulation before your arrival here. This places a burden of rapid assimilation upon us all and prompts the need yet again to take such steps next year to ensure that papers are made available earlier.

I am sure that this test of initiative will not spoil our enjoyment of the next two days, nor the benefit we and the industry will derive from them. It therefore gives me great pleasure to have the honour of declaring the first Convention of the British Wood Preserving and Damp-Proofing Association open.

B.W.P.D.A.ANNUAL CONVENTION 1990

SOME ASPECTS OF RESEARCH ON WOOD PROTECTION IN THE TIMBER DIVISION OF THE BUILDING RESEARCH ESTABLISHMENT (B.R.E.)

by Dr. A. F. Bravery, R. W. Berry, Dr. E. R. Miller and Dr. R. J. Orsler

Introduction

In the last review of P.R.L. work on wood protection to this Convention in 1986 (Morgan *et al.*, 1986), Dr. Morgan drew attention to the fact that it would indeed be the last review from P.R.L. when he described progress in preparation for the move to B.R.E. Garston. It is an interesting coincidence, in view of the closeness of co-operation between B.W.P.A. and F.P.R.L./P.R.L. over so many decades, that our first review under the new acronym of B.R.E. after leaving Princes Risborough, should be in the very year B.W.P.D.A. itself takes on a new acronym.

The transfer of operations from the P.R.L. site to B.R.E. at Garston took place at the end of 1988 and at an Open Day presentation in May 1989 many of our valued friends in B.W.P.D.A. joined others in viewing the new facilities established at Garston to bring forward more than 60 years of timber research from Princes Risborough (Fig. 1). The opportunity of closure of P.R.L. and transfer to Garston was also used to introduce re-organisation and rationalisation of the management of many activities. Accordingly work specifically on timber as a material, that on its strength characterisation and on its preservation and protection was established as the Timber Division. Other work on environmental chemistry, and on timber components and building systems was transferred to the relevant Groups at B.R.E. Garston. We still retain the P.R.L. connection, for our preservatives test site for ground contact trials is still maintained there. All other associated facilities including out-of-ground field trials, our sawmill, kilns, test exposure buildings (including the simulated roof space building presented by B.W.P.A.), insectaries, preservation plant room etc. all have been re-established on the Garston site. The new research laboratories for Timber Division are all integrated into a single specially adapted and newly constructed building and we are now enjoying the benefits this provides in facilitating much closer working relations between the different research groups.

Since the move to Garston there have been other important changes. The joint B.W.P.D.A./B.R.E. biological testing scheme has been re-established with the appointment in 1989 of Miss Lisa Spinnage as Biological Technician. The arrangement provides B.W.P.D.A. members in particular with a testing facility at B.R.E. which is independent of B.R.E.'s own priorities and staffing policies yet utilising all the unique and specialist facilities and expertise we have for this work.

During 1989 Dr. Belford, a past President of B.W.P.A. completed his term as a much valued and respected member of the B.R.E. Visitors Panel for the Materials Group within which Timber Division is managed. Dr. John Morgan retired in October 1989 after a long and distinguished career, including periods as Head of Preservation Section and later as Head of Timber Division.

On April 1st 1990 B.R.E. became an Executive Agency of the Department of the Environment under its Chief Executive Mr. Roger Courtney and Deputy Chief Executive Mr. Michael Baker. As an Executive Agency, the main role of B.R.E. continues to be to advise and undertake research for D.O.E. and other Government Departments. However, it will now be managed within a new framework giving us new financial freedoms and opportunities to develop our Consultancy activities in ways that can most effectively serve all our customers.

Classifying the Decay Resistance of Panel Products

Progress in studying the fungus resistance of panel products (Morgan *et al.*, 1986; Lea, 1982; Lea and Bravery, 1986) has reached the stage where work on improved methods of test is incorporated into a new British Standard due for publication during 1990 and replacing B.S.1982:1968. One of the most important uses to which the new Standard will be put is in classifying the resistance of board materials to decay-inducing fungi. B.S.6566:1985 Pt. 7 gives three classes for decay resistance in respect of plywoods, based on the sapwood content and durability rating of the wood species from which the veneers are made. However, no such system exists for other board materials. Furthermore, the results of B.R.E. research indicate that plywoods with specifications which would put them in different classes according to B.S.6566 Pt. 7 are not necessarily different in decay resistance when tested according to the revised B.S.1982 Pt. 1 (Table 1). All types of boards can be compared, regardless of thickness, by deriving a decay susceptibility index (D.S.I.) where

$$\text{DSI} = \frac{\text{mean mass loss (\%) board sample} \times 100}{\text{mean mass loss (\%) solid wood reference of the same thickness}}$$

The tests are conducted on specimens edge-sealed to prevent unduly harsh results with board types having more susceptible core material normally not accessible to surface colonisation by fungi. A notional mean D.S.I. can be computed for the two obligatory aggressive fungi used in the test (*Coniophora puteana* and *Pleurotus ostreatus*) after preconditioning to remove inhibitory volatiles from the resins.

The use of the D.S.I. concept can be applied to cataloguing of decay susceptibility for any particular end-use service situation. The absolute level of resistance required can be set by comparison with a reference standard selected on the basis of known performance in practice. For example, in the case of sheathing boards for timber frame housing, commercial experience suggests that sheathing grade Douglas fir-faced plywood and many other softwood plywoods such as Canadian and Siberian types, bonded with a water-resistant resin, can give a satisfactory performance. If the range of D.S.I.'s for these materials is set as the base-line for a performance standard for other board types, it suggests three main classes:

- Class 1. Boards which when tested edge-sealed have a mean D.S.I. not exceeding 10 ± 5 (equivalent to moderately durable timber)
- Class 2. Boards which when tested edge-sealed have a mean D.S.I. of greater than 10 ± 5 but less than 70 ± 5 (equivalent to non-durable timber)
- Class U. Boards which when tested edge-sealed have a mean D.S.I. greater than 70 ± 5.

This new classification (Fig. 2) does not in itself invalidate that provided in B.S.6566 Pt. 7 for plywoods. It does however offer a potentially more realistic basis for the specific end-use of sheathing board as well as encompassing board types for which no specific decay resistance classification exists at present.

Evaluating Surface Applied Fungicidal Preservatives

The efficacy of wood preservative fungicides is accepted as depending upon many factors, the two most important of

TABLE 1
Notional mean D.S.I. for two obligatory fungi and classification of durability

Material/timber		*Timber durability class or Plywood class to B.S.6566*	*Mean D.S.I.*	*Sheathing classification by D.S.I.*
Douglas fir		Moderately durable	1	1
Khays		Moderately durable	6	1
Spruce		Non-durable	44	2
Hemlock		Non-durable	48-67	2
Scots pine sapwood		Non-durable/perishable	81	U
Poplar		Perishable	68	2
Beech		Perishable	78	U
Birch		Perishable	81	U
Plywood				
Douglas fir throughout	UT*	M	38	2
	DV	M	1	1
	CCA	H	0	1
Douglas fir faced	UT	G	24-30	2
	CCA	H	0	1
CSP	UT	G	42-45	2
	DV	M	1-6	1
	CCA	H	0-1	1
SSP				
Birch/spruce	UT	G	47	2
	DV	M	3-6	1
	CCA	H	0	1
Other board types				
Waferboard (hardwood)		N/A	94	U
MDF		N/A	64	2
BIB		N/A	47-60	2

Notes:
*UT – untreated
DV – double vacuum treatment with organic solvent preservative
CCA – pressure impregnated with CCA
N/A – not applicable
CSP – Canadian softwood plywood
SSP – Siberian softwood plywood
MDF – Medium density fibreboard
BIB – Bitumen impregnated insulation board

which are the inherent effectiveness of the active fungicides used and the depth to which the preservative penetrates. Traditional and conventional accelerated laboratory tests of preservative efficacy involve impregnating small wood samples with the preservative to derive upper and lower limits of effectiveness, the so-called toxic values. Assessment of the fungicidal effectiveness of a preservative is based on comparisons of these toxic values. This approach gives a reasonable basis for assessing effectiveness and defining loading requirements for those preservatives intended to be impregnated into wood. However the data generated cannot so readily be applied to an 'envelope' situation where the preservative does not fully penetrate the wood.

It has long been B.R.E. philosophy that the effectiveness of such treatments should be assessed directly, as reported earlier to this Convention by Savory and Carey (1976). Indeed it was from this background that the now widely accepted L-joint approach to evaluating joinery preservatives was developed (Carey, 1982; Carey and Bravery, 1985).

In the present programme, a direct technique has been developed which is capable of measuring the efficacy derived from the combined effect of the active fungicide and its method of application (Carey and Bravery, 1989). The technique has the particular merit that it provides measurements in terms of periods of protection or 'life' of the treatment, compared with that provided by any chosen reference standard of known service performance.

In the current methodology, blocks 38 mm × 38 mm in cross section and 100 mm in length are first end-sealed, then treated with preservative on their longitudinal surfaces. A wide range of application methods can be used and it is also possible to artificially or naturally age the test blocks prior to infection. After preparation and preconditioning, holes are drilled into the test blocks to within preselected distances (usually 5, 10 and 15 mm) from the test face. The specimen is then challenged by bringing it into contact with a test fungus growing on a feeder block of untreated wood (Fig. 3) which can be selected as either a radial or tangential face. Growth of the test fungus through the treatment is monitored by placing baits (cotton wool buds) into the holes. These baits are replaced at intervals, the old baits being placed on a selective nutrient medium and growth of the test fungus recorded as present or absent after 14 days, The rate of colonisation can thus be determined which provides more information than do methods which assess attack by destructively examining the test blocks after a fixed period of time.

The method has proved very discriminating, distinguishing different rates of colonisation depending on whether the test fungus is growing in the radial direction through the wood or in the tangential direction; the radial direction is normally col-

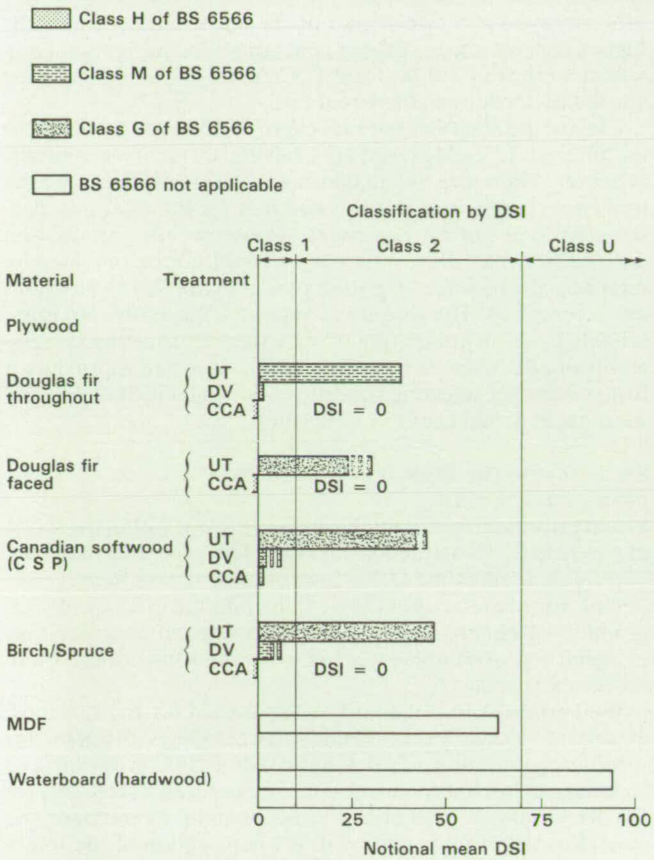


Fig. 2. Classification of durability of board materials and national mean D.S.I. (Z obligatory fungi).

onised faster despite the greater penetration of preservative that is achieved in this direction.

Results to date with a range of light organic solvent based preservatives indicate that major differences in the rate of colonisation occur only for the outer 5 mm zone. As soon as this zone has been breached, colonisation further into the test block occurs at more or less the same rate, irrespective of the preservative or method of application (brush, 3 min. dip or double vacuum).

An example of results with a range of concentrations of tri-n-butlytin oxide (TnBTO) and pentachlorophenol (PCP) is presented in Table 2; although use of these pesticides is now severely restricted, they form useful reference materials for test method evaluation. The mean rate of colonisation, combining radial and tangential rates of colonisation by the test fungus through the outer 5 mm, was calculated. This value was then corrected for solvent effects (by subtracting the value for the corresponding solvent treated controls, or when not available, the value for the untreated controls) to give a value referred to as the "Period of protection". In Table 2 the preservative treatments are listed in order of increasing effectiveness, when applied by 3 minute dip and challenged by *Coniophora puteana*. It is worth noting that the order of effectiveness is similar when the preservatives are applied by double vacuum treatment and challenged by *Coriolus versicolor*, the only difference being a reversal in the effectiveness of 1 per cent PCP and 0·75 per cent TnBTO. With 1·0 per cent TnBTO the advantages of the increasing penetration achieved with the different application methods is clearly seen in increased periods of protection.

More data are currently being generated in order to be able to set criteria for the evaluation of potential new treatments. Ultimately, it may be possible to establish minimum performance criteria for particular end-use categories, commodities or even service lives. Already the method has been prepared in European Standard format and is currently being evaluated with French and German porposals, by Working Group 9 of CEN/TC38.

Development of Laboratory Tests Against Soft Rot Microfungi

Attack of wood in service by fungi capable of causing soft rot decay is of great practical significance in severe exposure conditions, for example in ground contact. In the performance standards currently being developed by CEN/TC38 WG4 the absence of an accepted, unified test for soft rot presents a major obstacle to agreement on minimum test requirements, for there is at present no alternative to the ground contact field tests (EN 252). However, in the development of new products, there is a need for a much more rapid laboratory-based test, both for initial indication of activity and for evaluation under more realistic soil conditions.

Within Europe two different approaches have evolved to testing with soft rot fungi. One approach, favoured by France, Germany and Switzerland in particular, is based on determining toxic values in a medium of moist Vermiculite innoculated with a mixture of pure cultures of fungi known to cause soft rot attack. The other approach, favoured by the U.K. and the Scandinavian countries, takes into account interactions between the full range of micro- and other fungi that can occur in soil and derives a performance rate-curve for comparison with that of a reference standard. The approach proposed by the U.K. to resolving an apparent conflict in philosophies at the CEN/TC38 WG8 is to combine the two approaches to give a single, potentially more robust and reliable evaluation procedure.

In the initial test (Test 1) blocks measuring 40 × 15 × 5 mm of beech and Scots pine sapwood are fully impregnated with a range of concentrations of the test product. After drying, the test blocks are leached using the EN 84 method (B.S.5761 Pt.

Fig. 3. The method for evaluating surface supplied fungicidal preservatives.

TABLE 2

Period of protection (weeks) afforded by a range of preservative treatments

Treatment	*Coniophora puteana* FPRL 11E			*Coriolus versicolor* FPRL 28A	
	Single brush coat*	*3 min.† dip*	*Double* vacuum*	*Single* brush*	*Double† vacuum*
0·5% TnBTO		6·3	7·8		1·3
1·0% PCP		6·7	>16·3		5·3
0·75% TnBTO		11·7	>16·3		1·6
1·0% TnBTO	8·3	14·0	>16·3	1·0	6·6
3·0% PCP		19·2	>16·3		8·7
5·0% PCP		23·5			

*Corrected using value for untreated controls
†Corrected using value for solvent treated controls

2). A mixed spore suspension of six test fungi is then used to innoculate the test blocks which are buried in a Vermiculite medium. Following incubation at 26-28°C. for 12 weeks (beech) or 16 weeks (Scots pine sapwood) the mass losses of the blocks are determined and toxic values established. These values (the highest concentration permitting decay and the lowest concentration preventing decay) are then used in Test 2, in comparison with a C.C.A. standard.

Test 2 employs small test stakes (100 × 10 × 5 mm) of beech, and optionally Scots pine sapwood, treated with the selected concentrations of the test product and the appropriate concentration of the C.C.A. reference preservative (2·0 per cent m/m total salts for beech; 0·75 per cent m/m total salts for Scots pine sapwood). After drying, the test stakes are leached using the EN 84 method, then planted, vertically, in tanks of moist soil, leaving 20 mm protruding above the soil surface, and incubated at 28°C. (Fig. 4). Sets of replicates are removed at eight weekly intervals for exposure periods of up to 32 weeks or beyond. The mean corrected mass loss after each exposure period is used to construct decay rate curves for the test product which are compared with that of the C.C.A. reference.

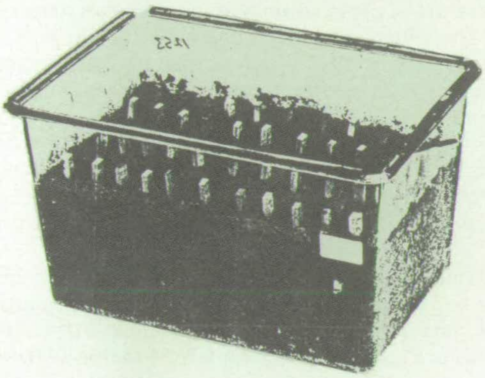


Fig. 4. Soil bed soft rot test.

The Test 2 type of soil bed methodology has been in use at B.R.E. over a number of years and is essentially the same as one of the methods used successfully by a anumber of co-operating laboratories in recent tests conducted by the International Research Group on Wood Preservation (Gray and Dickinson, 1989). The form of data generated in the test is illustrated in Fig. 5. It can be seen that the 2·0 per cent C.C.A. reference treatment decays at a steady rate throughout the exposure period; the first significant decay (>3·0 per cent mass loss) is normally recorded after about 12 weeks exposure. The lower concentration (0·25 per cent) of the test product provided protection for the first six weeks of exposure, but thereafter decayed at a rate similar to the untreated controls. The higher concentration (1·0 per cent) provided protection equivalent to that of 2·0 per cent C.C.A. for 24 weeks but then started to decay at an increased rate.

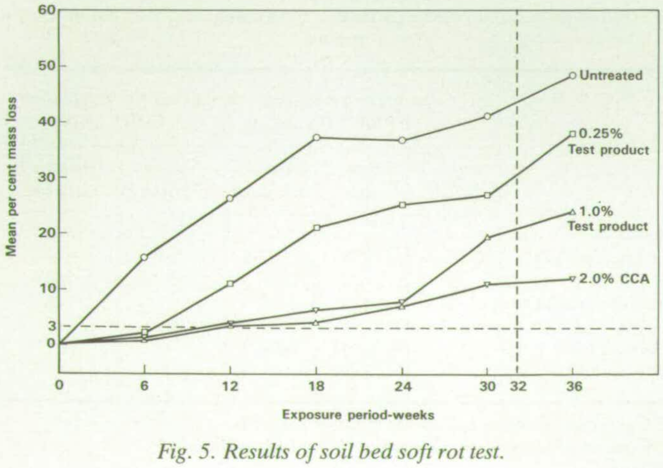


Fig. 5. Results of soil bed soft rot test.

Clearly the shape of the rate curves is likely to be different for different types of preservative having different mechanisms of action. Therefore the quantitative relationship between the rate curve for the test product and that for the reference preservative will not be consistent. However, the information derived from the decay rate curves could not be obtained by sampling after a single exposure period in the way toxic values are determined. The rate curve approach therefore, is a more reliable basis for comparing relative performance than assessments of effectiveness based on toxic values and it provides a firmer basis for selecting concentrations to be included in any subsequent ground contact field trials.

Determining the Efficacy of Eradicant Insecticidal Fluids

Wood preservatives for eradicant uses are not within the scope of the E.E.C. Construction Products Directive but there is a requirement under the U.K. Control of Pesticides Regulations (1986), for manufacturers to demonstrate the efficacy of such products. Reliable methods for assessing efficacy are also required for development of newer, environmentally more favourable products.

Well established, Standard methods exist for the two most important wood-boring beetles (B.S.5436:1977-EN48 for *Anobium punctatum* and B.S.5219:1986-EN22 for *Hylotrupes bajalus*). A third method is about to be published (EN 273) for *Lyctus brunneus*. Essentially these techniques measure the mortality of larvae caused by direct penetration of the remedial fluid. Both EN48 and EN22 suffer limitations which have been the subject of B.R.E. research.

A. punctatum (common furniture beetle)

Although many remedial products for use against *A. punctatum* still claim an initial penetrating action (which can be assessed by EN48) the widely adopted emulsion-based formulations rely almost entirely for their effectiveness on their action against emerging adult beetles. This change in mechanism has necessitated the development of new methodology to assess this mode of action.

The method initially developed at B.R.E. (Berry, 1982; Orsler and Berry, 1982) was based on a composite block consisting of an untreated infested core surrounded by treated veneers. A refinement of these principles using a one-piece block, was submitted for consideration and is now adopted by CEN/TC38 as a draft European Standard.

The method uses the same 30 × 50 × 100 mm block as EN48, the block being end-sealed and then treated by pipette with the test formulation. After drying the block can be submitted to an accelerated ageing procedure (B.S.5761 Pt.1-EN73) for active ingredients susceptible to volatile loss. After ageing the end seal is cut off and the block cross cut. Mature larvae are then introduced into the untreated core of the block and sealed in with plastic plates. A particular temperature regime is then used to induce the larvae to pupate and attempt emergence.

Assessment of the test is by counting emergence holes in treated surfaces and dissection of the blocks to establish the proportion of beetles killed by the treatment before completing emergence holes. Typical results for simple formulations based on commonly used insecticides are shown in Fig. 6.

The method is principally intended as a pass/fail test for it gives no measure of dose response. The only variable to be decided in relation to the formulation is the validity of the accelerated ageing procedure. This needs to represent losses of insecticide likely to occur during the first 4-5 years following a treatment after which no further active larvae are likely to be present in the timber.

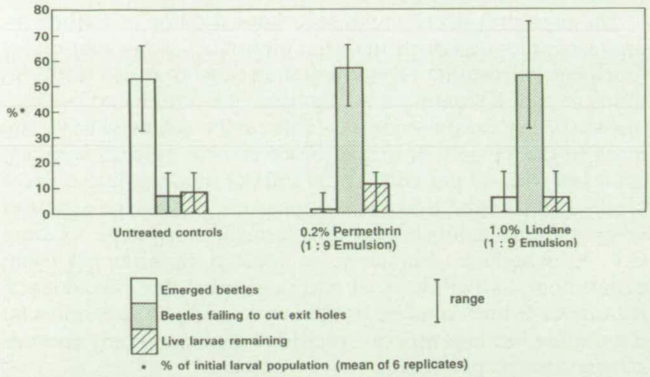


Fig. 6. Results from emergence test proposed as European standard (Test blocks aged to EN73 prior to challenge).

H. bajulus (House longhorn beetle)

House longhorn beetle is so aggressive and voracious as a wood-borer that a remedial fluid must be capable of killing the maximum number of larvae immediately it is applied to infested wood. It is therefore not acceptable to adopt the strategy implicit in the use of emulsions, where larval activity continues for some time before pupation. Reliance on the methodology of EN22 is therefore entirely appropriate.

However EN22 suffers two essentially practical disadvantages:

1) it employs large blocks of Scots pine sapwood which are difficult and therefore very expensive to obtain from normal commercial timber supplies.
2) the random distribution that develops as introduced larvae disperse themselves at different depths in such big blocks, leads to wide variations in the number killed on initial application of the fluid.

Various approaches have been attempted to improve the methodology and B.R.E. is co-operating in experiments co-ordinated by Working Group 6 of CEN/TC38.

The method currently under investigation is based on that initially developed at the Swiss Federal Material Testing Laboratory (E.M.P.A.) and consists of a sandwich block of two plates (Graf and Schimetter, 1982). One plate contains the larvae in specially machined cells and the other, which is held in place by an edge seal, acts as a cover plate (Fig. 7). The system ensures that all larvae are equidistant from the treated surface when the test fluid is applied to the cover plate immediately after assembly.

Results obtained so far surprisingly indicate that the new method appears to achieve less mortality, despite the smaller overall block size. Also variation between replicates remains high. One explanation for these results may lie in poor adhesion between the cover and base plates. Further discussion of measures to overcome the variability continues within TC38/WG6.

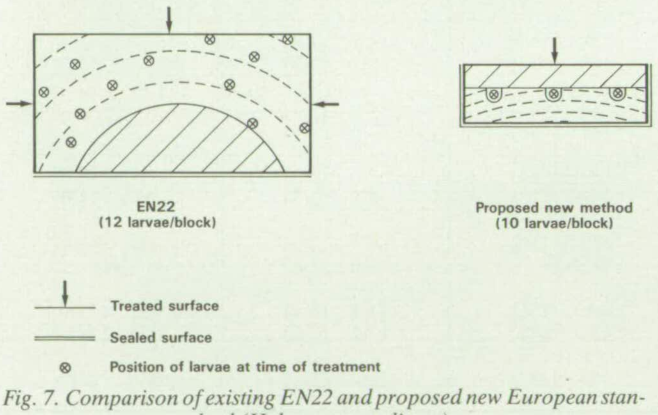


Fig. 7. Comparison of existing EN22 and proposed new European standard (Hylotrupes eradicant).

Preservative Treatments

We continue research on the response of commercially important timbers to preservative treatment. The work is commissioned either by the Construction Directorate of D.O.E. or by individual commercial interests but generally to meet a common need for a firm and independent technical basis for Codes and Standard Specifications.

Treatment of hem-fir

Hem-fir imported from Canada, consists of a mixture of western hemlock (*Tsuga heterophylla*) and amabilis fir (*Abies amabilis*) which can derive either from the coastal regions or the interior mountainous regions of British Columbia. In the present editions of the British Standards B.S.5589 and B.S.5268: Pt 5, this timber is classified as "non-durable" (treatment usually recommended) but "resistant" to preservative treatment. Although an exception has been made for doors, where schedules appropriate to "moderately resistant" timbers can be used, generally hem-fir is required to be subjected to the more severe treatment schedules. As a consequence there is a concern, particularly held by the Council of Forest Industries of Canada (C.O.F.I.), that over treatment would occur in some hem-fir, leading to problems of excessive preservative retentions with attendant increased costs and possible problems with 'bleeding' and drying. Accordingly, a co-sponsored study was initiated to investigate the double vacuum treatment of joinery-grade and high pressure/vacuum treatment of constructional-grade hem-fir currently being imported into the U.K.

The constructional-grade timber was segregated into four lots representing the two species involved and their two geographical sources. Similarly, joinery-grade timber, which is supplied from the coastal region only, was sub-divided into the two timber species. Fifty samples from each of the six groups were used in the treatment trials. No attempt was made to differentiate between sapwood and heartwood.

Samples were end-sealed either on one end only to allow measurement of longitudinal penetration, or on both ends to allow lateral penetration only to be measured. Treatment was carried out using either

(i) a 3 per cent solution of C.C.A. and high pressure schedules P2 and P4,

or

(ii) a white spirit solution of a copper carboxylate (0·4 per cent copper) and double vacuum schedules V1, V2, V4 and an experimental schedule (A).

Details of schedule parameters are given in Table 3. Uptake

TABLE 3
Details of schedules used in treatment of hem-fir

Schedule	*Initial vacuum*		*Pressure stage*		*Final vacuum*	
	vacuum	*time*	*pressure*	*time*	*vacuum*	*time*
	bar	*min*	*bar*	*min*	*bar*	*min*
V1	·33	3	0	3	·66	20
V2	·33	5	1	5	·66	20
V4	·83	10	1	60	·66	20
A	·66	10	1	10	·83	20
P2	·83	30	12	60	·83	10
P4	·83	60	12	180	·83	10

of preservative was measured by weight difference and, after drying, the samples were cross-cut and rip-sawn to allow measurement of penetration. Penetration patterns were enhanced by spraying with chrome azurol solution. Table 4 summarises the results obtained.

In general the results showed a high variability both between samples and within samples, making it difficult to define a single schedule that will always produce a reasonable level of treatment. Nevertheless recommendations have to be made to satisfy practical need.

For double vacuum treatments, Watson (1970) suggested that 3 mm penetration laterally and 38 mm longitudinally should provide reasonable protection and these values were used as the minimum performance criteria in the present experiments. For treatment with C.C.A. solutions the deepest penetration associated with an economic operation is accepted as the norm and usually includes a requirement for full sapwood penetration. Western hemlock was the more resistant of the two species so it is assumed that if a treatment is adjudged appropriate for this timber it will be more than adequate for amabilis fir.

Table 4 indicates that in the double vacuum experiments, V1 failed to achieve the minimum requirements of 3 mm lateral and 38 mm longitudinal penetration. The V_2 schedule also was not suitable because, though not so evident in Table 4, a large number of replicate samples were below the minimum penetration levels, even though the mean values exceeded the minima. Schedule V4, normally recommended for resistant timbers to be used for joinery components, produced excessively high uptakes for both species, with many samples greatly in excess of the minimum penetration, indeed often completely penetrated.

Accordingly an intermediate schedule (Schedule A) was studied in order to seek a more optimal process for double vacuum treatment of this type of material. The results were very encouraging, demonstrating that acceptable treatments can be obtained in terms not only of mean uptake and penetration but also in the proportion of treated samples above the minimum requirements adopted.

The high pressure/vacuum schedules used on construction-grade samples demonstrated that mountain-grown material is much more resistant to treatment than coastal-grown stock. So much so that if treatment is intended, it would be advantageous to specify coastal material. This can be achieved using the mark of the sawmill of origin. Since coastal western hemlock achieved over 80 per cent of the uptake of amabilis fir, there seems little doubt that satisfactory uptake and penetration levels can be achieved for the hem-fir mix using existing C.C.A. schedules. Similarly, in limited experiments using experimental schedule A, it was concluded that mixed stock for timber-frame could be treated to an acceptable level using the double vacuum process, provided that again only coastal-grown stock is specified.

Treatment of *Shorea* spp

In the recent past there was an increased usage of *Shorea* spp for joinery marketed as lauan, meranti or Philippine mahogany. However, the variable durability of the material led to recommendations for treatment which were incorporated in B.S. codes. Disquiet expressed in some quarters prompted a more detailed appraisal of its treatment characteristics and its natural durability and how they might be related to other recognisable features of current commercial stocks.

With commercial supplies of timber comprising several different species, one approach to specification of particular requirements is to use a readily identifiable characteristic such as colour or density. However, such characteristics often are not correlated directly with an individual species. Problems can then arise when the specification need is for properties such as durability and treatability, yet the appropriate material cannot easily be selected by colour or density.

For the B.R.E. study, about 100 pieces of *Shorea* spp timber (2,000 × 100 × 50) were obtained from the commercial stocks of two co-operating joinery manufacturers. The following characteristics were determined for each piece:

(i) density: using oven-dry cross sections and the method described in B.S.373:1957

TABLE 4

Penetration of preservative into hemlock and fir and uptake of samples with one end sealed

Timber	*Type*	*Origin*	*Schedule*	*Uptake (kg/m^3)*	*Penetration (mm)* Lateral	*Penetration (mm)* Longitudinal
Hemlock	Joinery	Coast	V1	21 (7·9)	1·8 (0·7)	66 (43)
			V2	50 (25)	4·1 (2·1)	175 (87)
			V4	243 (78)	6·7 (4·8)	430 (95)
			A	108 (46)	6·6 (4·8)	328 (93)
Fir	Joinery	Coast	V1	22 (6·8)	3·5 (2·7)	103 (77)
			V2	50 (15)	6·7 (4·8)	216 (114)
			V4	267 (75)	—	479 (32)
			A	91 (26)	12·5 (4·2)	408 (106)
Hemlock	Construction	Mountain	A	29 (9.6)	2·7 (1·6)	
		Coast	A	58 (32)	8·1 (5·7)	
Fir	Construction	Mountain	A	69 (43)	14·2 (7·4)	
		Coast	A	85 (48)	17·6 (5·6)	
Hemlock	Construction	Mountain	P2	199 (94)	3·0 (1·8)	97 (85)
			P4	258 (113)	3·8 (2·5)	114 (110)
	Construction	Coast	P2	359 (158)	4·3 (2·5)	284 (187)
			P4	ND	5·6 (5·6)	ND
Fir	Construction	Mountain	P2	440 (136)	11·4 (6·4)	451 (234)
			P4	487 (141)	12·2 (7·0)	459 (281)
		Coast	P2	470 (132)	12·2 (6·1)	446 (223)

( ) = standard deviation

(ii) hardness: using the Janka indentation method described in B.S.373:1957
(iii) colour: calculated as a reflectance value from measurements taken throughout the visible spectrum using a spectrophotometer
(iv) uptake and penetration of preservative: using the same techniques described in the hem-fir work above (only schedules V1 and V4 were used)
(v) resistance to decay: using both field trial and laboratory test methodology. The field trial experiments used stakes 20 × 20 mm and 40 × 40 mm in cross-section after the method described by Purslow (1976). Laboratory tests included assessments for basidiomycete attack (Anon, 1972) and soft rot attack (draft revision of B.S.1982:1968).

Data were then compiled and analysed for any correlations of colour, density or hardness with natural durability or treatability. Summary data from all the tests are presented in Table 5 where it can be seen that the two consignments proved very similar in general characteristics and indeed were considered collectively in comparing properties. The individual values obtained for each property were compared graphically and statistically with each other's property.

Most comparisons revealed poor correlation with at best only broad general trends. For example, Fig. 8 shows the level of correlation between colour and natural durability (mean weight loss). Though in the present work the relationship between density and durability was weak, in certain European countries the specification for the acceptance of *Shorea* spp timber for joinery use without treatment is written in terms of a limiting density. Using data in the B.R.E. study, and accepting that a weight loss of 10 per cent or less in the basidiomycete test may be equated to a rating of moderately durable (Anon, 1972), the limiting oven-dry density for such a rating would be >460 kg per cubic metre (probably equivalent to >530 kg per cubic metre air-dry density).

Applying this limiting density value to the samples of *Shorea* obtained for this work, 53 per cent of samples would not meet the requirement. If it is further required that only the darker-coloured material (R<100) be included, since it is less vulnerable to fungal attack, as our data suggests, then 58 per cent of the sample would not meet the requirements. If treatment using the V1 schedule is introduced, it can be seen that 18·5 per cent of the total sample, after treatment, would fail to achieve the moderately durable minimum, while only 6·6 per cent would fail if only the denser material was selected, reducing to 4·9 per cent if the selection included both the density and colour limitations (Table 6).

PERMANENCE OF PRESERVATIVES – ACCELERATED EVAPORATIVE AGEING

In testing the effectiveness of wood preservatives in the laboratory, the ability to predict their permanence from accelerated ageing techniques forms an essential part of the overall appraisal. Within Europe, the only agreed method for evaporative ageing is the Standard EN73 (B.S.5761, Pt. 1:19) which describes a wind tunnel preconditioning procedure to be implemented before biological testing. This is time-consuming, expensive to carry out and may not realistically represent the way a preservative is distributed after evaporative ageing. As an alternative, B.R.E. have been developing a vacuum oven technique which promises to be at least quicker and less

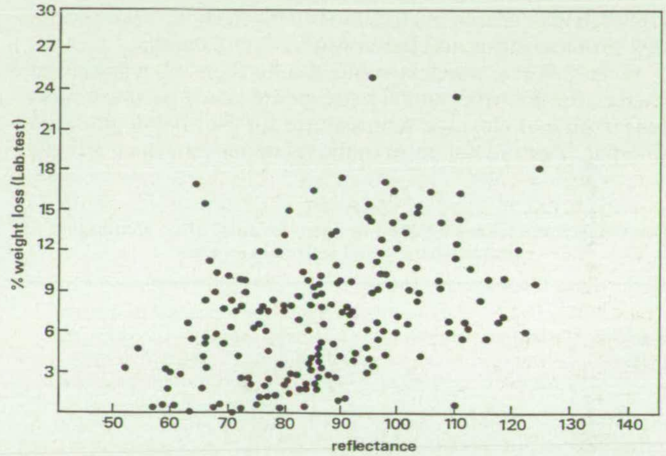


Fig. 8. Relationship between colour (reflectance) and natural durability (weight loss) for Shorea *spp.*

TABLE 5
Comparison of properties of *shorea* timber from two suppliers

Property	*SUPPLIER A*			*SUPPLIER B*		
	Mean	*Range*	*Median*	*Mean*	*Range*	*Median*
Density (kgm^3)	466 (60.6)	358 - 721	459	473 (76.1)	325 - 709	457
Hardness value	2501 (682.8)	1370 -5810	2300	2505 (823.1)	1170 -6180	2190
Reflectance value	90.0 (15.7)	57 - 124	89.5	81.9 (14.5)	52 - 124	83.4
Preservative uptake schedule V1, (kgm^3)	19.6 (18.3)	1.4- 111	14.0	9.8 (5.8)	4.4- 40	8.4
Preservative uptake schedule V4, (kgm^3)	74.1 (89.1)	6.4- 458	46.3	51.7 (36.3)	14 - 230	37.4
Side protection, schedule V1, (mm)	1.81 (2.54)	0 - 11.2	0.8	0.4 (0.7)	0 - 4.1	0.1
Side protection, schedule V4, (mm)	5.47 (6.31)	0 - 20	2.8	3.8 (5.4)	0 - 20	1.3
End penetration, schedule V1, (mm)	12.0 (28.3)	0 - 162	3.0	4.5 (12.5)	0 - 93	1.0
End penetration, schedule V4, (mm)	93.4 (84.3)	1 - 240	69.0	23.1 (49.9)	1 - 240	5.0
Mass loss (%) basidiomycete attack	8.3 (5.0)	0.6- 25.1	7.7	6.5 (4.3)	0.1- 16.4	6.7
Mass loss (%) schedule V4, (mm)	11.1 (5.6)	3.5- 33.3	9.6	3.7 (3.6)	0 - 13.5	3.6

(   ) = standard deviation

expensive than the wind tunnel method.

Preliminary work on this topic was reported in the B.R.E. review to this Convention in 1986 (Morgan *et al.*, 1986) and much of the work since then was included in a presentation to the I.R.G. in 1989 (Orsler and Holland, 1989).

Blocks of Scots pine sapwood measuring 15 × 50 × 50 mm and cut so that two of the 15 × 50 mm surfaces represented the tangential faces, were treated by surface application on the outer tangential surface only (i.e. that which was nearer the bark in the original tree) with a selection of light organic solvent wood preservatives. These were:

(i) 5 per cent pentachlorophenol in Shellsol E
(ii) 0·5 per cent lindane in white spirit
(iii) 2 per cent tributyltin oxide in white spirit
(iv) 2 per cent tributyltin naphthenate in white spirit.

Representative treated blocks for each preservative were then aged in the wind tunnel or the vacuum oven and analysed quantitatively to determine the detailed changes in preservative content arising from the ageing system. Examples of the results obtained are given in Fig. 9.

In general it was found that the wind tunnel and vacuum oven produced similar patterns of loss due to evaporation, although the vacuum oven did so in a much shorter time period and with less effort and less consumption of energy.

With TnBTO, which is vulnerable to thermal degradation, changes in the wind tunnel were greater because there was a longer time at elevated temperature for thermal degradation to occur. This did not occur in the vacuum oven which is therefore potentially more reliable for indicating losses strictly due to evaporation, the stated purpose of EN73 (B.S.5761: Pt. 1).

The risk of cross contamination of samples in the vacuum oven was checked by analysing untreated blocks placed alongside treated ones in the two equipments. This was considerably reduced by incorporating a slight air bleed into the system (see Table 7) and could be eliminated by modifying the vacuum oven so that each sample was conditioned in a separate compartment, as in the wind tunnel.

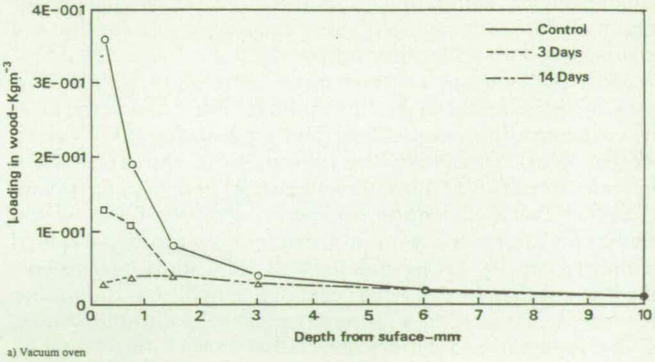
Finally it was noted that the increase in evaporation rate associated with a given rise in temperature (e.g. from 20°C. to 40°C. as in EN73) is different for the different compounds under tests. Using calculations based on the work by Guckel *et al.* (1982) increases in evaporation rate varied from four to 17 times for different compounds over the same 20°C. to 40°C. temperature rise. This indicates that the resistance of different wood preservatives to evaporative ageing cannot be compared quantitatively simply by accelerating the losses by elevating the temperature.

TABLE 6

Percentages of stakes classified as 'non-durable' after elimination of certain density and reflectance values

Oven dry density (kg/m^3)	*Total number of samples*	*Total number of samples R<100*	*Untreated (U) or treated (T)*	*Percentage of selected samples exceeding 10% weight loss by basidiomycete attack*	
				all materials	*R<100*
>325	195	158	U T	24.6 18.5	20.2 13.3
>400	170	143	U T	21.2 14.7	18.2 11.2
>420	151	134	U T	17.9 12.6	16.4 10.5
>420	140	124	U T	16.4 11.4	13.6 9.7
>440	131	116	U T	14.5 9.2	13.8 7.8
>450	113	102	U T	13.3 8.0	12.7 6.9
>460	91	82	U T	9.9 6.6	8.5 4.9
>470	77	68	U T	9.1 7.8	7.4 5.9
>480	72	63	U T	8.3 6.9	6.3 4.8
>500	50	40	U T	10.0 8.0	10.0 7.5

Notes-
(1) only the treated (U) samples were tested for decay
(2) treated = treatment by schedule V1
(3) the number of treated samples exceeding 10% weight loss was calculated by assuming that a preservative penetration of at least 3mm renders the timber "moderately durable or better"



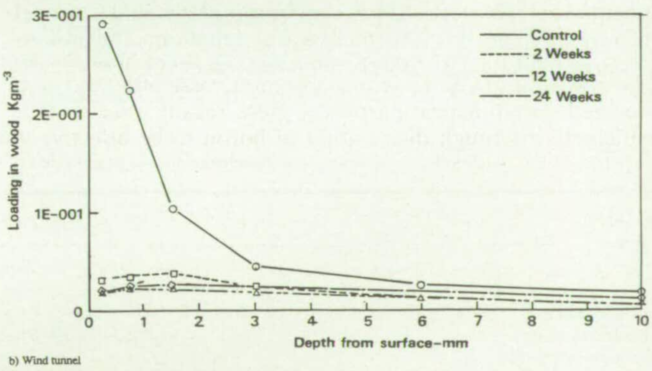


Fig. 9. Distribution profiles for Gamma HCH in Scots pine sapwood.

TABLE 7

Contamination of untreated blocks placed in the vacuum oven with Gamma HCH treated samples and conditioned both with and without an air bleed

Exposure Period (Days)	*Sample Increment (mm)*	*Concentration in Wood (kg m^{-3})*	
		Without air bleed	*With air bleed*
3	0 -0.5	0.037	0.011
	0.5-1.0	0.016	0.017
14	0 -0.5	0.033	0.015
	0.5-1.0	0.040	0.020

Distribution and Efficacy of Water-Soluble Solid Boron Implants

The use of water-soluble, diffusible preservative plugs, tablets and capsules for arresting decay and preventing further decay in exterior joinery has attracted considerable interest in the U.K. and work on their likely effectiveness has been reported to this Convention previously (Dicker *et al.*, 1983; Blow and Summers, 1985). B.R.E. has recently completed a co-sponsored laboratory study on fused rods of inorganic boron compounds. The work examined the ability of the boron to diffuse through wood under more or less steady state moisture conditions and the effectiveness of the migrating fungicide to control a representative aggressive decay fungus.

For the distribution studies, battens of Scots pine sapwood, spruce outerwood and the heartwood of western hemlock and amabilis fir were prepared, 40-50 mm in cross-section and 300-400 mm long. The battens were painted with a three-coat alkyd system on their lateral surfaces (except the spruce), vacuum impregnated with water and then allowed to dry naturally to a nominal moisture content determined by weight difference. A rod of fused disodium octaborate was inserted and sealed in a drilled hole in the centre of a tangential face of the batten (Fig. 10). The battens were wrapped in polythene sheet and stored in a cool room for 1, 2, 3 and 6 months.

After each time period, the distribution of the boron compound throughout the batten was determined quantitatively by analysing the nine samples derived from each 20 mm thick slice taken consecutively from each side of the implant (see Fig. 10). Boron content was determined spectrophotometrically using the circumin method (Williams, 1970). Moisture contents of all samples at the time of analysis were also determined.

The maximum extent of diffusion of boron after six months under the different conditions is given in Table 8. Results showed broadly similar tendencies irrespective of timber species, indicating that good longitudinal diffusion of boron can take place at moisture contents around 30-40 per cent but lateral diffusion at this level is limited. Substantial lateral diffusion was only achieved in the present study in one set of samples (spruce) where moisture contents reached 90 per cent. At the lower moisture contents studied (25 per cent or lower) which were below fibre saturation point, very little diffusion occurred. For practical purposes, these results indicate that sufficiently thorough distribution of boron to be effective is only likely to occur where water penetration has virtually saturated the wood (well in excess of fibre-saturation point around 28 per cent) and that at lower moisture contents capable of sustaining fungus growth, little diffusion is likely to occur.

Whether the very limited diffusion at lower moisture contents is adequate to have any benefit was studied in micro biological experiments using *Coniophora puteana*, an aggressive wood rotting fungus, relatively tolerant of boron. For this work a new assay technique was devised in which pre-drilled

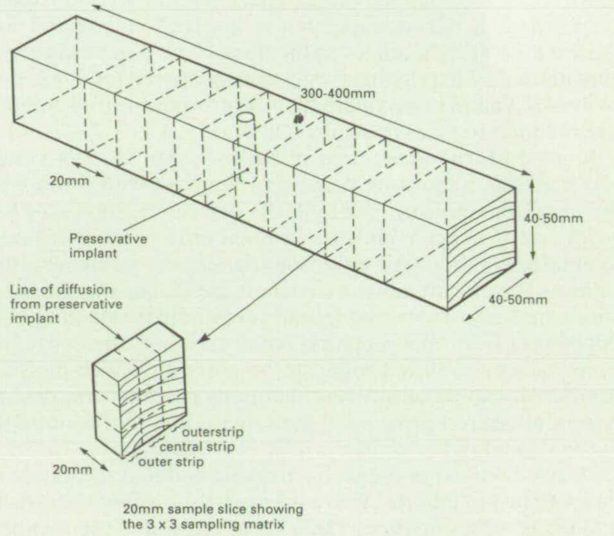


Fig. 10. Test batten and sampling technique for distribution studies with boron rods.

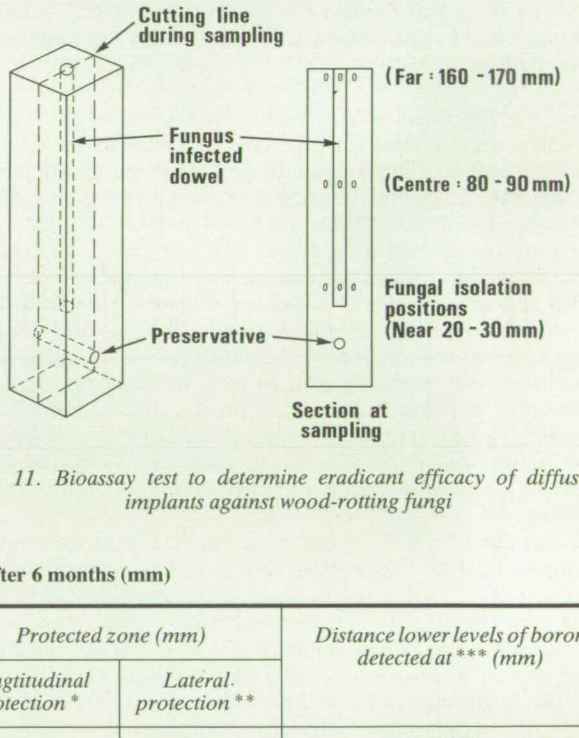


Fig. 11. Bioassay test to determine eradicant efficacy of diffusible implants against wood-rotting fungi

TABLE 8
Maximum diffusion of boron after 6 months (mm)

Timber species	*Target moisture %*	*Actual moisture %*	*Protected zone (mm)*		*Distance lower levels of boron detected at *** (mm)*
			*Longtitudinal protection **	*Lateral protection ***	
Scots pine	50 30	29-40 22-32	40 20	0 0	140 100
Spruce	50 30	22-91 14-19	220† 0	60 0	ne 60
Fir	50	23-40	60		180
Hemlock	50	24-36	100	0	180

Notes
* = central 15mm thick strip containing ≥ 1.5 kg/m^3
** = outer 15mm thick strips containing ≥ 1.5 kg/m^3
*** = lower level = < 1.5 kg/m^3
† = full length of sample
ne = not established

blocks of Scots pine sapwood and heartwood were impregnated with water to give steady state conditions with nominal moisture contents of 25 per cent and 50 per cent. The blocks were infected with the fungus from dowels inserted in the hole down the centre of each block. After the fungus had become established, a boron implant was inserted and sealed in a second hole at right angles to the dowel, the blocks were individually sealed in polythene bags and incubated for 4, 12, 18 or 24 weeks. Sample chips were then taken and cultured on selective medium to assess fungal viability (Fig. 11).

In general, the movement of boron within the test system correlated with moisture content rather than with wood type; the lower the moisture content, the less the migration of fungicide. At 25 per cent moisture content diffusion was sufficient to eliminate the fungus only from the closest sampling point, while at 50 per cent moisture content the fungus was gradually eliminated also from the second longitudinal sampling zone (80-90 mm from the implant). After 12 weeks the decay free zone was assessed and found to be correlated with moisture content. It should be stressed that in its present form this test system measured principally the longitudinal diffusion of the boron compound.

Clearly both experiments have confirmed that the extent of boron diffusion and its effectiveness in controlling the attacking fungus is dependent on the level of moisture in the timber. In addition, it would appear that at relatively low moisture contents, established wood-destroying fungi may be sustained but diffusion of water-soluble fungicide could be too limited to give extensive control unless the implants are placed suitably close together. The practical significance of this apparent limitation needs further study.

Moisture Uptake and Coating Performance

It is well recognised that the protection afforded to wood by an exterior wood coating is strongly dependent on its effectiveness in controlling wood moisture content. During recent years the ability of coatings to allow wet wood to dry out by virtue of 'breathing' or 'microporous' properties has been the subject of much discussion, though convincing experimental evidence of the value of microporosity is lacking. Moreover unpublished Scandinavian reports of problems of a localised form of decay by *Dacrymyces stillatus* in coated exterior timbers, suggest that overall levels of moisture content may be less important in determining performance than the precise distribution of the moisture. These essentially practical issues emphasise the need for a better understanding of the rates of absorption and spread of water into coated and uncoated wood and of their significance.

Recent effort in B.R.E. has been directed towards refining the initial surface absorption test (I.S.A.T.) described in B.S.1881:1971. In this test a panel is clamped, test face up, under a cap fitted with a gasket to ensure a water-tight seal. The outlets on the cap are connected to a reservoir of distilled water and to a horizontal, calibrated capillary tube. Water from the reservoir is admitted until the cap and the capillary are filled, and then turned off. Any absorption of water by the test surface can then be determined by timing the movement of the water meniscus along the capillary. A typical rate/time curve shows that absorption rate is initially high but slows as surface layers of cells are filled. Absorption rates for uncoated wood are determined from the slope of the initial linear portion of the curve.

Surface absorption rates for surfaces of Scots pine are shown in Table 9. They show the relatively high resistance of heartwood compared with sapwood, and emphasise not only the very high absorption rate of end-grain surfaces but also the enormous increases that occur following a period of natural weathering. Measurements for a variety of exterior wood stain basecoats have been completed and show an encouraging correlation with assessments of exterior field performance. The technique is also proving useful for assessing the comparative performance and permanence of end grain sealers.

TABLE 9

Surface water absorption rates for uncoated Scots pine (in ml m^{-2} h^{-1})

Surface		*Heartwood*	*Sapwood*
Side grain	UW	250	2500
	W	nt	41500
End grain	UW	3500	> 1m

Notes:
UW = unweathered
W = weathered
m = million
nt = not tested

The influence of paint permeability on moisture contents in exposed timber has been investigated in an exposure trial on L-joints prepared from softwood and hardwood species and coated with either a solvent-borne or water-borne paint system. The two coating systems used were selected to have a 10-fold difference in their water-vapour transmission rates measured by the I.S.O. Standard cup method (I.S.O.-R1195, 1970) – a conventional 3-coat alkyd gloss paint (7·6 gm^{-2} 24 hr^{-1}) and an acrylic emulsion paint (76 gm^{-2} 24 hr^{-1}). The coated L-joints were exposed to natural weathering with the paint system over the joint deliberately broken in order to ensure comparable and rapid rates of end-grain water entry. Moisture content was monitored over a 160 week period using a microwave meter and by weighing.

The effect of the permeability difference in the coatings applied to Scots pine sapwood was that those painted in acrylic consistently dried down to lower moisture contents in the summer months than did those coated with alkyd paints (Fig. 12). The minimum moisture content values for the acrylic and alkyd coat determined by weighing were about 25 per cent and 40 per cent respectively. However, when the amounts of moisture in excess of 20 per cent at each monitoring period are totalled to produce integrated values for each coating type (Table 10) there was little consistent difference between the coatings irrespective of timber type. Although it can be seen that values for the acrylic were marginally lower than for the alkyd in Scots pine sapwood, heartwood and in spruce, for the other, mostly more impermeable wood species, the values for the acrylic were higher than for the alkyd. Hence it is concluded that the 10-fold difference in water-vapour permeability did not significantly affect overall moisture conditions within the joints. As yet bio-assays have not been carried out to establish whether the different patterns that did occur might have influenced the microbial colonisation.

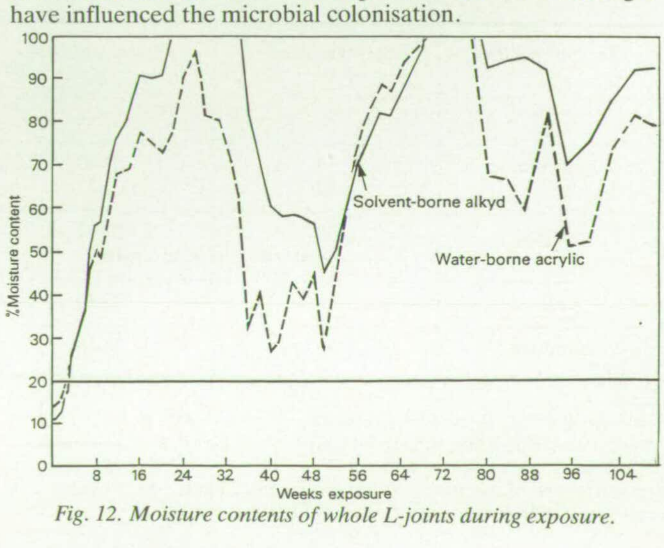


Fig. 12. Moisture contents of whole L-joints during exposure.

TABLE 10
Integrated moisture contents of complete L-joints

Timber	*Paint type*	
	Alkyd	*Acrylic*
Scots pine-sapwood	2974 ± 567	2484 ± 279
Scots pine-heartwood	352 ± 18	290 ± 58
Spruce	320 ± 59	308 ± 34
Douglas fir	99 ± 2	116 ± 15
Hemlock	402 ± 121	518 ± 55
Iroko	53	95
Lauan	5·5 ± 1·8	20 ± 1·0

Continuing studies on the performance of end grain sealers has employed a new technique based on 100 mm square transverse slices of Scots pine sapwood. The test sealer is applied to one face which is then placed in contact with a plywood base to simulate the moist conditions expected within a joint in service. The assembly can be disassembled at intervals to determine the water absorption properties of the test surface using the B.R.E. modified I.S.A.T. test.

A wide range of wood treatments have been examined and substantial differences in performance have been found (Table 11). In general, water repellent preservatives and stain basecoats can reduce the water absorption rate to less than one per cent of that of bare wood initially, but lose effectiveness rapidly on artificial ageing. Some solvent-borne primers retain their effectiveness well. The B.S.5358 lead reference primer and a two-pack polyurethane sealant have given particularly good results. Correlation between the artificial ageing test and outdoor exposure remains to be established but initial evidence suggests that 2,000 hours artificial ageing is equivalent to at least two years in an open joint situation.

European Standardisation

Commitments to European Standardisation activity in the wood preservation and coatings field have been particularly heavy in the last two years. The E.E.C. Construction Products directive was signed on December 21st, 1988 and requires implementation throughout the European Community by June 27th, 1991. Eurocode 5 "Common unified rules for timber structures" was produced in support of the Directive and the European Standardisation Committee (C.E.N.) has been commissioned to prepare a series of new Standards required to implement the Directive. The Committee in C.E.N. charged with preparing the necessary Standards relating to the Durability of wood and wood-based products is TC38. Since April 1988 when it began to react to its broader mandate from the E.E.C., TC38 has created 10 Working Groups each charged with preparing the particular Standards now needed to complement those already in place. Sponsored by the Construction Directorate of D.O.E. and with additional support from B.W.P.D.A. for travel, B.R.E. has made a major contribution in all 10 Working Groups. The list of Working Groups with their titles and U.K. contributors is given in Table 12 and the Standard titles with target dates in Table 13.

The Working Groups with the new and most difficult tasks are WG1 to 4 inclusive who have to produce not traditional methods of test but performance requirements. Their general tasks can be summarised as follows:

C.E.N./TC 38 Working Group 1 "Hazard classes". To define a hazard class system, associated with wood utilisation, based upon the earlier work of the European Homologation Committee;

C.E.N./TC 38 Working Group 2 "Natural durability". To produce a natural durability classification for timber; to list timbers commonly used in Europe; to establish a relationship between durability and hazard class;

C.E.N./TC 38 Working Group 3 "Performance of treated wood". To specify the performance requirements for treated wood according to hazard class; to produce a system for the identification of treated wood;

C.E.N./TC 38 Working Group 4 "Performance of preservatives (tests)". To specify performance levels for preservatives determined by biological tests; to select tests appropriate to hazard class; to produce a system for the identification of wood preservatives.

In all cases the working groups had to consider only pretreatment systems; remedial and curative treatments on timber *in situ* and sapstain treatments on green timber were excluded as they do not fall under the terms of the Construction Products Directive.

The draft Standard produced by WG1 has now been issued

TABLE 11
Results of water absorption tests on end grain sealers

Product		*Water absorption (µlh-1)*				
		0h	*500h*	*100h*	*1500h*	*2000h*
CONTROL	· Scots pine sapwood	35000	–	–	–	–
PRESERVATIVE	· OS. WR Grade (BS.5082/5358)	2500	5000	>50000	–	–
PRIMERS	Solvent-borne (BS.5358)	38	80	300	–	290
	Water-borne (BS.5082)	785	225	640	3240	5280
	Solvent-borne	23	107	167	410	438
	Lead type (BS. reference)	10	8	13	15	20
	Aluminium (leafing grade)	60	84	338	1424	2773
BASECOATS	Solvent-borne 1 (dipping grade)	112	475	1919	2130	10765
	Solvent-borne 2 (dipping grade)	214	124	417	610	1771
	Solvent-borne 3 (dipping grade)	124	250	3086	3500	7237
SEALANTS	Polyurethane (2 pack)	10	7	12	8	9

Notes Area of test cell 5674 mm^2
Results are means of duplicate measurements. Average error ± 40% of mean
h = hours of artificial weathering

TABLE 12
Working Groups and U.K. experts in C.E.N. Technical Committee 38

Working Group Reference	*Title*	*Date Established*	*Convenor*	*U.K.'s Nominated experts*	*B.S.I. Technical Committee*
WG1	Hazard classes	April 1988	Mr. A. Demange (France)	Mr. J. H. M. Worringham Dr. A. F. Bravery	WPC/2
WG2	Natural durability	April 1988	Dr. Willeitner (Germany)	Dr. D. A. Lewis Mr. R. P. Sharphouse	WPC/2
WG3	Performance of treated wood	April 1988	Mr. Jermer (Sweden)	Dr. F. W. Brooks Dr. R. J. Orsler	TIB/30
WG4	Performance of preservatives (tests)	April 1988	Dr. A. F. Bravery (U.K.)	Dr. D. J. Dickinson Dr. R. J. Orsler Dr. C. R. Coggins	WPC/10
WG5	Field testing out of soil contact	April 1988	Dr. A. F. Bravery (U.K.)	Dr. D. J. Dickinson	WPC/10
WG6	*Hylotrupes*	October 1988	Dr. Graf (Switzerland)	Dr. A. F. Bravery (Mr. D. Blow) Mr. R. W. Berry	WPC/10
WG7	Particle board and plywood	October 1988	Mrs. Kerner (Germany)	Dr. D. J. Dickinson Dr. A. F. Bravery (Dr. J. K. Carey)	WPC/10
WG8	Soft rot	October 1988	Mrs. Kerner (Germany)	Dr. D. J. Dickinson Dr. A. F. Bravery (Dr. J. K. Carey) Dr. C. R. Coggins	WPC/10
WG9	Preventative efficacy	October 1988	Mrs. Dirol (France)	Dr. D. J. Dickinson Dr. A. F. Bravery (Dr. J. K. Carey) Mr. A. R. M. Barr	WPC/10
WG10	*Lyctus*	October 1988	Mrs. Sermont	Dr. A. F. Bravery (Mr. D. Blow) Mr. R. W. Berry	
CG	Correspondence Group – Environment	October 1988	Dr. C. R. Coggins (U.K.)	Dr. F. W. Brooks	WPC/–/2

*delegated by WPC/–
( ) replacements for Dr. Bravery after April 1st, 1990

for public comment as pr EN 335. The first two drafts from WG2 are at an advanced stage and are expected to be issued as pr EN's in the autumn of 1990. The draft Standard from WG3 has been issued as pr EN 331. Drafts from WG4 are following a preliminary procedure of voting within TC38 before passing to the pr EN stage. This is because of the very strongly held differences of philosophy about the minimum number of tests that should be specified for compliance, exacerbated by some essential test methodology not yet having been Standardised. However the output from all four of these Working Groups of TC38 is available through the British Standards Institution.

The basic approach is to define five hazard classes representing the different fields of use for preservatives and treated wood (Table 14). The minimum testing requirements and performance to be achieved in them will be laid down, on the basis of which preservative products will be labelled as suitable for a given hazard class or classes. Requirements of treated wood for each hazard class will be defined in terms of minimum penetration and retention requirements, that is a results-type specification and not process-type. Finally the minimum level of durability (natural or conferred by preservative treatment) will be prescribed also by hazard class. Thus the specifier or user begins the specification process by deciding the appropriate hazard class for the commodity with which he is concerned. This will then dictate the durability level required, the type of preservative which is suitable and the minimum preservative treatments necessary. It will be for the specifier to decide how much extra security he requires by specifying higher standards than the minimum prescribed.

Collectively these Standards will create a whole new approach to specifying wood preservatives and treated wood in the U.K. and provide the framework which will dictate the marketing of such products throughout Europe.

The C.E.N. Technical Committee responsible for coating systems for wood is TC139. Its Working Group 2, under the B.R.E. Convenorship of Dr. Roy Miller, is well advanced in completing its first Standard which sets out a basis for classifying coating systems for wood based loosely on B.S.6592: Pt. 1: 1988. The criteria make no reference to composition, being concerned mainly with appearance and end-use. Thus performance is the over-riding consideration and it may be achieved by any composition depending upon particular technical preferences or innovations.

Discussions are also in progress on the requirements for performance tests for components in the three agreed end-use categories, stable (e.g. joinery), semi-stable (e.g. cladding) and non-stable (fencing). There is general agreement that the first step should be the definition of a methodology for a material exposure test, and collaborative trials are planned initially based on the Nordtest Build 229 accelerated performance test (NT Build 229; 1989) which it is believed could form the basis for a C.E.N. standard.

TABLE 13
Standards and target dates for each Working Group of C.E.N./TC38

Working Group references	*Standard Titles*	*Target date*
WG1	– Wood and wood-based products – – Definition of biological hazard classes – Annex – Guide for using of biological hazard classes	March 31st, 1990
WG2	– Natural durability of wood Part 1 – Principles of testing and classification of the natural durability of wood Part 2 – Natural durability and treatability of selected wood species of importance in Europe – Natural durability of wood – Durability classes and hazard classes	 April 30th, 1990 May 31st, 1990 January 31st, 1990
WG3	– Performance of treated wood according to risk classes – Identification of treated wood – Control of treated wood	April 1st, 1990 April 1st, 1990 April 1st, 1990
WG4	– Performance of preservatives as determined by biological tests – 1 – Tests for specific hazard classes – 2 – Minimum performance criteria in test – 3 – Identification of wood preservatives	 March 31st, 1990 March 31st, 1990 March 31st, 1990
WG5	– Field test out of ground contact	September 30th, 1990
WG6	– Eradicant test for *Hylotrupes*	none
WG7	– Wood-based panels: resistance to fungal attack	February 28th, 1990
WG8	– Preservative efficacy against soft rot	June 30th, 1991
WG9	– Method for determining the relative effectiveness of a wood preservative for use by surface process	December 31st, 1991
WG10	– Determination of toxic values against *Lyctus*	June 30th, 1990

TABLE 14
Definition of biological hazard classes prescribed in pr E.N.335

General conditions			*Conditions for Solid Wood*						
Hazard classes	*Situation in service*	*Description of exposure to wetting in service*	*Wood moisture content* (1)	*Fungi*			*Insects*		*Marine borers*
				basidio-mycetes	*soft rot*	*· blue stain · mould*	*beetles* (2)	*termites*	
1	Above ground ground (dry)	Permanently dry	Permanently <18%				U	L	
2	Above ground covered (risk of wetting)	Exposed to occasional wetting	Occasionally >20%	U		U	U	L	
3	Above ground not covered	Exposed to frequent wetting	Frequently >20%	U		U	U	L	
4	in contact with with ground or fresh water	Permanently exposed to wetting, in contact with ground or fresh water	Permanently >20%	U	U	U	U	L	
5	in salt water	Permanently exposed to wetting by salt water	Permanently >20%	U	U	U	U	L	U

The agents exist: Universally (U) throughout the European area or only locally (L)
(1) Moisture contents given in this table are for the purpose of describing hazard classes and are associated with the durability of structural and non-structural wood components. Moisture classes in draft Eurocode 5 define average moisture conditions and are for the purpose of assigning design stresses to structural wood components only and are entirely separate from the figures in this table.
(2) Beetles are universally present throughout the majority of the European area but the risk of attack varies greatly from high to insignificant.

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DISCUSSION ON PAPER 1

Chairman: The President

THE PRESIDENT: I am briefly without a microphone but I propose to allow this session to overrun by five minutes, such is my privilege which I will deny to any subsequent Chairman, and I will now ask DRS. ORSLER and MILLER and MR. BERRY to step up. I wondered whether anybody from the remedial Treatment Section might have a question to ask about emulsions and/or boron rods.

DR. N. BURGERS (Private Member): I thought that the experiment with boron rods was very interesting. They have been there for many, many years as you know, especially starting in Scandinavia too but I was astonished that we never see something about the bifluoride pills. In Holland a lot of experience has been gathered in using encirculable bifluoride pills in joinery. They are selling in great amounts now with great success and especially because the draw back on the boron rod is its spread laterally is relatively small. We achieve with the bifluorides a much greater spread and a quicker reaction and so we think that there is much perspective in that but we have not seen any results of any research in England as yet.

DR. A. F. BRAVERY: Well, I would only comment that you are quite right; we have not done any work on bifluorides and I am unaware of any published work within the United Kingdom anyway. Indeed, I am unaware of any published work anywhere on the distribution from these bifluorides. We have only seen some internal documents but nothing published.

DR. N. BURGERS (Private Member): Maybe they are internal publications but there are a number of publications and there are many results known in practice.

DR. D. J. DICKINSON (Imperial College): It is just a comment about the boron rod work. I think one of the principle differences of the work which was done in the past compared to this steady state work at BRE, is that a lot of the earlier work was essentially looking at the perspective efficacy of boron rods but before major decay was established. The work in poles for instance has been such that we have always been very careful to say it is a preventative system and not necessarily an eradicant system for well-established decay.

DR. A. F. BRAVERY: That is fair enough.

MR. L. D. A. SAUNDERS (Fosroc): I would like to direct my comment to DR. ORSLER. Reg has quite accurately highlighted the fact that the European test refers to evaporative loss, yet tests other things besides evaporative loss. He has quite accurately identified also a technique which solely looks at evaporative loss. Having done that, Reg, I wonder if you could comment on whether – in view of the Scandinavian suggestion that there should in fact be a test to look at thermal loss or thermal degradation, such as can occur under a paint film or as a result of thermal gain in a roof space – it is in fact useful to eliminate the problem of thermal breakdown.

DR. R. J. ORSLER: The point we are making in the paper and indeed that we have made before is that one should be perfectly clear about what one is measuring when developing an accelerated technique. I think that the original idea of the wind tunnel was to measure volatile losses, essentially for the organo-chlorine insecticides sprayed when spray-applied for remedial treatment.

Subsequently this method was used on a wider basis. Looking at it now in more detail it is quite clear that when it is applied to other preservatives systems, one is measuring more than just volatile losses. So it seems to me quite important that one concentrates again on what one was originally trying to do.

What you say is perfectly correct. One should turn again to the other preservative systems one is testing with this method and ask oneself whether one wants to look at these other characteristics. Certainly I would agree that thermal degradation is something on which one should focus attention. It does appear to occur and it can reduce the effectiveness of certain preservative systems, so I would go along with you and agree that we should look at thermal degradation but we should be careful not to superimpose different ageing characteristics on one another. The whole idea is that we should have a clear indication of how a preservative works and what its weaknesses are so that we can apply this to a detailed assessment of its effectiveness.

DR. C. R. COGGING (Rentokil): I think we really do need to congratulate the authors and the staff in the BRE Sections concerned, in demonstrating the excellent continued breadth and depth of work going on at Garston after the move from Princes Risborough. Chairman, I would like to ask Tony for a little bit more comment perhaps on the work on durability of board materials. In the text of the paper you said that experience suggest that sheathing grade Douglas fir, plywood and so on, can give a satisfactory performance. I suppose I am highlighting the words "can give a satisfactory performance". Those boards would seem to fall into your decay susceptibility index for Class 2, which equates to non-durable solid timber, and I wonder, coming to the point Chairman, if Tony would comment on the relationship between a Class 2 performance and the liklihood of exposure to wetting in service that you may have been able to identify in the timber framed housing investigation.

DR. A. F. BRAVERY: Thank you, Chris. Well of course, you have put your finger on the particularly difficult issue of calibrating this type of study. What I can say is that the selection of moderately durable solid wood is based on a concept of adequacy of performance of solid wood in practice and the basis that we initially set out to establish for our board materials was do much the same thing. We wanted to set a similar performance equivalent to moderately durable or better but found that if one sets that standand for panel products using the lab test, one sets a very high standard that most of the widely and extensively used panel products would not actually meet. Understandably there would then be an assertions that what we were doing was setting a new and much too high standard and an unrealistic standard in relation to what has been achieved in practice.

We therefore turned the logic on its head as it were and essentially said that, if the user industry claims that these particular panel products have given adequate performance in service and no one else can marshall the evidence to show that they have not, then these boards should be the reference for the particular situation we are considering. So we then built the classification system around that logic. We created a class that represented the spread of the products that complied with the basic standard, if one wanted to specify a higher standard, and a lower grade which would have to be used to exclude anything that was unreasonably vulnerable.

THE PRESIDENT: I am awfully sorry but we have used up my special time. I do not want to abuse that privilege. I think what Chris Coggins said about the breadth and depth of the work being done at BRE has really said all that I need to say. I think from my point of view as a remedial treatment member there are still a couple of big question marks which have been left out from this paper which I shall have some pleasure in taking up with the co-authors at some stage during the next 48 hours or so, probably shortly after the closing of the dinner tomorrow night.

Apart from that I am sure you will join me in expressing our appreciation to all the co-authors for the work they have done and for a most enjoyable presentation this morning. Thank you very much. (applause).

B.W.P.D.A. CONVENTION 1990

DEVELOPMENTS IN THE DANISH TREATMENT INDUSTRY AND RELATED RESEARCH AT THE DANISH TECHNOLOGICAL INSTITUTE

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Developments in the Danish Treatment Industry and related research at the Danish Technological Institute.

1. INTRODUCTION

The Danish wood treatment industry has been described in two previous papers to this convention. In the early 60's it was reported that creosote was the principle preservative in Denmark (Storm 1963) but, even at this time, it was difficult to get linesmen to handle creosoted poles. There have been many changes in the industry since that time, with the unions having an important role as catalysts for change. Among these changes can be listed.

1. the emergence of CCA (copper-chromium-arsenate) preservatives as the dominant product.
2. restriction of creosote to heavy duty commodities only i.e. sleepers and poles – leading to closure of the last creosote plant in Denmark in 1989.
3. the growth of double vacuum impregnation of windows
4. the industry's "trade agreement of 1988"
5. the introduction of new standards for preservation

During this period the industry has maintained its well organised structure where product quality has been controlled by a number of schemes and committees. These were described in the second paper referred to above (Sabroe 1974).

Although preservatives and standards have changed over the years, there has been a remarkable stability in the committee structure (Figure 1).

This stability is largely due to the efforts of Erik Borsholt, whose work as secretary of many of these committees has secured the position and respect they now have. The principle wood presevation committee is the TTU, though the majority of its work is conducted in sub-groups and ad-hoc groups, where the major activities relate to safety and standards. These activities are financed essentially by Danish industry and occasionally from public funds when and where appropriate.

To complete this brief introduction, recent statistics for 1989 for the Danish industry are given below (Danish Wood Presevation Control 1990):

Number of authorised factories	
Pressure treatment:	29
Double-vacuum treatment:	51
Pressure and double-vacuum:	2
	82

Volume of treated timber (excluding poles and sleepers)

Pressure treated:	208,589 m^3*
Vacuum-treated:	33,728 m^3

*includes 23,912 m^3 of spruce.

These bare statistics, however, do not reveal the extensive changes which have occurred during the last two years.

2. PROBLEMS FACED BY THE TREATMENT INDUSTRY

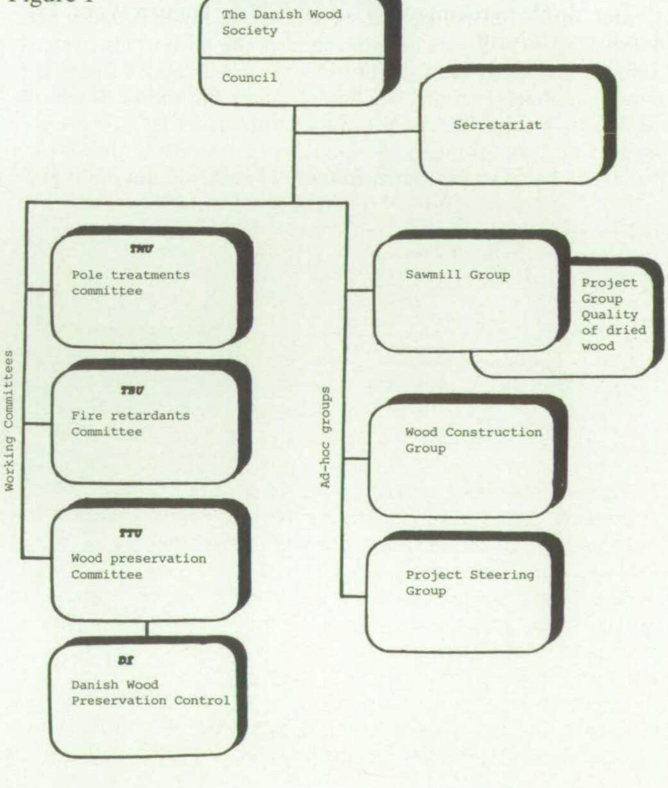
1988 was a tempestuous year for the wood treatment industry in Denmark. There were essentially four major problems:

1. A well orchestrated campaign by the trade unions, especially the union for joiners and carpenters, with support from some officers of the Danish Labour Inspection Service (Arbejdstilsynet), led to numerous alarming reports in the press. The criticisms were wide ranging and covered handling risks associated with wet and inadequately fixed wood, environmental pollution at impregnation plants, excessive and unnecessary use of treated wood and future problems with disposal of treated wood. The campaign led to a meeting involving the National Agency for Environmental Protection, the Danish Labour Inspection Service, the trade union concerned and representatives of TTU's environmental subgroup, after which the industry was requested to make proposals to improve the dryness and fixation and to consider the question of substitution of arsenic.
2. The requirements of the "Sevesco Directive" were now on the horizon with most of the treatment plants being required to submit a full registration together with a risk evaluation before July 1989. Those plants covered by the regulations (Miljøstyrelsen 1988) were included in a so-called "list of dangerous factories" which appeared at irregular intervals in the press.
3. In September 1988 the Danish Labour Inspection Service (Arbejdstilsynet 1988) amongst other things pointed out that CCA treated wood was covered by declaration no. 764 of 2nd December 1987. This automatically classifies any product which contains more than 0,1 per cent of any material on their list of carcinogens as a "dangerous product" requiring a series of user-data sheets.
4. Many of the larger treatment companies in Denmark have significant exports to West Germany and Switzerland. Switzerland had already announced its decision to ban the import of arsenic-treated wood from 31 August 1989 and the health authorities in Germany were actively seeking to deny the re-approval of CCA preservatives.

Although not under as much pressure as the CCA-treat-

Committee Structure of the Danish Wood Preservation Industry

Figure 1



ers, the joinery industry also had its problems. Here the accent was on the risks of "brain damage" from long-term exposure to organic solvents – the so-called Danish painters syndrome. There were repeated demands from workers' organisation for reduced exposure to solvents in all industries and the double-vacuum treatment of windows was no exception.

3. THE RESPONSE BY THE TREATMENT INDUSTRY

In August 1988 the industry held an open meeting where the problems were discussed and various suggestions for action were considered. After further meetings within the industry and with the authorities, the so-called "trade agreement of 1988" was signed in December by all companies using CCA preservatives and came into effect in 1st January 1989. At the same time the new revision of Danish Standard 2122 (Danish Standardiseringsråd 1989) also came into effect. The combined effects of these changes can be summarised as follows.

1. The introduction of a new treatment class – Class AB – for exterior timbers not in ground contact, i.e. equivalent to Hazard Class 3 (CEN 1990). As an interim measure, the required retentions were set at half the rententions required in Class A.
2. An extension of the fixation times from 3 days to 6 days in summer and 6 days to 14 days in winter for timber treated to Class A and AB. Fixation times for Class M were set at 7 days and 28 days respectively. These fixation times do not include days with an average temperature below 5°C and are valid only for CCA preservatives. There are concessions for indoor fixation and accelerated fixation.
3. The timber stacks are now stickered before treatment in a defined manner to promote run-off and drying.
4. Treated timber is delivered either dried to 30 per cent moisture content or stickered and drip-free.
5. The treatment plants now mark each pack of timber with the following information:
   Preservative
   Treatment class
   Treatment date
   Method of fixation
   Moisture content (eg. >30 per cent, <30 per cent)

The "trade agreement" is supervised by Danish Wood Preservation Control.

Whilst the Danish industry was able to act in unison regarding the above points, it was not so easy to find a solution to the request for substitution of arsenic. This will be discussed later in this section.

The ability of the industry to act co-operatively was again demonstrated in their approach to the risk evaluations demanded under the "Sevesco directive". The industry commissioned a firm of consulting engineers to make a detailed evaluation of risks associated with the chemicals, the plant and the process, taking a large treatment plant as the model. This model analysis was supported by a report for each plant covering the local conditions specific to that plant. By acting in this manner the cost to each company was significantly reduced. Unfortunately the outcome of all this work is still unknown because the authorities have not yet completed their deliberations.

The question of user-data sheets was also tackled in a coordinated manner. Data-sheets for the preservatives are supplied by the preservative supplier, whilst the treated wood (CCA) is covered by a comprehensive data sheet (TOP, 1989) following the model issued by the Danish Labour Inspection Service. Though not covered by the same legislation, a similar user-data sheet has also been produced for CCP (copper-chromium-phosphorus) treated wood (TOP 1990).

The final problem of restrictions or expected restrictions in certain export markets also had to be addressed, calling for a change to arsenic-free preservatives. It is also clear that such a move would ease the burdens mentioned above. Those factors which had the greatest influence is unknown to the author, but in any event, three of the largest companies opted in 1989 to change from CCA preservatives to a CCP product.

The result of these changes can be seen already in treatment statistics for 1989 (Danish Wood Preservation Control, 1990).

Preservative Type		No. of Factories
CCA	(copper-chromium-arsenic)	18
CCP	(copper-chromium-phosphorus)	10
CC	(copper-chromium)	1
C	(copper)	1

Preservative Class	Volume of treated wood (m^3)
M	678
A	49,258
AB	134,741
Unclassified (spruce)	23,912

A detailed analysis of the figures supplied by the industry to Danish Wood Preservation Control revealed that the amount of arsenic used in Denmark during 1989 was 69 per cent lower than it would have been if the above changes had not occurred. The amount of chromium used was 30 per cent lower. However, because of recent changes in the rententions demanded by the Nordic Wood Preservation Council (NWPC 1990) it is not possible to say if this trend will continue.

Though less dramatic than for pressure impregnation, the changes within the double-vacuum treatment industry must not be omitted. As already stated, the demand was for a reduction in the volume of organic solvent impregnated into the timber. The first generation of products approved by the Nordic Wood Preservation Council were approved at retentions of around 50 kg/m^3 in the outer 10 mm sapwood zone. Next came a group of products approved at around 40 kg/m^3, but this was about the lowest level practical if the penetration requirements were to be achieved. This obstacle was removed with the introduction of the new revision of DS 2122 in 1989. This, in principle, redefined the previous standard of treatment in terms of penetration and loading in the end-zones and the demand for lateral penetration was reduced from 10 mm to 5 mm. Figures 2, 3 and 4 compare the penetrations and loadings obtained in Scots pine (Pinus sylvestris) sapwood treated with processes estimated to meet the requirements of the original Class B, the new Class B and BS 5589 (desired service life 20 years). These figures show that the new Class B penetration requirements can be achieved with a significantly reduced gross retention. However, the treatment fluid must also be approved at this lower retention and therefore must be more effective as measured by laboratory tests.

The revised standard therefore permits the use of products and processes which result in lower absorption of organic sol-

Figure 2

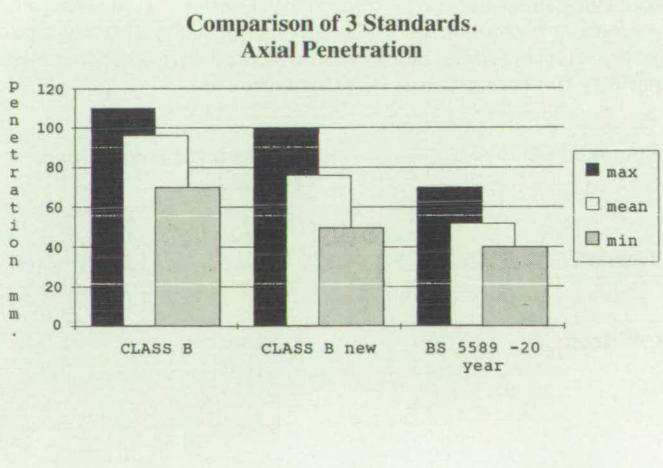


Figure 3

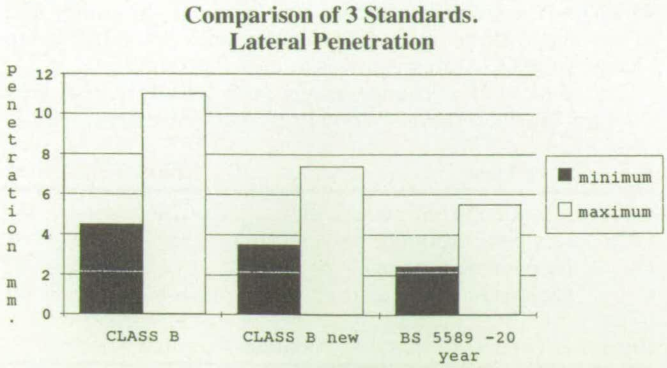
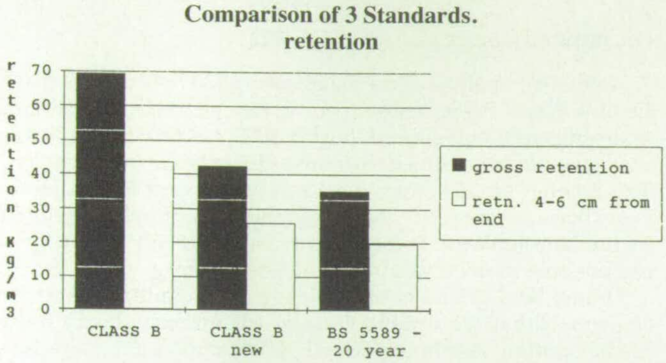


Figure 4



vents. The standard also harmonises the Nordic requirements more closely with those of the UK and proposed CEN standards. Today there are about 20 plants in Denmark using products approved at less than 30 kg/m^3, out of a total of 53 authorised plants.

4. Related Research and Technical Support from DTI

4.1 Fixation of Chromium – containing preservatives

During the discussion with authorities and unions, the role of DTI, through the TTU, has been to supply technical information and help in the interpretation of that information. This was by no means an easy task as much of the information has been generated at different times, in different countries using different formulations and different techniques. Most reports covering fixation of CCA preservatives present results in terms of the percentage of elements fixed under given conditions of time and temperature. However, from the viewpoint of safety, it is the absolute amount of unfixed chemical which is the relevant factor. A series of investigations was therefore commissioned and the author is grateful to Collstrop-Dansk Traeimpraegnering, Dalhof Larsen & Horneman, Dansk A-Trae and Rentokil Svenska AB for their permission to present some of the results here.

The technique used in our investigations consisted of squeezing the water out of treated blocks after various fixation periods, a technique used recently in the USA (McNamara 1989 a). Drying of the blocks was prevented during the fixation period. The preservatives investigated were:

	Declared composition	
Rentokil P50:	CrO_3	21,0%
	CuO	15,2%
	H_3PO_4	30,4%
Tanalith CCA paste:	$Na_2Cr_2O_72H_2O$	44,6%
	$CuSO_45H_2O$	34,6%
	$As_2O_52H_2O$	19,6%
Collstrop CB:	$CuCr_2O_7$	35,0%
	H_3BO_3	25,0%

Figure 5

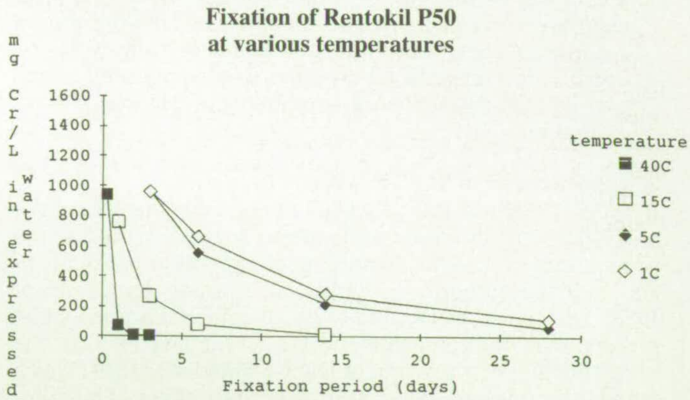


Figure 6

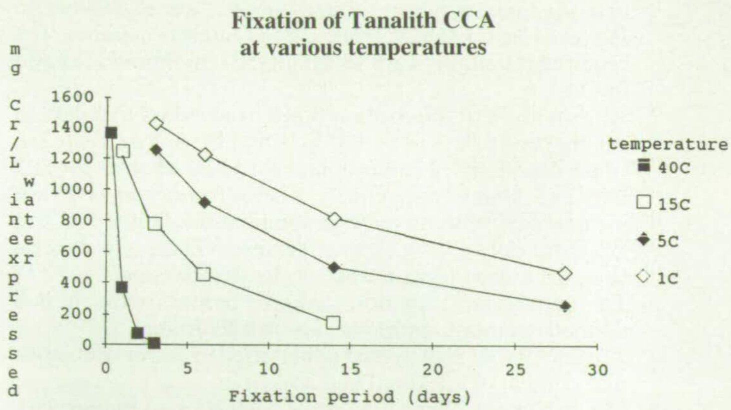


Figure 7

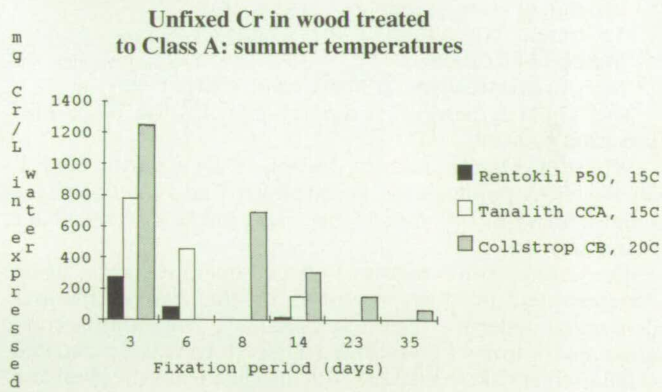
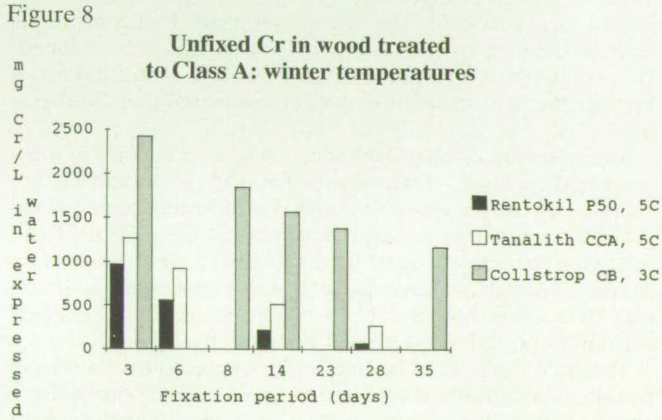


Figure 8



Since Cr (VI) is the slowest fixing (Wilson see References 1971) of the more toxic elements, our studies were restricted to this element.

The results are summarised in Figures 5-8 and represent the fixation rates of blocks treated to Class A, i.e. treated with solution concentrations of 3,0, 2,5 and 3,5% respectively. The measured chromium content in these solutions was 3350, 3900 and 4210 mg/L respectively. Figures 4 and 5 show the fixation of chromium from Rentokil P50 and Tanalith CCA at various temperatures. It is clear that CCP is a faster fixing formulation than the salt type CCA. Figures 7 and 8 present the fixation rate of Collstrop CB at summer and winter temperatures respectively and compare these with data extracted from Figures 5 and 6. The relative rates of fixation can be seen clearly i.e. CCP oxide > CCA salt > CCB oxide.

The fixation of chromium from Tanalith CCA expressed in terms of "% fixed" appears not to be greatly influenced by concentration (Wilson 1971) and our work has confirmed that this is true for Collstrop CB. This is also probably true for Rentokil P50 but confirmatory data has not been located. However, adopting this assumption, the amounts of unfixed chromium in timber treated to Class AB according to the latest approved rententions (NWPC 1990) can be predicted. This information is shown in Figures 9 and 10. Clearly, the CCB product fixes much slower than the CCP and CCA products. Also it is clear that an obligatory fixation period has its limitations in that it cannot cover the many variations of composition, concentration and temperature. In order to remove some of these limitations, the development of an on-site method to measure the unfixed chromium was undertaken.

Figure 9

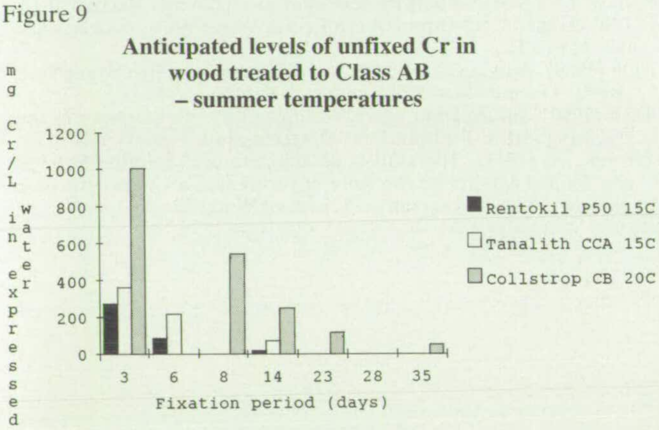
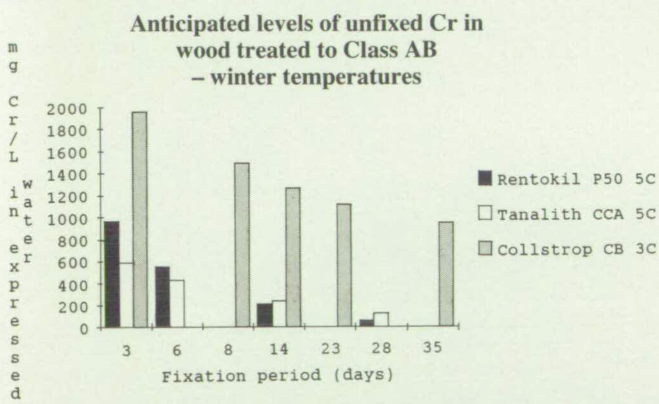


Figure 10



4.2 Measurement of fixation at the treatment plant

Two methods were considered. The first used the reagent chromotropric acid as described by Mc Namara (1989 b) whereby a core-boring from the treated timber is placed on a filter paper and a few drops of reagent are added. The colour transferred to the paper is then evaluated visually. This method was not recommended for adoption because it was felt that interpretation of the result was rather difficult. The reagent also has a limited shelf life.

The second method was to use a simple and relatively cheap kit for the analysis of water samples. This kit, supplied to Danish Technological Institute by The Danish Wood Treatment Company, consists of a small battery operated spectrophotometer, glass cells and capsules of reagent powder. The photometer is calibrated direct in mg/L of hexavalent chromium.

The technique involves leaching core-borings of defined volume in a defined volume of water, after which a 10 ml sample is reacted with a capsule of reagant and the colour is then measured.

It was first established that this method gave a reasonable indication of concentration of unfixed chromium within the wood. This was done by investigating the relationship between results obtained using this leaching technique and by the squeezing technique mentioned above. Figure 11 shows that this relationship is approximately linear. The scatter around the line could have been reduced if we had taken more borings and a correspondingly larger volume of leaching water.

In this case the practical details were: 1 boring, 4,2 mm dia. from the outer 20 mm of sapwood, was leached for 30 minutes in 50 ml of deionised water. By maintaining this wood/water/time relationship, it can be said that when the measured concentration lies below 0,5 mg/L, i.e. the upper working limit of the Hach photometer, then the wood has reached a level of fixation in the outer 20 mm sapwood equivalent to a chromium concentration of 200 mg/L in the water within the saturated wood structure.

The major problem that remains unsolved is to define an acceptable level of unfixed chromium at the point when wood is released from the treatment plant. The present demand in Denmark for CCA preservatives of 6 days in summer and 14 days in winter would typically lead to the following values (mg Cr/L):

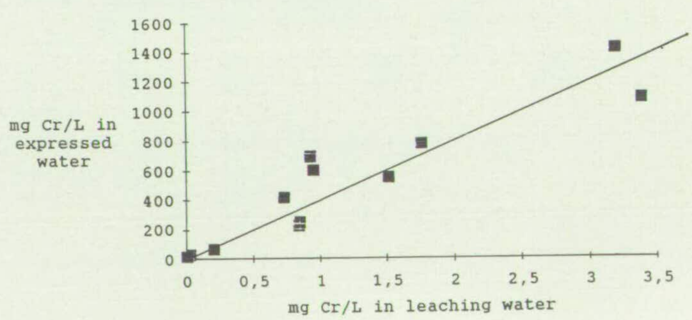
	Class A	Class AB
Summer	450	200
Winter	500	250

(extracted from Figures 7-10)

If say 500 mg/L could be adopted as the maximum level, then miinimum fixation periods for the various preservatives could be defined. In periods of cold weather, the operator could carry out an onsite check of the fixation level before deciding to release the timber. This combination of a minimum fixation period and on-site measurement should give both authorities and plant operators the confidence that the wood is adequately fixed before release.

Fig. 11

Relationship between unfixed Cr and Cr(VI) in leaching water.

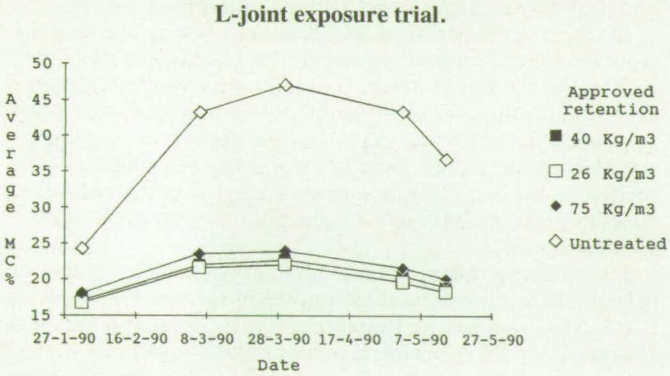


4.3 **Evaluation of the new Class B specification**

The basic changes in the new Class B requirements were presented in Section 3, and typical values for penetration and loading were given in Figs. 2-4. However, the protection of windows is more than a question of using the correct amounts of fungicide. The absorption of water in the joint areas is of fundamental importance. In order to compare the 'total performance' of timber treated according to the new requirements with timber treated according to the previous demands, it was decided to set up an L-joint trial. A trial, following, closely the proposed CEN method, was therefore established.

Three preservative systems were studied, covering products approved by NWPC at 75, 40 and 26 kg/m^3 respectively. The preservatives were applied by appropriate treatment schedules to meet the old standard for the first two products and the new standard for the third product. The L-joints were exposed at the start of this year. Already the difference between untreated and treated joints is clear, whilst the three sets of treated joints are behaving very similarly (Fig. 12).

Fig. 12



4.4 **Development of chromium and arsenic-free preservatives**

In 1989, DTI embarked upon a project, financed by the National Agency for Environmental Protection, to find alternatives to the traditional wood preservatives. In keeping with other chrome/arsenic free products already on the market in Scandinavia, copper has been retained as the main fungicide. Although the project is very much in the early stages, some interesting possibilities are already emerging. Perhaps at a future B.W.P.D.A. Convention it will be possible to present the results of this work.

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DISCUSSION ON PAPER 2

Chairman: T. C. Chiddle

MR T. C. CHIDDLE: I am sure we can expect a deluge of questions, particularly from the manufacturers and perhaps the research bodies.

MR G. A. EWBANK (Fosroc): Thank you very much, Len, for a very interesting and also very absorbing paper. As you know, the situation in the United Kingdom on C.C.A. is a requirement to hold for a minimum of 48 hours or until surface dry. I think the practice is that it is nearer 48 hours most of the time. What is your opinion of that now as a result of your tests?

MR L. SHEARD: As a result of our tests and also the fact I am no longer working in the United Kingdom I can perhaps be a little more critical that I might have been a few years ago. My opinion is that 48 hours is certainly not enough, especially in winter. One of the main criticisms from the Danish Unions was that there was actually free liquid lying on the surface of the timber, and at that time the minimum fixation period was 72 hours. More significantly, they were complaining about having to fasten cladding boards with nails when the timber was wet and they were literally hitting the nails and being sprayed in the face with solutions of copper-chromium-arsenate of unknown concentration.

MR M. CONNELL (Hicksons): You referred to the establishment of the Class AB retentions. I wonder if you could please comment on how these subsequently changed and what the implications are to the treaters who changed based on the original proposals.

MR L. SHEARD: The original notion was that the retentions for Class AB would be originally set at 50 per cent of the retentions for Class A. At that time the major preservative used in Denmark was C.C.A. and I think that was a reasonable standpoint. Very quickly after the introduction of the new Class AB some companies changed to copper-chrome-phosphorus and they were again using retentions at 50 per cent of the retention approved in Class A, which was 18 kilos per cubic metre.

At the time the standard came into effect in Denmark there was set up a series of EN113 laboratory tests financed by the N.W.P.C. so that this situation could be clarified. The results of those tests became available at the beginning of this year and the results for C.C.P. were disappointing.

The situations as it now stands is that copper-chrome-phosphorus is approved at the same retention, 18 kilos per cubic metre, in Class A and Class AB. There is a dispensation at the moment in force until 1st September for those companies using CCP in Denmark. Until then, they have the possibility to produce information to justify continuing treatment to 9 kilos. Whether they are able to come with that information I do not know. Only time will tell.

Regarding the current approved retentions for C.C.A., if we take Tanalith C, for example, salt type preservatives, these are approved at 15 kilos per cubic metre for Class A and following results of the EN113 tests they have been shown to be perhaps a little bit more effective than we anticipated. They are now approved at somewhat under the 50 per cent of Class A. To be precise 7 kilos per cubic metre for Tanalith C and – if I must continue using trade names – 5 kilos for Rentokil K33.

MR D. G. BUCKLEY (Protectahome): Thank you very much. I thoroughly enjoyed your dissertation. One of the points I found very interesting was that, when burnt, the resultant ash, apparently one teaspoon, will kill a child according to the Press which is quite horrific I would have thought. I wonder what the situation is, being a pure contractor, that where the building is subject to fire damage or using cut ends of C.C.A. treated timber, what should you do with the ash that remains in that building or what should you do with the cut ends of timber? Do you burn them?

MR L. SHEARD: If I can take the situation of the building first I suspect that the amount of C.C.A. contaminated ash would be relatively small in relation to the total waste from the building and, therefore, it would be so dilute as not to present a real problem. You can also say in a building fire that a lot of the arsenic will probably not be found in the ash. It would disappear with the smoke. It is volatile at high temperature.

The same thing could be said for the ash from an open fire, though perhaps rather more of the arsenic is left within the ash. I think the headlines in the newspapers are – as they usually are – quite alarmist. As for disposal of the ash it should, in principle, be disposed of in Denmark at least as a toxic waste and be sent to an organisation called Kommune Kemi who are responsible for destruction and disposal. How it would be dealt with in England, that I would not comment upon.

DR D. J DICKINSON (Imperial College): Can you comment on how this magic figure of 50 per cent was derived? From a biological point of view it seems a bit of a nonsense to me.

MR L. SHEARD: As I said, it was not me personally who gave the suggestion of 50 per cent, but looking at various standards that were in operation and also published results of laboratory tests the people concerned at the time thought it a reasonable standpoint for C.C.A. and did not really suspect a sudden switch on the part of the Danish industry to a non-C.C.A. product.

I really do not want to go into any more detail to justify that particular decision. It was a complex decision based not only on available technical data but also on the political situation which existed in Denmark at the time. The industry was under strong pressure to do something. It could have been even more severely restricted in it's activities had these changes not been introduced.

MR T. C. CHIDDLE: We are slap bang on time and I would like to offer my thanks. First of all, thanks for the lesson in basic Danish. That might prove very useful at some time somewhere and secondly may I thank you and congratulate you for presenting a paper which is interesting and relevant to all of us.

B.W.P.D.A. ANNUAL CONVENTION 1990

ENVIRONMENTAL LEGISLATION IN EUROPE: A REVIEW OF THE IMPLICATIONS OF CURRENT AND FUTURE LEGISLATION ON THE PRETREATMENT WOOD PRESERVATION INDUSTRY

by M. Connell and Dr. D. G. Anderson *Hickson Timber Products Limited*

1. Introduction

Three years ago at the B.W.P.A. Convention the authors reviewed E.E.C. regulations affecting the pretreatment preservation of wood (1987). This paper considers the accelerating rate of change and reviews current and likely future legislation and developments which will impact on the pretreatment (waterborne and light organic solvent) preservative industry. The increasing influence of the media and public opinion is discussed. The performance of the industry is considered in the context of an increased environmental awareness and steps to safeguard the future are recommended.

2. European Legislative Process

Dr. Bill Hunter of the European Commission's Directorate General for Employment, Industrial Relations and Social Affairs at a recent conference (1990) stated that prior to 1986 only 25 per cent of U.K. health and safety legislation derived from the Community. Between the years of 1986 and 1989 the percentage rose to 75 per cent and he forecasts this figure to increase. A European Health and Safety Agency is to be proposed, probably in October, 1990 as the main focus for all occupational health and safety activity in the European Community.

In considering the implications and likely development of legislation within Europe the role of the institutions requires consideration. The Single European Act (SEA) in 1987 marked the end of the period when legislation was principally affected by the EC Commission and the Council of Ministers. The European Parliament was given a significant role in determining the shape of directives whose legal basis is either Article 100A or Article 118A.

Article 118A in Paragraph 1 sets objectives for the Commission:

"Member states shall pay particular attention to encouraging improvements, especially in the working environment, as regards the health and safety of workers, and shall set as their objectives the harmonisation of conditions in this area, while maintaining the improvements made".

And Paragraph 2 sets out the means:

"In order to achieve the objectives in Paragraph 1, the Council, acting on a qualified majority on a proposal from the Commission, in co-operation with the European Parliament and after consultation with the Economic and Social Committee, shall adopt, by means of directives, minimum requirements for gradual implementation, having regard to the conditions and technical rules obtaining in each of the member states".

The involvement of the European Parliament brings an even greater political emphasis to the development of directives. This is illustrated graphically when considering the progress of the 8th and 9th Adaptions to EC Directive 76/769, "Marketing and Use".

The 8th Adaption considers the use of antifouling paint but includes important references to wood preservatives. In particular the use of arsenic in wood preservation is considered with the directive stating:

"Arsenic compounds may not be used as substances and constituents intended for use in the preservation of wood.

In this case, the ban does not apply to solutions of inorganic salts of the C.C.A. (copper-chromium-arsenic) type employed in industrial installations using vacuum or pressure to impregnate wood".

This derogation recognises the unique fixation properties of the C.C.A. mixture which makes the treated timber safe to use and non-hazardous in use in relation to environmental pollution potential.

In general the progress of this Adaption was fairly straightforward and a common position between the institutions was achieved. Consequently the directive was adopted on 21st December 1989.

However, the 9th Adaption has witnessed a much more complex and politically influenced route to become adopted. The current official position indicated the extremes of views held by the Commission and the Parliament and is reproduced below:

Dangerous substances (ninth amending directive) **1

– Proposal for a directive C.O.M. (88) 190 final – S.Y.N. 130

TEST PROPOSED BY THE COMMISSION OF THE EUROPEAN COMMUNITIES (*)	TEXT AMENDED BY THE EUROPEAN PARLIAMENT
Proposal from the Commission to the Council for a directive amending for the ninth time Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations	
Approved with the following amendments:	
Article 1 The following point is hereby added to Annex 1 to directive 76/769/EEC:	*AMENDMENT No. 1* The following point is hereby added to Annex 1 to directive 76/769/EEC:
23. Pentachlorophenol (C.A.S. No. 87-86-5) and its compounds	23. Pentachlorophenol (C.A.S. No. 87-86-5) and its compounds
Shall not be used in concentration equal to or greater than 0·1% by mass in substances or preparations placed on the market	The production and marketing of P.C.P. and its compounds shall be prohibited. The marketing and use of products treated with P.C.P. shall be prohibited
By way of exception, this provision shall not apply to substances and preparations intended for use:	By way of exception, this provision shall not apply to substances and preparations intended for use for research and investigation purposes
(a) in the treatment of wood in industrial installations	(a) deleted
(b) in the impregnation of heavy-duty textiles in industrial installations	(b) deleted
(c) as a synthesizing and/or processing agent in industry	(c) deleted
These exceptions shall be re-examined in the light of developments in knowledge and techniques in/not more than five years at the latest	Deleted
In addition, this provision shall not apply to wastes covered by Directives	Deleted

75/442/EEC and 78/319/EEC

(*) For full text see OJ No. C117, 4.5 1988 p14

The debate on the status of P.C.P. demonstrates the importance of the Parliament's new power in being able to prevent any common position text being adopted by the Council on qualified majority votes. On the other hand the Commission is recognising the increased status of the Parliament and a greater consensus is being developed.

3. Review of Legislation

3.1. **Health and Safety**

The examples presented in Section 2 represent directives aimed at specific substances. Since the SEA came into effect new directives have been mainly concerned with achieving harmonisation of *basic* legal principles.

An important example is the Framework Directive (89/391/EEC) adopted on 12th June 1989 and relating to the safety and health of workers. The directive

- applies to all sectors of work activity
- assigns primary responsibility for health and safety of employees to their employer
- sets out general principles for employers to follow in protecting health and safety, including:
  - (i) assessing workplace risks and introducing appropriate preventative measures
  - (ii) developing a coherent overall prevention policy
  - (iii) adapting work to the individual
  - (iv) co-operation between employers
- requires employers to designate competent personnel to take charge of health and safety activities, or use competent outside services
- provides for first aid, fire precautions and emergency arrangements
- requires employers to provide information and training for employees and to consult worker's representatives on health and safety measures
- requires employees to take care of their own and others' safety and to co-operate with their employer

In addition to this important Framework Directive, fire additional directives under Article 118A have been proposed setting out minimum requirements for:

- the workplace (89/654/EEC)
- use of work equipment (898/655/EEC)
- use of personal protective equipment (89/656/EEC)
- use of visual display units
- manual handling of loads

The first three of these directives have all been adopted and it is likely that the other two will also be adopted by 31st December 1992 by which time all the directives will have to be implemented.

Although many of the requirements are encompassed in U.K. legislation there are a number of fundamental changes which will impact on industry. Most important are the implications of the removal of the "so far as reasonably practicable" qualification which is in-built into much U.K. legislation. The directives replace this principle with a "force majeure" clause which limits employers' duties to "where occurrences are due to unusual and unforeseeable circumstances beyond the employer's control, or to exceptional events, the consequences of which could not have been avoided despite the exercise of due diligence".

Rules will be set regarding the types of equipment and the types of operations covered – up to 30 sets of regulations made under the Factories Act 1961 or H.A.S.A.W. Act 1974 will be affected.

In addition to the general legislative developments there are more specific developments relating to wood preservation. The most important of these are the Plant Protection Products Directive and a proposed new directive relating to non- agricultural pesticides.

D.G.V.I. have proposed a draft Directive on plant protection products (C.O.M. (89)34) which would incorporate all wood preservatives used for the control of sapstain and bluestain. The European Council have requested to the Commission for wood preservatives to be controlled in a co-ordinated manner and for the preparation of a framework directive on non-agricultural pesticides. A number of daughter directives for the various types has been proposed starting with wood preservatives. The objective will be to develop a co-ordinated strategy for wood preservatives within two years.

Although this has been accepted in principle, the Commission responsible has yet to agree. Both Commission D.G.I.I.I. (Marketing and Use) and D.G.X.I. (New Substances) are involved in this debate. The U.K. Government's Health and Safety Executive (H.S.E.) would wish to see antisapstain and bluestain products included in the new directive relating to wood preservatives.

3.2. **Environmental Legislation**

As with health and safety, in 1987, the European Community put environmental concerns on the agenda by amending the Treaty of Rome. The objectives stated are:

- to preserve, protect and improve the quality of the environment
- to contribute towards protecting human health
- to ensure a prudent and rational utilisation of national resources.

In August, 1989 the E.C. recommended that damage caused to people or to the environment by industrial waste should be the subject of civil liability i.e. the "polluter pays" principle. The right to sue will continue for 30 years after the waste has been disposed of. There will be unlimited liability on the produces of the waste. Damage to the environment encompasses fauna, flora, water, soil or air and harm to society at large.

Within the U.K., the Government has declared its intention to introduce legislation on environmental protection in the current Parliament. This will be provided for through the Environmental Protection Bill currently before Parliament. The scope of this Bill is far reaching and will impact on all aspects of the wood preservation industry. Its main provisions are to:

- improve the control of pollution arising from certain industrial processes (Integrated Pollution Control, I.P.C.)
- modify the functions of the regulatory and other authorities concerned in the collection and disposal of waste on land
- restate the law concerning statutory nuisances and improve the summary procedures for dealing with them
- make provisions for the control of the importation, exportation, use, supply or storage or prescribed substances

The objective of I.P.C. is to provide an approach to pollution control that considers discharges from prescribed industrial processes to all media – air, water and land. The proposals in the 'Green Bill' have originated from:

(i) The recommendation of the Royal Commission on Environmental Pollution that wastes should be disposed of according to the "Best Practical Environment Option" (B.P.E.O.)

(ii) The adoption of the Second International Conference on the Protection of the North Sea in 1987 of a precautionary approach towards the discharge of the most toxic, persistent, and bioaccumulative substances into the sea.

Prescribed processes and prescribed substances are listed in Appendices 1 and 2 respectively. For timber treatment there will be a further subdivision into Parts A and Parts B. Processes will be grouped in Part A if using prescribed substances. Policing of these processes will be through Her Majesty's Inspectorate of Pollution (H.M.I.P.). All other treatment plants will operate under Part B but will be policed by Local Authorities.

Part B relates to air pollution only. The Bill makes no provision for water and waste control for processes under Local Authority control; these would remain under National River and Waste Regulatory Authorities.

Encompassing the 'polluter pays' principle there will be authorisation and policing charges for both Part A and Part B processes. Current estimates for Part A are £1,000-£1,500 for initial application with an annual renewal fee of £400-£500. For Part B processes, costs are estimated at £400-£500 for initial application and an annual renewal fee of £400-£500. It is expected for there to be an introductory period of 2 years for Part B sites and 4 years for Part A sites.

A basic requirement on prescribed processes will be to employ the best available technology not entailing excessive cost (B.A.T.N.E.E.C.) to prevent the release of prescribed substances into any medium or where that is not practicable, to reduce such releases to a minimum and render them 'harmless'.

The second most important implication to the wood preservation industry is the introduction of a statutory duty of care when disposing of waste. The responsibility will transfer from the disposer to the producer of the waste who will need to ensure correct and safe disposal by a registered carrier to a licensed site.

The third Ministerial Conference on the North Sea was held in March 1990 resulting in the need for even tighter controls on industries emitting hazardous substances to air and water. The 1987 conference had set targets of a 50 per cent reduction of the most hazardous substances between 1985 and 1995. This has now been made more specific and in addition to all the substances on the U.K.'s "red list" (see Appendix 3), the following substances are added;

Copper	Azinphos-ethyl
Zinc	Fenthion
Lead	Parathion
Arsenic	Parathion-methyl
Chromium	Trichloroethylene
Nickel	Tetrachloroethylene
Carbon tetrachloride	Trichloroethane
Chloroform	Dioxins

The North Sea countries also agreed to "aim for a substantial reduction in the quantities of pesticides reaching the North Sea". Those which will be particularly affected in the U.K. include pentachlorophenol.

The examples cited relate to both general and specific directives which will impact on the pretreatment wood preservation industry. Other relevant legislation is illustrated in Appendix 43 as it applies within the E.E.C., to transport, and adoption within the U.K.

4. The Influence of Media and Pressure Groups

A recent Harris Poll carried out on behalf of the United Nations indicated there to be widespread public belief that the environment is deteriorating. This concern is being reflected in the growth and importance of 'green' issues both in dedicated and traditional political parties. Most of the general public obtain information on environmental issues by reading newspapers, listening to the radio or watching television. Unfortunately, much of the news is based on fear and emotion and inevitably is bad news. Pressure groups are enjoying huge membership increases with the associated financial benefits and are becoming far better placed to challenge traditional industrial practices. It is within this background that new regulation is being formed. National and international specialists have an increasingly difficult job in advising politicians or responsible legislative changes which will satisfy industry, media and therefore the voting general public.

There is no doubt that Companies are becoming even more aware that they have to put their businesses in order if they are to avoid ever-tighter governmental regulations to reduce a broad range of pollution problems.

The wood preservation industry uses chemicals which are classified as pesticides in most countries and is therefore subject to close media scrutiny.

In order to respond to unfair media criticism it is important to fully understand the 'tactics' employed. Elizabeth Whelan (1985) examines the myths and realities about a variety of chemicals and technologies and describes in detail the main techniques used by the media and pressure groups.

The underlying theme in most environmental reporting is that industry is totally to blame and does not care. In an address to the Society of Chemistry and Industry, Lindheim (1989) refers to polls carried out by the Chemical Industries Association in 1987 showing that fewer than one out of three people had a favourable view of the industry. Half of the respondents thought that the industry did not care about the environment, and over 90 per cent were concerned about chemical pollution. Three out of four Britons thought that the chemical industry did serious damage to the environment.

The facts, however do not fully support this view. Capital expenditure estimates for the Western European chemical industry (Financial Times 1989) indicate an increasing proportion of total investment being spent on environmental improvements – estimated at $23 billion.

But the problem is not simply one of public relations. The US Chemical Manufacturers' Association (C.M.A.) and the Canadian Chemical Producers' Association (C.C.P.A.) have both recognised there to be a performance problem in the wake of the Basle and Bhopal disasters. This recognition led to the development in Canada of the concept of 'responsible care' which has been adopted firstly in 1988 by the US Chemical manufacturers and subsequently by the C.I.A. in the U.K. It is designed to bring real improvements in environmental *performance* and stem the erosion of public confidence. Coggins (1990) describes the guiding principles and philosophy of the C.I.A. responsible care programme.

Although the record of the pretreatment industry is generally good, there have been a number of serious incidents reported in the U.K. over the past few years (E.N.D.S. 1990). Each spill attracts even greater media attention with questions being asked as to whether the industry operates adequate pollution measures. Whereas 10 years ago the incidents may have been 'shrugged off', the general public and politicians will no longer tolerate poor performance.

5. Performance in the Pretreatment Industry

5.1. **Product Stewardship**

The events and pace of change in the pretreatment industry has led to much greater co-operation and understanding between the suppliers and the user of wood preservatives. In terms of environmental impact and public perception it is the actions of the user which are likely to attract greatest attention. Generally the suppliers are members of the chemical industry and consequently can offer expert advice and instruction in correct treatment plant operation under 'product stewardship' responsible care type programmes. The programmes cover such areas as supply of preservative, design and installation of treatment plants, the treatment operation, post-treatment handling of timber, training, quality assurance and environmental auditing.

5.1.1. *Supply*

Preservatives are produced to consistent quality by manufacturers who satisfy the requirements of BS5750 – Part I/ISO 9001, 1987 Quality Assessment Schedule QAS/25/289. This schedule relates not only to manufacture and supply but also to product development.

The preservatives are packed into appropriate U.N.

approved packages and labelled to satisfy legislation under conveyance and use legislation. Vehicles used to deliver preservatives are also appropriately labelled and driven by competent drivers trained and equipped to deal with emergencies. Transport Emergency (T.R.E.M.) Cards are carried to assist emergency services in the event of an accident. Through the Chemical Industries Association a 'Chemsafe' scheme is operated in which chemical companies with specialist equipment and skills will respond to traffic accidents to assist emergency services on a 24 hours a day basis.

5.1.2. *Storage and Use*
The B.W.P.D.A., in conjunction with the H.S.E. have produced a "Code of Practice for the Safe Design and Operation of Timber Treatment Plants" (1989). This Code has already received one update and details all the design features and procedures necessary to comply with existing statutory requirements. The Code has attracted interest in other European countries and currently the Western European Institute for Wood Preservation (W.E.I.) is preparing a European version.

5.1.3. *Post-treatment Handling of Timber*
In order to protect the user it is vital that treated timber is not handled outside the treatment plant area until it has been held for the appropriate 'conditioning' period. This may be to allow fixation of the chemicals in the case of copper-chrome-arsenate treated timber or evaporation of the solvent in the case of light organic solvent preservative treated timber.

To protect the environment, freshly treated timber needs to be stored in contained drip dry areas or under cover until completion of the appropriate holding time.

5.1.4. *Training*
The importance of proper training cannot be over emphasised in ensuring good performance. This is recognised in the provisions of the Food and Environmental Protection Act 1985 where there is a requirement for users of wood preservatives to demonstrate 'competence'. The industry has generally a good record but is seeking to improve standards through the recently formed Training Committee in B.W.P.D.A.

Training is not only directed towards the plant operator. In today's business environment the managers of sites are often multifunctional and frequently have limited technical training. Management training through institutions such as Institute of Wood Science, T.R.A.D.A. etc. can often be complemented by specialist courses relating to wood preservation run by the chemical suppliers. The most recent example is assistance given in carrying out risk assessments to satisfy the requirements of the Control of Substances Hazardous to Health Regulations 1988.

5.1.5. *Quality Assurance*
In addition to the product development, manufacture, and supply of wood preservatives there is an increasing awareness of the need for effective quality management systems amongst treaters. Although initial progress has been slow a growing number of treaters have been able to demonstrate compliance with the requirements of B.S.5750: Part 2, 1987; I.S.O. 9002-1987 to meet Quality Assurance Schedule Q.A.S./4620/291.

5.1.6. *Provision of Information*
The legal basis for the provision of information on substances is contained primarily in the H.S.W. Act 1974, Sections 2 and 6. Section 6, as amended by the Consumer Protection Act 1987, places general duties upon manufacturers to provide adequate information about any risks to health and safety to which the inherent properties of the substance may give rise. The suppliers of preservatives not only fulfil this basic legal requirement through labelling, material safety data sheets, codes of practice, wall charts etc. but also provide user guidance for handling treated timber articles.

5.1.7. *Incident Response*
Assistance in dealing with the practical aspects of emergencies in addition to the more demanding requirements of dealing with the media are normally offered by suppliers.

5.1.8. *Environmental Auditing*
It was Dwight D. Eisenhower who stated that "The uninspected inevitably deteriorates" and this premise is rigorously enforced in quality assurance auditing. Fundamental in any product stewardship programme is the application of environmental auditing to monitor performance. This concept not only inspects hardware but also critically examines the environmental management performance at any particular site.

The industry is appreciative of the needs for the highest standards in product stewardship. In any environmental incident it is the industry which is put under the microscope. Although there may be legal actions resulting from individual incidents there is no doubt that adverse public perceptions will eventually convince politicians of the need for much more stringent regulations and which will impinge more on the industry's freedom to operate. The significant advances made in this area since the 1987 review indicate the industry to be moving the right way in improving performance.

5.2. **Research and Development**
5.2.1. *Product Development*
Connell, Cornfield and Williams (1990) review the effects of environmental pressures on the use of traditional wood preservatives and examine the progress made in the development of so-called "environment friendly" wood preservatives. They conclude that developments todate have not produced alternatives which are as effective for long-term performance and still have their own associated health and environmental hazards when compared to traditional products. The problems encountered in the introduction of new preservatives are illustrated by reference to case histories and the need for effective handling and containment procedures for all preservatives is discussed. However, quite rightly the industry and institutions continue to search for effective alternatives which are more forgiving to misuse. A number of promising candidates have been identified and these are reviewed in Connell et als paper.

5.2.2. *Process Development*
Accelerated fixation methods for chromium based preservatives have been studied and systems based on hot water and steam have been developed. In the U.K. and U.S.A. particular attention has been paid to achieving a high standard of surface appearance with minimal plant corrosion. Kiln fixation and drying schedules have been introduced for *Pinus* species and these have been described by Anderson (1989).

Properly installed and operated accelerated fixation systems can bring major improvements in on site environmental control and post-treatment handling. However poor plant design and lack of attention to selection of schedules appropriate to the species being treated can create major problems with plant corrosion and surface sludging thereby exacerbating the problems they originally set out to solve.

For L.O.S.P.'s, schedules have been developed to control release of solvent from treated timber. In designing equipment and operating procedures the temperatures and solvent levels must be carefully controlled to prevent the possibility of explosion of flammable vapours of exposure of workers to solvent fumes. Safe, effective methods of recovery of evaporated solvent have been designed and installed.

5.2.3. *Standards Development*
The Single European Act's main objective is to eliminate bar-

riers and create a single European trading market by the 31st December 1992. The harmonisation directive which considers wood preservatives is the Construction Products Directive (C.P.D.) and the responsibility for writing supporting technical specifications is delegated to standards organisations. Brooks (1989) reviews the progress in developing these standards and discusses the difficulties in reaching consensus across countries with much varied requirements for effective wood preservation. Nevertheless, draft standards have been produced and are currently undergoing public comment.

The directive itself defines five "essential requirements" of a construction as:
- mechanical resistance and stability
- safety in case of fire
- hygiene, health and the environment
- safety in use
- protection against noise
- energy economy and heat retention

Todate the standards organisations have only considered the technical harmonisation of wood preservatives and treated timber. However proposals have been made to the C.E.N. technical board suggesting protocols for assessing the compliance of treated timber with Essential Requirement 3 – hygiene, health and the environment. The proposal is based on the development of performance standards for preservative – treated wood based on evaporation into air or washing out (leaching) through contact with water.

In Scandinavia, pressures to reduce the quantities of chemicals used has led to the adoption of two new standards for wood preservation.

The N.W.P.C. Class AB is for waterborne preservative treatment of timber which will be exposed in out-of-ground contact (N.W.P.C., 1989). It is intended with this standard to achieve effective treatments with reduced chemical usage rather than use treatments irrespective of end use. This approach is more in line with UK practices and has been welcomed by the industry. However, in some cases, significant reduction in chemical usage for the Class AB is only achieved for the traditional preservative formulations (see Appendix 4).

With light organic solvent preservatives, emphasis has been placed on reduced solvent uptake. The N.W.P.C. Class B standard has been modified to allow reduction in solvent usage whilst maintaining performance. In order to meet the standard, treatments may be carried out using higher fungicide concentrations but lower solvent volumes than used previously. This approach can be adapted due to the Scandinavian standards being results rather than process orientated and therefore encouraging innovation in process development to achieve a desired end result. The main feature of the new European standards is the reliance on results performance and this will encourage further innovation in process development.

6. Assessment of Risk in the Pretreatment Industry

6.1. General Considerations

The U.K. Government's Health and Safety Executive (1988) explains the differences between hazard and risk as follows:

Hazard – the *potential* to cause harm and *inherent* in a substance
Risk – the *likelihood* that a substance will cause harm in the actual *circumstances of use*

The risk in any situation will depend on:
- the hazard inherent in the substance
- how it is used
- how it is controlled
- the dose and the time of exposure
- what is being done

The H.S.E. state that poor control can create a substantial risk, even from a substance with a low hazard and that with proper precautions or in certain forms, the risk of being harmed by the most hazardous substances can be adequately controlled.

When considering the pretreatment industry the parameters for assessing hazard and risk for treated timber are quite different from the assessment of handling the preservative at the timber treatment plant installation.

6.2. Wood Preservatives

6.2.1. *Health and Safety*

All wood preservatives in the UK are classified as pesticides under the Control of Pesticides Regulations 1986 and therefore are subject to the Control of Substances Hazardous to Health Regulations 1988 (C.O.S.H.H.). One of the main features of the C.O.S.H.H. Regulations is the requirement to carry out a risk assessment in terms of potential affects to the health of the treatment plant operator. The risk assessment takes into account the nature of the preservative and the control measures necessary to satisfy a safe working environment. The whole concept of risk assessment under these regulations (implementing E.C. Directive 80/1107/E.E.C. and I.L.O. Convention No.139) is an important development in minimising the likelihood that any preservative will cause harm in the actual circumstances of use. This concept is now becoming more widely adopted into European legislation and is to be welcomed.

Copper-chrome-arsenate (C.C.A.) preservatives are the most extensively used preservatives throughout Europe and the World. The individual components under certain conditions of use can cause serious health problems e.g. lung cancer may be associated with prolonged exposure to high levels of airborne arsenical dust and fumes.

However, in the forms used in wood preservation the risk can be more than adequately controlled. This is recognised by the H.S.E. (1989) who state that many people who use compounds containing arsenic are not exposed to any significant dust or fume hazard because of the form of the material, such as wood preservatives in a paste or cold liquid.

Risk assessment is not new to the wood preservation industry. Fifteen years ago Stalker and Cornwell (1975) considered the safe application of C.C.A. preservatives.

Studies of the health of workers in the preservation industry have been carried out by Budy & Rashad (1976), Flickinger and Lawrence (1982) and Gilbert, Duncan, Lederer and Wilkinson (1983). The results indicate no adverse health effects or increased mortality resulting from exposure to wood preservative chemicals at treatment plants.

6.2.2. *Environment*

Spillage of any wood preservative into the environment has the potential to cause serious harm. The design and operation of the plant and therefore crucial in controlling the likelihood of this occurring. The measures necessary are described in Section 5.1.2.

6.3. Treated Wood

6.3.1. *Health and Safety*

Whereas the treatment plant is an industrial installation operated in a controlled manner by trained operatives, treated timber is handled by construction workers and the general public. Provided the treated timber leaves the treatment plant in a condition 'safe to handle' there is no more risk to the user than if he were using untreated timber.

To satisfy this condition a number of factors need to be taken into account. The timber should be surface dry and free from sludge deposits irrespective of the type of preservative used for the treatment. The holding time for freshly treated timber will depend on such factors as the preservative used, the process used, the timber species and dimensions, temperature conditions, drying conditions etc.

Provided these conditions are met treated timber can be used safely in a wide number of applications. For example, C.C.A.-treated timber has been approved by the U.S. Food and Drug Administration (F.D.A., 1989) for use for the construction of silage and feed bunkers, as well as for water troughs for food producing animals.

Arsenault (1975) studied the permanence, effectiveness, durability and environmental considerations of C.C.A.-treated wood foundations and demonstrated the safety in many applications.

6.3.2. *Environment*

Environmental risk assessment should consider potential impact at both the treatment plant and in use. To protect the environment at the treatment plant the measures described in Section 5.1.2. should be adopted. The type of preservative and its permanence in the timber under ageing or leaching conditions will determine its ultimate end use.

Preservatives which are used in high hazard situations in permanent contact with soil or water require to be well fixed to remain effective. Arsenault (1975) reviews the permanence of C.C.A.-treated timber in this environment.

It is however, the question of the disposal of treated wood which is currently attracting most attention. At a recent I.R.G. conference (1990) in France this aspect was of greatest concern. Currently within Sweden there is much debate centred on the potential effects of treated timber on the environment both in use and on disposal. The most widely used preservative in Sweden is C.C.A. and perhaps due to the well known toxicity of 'arsenic' it is the arsenic pentoxide component of C.C.A. which is attracting most attention.

It is claimed by the Swedish Chemical Inspectorate (1990) that the use of C.C.A.-treated timber is creating an addition of arsenic and chromium to the aquatic environment. However it has been estimated by Bergman (1990) that within Sweden there is naturally occurring between 34 and 68 x 10^6 tonnes of arsenic (as As to a depth of 5 metres). The use and distribution of arsenic from treated timber is absolutely minimal in comparison to these quantities. Since the introduction of C.C.A. into Sweden some 25 years ago, approx. 8,000 tonnes of arsenic have been used in timber impregnation. Most of this arsenic is still fixed in the timber helping to provide long and safe service. The ability of the soil to fix arsenic means in fact there is a nett reduction of arsenic in aquatic environments. Taking Sweden as a whole over the past 25 years it has been calculated that there has been a relocation of 0·1 to 0·2 parts per thousand arsenic from arsenic originally located in copper ores to arsenic fixed in C.C.A. treated timber.

Within this debate it is important to understand that arsenic is produced in Sweden as a waste product from the mining of copper ores, and many thousands of tonnes are exported each year. Until the introduction of C.C.A. wood preservatives these waste materials were dumped with negative environmental effects. It is therefore proposed that far from being a burden to the environment the use of C.C.A. treated timber must be viewed as positively assisting a Swedish waste management problem.

Although the proposals in Sweden centre on their most widely used preservatives based on chromium, arsenic and creosote one of the proposed consequences is the establishment of an 'environmental tax' on treated timber. This tax is proposed to reduce the use of treated timber and accepts that alternative materials such as steel or plastic should be used. The logic of these proposals is currently under scrutiny but it is difficult to understand why the use of synthetic energy consuming materials should be so encouraged.

Nevertheless, treated timber at the end of its designed service use can often be recycled and reused. This is a process which should be encouraged and further studied. It is a problem of logistics rather than technology.

The Environmental Protection Agency (E.P.A.) in the U.S.A. applies a test procedure called the Extraction Procedure (E.P.) designed to identify wastes likely to leach hazardous concentrations of particular toxic constituents into groundwater under conditions of improper management. The E.P. was applied to C.C.A.-treated wood and in one year old samples there were no detectable amounts of copper or chrome and a barely detectable amount of arsenic.

In the U.K. a comprehensive technical memorandum dealing with the wastes arising from the uses of wood preservatives has been published by the Department of the Environment (1980).

7. Wood Preservation, the Future

Elkington (1987) states that in today's world, the permit of environmental excellence is no longer an option for industry; it is a pre-condition for business success. In considering developments over the short timescale of three years it is apparent that targets are constantly moving – new issues emerge and today's accepted standards will not be accepted tomorrow. The industry will come under closer scrutiny from government agencies, trade unions and the general public and it will need to satisfy them that its operations are environmentally acceptable.

Pretreated timber has many environmental advantages making it one of the most acceptable products on the environmental menu:

- Timber is one of man's few renewable resources. Trees absorb carbon dioxide and lock up carbon thus contributing beneficially to the greenhouse gas effect.
- The on-cost of pretreatment is rarely more than 15 per cent of the value of untreated wood.
- Pretreatment of less durable timbers allows softwoods to be used instead of scarce and environmentally sensitive hardwoods.
- It has been estimated that the added bill to the construction and allied industries would be $15 billion per annum should treated timber not be available.
- Timber consumption would increase by three to sixfold if pretreatment was not available.
- Timber has the added advantage over other constructional materials of requiring relatively small amounts of energy to process.

The Timber Research and Development Association (T.R.A.D.A.) have published a Viewpoint (1990) which reviews the ecological merits of timber. A comparison of the energy requirements needed to build a 2,200m^2 warehouse is reproduced in Table 1 below.

TABLE 1
Comparison of Building Energy Requirements.

Energy needed to manufacture and build a 2,200m^2 warehouse	
An all timber building	1·0
Concrete block, timber roof	1·7
Prefabricated steel throughout	2·1
Concrete tilt-up walls, timber roof	2·7
Prefabricated steel, Aluminium cladding	3·3
Study conducted in the U.S.A.	

- Timber has aesthetic appeal. Properly treated with modern wood protection systems its long-term durability, performance and beauty are significantly enhanced.

Having accepted the benefits and advantages of the finished article it is the environmental performance of the pretreatment industry which will ultimately decide its fate. Shaw (1990) describes governmental guidelines that industry should take to demonstrate its genuine commitment to industry. A modified version targeting the pretreatment industry is proposed:

1. Develop an environmental policy and ensure there is executive responsibility for implementation.
2. Involve staff at all levels – environmental responsibility belongs to everyone.
3. Prepare an action plan. Identify the areas where action is

required and set priorities. For treatment plants compliance with the B.W.P.D.A. Code of Practice must be an immediate priority. Treated timber must be delivered from site in a condition safe for the consumer to handle and use.

4. Allocate adequate resources. Improvements will require capital investment; investment which at time may be difficult to quantify. The bottom line may be survival.
5. Invest in research and development. The search for products and processes which are more environmentally acceptable must continue. In order to finance this research by industry and in the academic institutions it is vital the business remains profitable. Support the companies, suppliers and treaters who are investing in the future.
6. Educate and Train. Health, safety and environmental issues should be part of training programmes at all levels. The process should be continuous to adapt to changing standards.
7. Be a good neighbour. Poor environmental performance can disastrously affect the local population. Do not contaminate land, air or water.
8. Audit, Report and Act.
   Environmental performance should be assessed on a regular basis. Ensure that areas of concern are acted upon and compliance procedures established.
9. Minimise waste. Unnecessary waste is a luxury no company can afford. Poor housekeeping can result in contaminated waste which is no longer easy to dispose of.
10. Be aware and comply with existing legislative and technical standards and anticipate stricter regulations. The companies which survive will be those who understand what is going on.
11. Publicise genuine environmental performance. The environment is not always bad news.
12. Communicate
    It is important to keep the environmental debate on the agenda. Environmentalism in today's rapidly changing world is a relatively new science and there has been a sudden and massive increase in 'experts'. Although individual actions are important the debate should not be restricted to issues in isolation – the environment is global. Ensure that government, trade unions, environmental interest groups and the general public understand your business and that its benefits far outweigh the risks.

Only if these measures are adopted will the industry convince the general public of its ability to manage its affairs in an acceptable way – there is no easy answer.

As Whelan (1985) quotes, "Complete adaption to the environment means death. The essential point in all response is a desire to control the environment".

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Appendix 1

Proposed Schedule of Prescribed Processes

Fuel and Power Industry
1.1 Gasification processes
1.2 Carbonisation processes
1.3 Combustion processes

Production of Processing of Metals or Metal Compounds
2.1 Iron and steel processes
2.2 Non-ferrous metal processes
2.3 Smelting processes

Mineral Industry
3.1 Cement and lime processes
3.2 Absestos processes
3.3 Fibre processes
3.4 Mineral processes
3.5 Glass manufacturing processes
3.6 Ceramic process

Chemical Industry
4.1 Petrochemical processes
4.2 Organic chemical processes
4.3 Mineral acid processes
4.4 Halogen processes
4.5 Inorganic chemical processes
4.6 Chemical fertiliser processes
4.7 Chemical pesticide processes
4.8 Pharmaceutical processes
4.9 Bulk chemical storage processes

Waste Disposal Industry
5.1 Incineration processes
5.2 Chemical recovery processes
5.3 Chemical waste treatment processes
5.4 Waste derived fuel manufacturing processes

Other Industries
6.1 Paper-pulp manufacturing processes
6.2 Di-isocyanate processes
6.3 Tar and bitumen processes
6.4 Uranium processes
6.5 Coating processes
6.6 Printing ink and coating manufacturing processes
6.7 Timber processes
6.8 Animal and plant treatment processes

Appendix 2

The First U.K. Red List

Substance

Mercury and its compounds
Cadmium and its compounds
Gamma-hexachlorocyclohexane
DDT
Pentachlorophenol
Hexachlorobutadiene
Aldrin
Dieldrin
Endrin
Polychlorinated Biphenyls
Dichlorvos
1,2-Dichloroethane
Trichlorobenzene
Atrazine
Simazine
Tributyltin compounds
Triphenyltin compounds
Trifluralin
Fenitrothion
Azinphos-methyl
Malathion
Endosulfan

Further substances are expected to be added to the Red List in due course

Appendix 3

European Legislation	*Relating to*
76/769/E.E.C. 'Marketing and Use'; 8th Amendment	Arsenic in wood preservation
76/769/E.E.C. 'Marketing and Use'; 9th Amendment (proposed)	P.C.P. and its compounds
89/451/E.E.C.; 3rd Adaption to Paints Directive	Labelling requirements for lead in paints
89/391/E.E.C.	Framework Directive on health and safety at work
89/654/E.E.C.	Workplace safety
89/655/E.E.C.	Use of equipment at work
89/656/E.E.C.	Personal protective clothing
88/379/E.E.C.	Classification, Packaging and Labelling of Dangerous preparations (replacing the Solvents and Paints Directive)
87/302/E.E.C. 'Substances Directive'; 9th Amendment	Test methods of determination of toxicity and ecotoxicity properties
Council Regulation 1734/88	Notification of export of certain chemicals which are banned or severely restricted

U.K. Legislation	*Relating to*
Dangerous substances (Notification and Marketing of Sites) Regulations 1990 (S.I. 304)	Sites holding more than 25 te 25 te of a dangerous substance
Classification, Packaging and Labelling of Dangerous Substances (Amendment) Regulations 1989 (S.I. 2208)	
Pressure System and Transportable Gas Containers Regulations 1989 (S.I. 2169)	
Reporting of Industrial Diseases, and – Dangerous Occurrences Regulations (Amendment) 1989 (S.I. 1457)	extends reportable diseases and occurrences
Control of Industrial Air Pollution (Regulation of Works) Regulations 1989 (S.I. 318)	Air pollution
Health and Safety (Emissions into the Atmosphere) (Amendment) Regulations 1989 (S.I. 319)	
Control of Substances Hazardous to Health Regulations 1988 (S.I. 1657)	Use of hazardous substances at work
Control of Industrial Major Accident Hazards (Amendment) Regulations 1988 (S.I. 1462)	Amends processes and threshold values of certain dangerous substances
Collection and Disposal of Waste Regulations 1988 (S.I. 819)	Storage of 'special' waste
The Control of Pollution (Trans-frontier shipment of waste) Regulations 1988	Movement of hazardous waste
The Consumer Protection Act 1987	Modifies Section 6 or H.S.W. Act 1974 regarding provision of information
Health and Safety Information for Employees Regulations 1989 (S.I. 682)	Requirement to display information to employees
The Trade Effluents (Prescribed Processes and Substances) Regulations 1989 (S.I. 1156)	Prescribed substances including -HCH, PCP, and TBT compounds

Transport Legislation	*Relating to*
Road Traffic (carriage of Dangerous Substances in Packages etc.) (Amendment) Regulations 1989 (S.I. 105)	Harmonisation of U.K. conveyance legislation with agreed international standards
Packaging	From 1.5.90 no package of substances of Class 3, 6.1, or 8 may be shipped internationally by road or rail if not in U.N. certified packaging

Appendix 4

NORDISKA TRÄSKYDDSRADET – NTR
NORDIC WOOD PRESERVATION COUNCIL
Mannerheimvägen 40 D 87
00100 Helsingfors, Finland
Tel: 90-492 762. Telefax: 90-441 796

Förteckning Över Godkända Träskyddsmedel Nr. 36
Wood Preservatives Approved by the Nordic Wood Preservation Council 1(2) 1990-03-02

Träskyddsmedel	*Krav på upptagning i furusplintved (Pinus sylvestris) kg/m³ 1) Retention/Class* M	A	AB	B2)	*Godkännandet giltigt tom Approval valid until*	*Bevis nr. Certificate No.*
1. VATTENLÖSLIGA MEDEL/WATER-BORNE TYPE						
Basilit CFK		15	–	8	1993-12-31	1
*Celcure A oxid	30	15	7	7	1993-12-31	74
*Celcure AP 5	20	13	6	6	1991-12-31	90
*Celcure A/C33	30	15	7	7	1992-12-31	5
Celcure M	–	21	16	16	1992-12-31	6
*Celcure O (el 'N')	24	18	18	18	1992-12-31	7
*Celcure O oxid	–	18	–	–	1994-12-31	112
Celcure M(P)/CB(P)	–	21	–	–	1994-12-31	113
Defence 300 SL	–	–	8	8	1994-12-31	110
Cuprinol Tryck	–	40	–	–	1992-12-31	8
Injecta CKB	–	21	16	16	1993-12-31	102
Kemira CT86	–	40	19	19	1992-12-31	87

*Kemira K33 typ B	24	12	5	5	1993-12-31	12
*Kemira K33 typ C	24	12	5	5	1994-12-31	9
Kemira KB75	–	40	–	–	1994-12-31	76
*Kemira KC73	–	10	10	10	1993-12-31	11
Mitrol 48 Tryck	–	–	8	8	1992-12-31	66
*Mitrol CCA typ BS	30	15	–	–	1994-12-31	77
*OK-K33 typ C	24	12	5	5	1994-12-31	79
*Osmose K33 typ C	24	12	5	5	1991-12-31	88
*Rentokil K33	24	12	5	5	1991-12-31	7
Rentokil P50	–	18	18	18	1992-12-31	3
*Tanalith C (Tancas C)	30	15	7	7	1991-12-31	53
Tanalith CBC	–	24	18	18	1991-12-31	13
*Tanalith CC	–	18	18	18	1991-12-31	18
*Tanalith CC oxid 3416	–	10	10	10	1993-12-31	98
*Tanalith CCA oxid typ B/Tanalith K33	24	12	5	5	1994-12-31	16
*Tanalith CCA oxid typ C	24	12	5	5	1994-12-31	17
*Tanalith CCA pasta	30	15	7	7	1994-12-31	15
Tanalith 3419 CBC	–	13	10	10	1994-12-31	108
Tanalith 3420 CCP	–	18	18	18	1994-12-31	109
*Treat CCA-C	30	15	–	–	1993-12-31	68
Wolmanit CB	–	21	–	–	1991-12-31	30
Wolmanit CX-50	–	–	3	3	1993-12-31	103

1) Övriga träslag godkända av NTR lärk (Larix decidua, L. europae, L. eurolepis), Douglas (Pseudotsuga sp) samt västamerikansk hemlock (Tsuga heterophylla) och amrikansk silvergran (Abies amabilis) båada av kusttyp De Bäda senare träslagen försäljes under handelsnamnet 'Hem-Fir' från British Columbia i Kanada.

Vattenlösliga medel markarade med (*) är godkända i klass M, när virket impregnaras med det vetten lösliga medlet till klass A, torkas och därefter impregneras till klass A med kreosotolja (dubbelimpregnering)

Träskyddsmedel	*Krav på upptagning i furusplintved (Pinus sylvestris) kg/m³ 1) Retention/Class*				*Godkännandet giltigt tom Approval valid until*	*Bevis nr. Certificate No.*
	M	*A*	*AB*	*B*		
2. OLJELÖSLIGA MEDEL/ORGANIC SOLVENT TYPE						
AA-155 Vindu Träskydd	–	–	–	55	1994-12-31	78
AQUANTI Rentosol 30	–	–	–	30	1994-12-31	105
GORJ 22 gron kobber	–	–	–	75	1994-12-31	47
GORI vac 007	–	–	–	55	1993-12-31	70
GORI vac 014	–	–	–	55	1993-12-31	71
GORI vac 030	–	–	–	40	1991-12-31	58
GORI vac 032	–	–	–	40	1991-12-31	80
GORI vac 033	–	–	–	40	1991-12-31	81
GORI vac 034	–	–	–	40	1991-12-31	82
GORI vac TH60	–	–	–	55	1992-12-31	93
GORI vac TL61	–	–	–	40	1992-12-31	94
GORI vac TH62	–	–	–	40	1992-12-31	95
GORI vac TL63	–	–	–	40	1992-12-31	96
GORI vac TH80	–	–	–	26	1993-12-31	97
GORI vac TL81	–	–	–	26	1993-12-31	99
GORI vac TH82	–	–	–	26	1993-12-31	100
GORI vac TL83	–	–	–	26	1993-12-31	101
Hylosan SN WR	–	–	40	40	1994-12-31	26
Impregneringsolja K	445	150	–	–	1993-12-31	104
Konvac väske 6106-2000	–	–	–	40	1990-12-31	83
Kresotolja	400	135	–	–	1994-12-31	29
Protim 130	–	–	–	50	1993-12-31	30
Protim 130 WR	–	–	–	50	1993-12-31	31
Protim 130 WR Alkyd	–	–	–	50	1993-12-31	32
Rentosol A	–	–	–	60	1993-12-31	33
Sadolin Sadovac 2353	–	–	–	50	1991-12-31	59
Sadolin Sadovac 2353	–	–	–	50	1990-12-31	55
Sadolin Sadovac 2356	–	–	–	50	1990-12-31	56
Sadolin Sadovac 2365	–	–	–	50	1991-12-31	62
Sadolin Sadovac 2369	–	–	–	40	1992-12-31	67
Sadolin Sadovac 2379	–	–	–	50	1990-12-31	85
Sadolin Sadovac 2383	–	–	–	50	1991-12-31	89
Sadolin Sadovac 2386	–	–	–	50	1991-12-31	91
Sadolin Sadovac 2389	–	–	–	40	1992-12-31	97
Sadolin Sadovac 2395	–	–	–	25	1990-12-31	107
3-Spar Stan-Vac Miljo	–	–	–	60	1993-12-31	40
Stanvac 40	–	–	–	40	1990-12-31	84
Vacground AA 150	–	–	–	43	1993-12-31	42
Vacsol EWR 38	–	–	–	43	1990-12-31	52
Vacsol EWR 52 A	–	–	–	40	1992-12-31	43
Vacsol 2151	–	–	–	26	1995-12-31	100

2) Trå för klass M skall ha största möjlign splintvedshalt. Bearbetning av impregnerat trä i Klass M, A och AB bör undvikas. Om bearbetning oundviklig, skall bearbetade ytor efterbehandlas med ett lämpligt preparat.

Trä impregnerat enligt Klass B förutsätter att all hearbetning utförd före impregneringen.

Impregnering av profilerat trä till Klass B med vattenlösliga medel ställer särskilda krav pä impregnerings proceduren.

DISCUSSION ON PAPER 3

Chairman: E. A. Hilditch

MR. E. A. HILDITCH: Mike, you have slightly gone over the time you promised which means we are very restricted in the questions. Who would like to start the ball rolling?

MR. G. A. EWBANK (Fosroc): Thank you very much, Mike, for a very comprehensive and useful talk. I would like to try and focus in on this point of delivering treated timbers to the user in a safe state. You mentioned accelerated fixation for C.C.A.s and this is a very important development. I think there is a lot of potential. For this process the capital investment is much higher, the process time is longer and my personal feeling is that until there is some specific legislative requirement to use it then it will not be used in a big way in the United Kingdom because of political pressures. Yet at the same time Len made the point this morning that current practice with C.C.A. treated timber was perhaps less than desirable. Where is the issue going to go from here do you think?

MR. M. CONNELL: I think a true reflection of the situation regarding accelerated fixation, Gordon, is that it is not the panacea to solve all problems but it can certainly solve some problems in certain situations. I think in a cost-effective way it very much depends on the species that is being treated and obviously the preservative that is being used and we are talking mainly about chromium-based preservatives. In some situations as existing regulations and requirements are framed, there is not much incentive I would say to install accelerated fixation units but that, as you quite rightly say, could change.

There are several options for people who want to deliver safe timber to the ultimate user and accelerated fixation is one. It is a technique which will suit some treaters. It will not suit all treaters.

DR. D. G. ANDERSON: Just to add to that, the term "accelerated fixation" is perhaps a misnomer. What we are really looking for is control of fixation and that I think is likely to become a requirement in the fairly near future. It definitely is in Holland and it is in Denmark obviously and we would be wrong not to think that. Accelerated fixation is one way of controlling fixation. Other ways are kilning, raising the temperature, holding in buildings where the temperature can be controlled, and things of that nature.

MR. E. A. HILDITCH: Any more questions? Can I get one in? Mike, I know you are here on a sort of technical environmental platform but turn your mind to the money and all the measures necessary to do this are going to cost money. That money has got to be recovered by industry. Two questions: does the competitive structure of the industry allow the industry to recover that money, and what is the willingness of the public to pay that money?

MR. M. CONNELL: It is an interesting question and I think that possibly is a question you could almost throw at any industry at the moment in terms of the environment but in terms of timber preservation then, yes, I think there is scope for companies who do succeed in their research and development, not just on products but on processes. There is scope in product stewardship type schemes, quality schemes, etc., to recover let us say a premium for their efforts.

In terms of whether the public will pay, I do not think that is any longer a question. The public, whether they like it or not, will have to pay not just in our industry but in any industry. As we are seeing now, all sorts of reasons are being given for rises in food prices and I think we all know what the reasons are.

DR. D. G. ANDERSON: To add to what Mike is saying, whilst the timber preservation industry is under a threat from environmental costs, capital costs, then surely the competitive materials we are faced with – steel and concrete – are themselves being faced with equally significant increases in cost arising from environmental protection measures. So I think overall we can say that is not the cost of electricity going to rise dramatically and perhaps wood may be beneficially affected against some of the competitive materials because energy components in other materials tend to be greater. If energy costs go up one will see perhaps an increase in the differential.

MR. M. CONNELL: Perhaps just one small final comment, again I was looking at the results from another poll only earlier this week and the poll asked the question to industry as to how they saw the environmental issue, was it a threat, was it an opportunity? Seventy-nine per cent of all respondents thought that the environmental challenge presented an opportunity to them but what I think was more interesting was that only 29 per cent were actively doing anything to actually derive benefits from it.

MR. E. A. HILDITCH: We still have a missionary job to do. Within living memory we did a very good missionary job because we actually persuaded the timber industry to use preservatives. Do we have any more questions from the floor please?

DR. R. MURPHY (Imperial College): Mike, you mention the problems that C.C.A. was facing at the moment with chromium-arsenate in it. You have also made a very clear definition of hazard and risk. To what extent do you think that the risks inherent in C.C.A. eventually being, if you like, exposed in its usage because it strikes me certainly there are not many cases where the risk has become a hazard? It looks like C.C.A.s are facing being removed because of the hazard but to what extent do you feel the risk is being expressed?

MR. M. CONNELL: A good question. I believe the risk is being assessed more and more. I think in the United States in particular where the E.P.A. have these very stringent registration procedures, certainly the risks associated with C.C.A. are being continually evaluated and data is being submitted at a more comprehensive level all the time.

I think also that we are talking about a relatively new science in terms of risk assessment and I refer, I think, in my paper back to 1975 or 1976 when Stalker and Cornwell from Rentokil did an assessment of the safety of C.C.A. wood preservatives. I think that was a very good paper but it was a paper of its time and considered hazard and risk in a very much different way from the way that we are looking at them today.

As I explained regarding the arsenic cycle, we have got to look at the environmental aspects and the health and safety aspects in a much wider context perhaps than the old ways of classification, is it irritant, is it corrosive, is it toxic? Yes, we know all that. There products have been around a long time and I think you are quite right that you have to look at it in a much wider framework. Those sort of arguments and that kind of logic will ultimately decide the fate not just of C.C.A. but of all other preservatives.

DR. C. R. COGGINS (Rentokil): A good paper, Mike and David, and thanks very much. I very much subscribe to your comments about product stewardship as you know. The examples you gave of spillages arose from problems of one sort or another at treatment plants. It seems to be clear that one of the major threats to the future of preservatives in general, if you take Sweden for example where they are wanting to push people in other directions with regard to certain treated woods, is in the way they use it at treatment plants. That seems to be the area of greatest potential risk.

There has been a tremendous effort over the years to improve the standard of treatment plants which lies in encouragement, in training, design of plants and so on but one has still got problems arising with treatment plants.

In reviews that I have done, as you know, of this situation or this area I would refer to John Levy's paper in the early seventies where he identified the environmental issue as a crucial one in terms of the future of the industry. I wonder if you would hazard a guess on a scale of one to ten where we are today compared with the early seventies? Nearly 20 years have gone by. How long will it take us to achieve the level of good environmental protection and practice that we need to have in our own industry?

MR. M. CONNELL: Could I answer that question by only going back about eight years, Chris, because that is as long as I have got experience of within the industry? It is a good question. Certainly there have been significant improvements made. I do not think there is any doubt about that and I think the B.W.P.D.A. code of practice, although non-legislative, is a very, very important code of practice.

As you may be aware, there is a move at the moment by W.E.I. to adapt some of the principles from that code of practice and to prepare a European code of practice in terms of compliance. I think that if treatment plants do come up to that standard then on a scale of one to ten it would probably be nine or nine-and-a-half because I am sure we will not even reach perfection in that.

In terms of general movement certainly there does seem to be a greater commitment within the industry to improve. Certainly within the major groups in the timber treatment industry that is so and you are quite right when you say it is the timber treater I think where the main focus of attention is. The big groups are beginning to look to rationalise their operations. We are seeing the removal of the very small treatment sites and I think that trend will continue and we will see a rationalisation in bigger and better units.

So I think the industry can progress and I would hope that by 1992 or even 1995 we will see a situation of a green industry.

MR. E. A. HILDITCH: Thank you, Mike. We have now successfully overrun our time and so I must draw this session to a close. We must all thank the authors. The discussion perhaps in some way is only just beginning and we are only just seeing the real importance of this topic. We are a high profile industry. We are high profile in medical terms and much of what has been said in this paper has been directed in that way.

We also are a high profile industry on environmental matters in the media. We draw no comfort from the fact that there has been no great media upset in the last few months. There will be some more as sure as eggs are eggs and we must take account of what is being discussed to prepare ourselves and put ourselves into a better position to deal with this. I would ask you to thank the authors in the usual way please. *(Applause)*.

BIOTECHNICAL DEVELOPMENTS IN WOOD PRESERVATION AND DECAY DETECTION

by Professor B. King, J. W. Palfreyman, A. Bruce, G. M. Smith, D. Button and G. Mowe
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Introduction

The decay of wood by micro- and macro-organisms may take place in standing trees, can develop extensively and rapidly in the period after felling and before drying, and after wood has dried, dependent on environmental conditions, organism availability, state of preservation and innate material durability. Subject to these constraints once wood is infected it may continue to decay steadily, at a rate which is determined by the organism grouping which happens to be available to decay the substrate, under the particular set of environmental conditions in force, until the resource is ultimately depleted.

Biotechnology has been defined as the application of biological organisms, systems or processes to manufacturing or service industries (Anon, 1980). Traditionally, biotechnological processes were well recognised in brewing and dairy industries, however, the full potential and scope of the subject is now beginning to be realised with increased opportunities for commercial exploitation and inherent scientific interest in technologies such as genetic engineering, enzyme technology and plant biotechnology (Button, 1989). In the field of wood technology biotechnological processes, in the form of isolated enzymes and organisms (both fungi and bacteria) have been postulated for many years as methods to enhance wood permeability and produce biological control of wood decay. The degradative enzyme systems of decomposers are now being intensively researched in view of the great potential of these organisms to eliminate, effectively and acceptably, lignocellulose wastes, simple organic wastes including unwanted pesticides and as process agents for the paper and pulping industry.

Research in wood technology at Dundee Institute of Technology has, for many years, examined the mechanisms by which organisms colonise and invade wood and has attempted to quantify microbial presence in soil and wood and especially at interfaces during decomposition processes. Papers to this convention in 1976 and 1981 (Oxley, *et al.*, King, *et al.*) described the role of surface nutrients in wood on chemostimulation of soil micro-organisms and the development of "rhizosphere" effects in soil surrounding wood in preserved and unpreserved forms. This paper describes recent developments in wood technology research at Dundee Institute of Technology in biological control, immunotechnology and the use of enzyme assays in environmental monitoring.

Biological Control

When naturally decayed wood in the forest is examined it is sometimes possible to see decayed and discoloured regions with clear demarcation zones indicating intense competition between different fungal species, or individuals of the same species, for the capture or defence of resources. The sophistication of this balance is exemplified by the observation of Rayner (1986) who pointed out "it is important to bear in mind the fundamental nature of the fungal mycelium as a composite, indeterminate thallus often having considerable capacities for regeneration and internal communication, and for varying its pattern of development in response to changes in environmental conditions". The huge variety of organisms capable of invading and decaying wood ranging from the unicellular prokaryotic forms and the generally considered unsophisticated Zygomycotinia to the highly enzymatically and morphologically complex Basidiomyotina is a further complication. Despite this it is possible to observe at various stages in the microbial successions which take place in standing, felled or preserved wood, periods of stasis or microbial dominance, during which for nutritional, environmental or biotic reasons species or classes of organisms dominate, or exist as pseudo climax populations, for varying periods of time. During such "stasis" intervals other organisms or populations are precluded thus establishing a form of "biological control" of the resource.

The term biological control has been defined in many ways by many workers. Smith (1948) defined biological control as the suppression of a pest by means of the introduction, propagation and dissemination of the predators, parasites and diseases by which it is attacked. Baker and Cook (1974) defined it as the reduction in inoculum density or disease producing capacity of a pathogen or parasite, in its active or dormant state, by one or more organisms, this change being accomplished naturally or through manipulation of the environment. DeBach (1974) defined biological control as being part of the overall phenomenon of natural control, the latter being the regulation of populations of organisms by biotic or abiotic factors within more or less regular time limits.

Biological control of wood decay is not unknown. In the early fifties *Trichoderma* species were suggested to control post harvest deterioration of timber by Lindgren (1952) in conjunction with sodium fluoride, the first example of integrated control. Shields and Atwell (1963) suggested the same process in the early 1960s for post felling application and Rickard in the late '60s suggested the use of species of *Scytalidium* for control of internal decay of service poles.

Our work on biological control began in the early seventies with the late Tom Oxley and has been funded in part by Midlands Electricity, S.E.R.C. and North of Scotland Hydro Electricity and our objectives have included the examination of the use of biological agents to control internal decay of wooden distribution poles. As part of this study we have looked at the effects of a range of *Trichoderma* species, and a proprietary product, on control of decay of creosoted poles by *Lentinus lepideus*.

In recent years, an increasing awareness and concern over the use of toxic chemicals for wood preservation and the potentially hazardous effects these might have on the environment, particularly if they are leachable, has developed. The latter is a concern, for amongst others, the electricity supply industry since most distribution poles are located on land in the public domain or which is in agricultural usage. Environmental safety is therefore a matter of continued concern. Remedial treatments are frequently used by the electrical industry to enhance groundline protection and any new remedial treatment needs, in order to be cost effective, to be effective against target decay fungi *in situ* in pole interiors; simple to apply; have low human and environmental toxicity; and protect the poles for reasonable periods of time. While a number of alternative chemical treatments are receiving attention for use in pole interiors a more radical alternative is the use of biological control where fungal species provide a "more natural" control of fungal decay.

Work at this institute, in collaboration with both the electricity supply industry (U.K.) and the United States Department of Agriculture, Forest Products Laboratory, Madison, has, over the past 10 years, concentrated on the use of fungal agents and in particular *Trichoderma* spp. to control internal decay in creosoted pole interiors although control of other wood decay organisms and applications have also been studied. Work has included both laboratory studies to examine mechanistic aspects of fungal control as well as large scale field studies to determine the *in situ* performance of control agents.

Laboratory studies have shown that *Trichoderma* spp. are well able to kill a wide variety of wood decay agents including *L. lepideus*, the principal decay fungus isolated from creosoted poles. *Trichoderma* spp. have been shown to inhibit wood decay fungi by a variety of different mechanisms including: production of soluble toxic metabolites; production of lytic enzymes in association with chemotropic responses as part of a mycoparasitic process and via the production of toxic volatiles.

Since biological control agents are living entities their ability to become established and survive in any wooden commodity is influenced by the physical constraints of the environment. Field trials of a proprietary biological control product containing *Trichoderma* (Bruce and King, 1986) have shown that the organism can become established in upwards of 90 per cent of poles inoculated with the product and that the organism can remain viable in such poles for periods in excess of seven years. (Bruce *et al.*, 1990a).

Further field experiments involved the sacrificial sampling of a total of 40 full sized creosoted poles artificially inoculated with either *Trichoderma, L. lepideus* or a combination of both (Bruce and King, 1986a,b; Bruce *et al.*, 1990a). These experiments were set up to examine the field performance of the biological control product when applied as directed by the manufacturer. The results of these two experiments showed that while the level of control achieved did not compare with that claimed for chemical products there was a significant reduction in the level of decay produced particularly in those poles where the control agent was applied prior to the introduction of the decay fungus.

As with any biological control system where a new organism is to be introduced into an established microbial ecosystem, establishment of the introduced organism is likely to be difficult. The results of these field experiments indicated that the *Trichoderma* failed to thoroughly colonise the groundline regions of those poles which already had a large population of resident organisms and that even after extended incubation periods in the poles, colonisation by the control agent was disappointing. Fundamental to this problem is the need for a more complete understanding of the antagonistic mechanisms employed by the control agents when in wood. This is particularly so since experimental evidence indicates that the antagonistic capabilities of control agents including *Trichoderma* spp. are influenced by nutrient availability and thus laboratory test systems are not guaranteed to provide an accurate reflection of what might occur in wood in the field.

Of concern to any user of wooden products is the permanence of any protective effect produced by a preservative treatment. Chemical preservatives depend upon the fixation and relative leachability of the active chemicals. Biological control may or may not be dependent on the continued viability of the organism. Work at this and other institutes has shown that wood blocks pretreated with *Trichoderma* are resistant to decay by selected wood decay fungi even if the control organism is killed in the blocks prior to exposure to the decay fungi. More importantly Bruce *et al.* (1990b) have shown that material removed from areas of creosoted poles and known, by isolation studies, to be colonised by *Trichoderma* spp. was resistant to decay by brown rot basidiomycetes when exposed using standard soil block test methods. The material used in this experiment was taken from poles which had been inoculated with the proprietary biological control product seven years earlier thereby showing the residual nature of the protective effect in the poles over this period.

While colonisation of the entire groundline region might be more likely using a different inoculation pattern and/or delivery system further research of the parameters which influence the ability of the control agent to compete with the resident pole microflora is required before the efficacy of the system can be improved. Furthermore, a more complete understanding of the processes involved in the biological control of *L. lepideus* might allow the development of more effective control agents using sophisticated techniques now available in biotechnology.

Enzyme Assays

In an extensive review of the subject, Mowe (1983) considered that a major problem in quantifying microbial populations in soil is that widely varying values are obtained depending on the measurement techniques employed. Direct counts, *i.e.* by microscopic examination, generally gave estimates of cell numbers and hyphal lengths several hundred times greater than other methods used *e.g.* viable counts. Furthermore, direct microscopic observations of soil microflora were difficult because of the opaque nature of soil particles. To overcome this problem, microscopic estimation of numbers of bacterial cells and fungal hyphal lengths are generally undertaken on small amounts of soil dispersed in water of known volume. These are then mixed with molten agar and thin agar films prepared and mounted on microscope slides which can then be stained. Bacterial numbers and hyphal lengths thus determined can then be used to estimate biomass.

Mowe (*op. cit*) was of the opinion that a major constraint of direct observation of stained thin soil films was their inability to distinguish between viable and non-viable organisms although this constraint had been partially overcome, for fungi, by use of phase contrast microscopy and special vital staining techniques. However, counting of viable bacterial cells, by serial dilutions from dispersed soil in water, had the drawback of media selectivity with growth of disparate taxonomic groups of bacteria either promoted or restricted. Thus complex procedures and numerous selective media are required in order not to omit major bacterial groupings. Furthermore such methods did not provide useful quantitative data on fungal populations because of the filamentous nature of fungal growth and the inability to distinguish between colonies arising from hyphal fragments as opposed to spores.

Mowe also observed that biochemical determination of soil microbial biomass could be undertaken by a number of methods. Hexosamine assays measure amounts of fungal cell wall material but are only effective for pure culture determinations with individual fungi due to variation in hexosamine content of cell walls between different fungal species. Adenosine triphosphate content of the microflora in soil is presently undergoing extensive investigation as a possible effective and reliable evaluator of soil microbial biomass. A.T.P. is present in cells of all organisms, it is however strongly absorbed into clay particles in soil and is only stable outside cell walls for limited time periods dependent on the chemical and physical environment. To overcome these problems soil is flooded, prior to A.T.P. extraction from cells, with a compound which occupies the sites on the clay particles which would absorb the A.T.P. and the A.T.P. molecule stabilised by addition of buffers to the soil at low temperatures. Once A.T.P. has been extracted its soil concentration is determined by measuring the relative quantity of light produced when the A.T.P. is mixed with luciferin – luciferase in a luminometer and light output values compared to a standard curve.

Measurement of soil microbial activity can also be undertaken by enzyme assays which include assays for cellulases, amylases, invertases and pectinases. Such methods are of limited value because of substrate specificity, however, enzymes with more general substrate specificity such as dehydrogenases and which are present in all organisms give a more useful indication of overall activity as they are a direct measure of the metabolic respiratory apparatus. Dehydrogenase assays are straight forward colorimetric procedures which allow a high through put.

In a series of soil burial experiments using untreated and C.C.A. treated small blocks of lime and pine, Mowe (1983) showed that during the first week after burial dehydrogenase activity in soil around untreated wood blocks showed an increase but remained unchanged in soil about perspex blocks. By week 2 activity had increased in soil about both untreated wood and control blocks. During weeks 2-3 dehydrogenase activity declined rapidly in soil about the inert controls but remained high or continued to increase in soil within 3 mm of untreated wood blocks. During the period from weeks 3-24 dehydrogenase activity about inert control blocks showed a continued though more gradual decline and by week 24 was at a level below that at 0 week. Dehydrogenase activity around untreated blocks continued to increase but that in soil around C.C.A. treated blocks was substantially less than that around untreated blocks although still greater than that about inert controls.

Mowe's results (Mowe, 1983) also showed that fungal hyphal lengths in soil were significantly correlated with dehydrogenase activity in soil, and also with mass loss and nitrogen concentration in wood. There was a build up of both bacterial numbers and fungal biomass in soil surrounding wood samples as decay progressed with time, and such bacterial numbers and fungal biomass were related to mass loss from the wood.

A relationship between the biological events occurring in wood and soil was thus positively established and the hypothesis that wood, even when preserved or leached, strongly influences the microbial activity in soil was supported. Further work by Green (1988) confirmed Mowe's hypothesis. While these results were produced using a range of small wood block sizes we are now investigating the process of using enzymatic methods to determine biological effects of preservatives in full size poles on soil microflora (Hainey, 1990) and it is possible that such techniques may be a useful further means of environmentally monitoring the effects of biocides on soil systems.

Molecular Analyses

Despite the excellence of current timber preservation treatment methods there is still much untreated and badly maintained timber in service in the U.K. Current methodology for assessing decay and determining the type of decay largely depends on a visual observation of wood combined with experience of specific decay situations and, potentially, the use of isolation methods. However occasions often arise when there is disagreement on the nature of an outbreak of decay and if a decay outbreak is determined only after serious structural damage has taken place it may be too late to rectify the situation except at high cost. Such considerations suggested that there was a need for the development of new methods to assist in the identification of types of timber decay, and that there was also a need for systems that could detect organisms before they had caused large scale damage to timber. To be of use such methods would need to be developed around relatively simple technologies, ones which have been successfully exploited in other areas of biotechnology.

Research at D.I.T. has therefore been directed towards developing systems for detecting decay organisms rather than detecting the decay caused by the organism. Whilst the latter question can be approached by a variety of chemical and physical techniques, detection of an organism is essentially a biological problem and one that has been approached in our studies by use of biological techniques.

Recent trends in biology in many areas of research and development have been in the direction of molecular biology. By this is meant the understanding and analysis of biology in terms of the molecules that are involved in biological processes and structures. There are a wide range of different molecules involved in life processes but the two most important classes of molecule, at least in molecular biology, are nucleic acids, in the form of D.N.A. and R.N.A., and proteins. Nucleic acids represent the blueprint for biological systems, proteins represent the work horses and machinery for these processes. Both types of molecule are important in making an organism what it is and in keeping it that way. The working hypothesis at Dundee Institute of Technology has therefore been that it should be possible to identify an organism on the basis of its molecules, and, given sufficient sensitivity, detect it on the basis of its molecules. Since the whole of medical diagnosis of infections depends upon identification based on proteins and nucleic acids this hypothesis seemed well founded. We have decided for the moment to disregard nucleic acids not because they have limited potential but rather because at present there is no evidence of their exploitation in decay organism detection and because the techniques associated with nucleic acid analysis are, in many cases, much more sophisticated than those associated with proteins.

To use proteins as detection/identification systems certain requirements are necessary e.g. techniques for detecting proteins and for identifying particular proteins from particular organisms are needed. These requirements are very basic to molecular biology and, for example, protein detection can be undertaken by a wide range of highly sensitive techniques. Likewise identifying particular proteins is a relatively simple task even if such proteins represent only a tiny component of a complex mixture. The two most popular and widely used methods for protein analysis are electrophoresis (sodium dodecyl sulphate polyacrylamide gel electrophoresis; S.D.S.-P.A.G.E. (Laemmli, 1970; Marsden *et al.*, 1978) and a set of techniques called immunotechnology (Edwards, 1985). Both these methods are as applicable to fungal decay organisms in wood as they are to other areas of mycology including medical mycology, plant pathology and post harvest deterioration.

Considering first S.D.S.-P.A.G.E.: this procedure involves separating protein molecules on a gel matrix made of polyacrylamide. The proteins are separated by the implementation of an electric current through the gel and proteins move in the field according to their size, small molecules move fast, large molecules move slowly. After separation the proteins need to be visualised in some way and this is normally achieved by application of a stain. The type of staining system used in our studies relies on the interaciton of silver salts with the separated proteins in a system that is not unlike photography (Blum *et al.*, 1987). This method can detect nanogram amounts of protein. The outcome of the technique is a series of bands on a gel which can be considered to produce a type of fingerprint of the sample analysed.

Immunotechnology depends upon the development of molecular probes called antibodies. Antibodies are produced in the bodies of animals in response to assault by bacteria, viruses etc. and their normal function is to assist in the destruction of the invading pathogen. An important feature of antibodies is their ability to be highly specific so the antibody produced against a specific antigen will not react with another. Surprisingly it is possible to produce antibodies against almost any type of biological macromolecule or organism just by injecting the substance of interest into an appropriate animal. Often a rabbit or a mouse is used though recent developments in immunotechnology are moving away from the use of animals and antibodies can be produced, for example, by genetic cloning experiments using bacteria. The overall shape of an antibody is often represented as a Y, the arms of the Y are involved in binding to an antigen, the stem of the Y can be modified in any number of ways to make it visible in some type of apparatus. For example it can be radioactively labelled, labelled with a fluorescence marker or labelled with an enzyme which can itself produce a colour change.

Studies at D.I.T. have used both S.D.S.-P.A.G.E. and immunotechnology to analyse two specific decay organisms, viz. *Serpula lacrymans* and *Lentinus lepideus*. A major problem in any type of molecular study of basidiomycetes of these types relates to the fact that they appear in so many different guises *e.g.* as fruit bodies, as mycelia and as spores. Initial work has been directed towards the identification of *Serpula* in laboratory cultures since this is the system over which we have the most control. The objectives of this study were to determine if consistent molecular profiles of *S. lacrymans* could be found, to compare such profiles with those obtained from other organisms, to try to identify specific markers for *Serpula* and to look for those markers in infected wood. To initiate this work we were veyr kindly provided with a set of diverse isolates of *Serpula* by Dr. Bryan Hegarty of Rohm and Haas. These isolates were obtained during the last 60 years from sites all round the world and these isolates have been supplemented by new isolates from Dundee. We also needed a supply of non-*Serpula* decay fungi and many of these have come from the National Collection of Wood Rotting Fungi at B.R.E.

The first studies undertaken were designed to determine if a consistent banding pattern could be produced for a given isolate when grown in agar and in wood. *S. lacrymans* F.P.R.L. 12C was used for this purpose and it was possible to show a consistency in the organism when grown in different culture media and through a number of generations (Vigrow *et al.*, 1989). Comparing the range of *Serpula* isolates which have been examined reveals that most of them have banding patterns very similar, if not identical, to F.P.R.L. 12C. There are, however, two exceptions, which whilst they show similarities to *S. lacrymans* also show certain differences. One of these organisms was suggested to be, on the basis of morphology, not *S. lacrymans* at all but rather *S. himantioides* a closely related organism (Schmidt and Kebernik, 1989). When an S.D.S.-P.A.G.E. profile for this organism was compared with that of a bona fide *S. himantioides* its profile was identical. At the same time two other *Serpula* species were investigated since it was thought that they might have patterns similar to *S. himantioides* and *S. lacrymans*. Surprisingly the two organisms analysed, *S. tignicola* and *S. pinastri*, seemed very different from both *S. himantioides* and *S. lacrymans*. However questioning of the taxonomists associated with the naming of these organisms, has revealed that neither is now considered to be a true *Serpula* (they are now considered to belong to the genus *Leucogyrophana*) a change which our molecular study would fully endorse (Palfreyman *et al.*, 1990a).

It should be noted that the two isolates which differed from *S. lacrymans* F.P.R.L. 12C nevertheless showed similarities to the type organism differing only in the molecular weights of a relatively few components. On the basis of the gel patterns obtained in these studies it has been possible to construct diagrams which allow some quantitative measurement to be made relating one organism to another. We have achieved this by use of a similarity index. The number of common bands between a standard preparation of an organis, *e.g.* F.P.R.L. 12C and the suspected *Serpula* is estimated and quoted as a percentage (Palfreyman *et al.*, 1990b).

Obviously if S.D.S.-P.A.G.E. is to be used for identification and detection it needs to be able to distinguish between other types of organism. S.D.S.-P.A.G.E. profiles for other wood decay organisms showed that there are very great differences between the patterns that are obtained for them (Palfreyman *et al.*, 1991). Again diagrams can be constructed from such gels and percentage similarities between profiles for different organisms and *Serpula* estimated. Results obtained for this type of analysis indicate that values of less than 30 per cent are found for all organisms in non-*Serpula* genera tested to date, the highest value being obtained for the organism *Poria incrassata* which, interestingly, is always quoted as being the U.S. equivalent of *S. lacrymans* (Cartwright and Findlay, 1958) and may also be more correctly placed in the genus *Serpula* (Hennebert and Decock, personal communication).

Confirmation that this type of analysis can be used to identify not only *Serpula* but other decay organisms has come from the identification of a number of field isolates. These studies have used organisms isolated and grown up in standard systems. Attempts have also been made to analyse mycelial and strand material gathered from field sites and in these instances some variability between samples has been found. In particular, for example, strand and spore material give very different banding patterns from material gathered from fruit bodies or flushes of mycelia (Palfreyman *et al.*, 1990b).

Studies of decay organisms in infected wood have been largely limited, to date, to laboratory decayed wood blocks. Perhaps, not surprisingly, uninfected wood produces very few, if any, bands on S.D.S.-P.A.G.E. This is probably due to two reasons, first there are very low nitrogen levels, and therefore protein levels, in wood and second it is probable that any protein will not be extracted from uninfected wood since it will be bound up in wood cell walls. However once timber becomes infected with *S. lacrymans*, bands start to appear in the wood and though a different banding from that found in the standard preparation of F.P.R.L. 12C can be seen there are a number of similarities. The conclusions of this part of the study can be summarised thus. Consistent banding patterns can be found for *S. lacrymans*, most isolates of *S. lacrymans* have similar patterns, other organisms have different patterns and a *S. lacrymans* pattern can be determined in extracts of infected wood.

The next stage of the research programme relates to the direct application of S.D.S.-P.A.G.E. to the analysis of infected timber samples. However when analysing field samples of infected wood directly by this technique, any *Serpula* bands may be masked by banding patterns for other organisms. To overcome this problem a specific molecular probe is required and this is where antibody based techniques become essential. We have developed an antiserum against *S. lacrymans* and used this in a number of related techniques coming under the heading of immunoblotting. Essentially extracts of an organism are bound on to nitrocellulose and then the bound components are detected using the antibody. At the end of the experiment a dot, or a set of bands, is produced. A high degree of cross reactivity can sometimes take place (*i.e.* a number of organisms can be identified by the one antibody) and this has led to the development of more specific antibody based probes called monoclonal antibodies but these are not discussed in this paper. Suffice it to say that it should be possible to produce antibody based reagents that can work in this type of simple assay and which have a high degree of specificity. Even non-specific reagents have allowed interesting experiments to be undertaken. First by combining immunoblotting with S.D.S.-P.A.G.E. in a technique called western blotting (Towbin and Gordon, 1984) it is possible to show that a range of different decay fungi show different banding patterns and also that some organisms cross react a great deal more strongly than others. Furthermore, as might be expected, isolates of *S. lacrymans* all gave similar banding patterns (Palfreyman *et al.*, 1988) with the exception of the organism that has now been identified as *S. himantioides*. Interestingly the banding pattern for *S. himantioides* was very much more like *S. lacrymans* than any other organism that has been tested. The other former *Serpula's*, *S. tignicola* and *S. pinastri*, gave very different patterns. Investigation of *S. lacrymans* grown in wood gave a somewhat different pattern through the major antigens being processed differently when the organism was grown in wood. It is also possible using other antibody based technologies to stain hyphae for microscopic analysis, to detect enzymes released from the hyphal cell wall and to detect hyphae growing in infected wood.

Molecular analyses have also been applied to the organism *L. lepideus*, an organism involved in the premature failure of creosote treated distribution poles. An antiserum which reacted strongly with *L. lepideus* has been produced. Using another type of immunotechnological procedure cross reactivity with other organisms was demonstrated. However since the cross reactivity was largely limited to basidiomycetes this was not a serious drawback. Indeed in some ways it could be an advantage since detection of any basidiomycete in a distribution pole would provide valuable information.

Blotting procedures, analogous to the ones used for *S. lacry-*

mans have indicated that *L. lepideus* contains unique antigens (Glancy *et al* 1989) and that it would therefore be possible to produce more specific probes for the organism. Before continuing these studies our major concern was to determine if the process could be used for detection of *L. lepideus* in the field, and accordingly, the first experiments undertaken were designed to assay *L. lepideus* in infected wood blocks. These results showed that uninfected wood blocks always produced negative results in dot blot assays. Highly infected blocks, i.e. those showing extensive weight loss, showed good response in the assay. Blocks with no weight loss, which were presumably at an early stage of decay, were also positive in the assay indicating that early detection of decay is possible.

A small field trial was undertaken using 9 pole stubs inoculated with *L. lepideus<fo-1>* and sampled at various stages after inoculation for microbiological determination of organism colonisation and for the reaction in the immunoassay. There were many more immunologically positive samples than microbiologically positive samples. The number of positive isolations of *L. lepideus* was only 31 out of 452 samples assayed. By contrast 277 out of 511 samples were positive in the immunoassay. Different poles gave very different sets of results (Glancy *et al* 1989). Initial observation tended to suggest that *L. lepideus* positive samples were generally situated close to immunoassay positive samples and this was supported by statistical analysis. A variety of statistical tests confirmed that there was a significant relationship between high immunoassay scores and *L. lepideus* positive samples and no such correlation was found with any other type of microorganism tested.

Whilst studies in protein analysis and immunotechnology are still relatively undeveloped results obtained to date indicate that techniques have an enormous amount of potential which will be more fully exploited in the future as it has been in a wide range of other areas of biology. The needs of organism detection in timber decay may not be identical to, for example, the needs of detection systems in medical diagnosis, in agriculture and forestry or in food analysis. That molecular systems contribute greatly and increasingly in each of these areas implies that the possible use of such systems in decay detection should not be ignored. Current developments in molecular biology and biotechnology suggest that simply looking at a piece of timber is not the best way of telling if it is decayed and identifying the relevant decay organism.

Many of the studies reported in this paper have involved research on laboratory samples. Much early work in other areas of molecular diagnosis was similarly on laboratory systems. Other fields indicate that these laboratory studies will be applicable to real life situations and the long process of demonstrating the field value, to timber technologists, of some of the techniques and reagents of molecular biology has just begun.

Conclusions

1. While biological control systems for wood decay are not yet at the stage of being a ready alternative to chemical treatments for pole protection they are able to control decay *in situ* in pole interiors for periods of up to seven years after treatment. If problems associated with inadequate colonisation of the organisms can be satisfactorily remedied and if a process technology can be developed, biological control may well have a potential, perhaps when used in an integrated form, in the remedial treatment of wood poles and other materials.
2. Enzyme assays of soil systems, when carefully selected and approved, may provide an easy means for the environmental monitoring of soil systems exposed to treated wood and even provide a system for detection of early decay especially by soft rot fungi.
3. Molecular techniques, especially when applied to basidiomycete organisms, have an enormous potential for the early detection and identification of decay organisms and in understanding decomposition processes. Their further development will also be of substantial use in quantifying biomass aspects of the decomposition process and thus measuring the biological events involved in wood decay and preservative performance.

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DISCUSSION ON PAPER 4

Chairman: T. D. Settle

MR T. D. SETTLE: Thank you very much. If there are any questions we have time for a few.

D. LOWE (Fosroc): Could I ask Dr. Palfreyman, when using the S.D.S.-P.A.G.E. method you said "timber suspected of being infected by *Serpula* could be compared with timber that was known to be infected with the dry rot fungus". To do this would the timber species that you use have to be identical in both cases? Would that interfere with the pattern you obtained?

DR. J. W. PALFREYMAN: We have looked at two timber species so far to answer this very important question. We have looked at pine and lime infected wood blocks and have found that extracts of these two species give us identical patterns on the S.D.S.-P.A.G.E. Now I am not necessarily going to infer from that that this will be true for all wood species but so far as we have looked at the moment, it looks as if we will get a consistent pattern.

DR. R. MURPHY (Imperial College): I have got a comment for Bernard King and a question for John Palfreyman. Bernard, when you were discussing the work on fungal populations and soil around treated and preservative treated wood you raised the intriguing question of using these populations and correlating them with background metal levels. You may remember some work I did several years ago now where we did in fact do that and we found a correlation between levels of copper tolerant fungi and the quantity of copper released from C.C.A. treated wood. Secondly, I think the enzyme activity is a very good way to go to measure activity but I do think the quality of the microbial population changes and you can find, well we found, increases in the proportion of certain organisms. Do you want to deal with that first?

PROFESSOR B. KING: I note your comment. The paper we presented today goes through the various loops of quantifying biomass in soil systems by means of measuring activity – not looking at populations by means of isolation. There are a large number of different techniques that can be used to study biomass; isolation techniques have many disadvantages and biomass measurement *per se* (e.g. by mycelial measurement) equally have disadvantages – these are discussed in the paper. Our particular interest is in measuring and relating actual metabolic activity in soil and wood to preservative treatments and extending these to molecular studies thus determining toxic effects of biocides in and to soil. Such effects would not necessarily be revealed by isolation or mycelial studies.

DR. R. MURPHY (Imperial College): The question I had for John was, have you got any ideas what the distinctive proteins are that you are detecting in your S.D.S.-P.A.G.E. and in the immunolabelling?

DR. J. W. PALFREYMAN: The material that we are looking at in our gels is from washed mycelium so that it represents a spectrum of all the proteins which are present within the organisms and so I really do not have any idea what the function of any of these proteins is.

We have not looked, as yet, at the secreted proteins of the different organisms and if we did that then perhaps we would be able to relate some of the proteins to a particular function by running zymograms. The extracts we are studying represent a very complex mixture. We can identify perhaps thirty or forty different proteins but there are many, many more that we are resolving at present.

MR. E. A. HILLDITCH (Cuprinol): You started one part of your work with a number of examples of *Serpula lacrymans* from reliable sources. Some of them were not *Serpula*. Is there an implication here that perhaps sometimes dry rot is not due to *Serpula lacrymans*?

DR J. W. PALFREYMAN: Dry rot can be defined as rot caused by Serpula lacrymans, though I believe that there is some dispute as to what to call rot caused by *S. himantioides*. Whether or not rot outbreaks that are called dry rot are always dry rot or not is certainly a question I would not like to answer but I know from my work in the Institute that individuals are unhappy sometimes at the diagnosis of dry rot and there can be disagreement between companies.

DR. A. F. BRAVERY (B.R.E.): The question is to John. Many years ago now we did some very similar work looking at a form of gel electrophoresis with extra cellular culture filtrates and we exposed the extra cellular culture filtrates to low doses of preservative solutions. We saw that certain bands in the protein pattern were knocked out and it was predictable and reproducible.

I have two questions. Firstly, have you yet introduced the preservative dimension into your studies, and secondly, might the presence and influence of the preservatives somewhere on the sample, the unknown sample, produce an anomalous band pattern that will cause you to misidentify or mistype the isolate?

DR. J. W. PALFREYMAN: The first point is that we have not looked at the effect of preservatives as yet on the banding pattern but we certainly have found you do occasionally see different types of banding patterns in different circumstances and this may be associated with perhaps the growth phase of the organism.

The second point, would you misidentify? Well, I think this is where you need a specific molecular probe which is just reacting to one band perhaps which you know is always present. However, the answer to your question is probably no. I suspect that changes caused by preservatives would be minor compared to the differences found between organism profiles.

MR. T. D. SETTLE: I would like to thank John and Bernard for a very interesting paper. I would ask you to show your appreciation in the normal manner.

(*applause*)

MOISTURE CONTENT CONTROL OF WOOD BEFORE PRESERVATIVE PROCESSING

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1. Introduction

There is general acceptance that the moisture content of timber should be assessed and, if necessary, reduced before treatment with a wood preservative. Why this should be necessary is perhaps less clearly understood; how the charge should be dried, whose responsibility it is and what are the consequences of not doing so are often even more hazy. This paper sets out to discuss some of the issues involved.

2. Brief Review of Wood/Moisture Relationships

Water is a chemical constituent of wood. A proportion of the moisture in the living tree and all the moisture in wood in our-of-ground contact service is chemically bound in various degrees to the cellulosic and other constituents of the cell walls. The lower the moisture content of the piece of wood the more firmly is the remaining water bonded, to the extent where attempting to drive it all off by oven-drying at 103°C causes chemical degradation of the cell wall constituents.

Wood evolved to hold the foliage and reproductive elements of trees up in the air. Dry wood is stronger and stiffer than wet at least in the lower range of moisture content. It is therefore difficult to see whether there is any advantage to wood in a tree being wet or whether it is just a consequence of the chemical constituents that have evolved to fulfill the structural function. It may, of course, have something to do with the plastic and fatigue-resistant properties required by trees to withstand up to centuries of wind buffetting.

The other point to remember about water in the living tree is that it is the transport medium for mineral nutrients from the soil, and photosynthesized products for growth, respiration and storage. The zone of sapwood which is functional in mineral transport (usually only the outer few annual rings or their equivalent and not the whole sapwood zone) is almost completely saturated. Air embolism of the cell cavities impairs the transport function. The moisture content of this zone, expressed on the conventional dry weight basis is therefore a function of the cell wall to cell void volume, i.e. the oven dry density, and can be several hundred percent in low density timber.

Inside this zone of complete saturation is sapwood which is less effective in upward water transport due to air bubbles in the cell cavities. Typically the sapwood is drier as the heartwood is approached. This does not mean that all the cell cavities in a particular zone are three-quarters or two-thirds full but that varying proportions of cells have different amounts of water in their voids. Heartwood, by definition, is dead tissue, has no conducting function and is usually drier than the adjacent sapwood. It may even approach fibre saturation point (f.s.p.).

F.s.p. is a rather notional concept representing a condition where the cell cavities are all empty of liquid (chemically unbound) water but the cell wall structure is fully saturated and in the swollen state. To achieve this state in practice is at least very difficult. In almost every piece of real timber in the 25-35 per cent m.c. range that covers the f.s.p. of different species/densities, some parts will be wetter and others drier than f.s.p. As a concept, however, it is important because it represents the theoretical moisture content point below which shrinkage starts as water is removed from the cell wall structure, or above which swelling due to water absorption and bulking of the cell wall stops.

Three methods of moisture content measurement are available. Only one of these is a direct method, the distillation method, where a ground-up sample of the wood is extracted with a non-water-miscible solvent such as toluene at moderate temperatures, the water removed, and measured directly. Oven drying is an indirect method because it measures weight loss, a component of which may be volatiles other than water. Nevertheless it is the yardstick method because of its convenience and good reproduceability. Variations on the standard method of drying to constant weight (variously defined) in a ventilated oven held between 101 and 105°C have been developed to speed up the assessment. Sample blocks may be dried in a matter of minutes in a microwave oven; milled or similarly finely divided samples can be dried by infra-red radiation in seconds and weight loss measured. The techniques are all destructive to some extent and are time-consuming. The most practical method exploits the change in electrical properties of wood with changes in moisture content. That property most widely employed by moisture meter manufacturers is electrical resistance although capacitance/power loss meters find practical application particularly in fixed, quality control applications. The practical limitations of portable resistance-type moisture meters will be considered later but it is worth pointing out a fundamental limitation. This is that the very small changes in resistance with increasing moisture content above about 25 per cent m.c. and the very large changes below about 10 per cent put practical limitations on the range over which meters are acceptably accurate.

3. Effect of Moisture Content on Preservative Processing

Water-based diffusion and sap-displacement methods are obviously in a different category to the vacuum-pressure and double-vacuum methods dominant in the U.K. preservation industry. To achieve nominally complete penetration they require consistently high timber moisture contents (but not full saturation) at the time of treatment. If they achieve through-and-through treatment, the consequences of subsequent uncontrolled drying will be of no protective significance but may be important for structural and/or appearance reasons.

These processes are not currently in widespread commercial use in the UK and attention will be concentrated on the full-cell vacuum-pressure and double-vacuum processes that are.

3.1. Requirements of British Standards for moisture content before treatment

3.1.1. *B.S. 5268: Part 5: 1989. Structural use of timber. Code of practice for the preservative treatment of structural timber*

Clause 7.1.3. deals with the moisture content requirement under the more general heading of "preparation of timber before preservative treatment." The overall requirement is – "It is essential that the moisture content of the timber is at the correct level* for the type of treatment to be received." (The asterisk refers to particular requirements for transmission poles laid down in B.S. 1990: Part 1: 1984.) The specific requirements are then itemised:

Boron diffusion	> 50% m.c.
Creosote	Boulton process if > 28% (B.S. 913)
All other treatments	< 28% throughout zone to be treated

"For creosote and C.C.A. treatment it is essential to dry to this moisture content before treatment, and for certain end-use situations a lower moisture content may be required."

". . . organic solvent preservatives . . . at the moisture content consistent with their end use."

B.S. 4072: Part 2 and B.S. 913 are referenced for methods of determining moisture content.

The previous version of this standard, dated 1977, contains no requirement for moisture content before treatment but references B.S. 4072 amongst others.

3.1.2. *B.S. 5589: 1989. British Standard Code of Practice for Preservation of Timber*
Clause 6.1.3. is identical to the above as a result of the alignment of the two standards during their recent revision. The original version of this standard, published in 1978, requires moisture content to be below 28 per cent throughout the zone to be treated (except for diffusion treatments with boron salts). By way of explanation it states "Preservative solutions cannot penetrate capillaries blocked by free water." It also suggests that it may be preferable for some commodities to treat at lower moisture contents, nearer those required for the finished product. It then references the treatment specifications in the document for methods of determining moisture content.

3.1.3. *B.S. 4072: Part 2: 1987 Wood Preservation by means of copper/chromium/arsenic compositions*
Clause 5.1.3. requires that, unless otherwise specified in a relevant commodity specification, timber must have an average moisture content not exceeding 28 per cent m/m, oven dry basis. Appendix D gives procedures for an oven dry and a moisture meter method of moisture content determination which are presumably considered equivalent in terms of validity and accuracy. Specific requirements are laid down for overhead line poles where "the maximum average moisture content in the charge shall be not more than 28 per cent (m/m) on an oven dry basis for the outer 50 mm. The moisture content of any individual pole shall not exceed 30 per cent (m/m)." Appendix B of B.S. 1990: Part 1: 1984 is referenced for the required method of sampling and moisture content determination.

The 1974 version of this standard, originally written in results-type form on a batch basis, required (except for poles) timber to be seasoned to an average moisture content of not more than 25 per cent. Large-section timbers with a smallest dimension of ≥ 150 mm were given a dispensation in that the requirement applied only to the outer 25 mm or the full depth of the sapwood whichever was the greater. An oven-drying method of moisture content determination was given as being appropriate.

3.1.4. *B.S. 5707: Part 3: 1980 Solutions of wood preservatives in organic solvents. Part 3. Methods of treatment*
Clause 3.3. Moisture – requires that "The moisture content of timber selected shall not exceed 28 per cent (m/m), determined as described in B.S. 5666: Part 1." A note to this clause reads "For some commodities it is preferable to treat timber at a lower moisture content, nearer to that found in the finished product."

3.1.5. *B.S. 144: Part 2: 1990 Wood preservation using coal tar creosote. Part 2. Methods for timber treatments*
Pretreatment moisture content requirements are specified in clause 4.1.3. Any material/product standard relating to timber being treated take precedence over the general requirement that the average moisture content must be not greater than 28 per cent m/m on an oven dry basis. Appendix A gives both an oven-drying and a moisture meter method for determining this average. Unique to this standard is the possibility of using the Boulton process to reduce the moisture content to the required level.

This standard has only recently superceded B.S. 913: 1973 Wood preservation by means of pressure creosoting, which required that "The average moisture content of the seasoned timber . . . shall not exceed 28 per cent." The paragraph which follows unusually addresses the question of variability between the pieces of timber which go to make up the 'average' moisture content. It reads "Owing to the natural variability in the drying rates and equilibrium moisture contents of timber, the moisture content of the individual samples may cover a considerable range above and below the average value. Occasinally a small percentage could well be as much as 5 per cent or 10 per cent on either side of the average value." It is not clear from the text whether the percentages refer to moisture content percentages i.e. from 18 to 38 per cent moisture content.

3.2. **Discussion of moisture content requirements in preservation standards**
Two main points emerge from this summary of current and recent British standards:
1) there seems to be something significant about a moisture content of 28 per cent;
2) the requirements, when examined critically, are really very imprecise and often pass the responsibility on to the appropriate commodity specification.

The figure of 28 per cent occurs in all the current preservation standards referenced, although it was 25 per cent in B.S. 4072: 1974. The early version of B.S. 5589 seems to indicate that it is the absence of free water i.e. fibre saturation point, that is determining this 28 per cent m.c. threshold although this is not stated explicitly and is not mentioned elsewhere. The clear implication is that wood above 28 per cent (or f.s.p.?) will have free water (i.e. not bound chemically to the cell wall constituents) and this will make it resistant to penetration by preservatives, regardless of whether these are organic solvent, creosote or water-borne types. This may be valid theoretically but the way the requirement is expressed suggests that the practicalities have not been fully considered. In many cases the "not exceeding 28 per cent" refers to an average moisture content without stating whether a piece average or a charge/batch average is meant. B.S. 5268: Part 5 and B.S. 5589 in their latest versions require the moisture content to be below 28 per cent in the zone to be treated – but they are both process-type specifications. They are also in conflict with B.S. 4072 and B.S. 913 which have an 'average' requirement and with B.S. 5707 which refers to 'timber with selected' presumably as samples for checking moisture content since full-scale checking is impractical.

Whatever commercial method is used to dry timber from green to a moisture content suitable for preservative treatment there will inevitably be variation within pieces and between different pieces in a charge. Within a piece, most of the variation will be through the thickness of the piece from the drier outer layers to the wetter core. Taking an average moisture content from a full cross-sectional slice will average this variation in moisture content through the thickness and possibly obscure the presence of a wet, difficult-to-penetrate core. Some recent work measuring the moisture content of kiln loads of softwood after drying would not indicate that the statement about moisture content variability after drying in B.S. 913 is pessimistic.

Collecting together the guidance/requirements for moisture content control before preservative processing in the U.K. standards considered and paraphrasing them in general terms could result in a statement such as:

> "timber to be processed shall not be above f.s.p. (or 28 per cent m.c.) under any circumstances and where commodity specifications lay down requirements for moisture content, should conform with these i.e. be at or near the average moisture content achieved in service."

Moisture contents laid down in commodity specifications are usually maxima chosen to minimise problems due to shrinkage, distortion and surface checking. In B.S. 5268: Part 2 dealing with structural timber, an upper limit on moisture content at installation is put in to prevent loading green timber to levels determined on dry (< 18 per cent m.c.) design stresses.

3.3. **Requirements of some British Commodity Standards**
3.3.1. *B.S. 1186: Part 1: 1986 Timber for and workmanship in joinery*
The aim of Section 3, Moisture content, of this standard is

stated in a preliminary note to be to minimize any movement or distortion by ensuring that the moisture content of the timber is close to that which will be attained in service. The requirements are for average percentage moisture contents and maximum individual moisture content readings as follows:

	Acceptable range of average m.c., %	*Maximum reading, %*
External floor level hardwood sills and thresholds	16-22	Hardwood 25
		Softwood
Other external joinery	13-19	23
Internal joinery, intermittent heating	13-17	20
Internal joinery, continuous heating to 12-19°C	10-14	20
Internal joinery, continuous heating to 20-24°C	8-12	20

There is also a requirement to limit the moisture content disparity between adjacent pieces in a joinery component. A resistance-type moisture meter is specified for moisture content measurement.

3.3.2. *B.S. 5268: Part 2: 1984 Structural use of timber: Part 2 Code of practice for permissible stress design, materials and workmanship*
This standard discusses moisture content in terms of supply, shrinkage, strength effects and decay resistance. The primary concern appears to be to avoid overloading green timber and it is left to the designer/specifier to assess the moisture contents which will be acdeptable in particular cases. A table for guidance is given as follows:

Situation	*Average service m.c., %*	*M.c. which should not be exceeded at erection, %*
Fully exposed external uses	18 or above	—
Covered and generally unheated	18	24
Covered and generally heated	16	21
Internal, continuously heated	14	19

It is interesting to note that no maximum moisture content is recommended for fully exposed external uses despite the realisation that average service moisture contents of 18 per cent may be reached. Minimum service moisture contents substantially below these can be expected in dry periods.

3.3.3. *B.S. 4169: 1988 Manufacture of glued-laminated timber structural members*
Average moisture contents of laminations at the time of gluing are required to be in accordance with the adhesive manufacturer's instructions and compatible with expected equilibrium m.c. in service. The table is very similar to that for B.S. 5268 except for 16 read 14 and for 14 read 11. Moisture meter or oven-drying methods of measurement are specified.

3.3.4. *Other commodity specifications*
There are many other commodity specifications which include moisture content clauses but for brevity these are not considered in detail. A longer list is included in the T.R.A.D.A. Wood Information Sheet entitled 'Moisture content of timber – its importance and specification.'

3.4. **Significance of pretreatment moisture content**
In preservative treatment terms there are two aspects to the need to control moisture content before processing is carried out, (i) to enable effective penetration by the preservative, and (ii) to prevent subsequent drying causing splits and checks which penetrate through the envelope of protective treatment.

3.4.1. *Effect of moisture content on preservative penetration*
Most of the timber species in the U.K. which are both commercially important and frequently require preservative treatment are not readily impregnated. Full sapwood penetration of species with permeable/moderately resistant sapwood is usually expected for high hazard applications but most heartwoods and some important sapwoods rely on protective shell treatments. Since, in general, the deeper the lateral penetration of preservative the more reliable the protective treatment, it follows that maximising the available permeability to treatment fluids is at a premium. In this connection it is interesting to recall that the reference data on treatability of timbers obtained by the Princes Risborough Laboratory and embodied in both British and forthcoming European Standards was based on material air dried, after conversion from logs, to about 18 per cent m.c.

It is stating the obvious to point out the impossibility of squeezing fluid preservative into wood already saturated with water. This extreme is as unrealistic as treating oven-dried wood. What is of practical significance is the effect that moisture contents in the range of about 14-20 per cent for out-of-ground contact uses and above f.s.p. for submerged uses have on preservative penetration.

A keyword/database search for recent published information on this topic has revealed very little of relevance. A considerable amount of research has been carried out on gas and liquid flow through wood, sometimes at different moisture contents, but usually the more fundamental aspects are the motivation rather than lateral penetration by liquids in which the timber is fully immersed. The distinction is probably best made by using the term 'treatability' for the latter as opposed to the more general term 'permeability.'

Most of the commercially significant softwoods have bordered pits which contain tori. When aspirated, such pits form an effective barrier across the otherwise major path of liquid flow. Aspiration occurs in the living tree as a defensive response to embolism of transpiration columns but is much more prevalent as wood is dried towards f.s.p. (Siau, 1984). Earlywood tracheids are also more prone to aspiration than those of the latewood with the result that dry latewood is usually more permeable than Earlywood. Permeability is found to decrease as wood dries, especially the earlywood of sapwood, and the effect is more pronounced, the more severe the drying conditions (Bramhall and Wilson (1971), Comstock and Cote (1968), etc.). That the effect, which may result in a one hundredfold decrease in permeability from green to air dry, is due to pit aspiration is supported by evidence from freeze drying and solvent-exchange drying (e.g. Petty 1978). Both these techniques avoid the development of high surface tension forces as free water is withdrawn from the capillaries which in turn results in pit aspiration. The increase in permeability which results from steaming is attributed to de-aspiration in conjunction with some hydrolysis of the pit membranes (Nicholas and Thomas, 1968).

As far as is known, these effects have not been investigated in relation to treatability, yet it is of significance to the practical treatability of softwoods. Rapid drying conditions, whether n a kiln or air drying, results in the generation of steep moisture content gradients. Under these conditions, the piece on average may be at say 28 per cent but the outer layers will be well below f.s.p. and heavily aspirated whilst the inner layers will still contain free water. The former effectively blocks the main route for liquid penetration whilst the latter imposes resistance to liquids due to the effects of the menisci in the capillaries. Once aspirated, the tori appear to bond to the pit borders chemically in such a way that makes deaspiration difficult (e.g.

steaming or prolonged water soaking needed).

In his paper presented to the 1986 B.W.P.A. Convention, Baines (1986) attributes much of the difference in treatability of spruce from imported and British-grown sources to differences in moisture content. Imported material is typically kiln dried and able to be treated with conventional vacuum pressure techniques. The effect of both high and low moisture contents on the effectiveness of the oscillating pressure method reported in this paper support the theories of the importance of pit aspiration on fluid penetration. Trials on steaming of spruce timber at various moisture contents and for various periods proved inconclusive overall. In dry sapwood, steaming appeared to raise the moisture content of the outer layers and hinder penetration rather than deaspirate pits and improve treatment with C.C.A.

Data presented by Baines in connection with these experiments on the effect of steaming on C.C.A. treatment of spruce show, despite considerable variation, that the highest uptakes of preservative by sapwood occurs at the moisture content of 28 per cent m.c. regardless of whether or not steaming was carried out and for how long (Figure 1). The results for heartwood and heartwood/sapwood combined are unclear.

Experimentation on Pinus radiata and Pinus pinaster at 25, 50, 75 and 100 per cent m.c. reported by Coetzee and Laar (1977) led to the conclusion that wood can be treated effectively with C.C.A. at moisture contents above 25 per cent (the maximum specified in S. African and U.S. specifications at the time). The results varied between the species and with density but overall indicated for these two species that penetratability of the C.C.A. solutions was not reduced by impregnating wood at reasonable higher moisture contents.

At about the same time, work on Pinus radiata was being carried out in New Zealand (Sing-hai Chong 1977). Sapwood at 6 moisture content levels between 25 and 50 per cent m.c. was treated with C.C.A. at 2 and 4 per cent concentration. In both cases the maximum retentions were highest at the lowest moisture content (Figure 2) and the simple linear regressions were statistically highly significant. All samples were fully penetrated.

It may be that other information of practical relevance and on species important to the preservation industry in the U.K. is available either in unpublished form or as part of studies directed at other relationships. It does appear however that the subject of optimum moisture contents to maximise penetration of refractory species and the influence of the method of drying has been neglected relative to its commercial importance. Is it possible for instance that a significant proportion of the variability in treatability which is often found in batches of timber is due to small-scale variations in moisture content and drying history? If so, is it feasible to develop drying techniques and schedules which maximise the potential treatability of a refractory species?

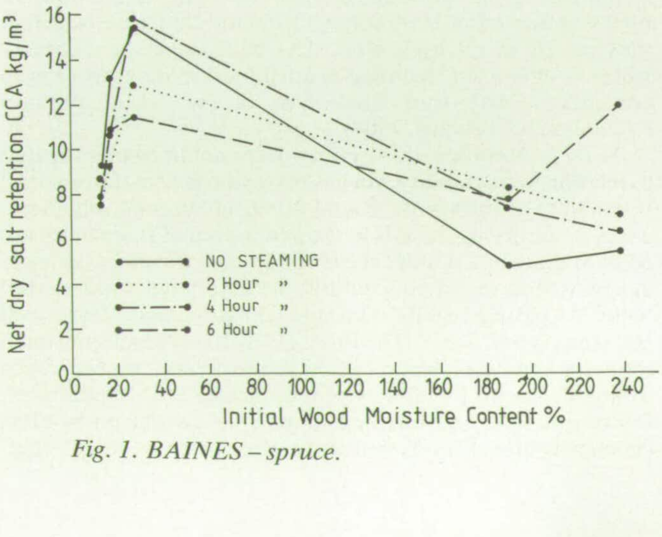

Fig. 1. BAINES – spruce.

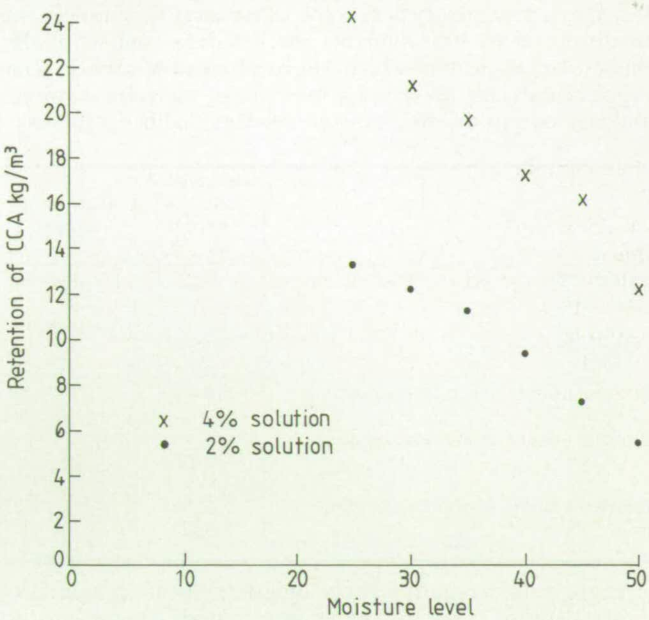

Fig. 2. CHONG – P.radiata.

3.4.2. *The significance of splitting and checking*

Shrinkage takes place as timber dries below the f.s.p. The rate differs between the radial and tangential directions. The moisture content of timber drying from the outside varies through the thickness of the piece with f.s.p. being reached first in the outer layers whilst the interior is fully swollen. The result is that uncontrolled drying from f.s.p. to typical in-service moisture contents of 12-15 per cent m.c. can often lead to splitting and surface checking. Subsequent fluctuations in equilibrium moisture content in response to weather or seasonal heating requirements can also cause or exacerbate splitting and checking. It is also worth remembering that some components can be most at risk from rapid surface drying during storage or construction rather than actually in service.

If this response of timber to drying is coupled with a need to rely on shell protection, it follows that it is necessary to dry down under controlled conditions to (or even below) the average in-service moisture content before treatment with preservative or to conduct this controlled drying afterwards to prevent splitting/checking. This requirement applies whether a swelling or non-swelling solvent is used. Certain commodities, notably round ones such as posts and poles, will inevitably split during drying. The treatment specification for transmission poles is aimed at achieving penetration of preservative deep enough to prevent splits subsequently developing through the treated zone and allowing infection of the unprotected core. Posts rarely seem to receive the same consideration.

Under favourable conditions, internal structural timbers such as timber-frame studs, trussed rafters and carcassing timber should not split or check so as to allow fungal infection through the protective shell if the moisture content is at or near the in-service equilibrium. That such splitting could occur during hot, dry weather whilst timber eventually for interior use is exposed during storage or construction does pose a theoretical threat. Whether it is important in practical terms is debatable.

4. Methods of Drying Before Processing

Processes ranging from air drying at ambient temperatures to batch kiln drying at temperatures above the boiling point of water and many intermediate variations are currently applied to timber as commercial processes. It must be assumed that each system is reasonably appropriate given the circumstances of space, capital equipment cost, operator skill, volume output, quality of drying required and many other factors that go into the equation. Perhaps not many drying operations approach theoretically possible efficiency levels but then few processing plants can afford to give the designer of a drying strategy a completely free hand.

This section will consider some of the more basic aspects of air, dehumidifier and heat-and-vent batch drying as typically applied in the U.K.

4.1. **Air drying**

This is a very crude form of solar drying in that air, heated to ambient temperatures by the sun and therefore usually below the relative humidity with which the timber is in equilibrium, is encouraged to blow over the wet wood surfaces and absorb moisture as it does so. It is an apparently very cheap process since the energy required to evaporate the moisture is free.

When costed realistically however it is usually less attractive in commercial terms – it is a slow process in temperate climates, large stocks and storage areas are required per unit output of dried timber, the process is difficult to control and the consistency of out-turn moisture content is usually low and varies seasonally. Measures such as roof protection, stack orientation and repiling with sticks of thickness appropriate to prevailing drying conditions are possibilities for improving the quality of drying and minimising degrade but are expensive and rarely practised. The main problems are however the slow rate of drying (which may even be negative) during the winter months in our climate, the impossibility of attaining moisture contents below about 18 per cent consistently, and the variation in final moisture content between pieces due to variations in conditions in different parts of the stack.

Solar driers of the 'greenhouse' type overcome all these deficiencies to some extent but control is still usually a problem – too rapid heating/drying on clear, sunny days can damage a load being dried irreversibly in a very short time, even in the U.K. climate. A useful combination of simple air drying to bring high initial moisture contents down to 30-40 per cent m.c. followed by a 'finishing off' under a solar drier probably has more potential than has yet been realised.

Solar drying alone, or in combination, is often likely to be suitable for drying fence posts, horticultural stakes and poles, and similar commodities before treatment. Here, control of the drying rate to prevent splitting and checking is not as critical as with most sawn goods. Indeed, it is better if any checking/splitting that is going to occur with posts happens before preservative treatment. Fan-assisted air circulation is highly desirable when drying sawn products in stick but less necessary where self-piled poles or stakes are involved. If the time taken to dry timber is relatively unimportant then greater consistency of final moisture content can be achieved by extending the process even if the variation in initial moisture content is high. This is an advantage of the air drying system, either on its own or as a 'pre-drying' stage but careful stack design and siting are required if this is not to be negated by variation due to different drying conditions from side to centre and top to bottom of the stack.

To summarise, air drying will not in the U.K., consistently allow drying down to end-use moisture contents of many commodities but, carried out thoughtfully can very usefully reduce initial moisture contents and variability prior to a more controlled drying process.

4.2. **Dehumidifier drying**

Drying by dehumidifier involves stacking the timber, separated by stickers to allow air flow, in an air-tight, usually insulated chamber. The relative humidity of the air is maintained at appropriate levels by condensing out excess moisture on the evaporator of a heat pump and draining it away as liquid. The operating unit may be external to the 'kiln' or sited within it. Dehumidifiers are energy efficent in comparison with other conventional drying methods but all commercial systems are currently electrically powered which can erode this advantage.

Two types of dehumidifiers have been identified depending on the maximum operating temperature of the unit but developments are making the situation more complex. Typically a low-temperature dehumidifier will operate at kiln temperatures up to about 50°C. Since the rate of drying is higher at higher temperatures, these systems dry timber slowly in comparison with conventional kilns or the so-called high temperature dehumidifiers operating at up to about 85°C. Such slow drying can have benefit in that drying-induced degrade is less likely and therefore less operator skill and attention are necessary. It does mean however that the throughput per drying unit is limited. Being of low-temperature operation the kiln enclosure can be of relatively cheap construction. Although we know of no studies which would substantiate it, the relatively slow rate of drying and the greater efficiency of dehumidifiers at high relative humidities suggest that they should be better at producing a consistently dried end product from timber at widely varying initial moisture contents. This advantage of such consistency is that the need to overdry the majority of a load in order to bring the few initially very wet pieces within specification is avoided or reduced.

Low temperature dehumidifiers have had specially derived drying schedules produced for them. These are available from the suppliers of the equipment. High temperature systems can be used to achieve most of the schedules recommended for conventional batch drying. Additional equipment may be required if steaming or reconditioning treatments are to be undertaken.

4.3. **Kiln drying**

This term is imprecise. Many different systems of stacking timber in enclosures and allowing heated air, with or without forced circulation, to dry the timber have been tried and several still find use in different parts of the world. A typical commercial kiln in the U.K. uses air heated, by heat exchangers or direct firing, to temperatures between 35 and 95°C., (B.R.E. Timber Drying Manual 1986) and with circulation forced by side or overhead fans to dry timber stacked and loaded direct by forklift or on a carriage/rail system. Humidity of the kiln atmosphere is controlled by injecting steam or cold water spray when it has to be raised or venting hot humid air to atmosphere and replacing it with fresh air then raised to operating temperature. Heat recovery from the vented air may be employed and variable-speed fans used in more modern installations.

All kilns currently operating in the U.K. are batch kilns with only one exception, a progressive kiln drying British-grown softwood. Batch kilns have a static load and vary the temperature and humidity of the kiln atmosphere and the direction of air flow through the load to 'optimise' the rate of drying. A progressive kiln moves the load through progressively ore severe drying conditions as it becomes drier. Such kilns are in widespread use in Scandinavia for producing 'shipping-dry' softwood. They are best suited to drying large volumes of consistent timber to the same end point. Batch kilns are more versatile and easier to control.

By the term 'optimise' is meant achieving a balance between the rate of drying and the quality of the dried timber. Obviously the quality demands vary with the intended end use but would typically include an absence of distortion, splitting, honeycombing, collapse and discoloration, and a uniformity of moisture content both within pieces and throughout loads. Just as preservative processors have to cope with variations in the treatability of timber in their loads, the kiln operator is faced with loads which not only vary in initial moisture content as a result of heartwood-sapwood differences and pre-kilning storage conditions but also in drying behaviour due to growth-ring orientation. Steep moisture content gradients can result in casehardening, which, through not significant in carcassing, can cause severe wastage during remanufacture.

On top of this variation in the timber the operator must contend with a kiln which will not be uniform in terms of the drying conditions it provides. This is due mainly to deficiencies in air flow which are both difficult to identify and overcome. Where drying specifications with narrow tolerances or upper limits of variation close to the target averages are strictly enforced, the strategy is often to overdry the majority of pieces in order to bring the wetter outliers into conformity. The alternative is to apply an equalising or conditioning treatment at the end of the drying phase in order to achieve greater uniformity. Neither course is popular because it extends the time the timber spends in the kiln and reduces throughput. Some overseas mills are sorting their timber before kilning into loads with greater uniformity of initial moisture content in order to achieve energy savings and greater consistency of out-turn moisture content.

Whether the demands for a more consistent out-turn moisture content in kiln loads comes from the user of timber or a treatment processor, many kiln operators need to put more effort into improving this aspect of their product. As with preservative penetration and loading within a charge, it is difficult and time-consuming to check this consistency within and between pieces. Probably very few kiln operators or their supervisors (outside the field of very demanding drying typified by the furniture industry) have much idea of how the moisture content of pieces in a load (other than the kiln-control samples) varies at the end of the drying process.

5. Practical Aspects of Moisture Content Measurement

In the context of this paper, moisture content measurement is a quality control check on goods undergoing processing. As such it needs to be reliable on a sampling basis and rapid both in terms of the labour content and availability of the results. It should be non-destructive, objective and checkable. It needs to measure not the average moisture content of the charge of timber but, on the somewhat questionable assumption that only wet pieces give difficulties with penetration, the upper limit of excursions. This upper wet limit should apply not to the piece average but to thew wettest portion of the zone that is required/expected to be effectively penetrated by the preservative.

5.1. **Oven-drying and distillation methods**

Neither of these methods is considered practical on a routine basis. Both are time-consuming (extremely so if within-piece variations are to be measured) and the results can take up to 24 hours to become available, depending on the details of the method. That said, they are potentially more reproducable and repeatable than moisture meter measurements and therefore have a role as reference or dispute procedures.

5.2. **Moisture meters**

Used with care and thought, a correctly calibrated resistance-type moisture meter, adjusted for temperature and species, can be a reliable and acceptable instrument for quality control purposes. It is not foolproof, however, and is capable of being misused either accidentally or deliberately. A fuller discussion of the advantages and limitations of such meters can be found in T.R.A.D.A. Wood Information Sheet 4/18 'Moisture meters for wood' and James (1988) discussed more fundamental aspects of their design and performance.

Capacitance meters will not be considered here because of the difficulty of calibrating them (readings depend on the density of the wood as well as its moisture content) and their inability to record moisture content at different depths and so establish moisture content gradients through the thickness of a piece.

The difficulty with using a moisture meter for quality control stems from the fact that each measurement determines the maximum moisture content of wood with which both of a pair of electrodes separated by approximately 20 mm are in contact. In other words it is a spot reading in terms of both the wood surface and depth within the piece. Many such readings are needed to assess the likely moisture content within a charge to be processed with preservative. This number can be calculated using statistical techniques and it depends on the variability of readings as well as the accurcy required. It is almost always greater than one expects or can afford the time to take! It also requires that readings be taken at random points within a load. This is just not practical in an industrial situation. The problem is not that of establishing where the required number of random points are but in getting access to them. Using a moisture meter does not fit happily into the process of making up sticked packs for the treatment vessel and in any case many commodities are treated in loosely-bundled form without ever being broken open at the processing plant.

Resistance-type meters do not work reliably with the electrodes driven into the end grain and anyway, false results would be obtained because the ends dry (or wet) faster than the middles. The outsides of packs are accessible but likewise are prone to giving results unrepresentative of the interior pieces. This is certainly true if the pack has recently left a kiln for the outside pieces will be drier and, because they dry from three sides rather than just top and bottom, will have unrepresentative moisture distributions.

Meters equipped with surface-type or pin-type uninsulated electrodes have major limitations and cannot be used to determine the moisture content at different depths in the timber. To have the correct type of insulated-electrode probe is more important than the type/model of meter to which it is attached (as long as the two are compatible and the meter is of the required accuracy).

It was said earlier that it is extremely difficult to make a meter which is accurate outside a wood moisture content range of about 10-25 per cent m.c. Some meters claim to be able to measure outside this range particularly at higher moisture contents (up to 120 per cent in one case) but these claims have not been substantiated by an independent authority as far as we are aware. This limitation is not of great significance in the preservative processing quality control use being advocated if more attention is paid to the requirements for moisture contents to be at or near those to be achieved in service rather than the upper limit of 28 per cent m.c. This attitude would require that most timber to be treated would need to be dried to between 10 and 18 per cent m.c. before processing. Only that which was going immediatelsy into a consistently wet environment (submerged or permanently buried) could justifiably be treated at around f.s.p. Even fence posts would need to be dried to 12 per cent m.c. or so in order to provide enduring protection to the above-ground parts.

Using a resistance type meter to screen timber at 28-30 per cent m.c. is possibly working at the limit of its range of calibration/accuracy unless this has been specifically established for the type of timber being assessed.

It is being argued that a resistance-type meter is currently the only practical tool for a preservative processor faced with the task of checking upper limits of moisture content within charges before allowing them to go forward for treatment. Howeve,r we lack the necessary techniques to use such meters effectively and the knowledge from which to develop procedures which are both acceptably reliable and practicable in the industrial context.

6. Conclusions

(i) More work needs doing to investigate the potential implications of moisture content, its distribution within the piece of timber and the drying process by which it was brought about on the penetration and loading achieved with commercial preservative processing.

(ii) Based on this should be drawn up practically realistic methods for measuring the moisture content of charges before treatment in relation to practically meaningful limits.

(iii) More emphasis needs to be placed in codes and standards on achieving end-use service moisture contents before treatment even if the treatment is waterborne and wets up the outer layers again. The situation is similar to that of pre/post-treatment machining except that reinstatement of treatment to checks and splits is not practical, unlike retreatment of cut ends.

(iv) The desirability of establishing quality standards for pre-treatment drying of different commodities/products should be investigated.

(v) Harmonisation of European standards on wood preservation will mean that the U.K. will shortly have to change from process-type specifications to those based on the achievement of specified results for penetration and/or loading. Since the obtaining of these results will be the responsibilityof the processor it is quite likely that the preservative standards will no longer contain requirements for moisture content before treatment. However, the relationships still require to be known by the processor for him to be able to achieve, consistently, the results required. With a better understanding of the practical implications of moisture content at the time of treatment on the quality of that treatment, it may be possible to tighten the compliance limits to levels which give more confidence in the consistencyof treatment.

(vi) There may well be a basic conflict for the less permeable types of timber between that dried to a moisture/content that will maximise penetration and the need to dry before preservative treatment to moisture contents appropriate to storage and/or end use levels to avoid subsequent fissuring which could expose untreated timber to infection.

(vii) Hunt and Garratt stated in 1967 that "The most favourable moisture content for treatment has not been determined but probably varies somewhat for different species, preservatives and methods of treatment." This still seems to hold true.

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DECAY RESISTANCE OF CHEMICALLY MODIFIED WOOD

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1. Introduction

Fungal attack of wood is of worldwide concern. Failure results from complex biochemical processes which are at present poorly understood. The present understanding of the processes of decay suggests that enzymes and reactive free radical systems are involved in solubilising the solid wood cell wall material. Brown and white rot fungi of the basidiomycotina are distinguished among the fungi as causing most damage to the wood structure. These fungi are thus the most investigated groups of decay fungi. This diverse group of fungi show a variety of differences in their responses to various factors e.g. different exposure conditions, preservative tolerance, wood species preferences.

In recent years there has been much pressure to introduce novel systems of wood preservation. At early stages of testing, conventional chemical approaches to wood preservation have attempted to introduce new chemicals based on the relative ability of selective poisons to control the activities of specific active decay fungi in susceptible wood species under controlled laboratory conditions.

A less conventional approach to applying selective poisons is to react the wood with chemicals which modify the predominant wood components (cellulose, hemicellulose and lignin) without leaving toxic residues within the wood. This approach is termed chemical modification and extends to the desirable alteration of a number of wood properties. Current application methods for such chemical reactants only differ marginally from those of many conventional wood preservatives. Typically small pieces of wood are treated under pressure in a mixture of excess reactant and swelling solvent. Reaction rate occurs favourably at elevated temperature in the presence of a catalyst. Under these conditions reactions tend to show first order kinetics and the extent of treatment is controlled by reaction temperature and time. After treatment, reactions are quenched by lowering the temperature. Excess residual reagent is removed using a clean up solvent system. Retentions of reactant are expressed in terms of weight percent gain (W.P.G.).

A variety of different reactants have been applied to wood to achieve this (Rowell, 1983). Substitution reactions (Fig. 1) between monofunctional or difunctional isocyanates and wood components, forming urethanes have been investigated: some have shown promise (Table 1) in minimising the effects of decay fungi (Rowell and Ellis, 1979; Rowell, 1980; Kalnins, 1982; Ellis and Rowell, 1984).

$$\underset{\text{Isocyanate}}{R-N=C=O} + \underset{\text{Wood}}{HO-\text{Wood}} \rightarrow \underset{\text{Reacted Wood}}{R-\overset{\displaystyle H}{\overset{|}{N}}-\overset{\displaystyle O}{\overset{\|}{C}}-O-\text{Wood}}$$

Fig. 1. General equation showing isocyanate reaction.

Rowell and Ellis (1979) showed that substitution rections between methyl isocyanate and the hydroxyl groups of Southern pine at modification levels of between 20 and 25 W.P.G. resulted in control of decay by *Gloeophyllum trabeum*. At lower levels of modification (>10 W.P.G.), Kalnins (1982) achieved nearly complete protection against *G. trabeum, Lentinus lepideus* and *Coriolus versicolor* in Southern pine and Sweetgum, using methyl and allyl isocyanates. Ellis and Rowell (1984) used various short-chain monofunctional isocyanates (ethyl, n-propyl and n-butyl) and a difunctional isocyanate (isophorone diisocyanate) in Southern pine against *G. trabeum*. According to Ellis and Rowell (1982) the best decay resistance was shown with butyl isocyanate at >18 W.P.G. The least effective was the difunctional isophorone diisocyanate: this showed 11 per cent losses in sample mass at the maximum modification level of 38 W.P.G. Thus the efficacy of protection is dependent on the nature of the substituent groups and the extent of modification. Furthermore the type of catalysis used appears to affect the results (Ellis and Rowell, 1984).

TABLE 1
Summary of fungal decay resistance tests performed on isocyanates in whole wood

Isocyanate Type	*Test fungus*	*Estimated threshold W.P.G.*	*Reference*
Methyl[1]	*Gloeophyllum trabeum*	>19	Rowell, 1980 Rowell & Ellis, 1979
Methyl[2]	*G. trabeum*	>10	Kalnins, 1982
	Lentinus lepideus	>10	
	Coriolus versicolor	>10	
Ethyl[3]	*G. trabeum*	15-26	Ellis & Rowell, 1984
n-Propyl[1]	*G. trabeum*	<10	Ellis & Rowell, 1984
n-Propyl[4]	*G. trabeum*	11-19	
n-Butyl[4]	*G. trabeum*	<18	Ellis & Rowell, 1984
Allyl[2]	*G. trabeum*	>10	Kalnins, 1982
	L. lepideus	>10	
	C. versicolor	>10	
Isophorone[5]	*G. trabeum*	>38	Ellis & Rowell, 1984
Allyl isothiocyanate[2]	*G. trabeum*	>10	Kalnins, 1982
	L. lepideus	>10	
	C. versicolor	>10	

Note: Type of catalyst 1 – triethylamine; 2 – pyridine; 3 – none; 4 – dimethylformamide; 5 – dimethylsulphoxide.

The reasons for the effectiveness of bonded wood urethane in reducing fungal decay are currently being investigated. The purpose of this study is to screen further isocyanates in a systemmatic manner: the results of previous work have shown that increased chain length in straight chain aliphatic isocyanates from methyl to butyl has increased bio-protection performance. Thus effectiveness of further increases in chain length with mono- and di-functional isocyanates against attack by a standard range of brown and white rot fungi is reported here.

2. Materials and Methods

2.1. Specimen treatment

Corsican pine (*Pinus nigra* Schneid) sapwood blocks of dimensions 20 × 20 × 10 mm were cut with the last dimension in the grain direction. Sets of 30 replicates were acetone extracted in a Soxhlet apparatus for two hours and were then oven dried at 105°C for 24 hours and weighed.

Each set of 30 replicates was reacted in 750 ml. of a 1M solution of the appropriate isocyanate (n-butyl, hexyl or 1,6-diisocyanatohexane) in acetone (solvent):pyridine (base catalyst) 1:1 mixture. Desired levels of modification (4 to 5 intervals between 5 and 35 W.P.G.) were achieved by variation in reaction times. For reaction the dry wood samples were placed in a stainless steel reaction cylinder, 300 mm long × 90 mm diameter, and argon was introduced to maintain a dry internal atmosphere. The reagent solution was added and the reaction cylinder was placed in a heated oil bath at 100°C. At the end of the reaction time the reaction was stopped by cooling the cylinder in tap water. The reacted blocks were rinsed and extracted with acetone in a Soxhlet extractor for four hours. Following this clean up procedure the blocks were oven dried as above and reweighed. They were then equilibrated to equilibrium moisture content (E.M.C.) at 20°C, 65 per cent relative humidity.

In addition, two sets of 30 control blocks were heated in either dry pyridine or 1:1 pyridine:acetone mixture for one hour in a reaction flask. After treatment, control were subjected to the same clean up and conditioning procedure as the reacted specimens.

Differences in dry weight before and after reaction were determined and the extent of reaction was calculated as weight percent gain (W.P.G.).

Dimensions of each specimen (radial, tangential and longitudinal) were taken with a micrometer before and after reactions to the different weight gains.

Samples subjected to high and low modification levels were analysed by infra-red (Perkin-Elmer 1310 spectrophotometer for carbonyl group increase at 1730-1680 cm^1 using the KBr disc method).

2.2. **Decay Test**

Each set of 30 reacted and control blocks at each level of modification were subdivided into five groups of six replicates for exposure to active decay fungi (Table 2) by the soil block (ASTM D-1413-76) test method. Weight loss and final block moisture contents were assessed after 16 weeks incubation at 22° C *(C. puteana)* or 27°C (other test fungi). An additional set of sterile control blocks were used to assess operational control losses.

All three isocyanates were challenged by *C. puteana* while only butyl isocyanate and diisocyanatohexane were challenged by the other test fungi.

TABLE 2
Test fungal strains and their origins

Fungus	*Strain No.*	*Decay type*	*Source**
Coniophora puteana	P.R.L. 11R	Brown rot	1
Gloeophyllum trabeum	P.R.L. 108N	Brown rot	1
Coriolus versicolor	P.R.L. 28G	White rot	1
Pycnoporus sanguineus	D.P.F.44	White rot	2

*Note: 1. B.R.S., Garston, Watford, U.K.
2. Departmento de Produtos Florestais/INPA, Manaus, Brazil

The levels of modification necessary to achieve protection were determined by examining the intersects of the operational control losses with those of the modified blocks. Linear regression analysis was employed for this purpose: in addition this gives an estimate of goodness of fit of the data to the decay threshold values obtained.

2.3. **Examination of decayed material**

Blocks exposed to decay fungi were examined internally after splitting open with a razor blades. After noting their internal condition sections were prepared for light microscopy and material was fixed, dehydrated and critical point dried for Scanning Electron Microscopy (SEM). Light microscopy examination was performed on a Leitz Orthoplan microscope; SEM was performed at 10kV on an Hitachi S-520.

3. Results

3.1. **Isocyanate treatments**

The Corsican pine blocks were satisfactorily reacted with isocyanates (Table 3) to varying levels of modification. The reactions with the monofunctional isocyanates proved more predictable than those with the difunctional isocyanate (Fig. 2). In addition it proved difficult to achieve high levels of modification with the difunctionals isocyanate despite a considerably extended reaction time (11520 min). Higher addition of isocyanates could only be achieved by retreatment with fresh reagent.

Infra-red spectra (Fig. 3) of control and modified samples confirmed the occurrence of wood:isocyanate reaction.

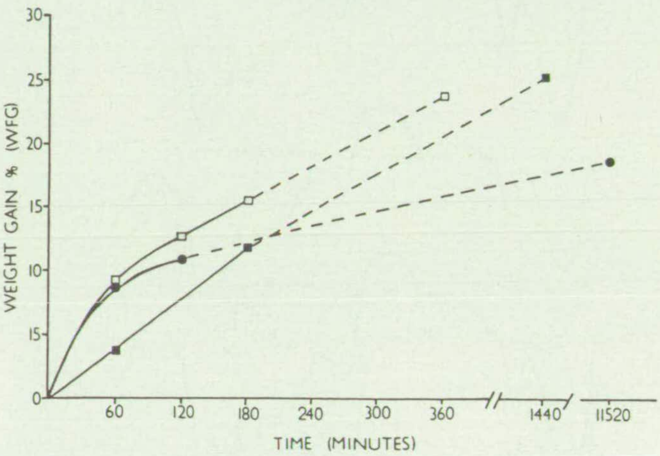


Fig. 2. Reaction rates of Corsican pine blocks with isocyanates (□—□ BuNCO, ■—■ HeNCO, ●—● HDI).

TABLE 3
Weight percent gain (W.P.G.) of oven dried samples of Corsican pine after reaction with isocyanates (number of replicates = 30)

Isocyanate	*W.P.G.*	*S.D.[1]*	*Reaction Time (mins.)*
n-Butyl	5·80	0·41	30
	9·83	0·42	72
	15·64*	0·64	255
	20·45	0·84	732
	31·41†	0·81	765
Hexyl	5·37	0·11	102
	10·93	0·10	235
	15·11	0·60	600
	25·58*	0·50	1440
	29·98*	0·23	360
1,6-diisocyanatohexane	6·72	0·66	12
	11·57	0·65	116
	14·70	0·92	1440
	21·81*	0·82	1800

Note: 1 – S.D. = standard deviation of weight percent gain (W.P.G.)
* – two reactions were performed to achieve this W.P.G.
† – three reactions were performed to achieve this W.P.G.

3.2. **Volume increases caused by treatments**

The volumetric increases (Table 4) caused by the butyl isocyanate (BuNCO) treatments are expected to be approximately proportional to the volumetric quantity of chemical added. Increases in wood volume were greater for those reacted with hexyl isocyanate (HeNCO) when compared to the amount of chemical added on. Conversely, samples modified with difunctional isocyanate, diisocyanatohexane (HDI), has less volume increase than would be expected from WPG data. In all cases swelling was greatest in the tangential, followed by the radial direction.

3.3 **Efficacy of treatments in preventing decay**

The data from all tests were plotted and the fit shown by linear

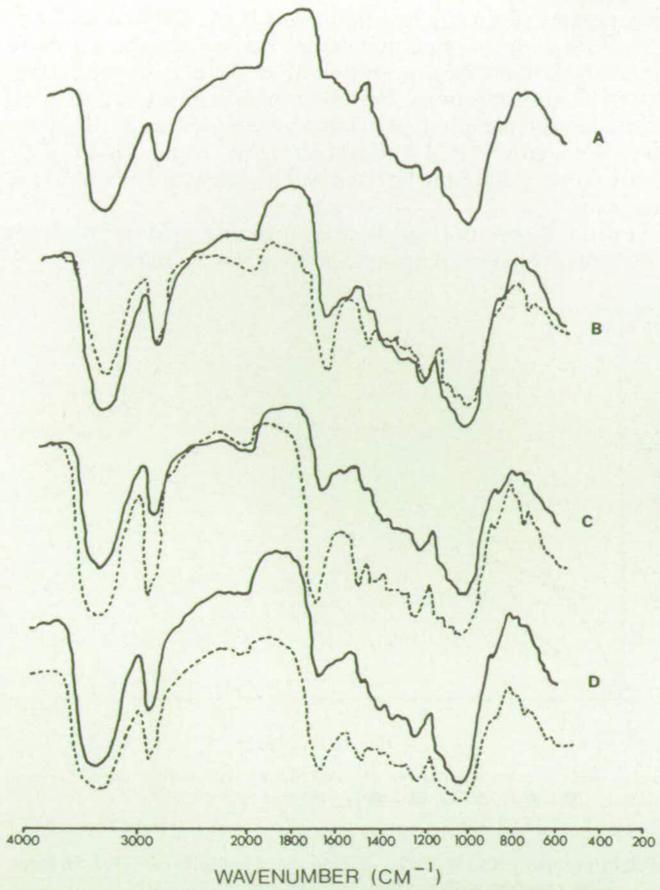


Fig. 3. Infra-red spectra of unmodified and modified Corsican pine. A) Control, B) n-butyl isocyanate —— 5 WPG; - - - 31 WPG, C) hexyl isocyanate —— 5 WPG; - - - 25 WPG, D) 1,6-diisocyanatohexane —— 6 WPG; - - - 22 WPG.

TABLE 4

Volume changes in Corsican pine blocks after chemical modification (number of replicates = 5)

Isocyanate	*W.P.G.*	*Increase in wood volume (%)*	*Calculated volume of chemical added*
Pyridine*	–	0·90	–
Pyridine: Acetone*	–	1·10	–
n-Butyl (BuNCO)	4·70	4·48	3·24
	9·33	5·45	6·18
	16·61	9·51	10·57
	19·92	13·37	13·63
Hexyl (HeNCO)	5·36	3·94	2·18
	10·89	7·52	4·28
	15·31	9·14	5·85
	30·05	15·30	11·81
1,6-diisocyanatohexane (HDI)	6·42	2·52	3·60
	10·15	3·87	5·64
	14·75	5·79	8·26

Note: BuNCO density = 0·88, HeNCO density = 1·2, HDI density = 1·04.
*Unmodified control samples.

regression analysis indicates a positive relationship between extent of modification and decay resistance (Figs. 4-7, Table 5). The threshold values showed greater variability between the four fungi (*C. puteana*, *G. trabeum*, *C. versicolor* and *P. sanguineus*) than between the different isocyanate modification types.

Blocks exposed to the brown rot fungus *C. puteana* (Fig. 4a-c) showed the highest threshold WPG protection values at 15.5 (BuNCO), 18 (HeNCO) and 13.6 (HDI). Less modification was required to achieve protection against the other brown rot fungus, *G. trabeum* (Fig. 5a, b). For this fungus WPG thresholds of 10 (BuNCO) and 10.6 (HDI) were noted.

The threshold WPG values for the white rot fungi (Figs. 6a, b and 7a, b), (*C. versicolor* and *P. sanguineus* (9.6, 12.2, BuNCO: 10.3, 11.7, HDI) showed nearly the same threshold response to the isocyanate treatments as the brown rot fungus, *G. trabeum*, irrespective of the treatment applied. The weight losses caused by *G. trabeum* were greater, however.

Weight losses for *G. trabeum* in control samples (Table 5) treated with pyridine alone were considerably greater than for pyridine acetone (29% pyridine, 18% pyridine:acetone); the values for the other fungi were similar for both pyridine and pyridine:acetone mixtures.

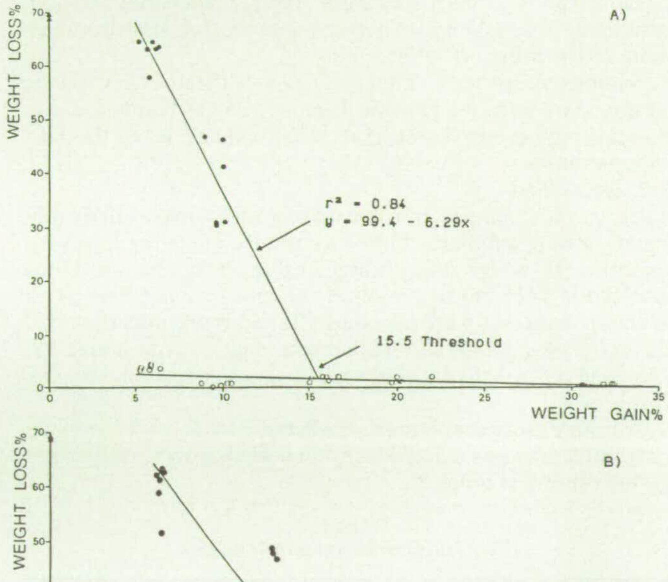


Fig. 4. Efficacy of A) n-butyl, B) hexyl isocyanate and C) 1,6-diisocyanatohexane modified Corsican pine after 16 weeks exposure to Coniophora puteana *in a soil block test (●—● decay + operational loss, ○—○ operational loss, ▲ pyridine control, △ pyridine:acetone control).*

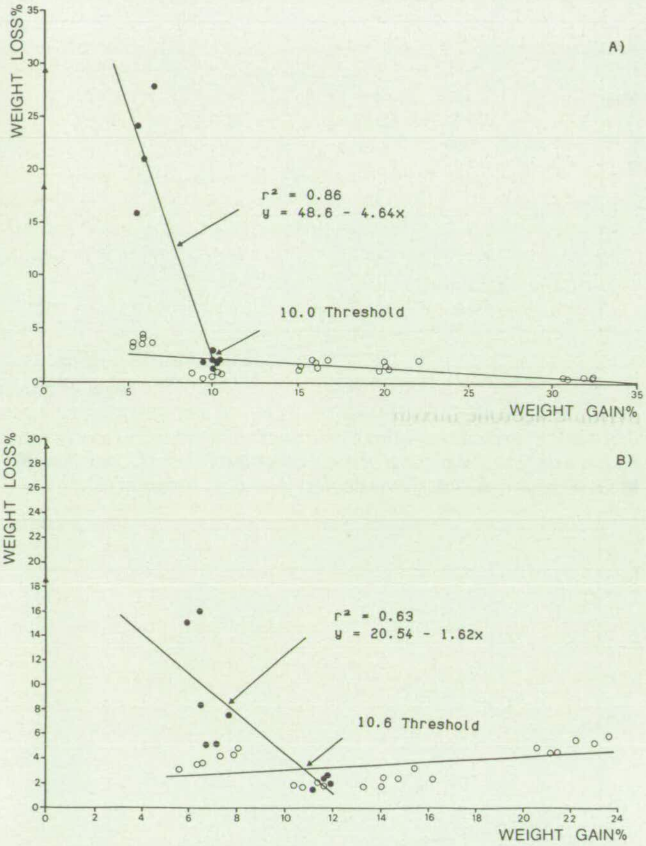


Fig. 5. Efficiacy of A) n-butyl and B) 1,6-diisocyanatohexane modified Corsican pine after 16 weeks exposure to Gloeophyllum trabeum *in a soil block test (●—● decay + operational loss, ○—○ operational loss, △ pyridine control, ▲ pyridine:acetone control).*

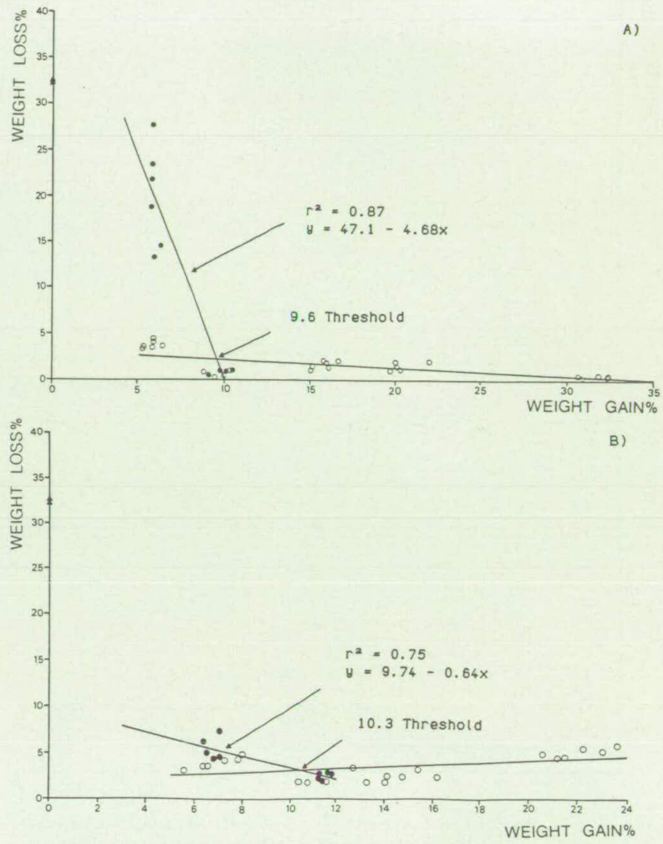


Fig. 6. Efficacy of A) n-butyl and B) 1.6-diisocyanatohexane modified Corsican pine after 16 weeks exposure to Coriolus versicolor *in a soil block test (●—● decay + operational loss, ○—○ operational loss, ▲ pyridine control, △ pyridine:acetone control).*

TABLE 5

Average and standard deviation (in brackets) of weight loss percent in isocyanate modified Corsican pine sapwood after 16 weeks exposure to decay fungi in soil block test. Threshold control values for each of the isocyanates are emphasised

Chemical	*Weight percent gain*	*% weight loss after exposure to*				
		C. puteana	*G. trabeum*	*C. versicolor*	*P. sanguineus*	*Sterile control*
Pyridine (control)	0	69·81 (1·02)	29·47 (4·10)	32·55 (3·74)	40·27 (1·73)	2·67 (0·43)
Pyridine + acetone (control)	0	69·31 (1·40)	18·48 (13·82)	32·42 (3·00)	37·23 (6·84)	1·86 (0·31)
n-Butyl Isocyanate	5·80	62·70 (2·47)	22·27 (5·09)	19·90 (5·48)	18·38 (3·25)	3·79 (0·40)
	9·83	37·73 (7·92)	2·03 (0·55)	0·93 (0·19)	7·22 (3·42)	0·64 (0·26)
	15·64	0·63 (0·46)	1·02 (0·55)	1·20 (0·26)	0·96 (0·38)	1·72 (0·40
	20·45	1·21 (0·45)	0·91 (0·45)	1·25 (0·50)	0·89 (0·41)	1·54 (0·41)
	31·41	0·30 (0·07)	0·53 (0·05)	0·51 (0·06)	0·42 (0·29)	0·51 (0·07)
	Threshold	15.5	10·0	9·6	12·2	
Hexyl Isocyanate	5·37	60·09 (4·34)	NT	NT	NT	1·01 (0·16)
	10·93	41·35 (7·43)	NT	NT	NT	0·36 (0·06)
	15·11	5·57 (3·42)	NT	NT	NT	0·11 (0·09)
	25·58	0·00 (0·00)	NT	NT	NT	0·10 (0·13)
	29·98	0·20 (0·16)	NT	NT	NT	0·49 (0·08)
	Threshold	18.0				
1,6-diisocyanatohexane	6·72	49·70 (3·09)	15·48 (0·69)	5·18 (1·35)	9·94 (0·82)	3·94 (0·62)
	11·57	13·04 (1·68)	2·26 (0·47)	2·30 (0·46)	2·41 (0·47)	2·11 (0·64)
	14·70	2·01 (0·96)	1·92 (0·63)	1·99 (0·38)	1·71 (0·44)	2·30 (0·52)
	21·81	5·25 (1·04)	4·59 (0·48)	4·85 (0·20)	4·62 (0·19)	5·06 (0·54)
	Threshold	13.6	10·6	10·3	11·7	

Note: NT = not tested.

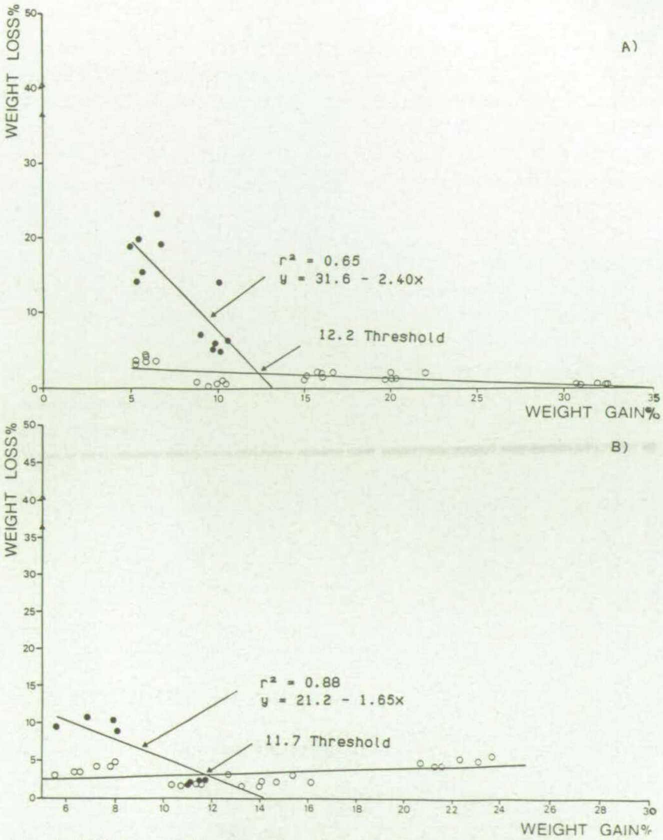


Fig. 7. Efficacy of A) n-butyl and B) 1,6-diisocyanatohexane modified Corsican pine after 16 weeks exposure to Pycnoporus sanguineus *in a soil block test (●—● decay + operational loss, ○—○ operational loss, ▲ pyridine control, △ pyridine:acetone control).*

3.4. Moisture content after soil-block tests

Sterile control unmodified blocks reached average moisture contents of 31.8% during the tests whilst isocytanate modified specimens reached lower moisture contents (Fig. 8). The moisture contents showed a consistent decrease with increasing extent of modification (Fig. 8).

Moisture content was influenced by decay fungi, isocyanate treatment and by the interaction of these two factors (Table 6). Statistical analysis showed these to be highly significant (P<0.001). The influence of the decay fungi on the block moisture contents was most pronounced at low modification levels (Figs. 9 and 10). *Coniophora puteana* proved capable of wetting the blocks sufficiently for decay to develop. With the other test fungi the moisture contents were below those generally regarded as necessary to allow decay to occur.

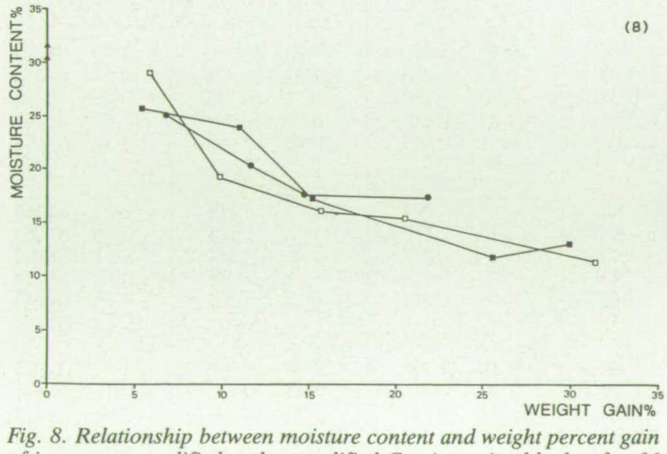


Fig. 8. Relationship between moisture content and weight percent gain of isocyanate modified and unmodified Corsican pine blocks after 16 weeks incubation under sterile conditions in a soil block test (□—□ n-BuNCO, ■—■ HeNCO, ●—● HDI).

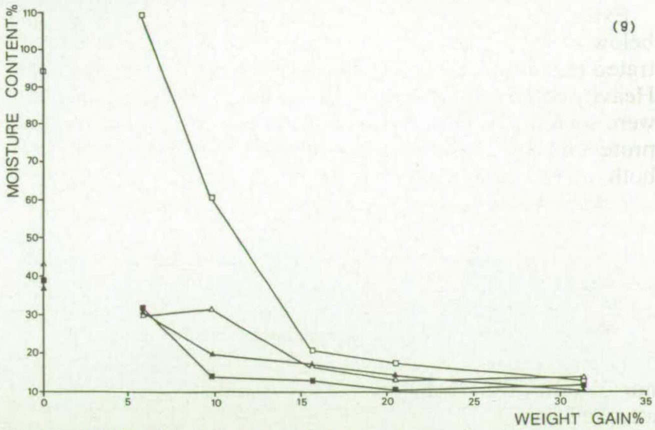


Fig. 9. Relationship between moisture content and weight percent gain of n-butyl isocyanate modified Corsican pine blocks after 16 weeks incubation with four decay fungi in a soil block test (□—□ C. puteana, *■—■* G. trabeum, *▲—▲* C. versicolor, *△—△* P. sanguineus*).*

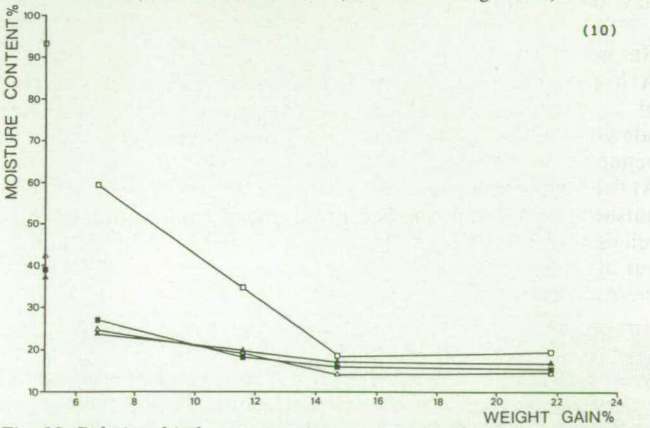


Fig. 10. Relationship between moisture content and weight percent gain of 1,6-diisocyanatohexane modified Corsican pine blocks after 16 weeks incubation with four decay fungi in a soil block test (□—□ C. puteana, *■8♦* G. trabeum, *▲—▲* C. versicolor, *△8△* P. sanguineus*).*

TABLE 6

A summary of the ANOVA tables showing the difference in mean moisture content among treatments. A). n-Butyl isocyanate samples; B). 1,6-diisocyanatohexane samples

A). n-Butyl isocyanate

Source of variation	*% S.S.*	*d.f.*	*P.*
Fungal species (F.S.)	11·70	3	<0·001
W.P.G.'s	18·93	4	<0·001
Interaction F.S. & W.P.G.'s	69·16	12	<0·001
Residual	0·21	60	

B). 1,6-diisocyanatohexane

Source of variation	*% S.S.*	*d.f.*	*P.*
Fungal species (F.S.)	29·58	3	<0·001
W.P.G.'s	38·63	3	<0·001
Interaction F.S. & W.P.G.'s	30·04	9	<0·001
Residual	1·75	48	

3.5. Gross distribution of decay within the blocks

Visual examination of the external and internal condition of the blocks modified to levels above the threshold protection values showed that the blocks were apparently internally sound.

Examination of the brown rotted blocks tested to levels just below the threshold values revealed that attack was concentrated only in the latewood of the outer areas of the samples. Heavily colonised areas of both early and latewood tracheids were seen in the block centres indicating an envelope type of protection (Fig. 11). At the low modification levels (<6 WPG) both early and latewood areas of the blocks were heavily attacked throughout the specimens. When exposed to *C. puteana* these heavily attacked blocks showed severe shrinkage and wall cracking. With *G. trabeum* shrinkage and cracking was less.

White rot attack by *C. versicolor* and *P. sanguineus* showed no distinguishing bleaching or discoloration of the blocks. Even at the low level of modification treatment neither early nor latewood growth rings bands appeared preferentially attacked.

3.6 Microscopic distribution of decay and hyphae

Microscopic examination of hyphal distribution revealed distinct decay patterns in relation to treatment levels.

BROWN ROT:
At low levels of chemical modification (<6%) mycelial strands of *C. puteana* were widely distributed in both early and latewood tracheids and in the rays. Pit membrane removal, pit penetration and bore hole formation were noted (Fig, 12a, b). At the higher sub-threshold values (ca. 10%) latewood on the outside of the block showed pronounced colonisation of the cell lumina, although hyphae were seen in this region throughout all cell types, even in sound tracheids. In the insides of these blocks extensive colonisation, similar to that of lower

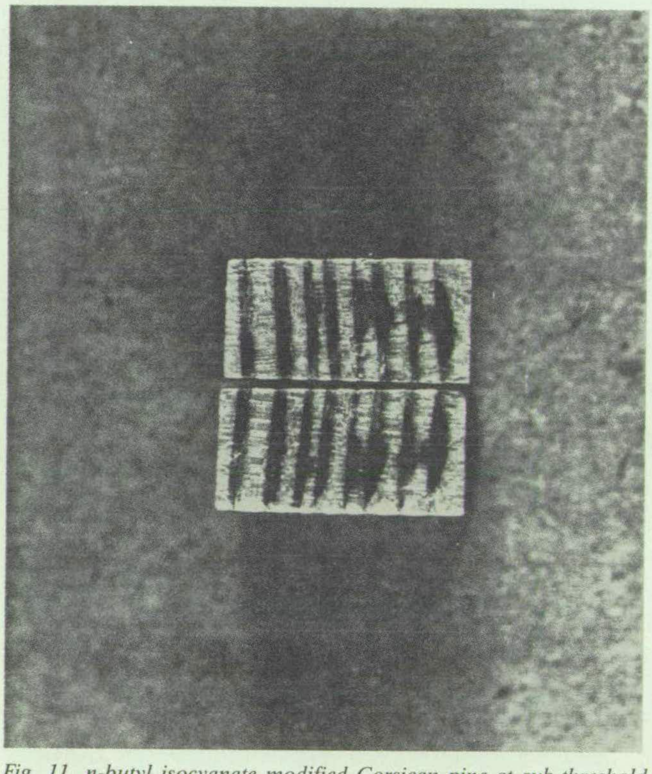
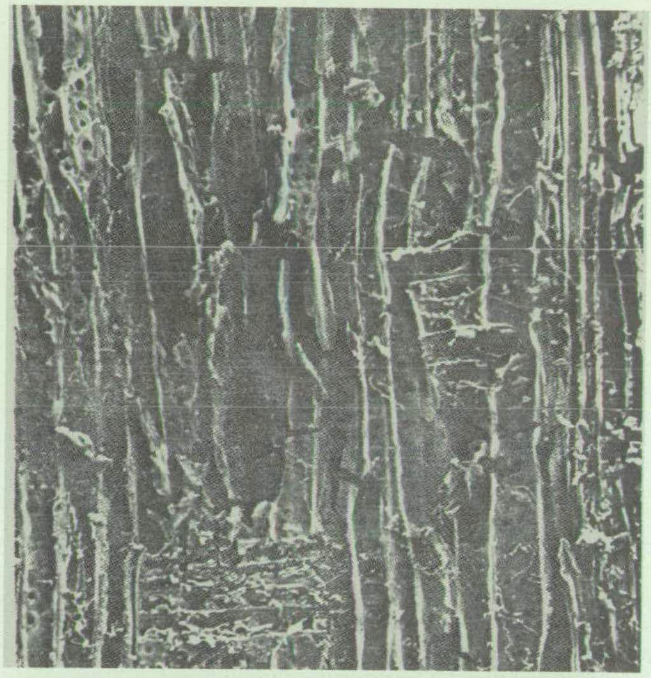


Fig. 11. n-butyl isocyanate modified Corsican pine at sub-threshold WPG exposed to C. puteana *in the soil block test. The block shows an outer envelope of protection with localised decay in latewood areas inside the block.*

modification levels, was seen. At higher levels of modification (>14%) a few hyphae were noted in the rays and in the latewood tracheids. Observations made on *G. trabeum* infected modified wood were essentially similar although the extent of hyphal colonisation was less at the higher levels of modification.

WHITE ROT:
The unmodified control samples of blocks decayed by *C. versicolor* and *P. sanguineus* showed colonisation of all tissues, bore hole formation and generalised erosion patterns over the wood cell wall surfaces. At low levels of modification fewer hyphae were visible with the majority being located in the ray parenchyma. In the axial tracheids more hyphae were visible in the latewood. At higher modfication levels (>9% WPG) hyphal colonisation in the blocks was less: in some cases no internal hyphae were noted.

Diisocyanatohexane treated blocks showed less hyphal colonisation by white rot fungi than those reacted with butyl isocyanate.



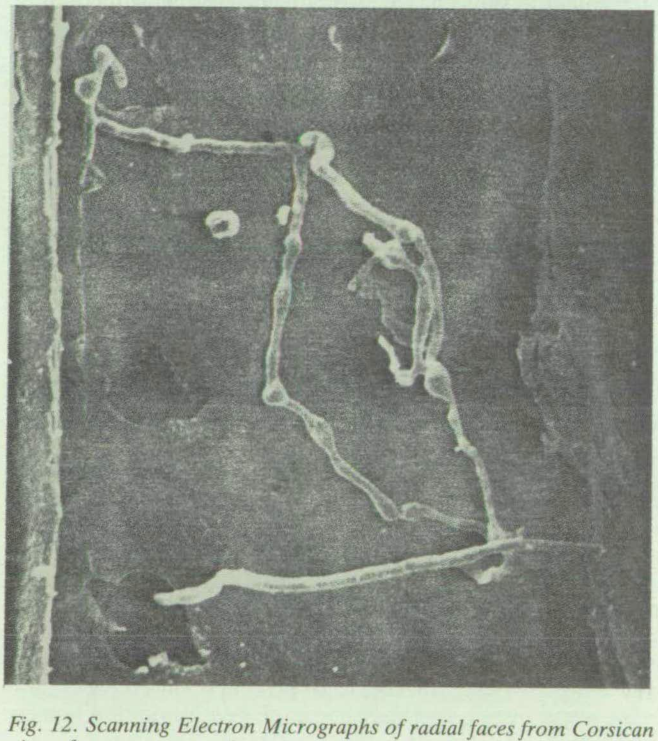


Fig. 12. Scanning Electron Micrographs of radial faces from Corsican pine after exposure to C. puteana *in soil block tests. a) unmodified wood showing heavily decayed faces, b) sub-threshold WPG n-butyl isocysnste modified sample.*

4. Discussion

Chemical modification with the three isocyanates tested afforded substantial bio-protection of Corsican pine against *C. puteana*, *G. trabeum*, *P. sanguineus* and *C. versicolor*. This was achieved without the presence of toxic chemicals after treatment and at levels of reaction not causing major loss of mechanical properties.

Earlier soil block decay tests by Ellis & Rowell (1982) show adequate decay resistance against *G. trabeum* in Southern pine treated with BuNCO to 18 WPG. In the current work, a lower WPG (10), was sufficient to prevent decay by *G. trabeum)* in Corsican pine modified with BuNCO using a matched soivent (pyridine:acetone). Ellis & Rowell do not comment on the performance of blocks treated to lower levels hence it is not possible to compare our data precisely with those of Ellis & Rowell. The level of protection observed in our work is similar to that reported by Kalnins (1982) who used *G. trabeum)*, *Lentinus lepideus* and *C. versicolor* as test organisms againt wood blocks treated with a range of pyridine catalysed isocyanates.

There are no published data on the use of HeNCO and HDI in fungal decay tests on whole wood. The data reported here suggests that the monofunctional HeNCO may be less effective than either BuNCO or the difunctional HDI. Thus the small increase in chain length between butyl and hexyl monofunctional isocyanates does not appear to have given an improvement in performance with the catalysts and swelling systems used in this work. There appears to be little difference in threshold values between BuNCO and HDI. However the intensity of decay (% weight loss) at treatment levels below the threshold values suggests that the four fingi were more affected by samples reacted with HDI than with BuNCO.

The envolope protection effect and the enhanced attack of the latewood regions in the blocks exposed to lower modification levels can be explained by the reagent concentration being too low in the rection vessel. Thus the solution entering narrow latewood lumina contains insufficient reagent to give adequate reaction with the surrounding thick cell wall. Hence the reaction may become diffusion controlled, with inadequate reagent diffusing into the cell spaces to replenish that used up in early stages of the reaction. This effect has important implications for the treatment of larger sized pieces of wood.

To date few studies have addressed the mechanism of bio-protection afforded by non toxic forms of chemical modification. According to Rowell (1983) there are two major machines. One hypothesis proposes that modification alters the wood cell wall substrates so that fungal enzyme degradation systems may be unable to bind or act on the altered wood components. Another hypothesis proposes that the hydrophobic effect of chemical modification within the wall limits the accessibility of water to wood hydroxyl groups. This limits the available water *within* the wood cell wall. Chemical modification may also physically block the microcapillaries in the swollen wood cell wall so that degradation enzymes and other large molecules are unable to travel within it.

Chemical modification with the isocyanates at the 10-15 WPG treatment level appears to have prevented the sterile blocks from wetting sufficiently for any fungal decay to occur (Fig. 8). Moisture content shows decrease with increase in modification level. It is possible that the fibre saturation point values are decreased with increasing modification as fewer wood cell wall hydroxyis are available for water bonding.

When similar blocks were exposed to *G. trabeum*, *C. versicolor* and *P. sanguineus* the fungi were unable to wet the blocks sufficiently to allow decay (Fig. 9). However, modified blocks exposed to *C. puteana* showed higher threshold modification values (15·5, 18 and 13·6: for BuNCO, HeNCO and HDI respectively) and sub-threshold value modified blocks showed considerable wetting. It is not known whether the degree of wetting is controlled by the ability of the fungus to wet the wood cell wall or by the presence of extensive fungal biomass within the blocks. Whatever the reason however, the lowered moisture content appears to have been the major limiting factor in reducing the level of hyphal colonisation within the wood blocks and controlling decay in these tests. Further investigations to examine other hypotheses, stated above, including the susceptibility of modified wood polymers to fungal degradation and microcapillary blocking effects are in progress.

The work reported suggests that reduction in the hydrophilic character of wood may bring about significant levels of preservation against fungal attack. It seems likely however that the hydrophobic modifying group must be introduced within the wood cell wall not simply attached to exposed cell wall surfaces.

5. Conclusions

The results of this work show that the catalysed isocyanate reactions with Corsican pine wood blocks can provide protection against decay and a reduction in fungal activity within wood blocks.

Limited water access to modified specimens suppressed colonisation and decay by **G. trabeum** and *P. sanguineus* at 10, 9·6 and 12·2 WPG in BuNCO reacted blocks and at 10·6, 10·3 and 11·7 WPG in HDI reacted samples.

The similar threshold control values obtained for these three fungi for the BuNCO and HDI reacted samples, suggest that monofunctional and difunctional isocyanate reactions with wood hydroxyis do not give different preservative properties despite possibility to cell wall polymer cross linking reactions with HDI.

Control of decay caused by *C. puteana* required greater modification of the wood. Threshold control values for *C. puteana* were estimated at 15·5, 16 and 13·6 WP-G for BuNCO, HeNCO nd HDI respectively. These results indicate HeNCO may be somewhat less effective in controlling decay than the other two isocyanates used. At this stage however, the evidence presented suggests that reaction with three isocyanates affords control against fungal decay at modest levels of modification. It seems likely that the control is brought about at least in part by the associated reduction in moisture content. The ability of *C. puteana* to provide moisture from source to wood may explain the apparently greater tolerance shown by this fungas to urethane modification.

6. Acknowledgements

The authors acknowledge Drs. W. B. Banks and H. A. Earl for help and discussion and the Brazilian Government for Scholarship assistance for FCC.

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DISCUSSION ON PAPER 6

Chairman: Dr. C. R. Coggins

DR. C. R. COGGINS: Thank you very much, Fatima and Mike. We now have some time for questions and can I ask you please to wait for the roving microphone.

DR. A. F. BRAVERY (B.R.E.): Thank you very much, Mike, a very interesting paper and a very rational, objective and careful study. I wanted just to take up the photograph you showed where you referred to the envelope treatment. Looking at the photograph, the envelope is at best very thin. Is that at or close to the threshold W.P.G.s that you have been quoting or is it sub-threshold level.

MISS F. CARDIAS: Sub-threshold.

DR A. F. BRAVERY: It is sub-threshold then because it looks as though there is a fundamental penetration distribution difficulty to be overcome here.

DR. M. HALE: Yes, the treatment system did not involve vacuum systems.

MISS F. CARDIAS: In the reaction cylinder some pressure is built up due to heating but we do not have a homogeneous distribution of the modification. You could say that we did not have very good penetration because the middle of the block was not treated.

DR. A. F. BRAVERY: One supplementary question if I may. Have you actually tried to physically wet the blocks out by impregnating them? The amount of passive wetting in the fungal test system may have been slight but I wonder if the blocks can actually receive more water if you physically introduce it?

MISS F. CARDIAS: I did not try to physically wet these blocks but I have exposed a different block size in very high moisture content unsterilised soil. With this soft rot type of test I still have very good bio-protection.

DR. M. HALE: I think you can increase the moisture content of this material in the lumina but you do not increase the wetting in the wood cell wall and so your fibre saturation point is depressed in this material. I personally have not produced data to support these views but work has been published on Acetylated Wood by Rowell and Banks (1987).

(Rowell, R. M. and Banks, W. B. (1987). Tensile strength and toughness of Acetylated Pine and lime flakes. *British Polymer Journal,* **19:** 479-482).

MISS F. CARDIAS: Varlone Martins, currently working at Bangor, has produced substantial data on the supression of water uptake in isocyanate modified wood and the alteration of absorption isotherms.

MR. D. LOVE (Rhone-Poulenc/Manchem): I would like to ask two questions of a chemical nature. First of all, have you any idea what the proportion of available hydroxyl groups are, in fact, reacted by your isocyanates? Secondly, has any work been done to your knowledge using dioisocyanates of varying chain length to perhaps see the effect of inter versus intra molecular hydroxyl bridging? I am thinking perhaps that you could bridge two polymer chains in the cellulose structure.

DR. M. HALE: We do not have precise data on what proportion of the available hydroxyl groups have been reacted within the wood.

MISS F. CARDIAS: We have the theoretical part because we know the composition of the wood, *i.e.* we know roughly how much carbohydrate and how much lignin we have. Thus the amount of chemical supplied for reaction was in abundant excess of the amount of hydroxyl groups available in the test specimens. The weight per cent gain achieved with monofunctional isocyanates is proportional to the number of hydroxyls reacted.

DR. M. HALE: I would imagine that very few of the total hydroxyl groups are reacted because of the accessibility of the cellulose hydroxyls to reactions. If you look at reactions in the cell wall you will find that a lot of the reactions appear to get on to the lignin hydroxyls at the lower levels of modification. Fungi have at least to modify lignin, possibly at these centres, in order to degrade the other components of the wood cell wall. With some isocyanates you can continue to react of the wood cell wall up to exceedingly high weight per cent gain. Here we are talking above 25 per cent; if you continue to react you can get up to say 180 and 190 per cent weight gains with some isocyanates: under these conditions blocks blow apart and you end up with masses of hydrophobic wood fibre. Under these conditions of high weight per cent gain some reaction into the cellulose possibly occurs.

That apart we have attempted to answer your first question about what proportion of hydroxyls would react. Here we are of course more concerned with the biological aspects.

The second question you ask is about the chain with di-isocyanate. We have looked at various commercial di-isocyanates, the more commercial ones, to bond wood chips together in particle board manufacture by the process patented by Bangor. Our press boards bonded this way allow inter fibre bonding and this data should be available from our people who make these boards.

MR. D. LOWE (Rhone-Poulenc/Manchem): Is there any evidence that you can, in fact, control the inter and intra molecular hydroxyls.

DR. M. HALE: Well, we have not tried mixtures in that respect and it is very difficult to know exactly what your reactions are because you could not only get bridged reactions but you could get other reactions under certain conditions.

MR. D. LOWE: I see the problems, thank you very much.

DR. M. MURPHY (Imperial College): Thank you for your paper, Mike, it is very interesting. Why did you extract the samples before reacting them with isocyanates?

DR. M. HALE: Well, my view is that extraction is done to avoid further extraction during reactions which would interfere with the calculation of weight changes. Fatima may like to comment.

MISS F. CARDIAS: To achieve good preservation we have to react the non extractable fraction of the wood components. Isocyanates are very reactive and so it is sensible to take out the extractable part because there is no point in reacting the leachable material in the wood. It is better to have the structural material reacted in order to have fixed isocyanate/wood fibre material.

DR. R. MURPHY: Do you think if you left the extracts or the components . . . .

MISS F. CARDIAS: They are going to react with the isocyanates. Yes, I think so.

DR. R. MURPHY: Just to follow up what Tony mentioned as well, it seems from your work you have indicated that inhibition of colonisation because you make the wood more hydrophobic and it depresses the moisture content, is one of the mechanisms by which this isocyanate protection can work but do you think if liquid water was able to penetrate the treated wood block even though the cell wall is made more hydrophobic you might find that you have quite a high degree of colonisation.

DR. M. HALE: I think your comments are something which has been sitting in my mind for quite a long time. You mentioned that if you managed to get the wood wet enough, are you still going to get colonisation and are you still going to achieve protection when you do that? For example some fungi will be quite happy to live in almost saturated wood and some types of fungi would be quite happy top decay under those conditions.

I think the performance would be quite good because you are locking up the wood cell wallthus we are not totally relying on the hydrophobic hypothesis. You can press particleboards from isocyanate modified flakes and still get good performance under moist conditions. So I would suggest that you still have substantial protection.

DR. D. J. DICKINSON: This is just a follow on from what you have been saying, Mike. One of the techniques that we have been using in study is the effect of preservatives and getting away from water relationship and anatomy problems is to use modified thin section techniques and it struck me, listening to what you were saying, that if you use a thin section technique on that wood you might get some very good indications as to the mechanisms of the protection. I think I can remember a young scientist reporting on it and actually doing work in this area.

DR. M. HALE: Well, I really would not want to talk about the work we are doing on modified thin sections to a great extent at the moment. We have done a considerable number of soil thin section work with chemically modified material and we would like to report on that at another meeting elsewhere. There are many advantages to using thin section work because you are using far less reagent and you can get much more homogeneous reactions. We have recently been developing thin section work for use with brown rots. Currently we have had the wood moisture content very high, possibly too high for good brown rot activity, and we are not getting any decay of modified material under those conditions.

MR. D. CAHILL (Irish Science Agency): Mike, I want to refer to a paper of a review document of Lundquist where he points to the future regarding chemical modification and he suggests strongly that the main application would be in the protection of board materials as opposed to the sawn timber. Would you comment on that?

DR. M. HALE: Yes, I quite agree with that. We felt that you have to look at what was going on in slightly larger chipped material because we are making boards at the moment. At the levels of chemical add on we had originally achieved for some of board manufacturing processes we did not have absolute bio-protection. When you look at the data for the reactions, we have something like 10 per cent of chemical add on in our chips within the boards. For good bio-protection we will need slightly longer cook times prior to pressing to achieve modification in the 15+ W.P.G. We do believe in the short term, the next thing in chemical modification is going to be boards modified by various chemicals. As you probably know, the Biocomposites centre is now building a unique pilot board plant to take this into account.

MR. L. SHEARD (Danish Technological Institute): You have referred to protection regarding the use of poisonous substances in what you describe as a fairly complex process using some rather nasty solvents. I wonder if you would comment on the efficiency of your solvent recovery process.

That is one question, the second question related to all projects. I wonder if you could comment on the possibility of long term low level emissions of waste from isocyanate products. It is something parallel to the situation you have had with formaldehyde. Thirdly, that your effective per cent weight gains of 15 per cent, you are talking about impregnating something in the order of 75 kilos per cubic metre. I wonder if you could then comment on the possibility of the emission of toxic gases under combustion. As you know, toxic gases from polyurethane foams are bad news at the moment in furniture.

DR. M. HALE: Thank you. This is a question I planted with the Chairman in case it did not come up. Toxic gas emission from burning treated wood itself from the environmentalist's view may be a problem. Burning isocyanate modified wood may, and I do not have data to show, cause significant problems, but the levels of urethane present are much lower than in polyurethane foams. We do not necessarily consider isocyanate modification in this case as being what we will end up with as an industrial process.

We are using isocyanate modification here as an example system to show how modification works. We are trying to look at the mechanism for protection. We are following the idea that moisture modification is a key feature in that and so we start with isocyanate. Isocyanate may not be the final answer. One the other hand, we may well learn to deal with these gaseous emissions by burning them under particular conditions. As far as I know the material we are working with is no more flammable than ordinary C.C.A.-type treated wood but I do not have the data to support that.

Low level emissions from U.F.s are caused by a number of factors due to the molar mixes of U.F. resins and a certain number of hydrolytic reactions occur with materials. Our clean up procedures take out unreactive material and further unreactive material then reacts with water which is present in the air to give you your urethanes. So we do not envisage any problems with isocyanates because they will continue to react with the wood and any water that is lying around, *i.e.* as water vapour. The best way to neutralise the isocyanate is the use of water.

Emission of things like pyridine; once again pyridine is what we have used in this particular study because it is comparable with work which was done in the past. Solvent recovery, is that your other question?

MR. L. SHEARD: It was the efficiency of solvent removed from the treated timber afterwards that I was interested in.

DR. M. HALE: Well, we are really scientists working in the laboratory. We have not looked at efficient methods of getting our solvents out. We are merely using oven dried material which brings our solvents out and is best obviously done in proper safe conditions. If you look at some of the I.R. spectra you find there are no free isocyanates lying around and there are no peaks which are attributable to solvents.

DR. C. R. COGGINS: Thank you very much for a very lively topic, and a stimulating discussion from Fatima and Mike. I think we have been very privileged to have an insight to this work which is obviously at the leading edge of technology in this area. Mike has intimated a couple of times that this is not necessarily an indication of where the technology will end. It is going to lead to new areas and I think the prospect for preventing decay in solid timber and composite material simply by excluding water rather than using bio-cides is an exciting prospect. Thank you, Mike, thank you, Fatima and please join with me in expressing our thanks. *(Applause)*.

B.W.P.D.A. CONVENTION 1990

THE EFFECTS OF PESTICIDES ON HISTORIC MATERIAL

by R. E. Child

1. Introduction

The toxicological effects of pesticides are, in general, well researched and recognised. However little work has been carried out on the propensity of some materials to damage cultural property. Pesticide formulations are designed to be safe in use and to cause no harmful side effects on the objects they are protecting, but can in some instances still cause long term problems.

Many historic objects are highly prone to deterioration owing to their age, fragility, poor technology and having outlived their designed life-span. Conservation practice in museums and other repositories of historic material, demands rigourous standards of testing treatments to ensure their suitability for the indefinite preservation of the objects. It was as part of that testing regime that the damaging effects of some biocides on some materials was noticed.

The following categories of pesticides considered, are those insecticides and fungicides commonly used in the treatment of historic, artistic and natural history material, in this country, and which are cleared for use under the Pesticides Regulations Act 1986. The method of application, the carriers, solvents, adjuvants, etc., will also be considered where they are harmful.

Fumigants

Methyl Bromide (Bromomethane) CH_3Br

Use in museums: as a general fumigant insecticide against most insect pests.

Effect on objects

At *normal temperatures* (10-20°C.), and *low relative humidities* (<65 per cent R.H.) and when used at the standard dose rate of 16 gm/m^3 for short fumigation times, there is little detectable effect on most materials. Damp materials or those with a high moisture content may be adversely affected (see later).

At *high temperatures* methyl bromide can decompose to give corrosive vapours of hydrogen bromide that are damaging to most classes of materials.

At *high humidities and concentrations* methyl bromide reacts with organic-sulphur containing materials such as animal proteins, some rubbers and plastics, and has been known to produce a residual mercaptan-like smell which airs off with time, but may leave a permanent weakening of the object. Some paper materials have been yellowed and weakened after fumigation, and photographic materials tarnished.

It is recommended that sulphur-containing material such as wool, leather, parchment, vellum, horsehair (in upholstered furniture etc.), natural history specimens, and paper and photographic prints and negatives, should not be fumigated in highly humid conditions or if the objects themselves have a high moisture content (>15 per cent E.M.C.).

When used in warm, dry conditions with good gas mixing to avoid stratification, methyl bromide appears to be an effective and non-injurious fumigant. It should be used in its pure form and not with the warning lachrymatory additive chloropicrin, which is known to cause corrosion of metals in humid conditions and to change some pigment colours.

Phosphine PH_3

Use in museums: as a fumigant insecticide, particularly against wood-borers in structural timbers.

Effect on objects

Phosphine is not highly regarded as a museum fumigant primarily because of its flammability, and its generation by the reaction of a metal phosphide with moisture, which could lead to unacceptable high humidities.

Mr. R. E. Child: We had a shortage of material and so it really was not a very good test. We distributed them at a distance of 10 metres apart in both the furniture stores of my museum and also external display areas where we knew there was active *Anobium*. We did just the standard blank against a pheremone baited trap using a modified cockroach type, sticky blunder trap system, and there was just no result from any of it. The blank blunders and the pheremone blunder traps were both ignored completely by the woodworm.

Dr. A. F. Bravery: Have those particular traps been used in a situation where there is a very high population of *anobium* beetles nearby just simply to test their ability to attract in the first place?

Mr. R. E. Child: No, that I think was the failure of the whole experiment really; that this material became available rather suddenly and we lacked a good site to try it out on. Really just to try out the exercise, because the material was there, we tried it on that site at my own museum knowing that there was active *Anobium* infestations both outside and in structural wood in a barn and also inside our store of furniture. It was really just a trial, just a try out, and it was not published. We never did much more to it because of that. It was not really very good.

Dr. A. F. Bravery: Perhaps we might get together. We can produce adult *Anobium* at any time of the year in some numbers.

Mr. R. E. Child: Yes, I think that is the way to do it.

Mr. E. A. Hilditch (Cuprinol): It really was a most excellent paper you presented. You have not had a chance to use your Welsh. Your dry rot; was it indeed dry rot? It looked to me more like *asterostroma*.

Mr. R. E. Child: You are undoubtedly correct. I am not very good at the rots.

Mr. E. A. Hilditch: Do not rely on my recognition from a slide.

Mr. E. M. Buchan (Private Member): You mentioned three fumigants I think, dichlorvos, methyl bromide and phostoxin. There was one in common use in the United States for many years and they used it in tenting operations in buildings, which must have included metals as well as all textiles, called Vikane. I do not know the chemical composition of it. Have you tried that?

Mr. R. E. Child: No, it is not cleared for use in this country. In the United States it is very commonly used, Vikane, sulphuryl fluoride, is the most common fumigant because it has advantages over methyl bromide. They are now just beginning to discover that there are one or two problems with it. Again all the problems associated with these fumigant gases are associated with high humidities. If you reduce humidity in the treatment, reduce the moisture content in the object, there is no problem. That is also true of the retention of the gas. Ethylene oxide, which is now not used, the retention of the gases was associated with higher humidities.

Mr. L. B. Woodhouse: Thank you very much, Bob. I think we have been very fortunate in having Bob Child speak to us this afternoon. Many remedial papers have not been terribly practical and I think that we all found this very entertaining as well as educational. We hope to have the opportunity of hearing from you some time in the future. *(Applause)*.

At *high humidities* phosphine will react with most metals, tarnishing and corroding them; particularly vulnerable are objects made of copper or silver, or their alloys. The corrosive nature of phosphine is thought to be enhanced by some aerial pollutants such as salt and ammonia.

Inert Gases (Carbon dioxide, Nitrogen, etc.)
At present inert gases are not cleared for fumigation use, but carbon dioxide is at present being evaluated for clearance under the 1986 Act. Inert gases offer an attractive alternative to conventional fumigants with their low toxicities and few side effects on objects.
Use in museums: as fumigants against most stored product pests especially where conventional materials may be inappropriate, such as damp woollen costume. Also inert gases are increasingly used in the long term storage of sensitive objects such as fur coats, butterfly collections, etc.

Effect on objects
At *high humidities* carbon dioxide fumigation can cause a slight lowering of the pH owing to the formation of carbonic acid. The reaction appears to be reversible with the pH returning to normal after release of the gas, and no harmful effects on objects have been observed. However there is concern that fumigations may be carried out at higher than ambient temperatures to increase their efficiency of kill, and to decrease fumigation time. The higher temperature (~35°C.) may produce unacceptable humidity changes when used on fragile objects.

Para-Dichlorobenzene (P.D.B.)
Use in museums: P.D.B. is still commonly used in museums as a fumigant despite serious doubts as to its effectiveness and conern over its health hazards.

Effect on objects
There are few reports of damage occurring on objects through the use of P.D.B., but some tests have indicated certain materials are at risk. The solvent action of the vapour can cause the migration of dirt etc. causing localised staining, and can soften and distort some plastics, resins and waxes. Cellulose nitrate (a common ingredient of varnishes, adhesives, and plastics), polystyrene and animal glues are known to be affected. In some tests paper products were found to be discoloured and weakened while some pigment colours were found to be altered, by exposure to P.D.B. vapours.

Dichlorvos (2-2 dichlorovinyl dimethyl phosphate). D.D.V.P.
Use in museums: Dichlorvos, commonly known by its trade name Vapona, is normally used as a fumigant absorbed onto polyvinyl chloride strips. It has been recommended for the protection of vulnerable natural history specimens and textiles by installing the strips into stores, display cases and storage boxes.

Effect on objects
D.D.V.P. when used at the correct dosage rate of, typically, 0·3 p.p.m. atomospheric concentration, and at low relative humidities appears to be relatively harmless. However at higher humidities D.D.V.P. can hydrolyse to dimethyl hydrogen phosphate and dichloroacetaldehyde. Further oxidation can give chloroacetic acids which can often be detected by their acrid sour odour.

At high concentrations and humidities, D.D.V.P. adversely affects most metals – iron and steel will corrode, copper, brass and silver will tarnish, and tin, lead and zinc can develop a white coating. A number of natural and synthetic resins and plastics were softened by exposure to high levels of D.D.V.P. vapour, and some Acid Red carpet dyes were discoloured.

It is recommended that D.D.V.P. strips be used only in cool (<20°C.) and dry (<60 per cent R.H.) conditions at the recommended dosage of one strip/30 m^3. In order to minimise any dangers to health it is advisable not to use them in constantly occupied areas, and to use them only during the insect flying season.

Naphthalene, Thymol, Carbon Disulphide, Carbon Tetrachloride, Ethylene Oxide
These fumigants are still recommended for use in some publications. None of them are now cleared for pesticide use in museums and will not be considered further.

INSECTICIDES

Gamma-H.C.H. (Lindane) 1,2,3,4,5,6-hexachlorocyclohexane
Use in museums: H.C.H. was the foremost insecticide used in museums for the treatment of woodboring pests and because of its high vapour pressure, it was extensively used as a fumigant in sealed storage boxes of material susceptible to insect attack. Its use has declined rapidly recently owing to worries over its toxicity.

Effect on objects
H.C.H. was popular in insecticidal formulations because of its effectiveness and stability. There have been few reports of any damaging aspects of its use in museums and test data has only indicated that it might weaken some paper materials at high vapour concentrations.

Permethrin (and other synthetic pyrethroids)
Use in museums: as a safer alternative to H.C.H. in most insecticidal treatments, especially in solvent formulations for the treatment of woodborers.

Effect on objects
Permethrin, despite being relatively new and untried appears not to react adversely with historic material.

Bendiocarb (A carbamate insecticide)
The commercial preparations – Ficam W etc., appear to be non-staining and non-corrosive and suitable for museum use.

FORMULATION CHARACTERISTICS

Aerosols
Aerosol applications of insecticides were formally based on an organic solvent and a chlorofluorocarbon gas propellant. "Ozone friendly" aerosols, now superceding them are usually based on a methylene chloride/petroleum distillate solvent with butane propellant. Occasionally an emulsifier and water are added to the formulation.

When used as an atmospheric insecticide and not directly on objects, little damage has been noted. However direct spraying can cause wetting, solvent damage, staining and dye migration.

Smoke Generators
The insecticides often used in smoke generators in museum situations – lindane and permethrin, are themselves seldom damaging. The burning mixture used in the smoke generation is however potentially so, as it is often based on chlorate and nitrate oxidising agents which decompose on combustion to form corrosive gases of hydrogen chloride and nitrogen oxides. Some rusting of historic ironwork has been blamed on smoke generators used to control *Xestobium rufovillosum* in historic buildings but the information is scant.

Insecticidal Dusts
Many residual dust formulations contain a proportion of petroleum distillate to increase their adhesion to surfaces. When used directly on some materials such as books and textiles soiling has resulted from the retention of dirt and dust, and staining from the absorbance of the distillate.

Organic Solvents
Most treatments against wood-boring insect pests in historic

material are based on local application of insecticides dissolved in organic solvents, usually an odourless petroleum distillate. The effect of the solvent is often of staining when it acts as a carrier for dirt into absorbant surfaces, and occasionally by direct solvent action on some dyes and surface finishes.

Emulsions and Water-Based Formulations

The harmful effect of emulsion formulations is in the solvent make-up- of the product. Methylene chloride, toluene, and ethanol are all powerful solvents that are used in commercial insecticides together with a variety of other emulsifiers and additives. Many traditional finishes are damaged or visually impaired by such chemicals and long term damage is suspected on some early synthetic rubbers and plastics.

The water content of some insecticidal treatments has long been a source of concern to conservators in museums both for the direct damage that the water can do and also by the more insidious effects of high humidities caused by the evaporating moisture.

General Recommendations for the Use of Insecticides on Historic Material and in Historic Buildings

(1) The building and its contents should be checked for materials at risk. These would include sensitive items such as historic wallpaper and wallhangings (often frame mounted off the wall), carpets and upholstered furniture. Books, and unglazed and unbacked pictures are particularly at risk.

(2) The proposed treatment should be agreed with the owner and samples of the materials to be used offered to him to allow for their testing on sensitive items.

(3) In general, the treatments should only be carried out in warm dry conditions. Where high humidities above 60 per cent may prove problematical, the preliminary and post treatment use of dehumidifiers for two to three days is advisable, especially where water based treatments are used.

(4) Minimum intervention treatments followed by follow-up surveys offer a safe alternative to risky full-guarantee saturation treatments.

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DISCUSSION ON PAPER 7

Chairman: L. B. Woodhouse

Mr. L. B. Woodhouse: Thank you very much, Bob. We now have a short while for questions. Bob has assured me that if he does not like the questions he will answer in Welsh!

Dr. J. Keenlyside (Hutton and Rostron): You said that you had tried the woodworm trap and that it was a complete disaster. Is that because males are not attracted to the trap at all, as you mentioned for the others, I think, or because enough males are getting by the trap to produce the next generation of woodworm.

Mr. R. E. Child: We think both. We think the pheremone was not attractive enough and we also think the adult Anobium do not move around enough. I work closely with both M.A.F.F. and with the people who design the traps, Agrisense – B.C.S. Limited, and we are trying out different pheremones in different kinds of traps. We have at the moment Anthrenus baits and moth ones, and the Anthrenus ones appear to be very successful. As I say, it is frustrating because as soon as you experiment with Anthrenus verbasci pheremone in the trap, you discover that a different species – Anthrenus sarnicus or fuscus are the pest, and these are not attracted.

Mr. G. Baker (Peter Cox Preservation): If I could say, Mr. Child, I enjoyed your paper enormously, especially your humour about the Welsh. You have strongly advocated the need for continual inspection and vigilance in looking at the items likely to be infested by all manner of pests. Does this suggest the National Trust are paying fees for these inspections or handing out free membership?

Mr. R. E. Child: They will not even give me free membership!

Mr. G. Baker: So we can expect a fee for an annual inspection, can we?

Mr. R. E. Child: I would indeed, yes. If you consider the considerable savings that can be possible. One of the National Trust's properties I recently inspected was infested with *Ptinus tectus*, the Australian spider beetle, in it's library of valuable books.

The Trust was planning to remove all the books to send them to the book conservator to be checked and treated and the room and its contents treated by a full scale insecticide spraying. With a very simple inspection we found the source of the infestation and we found the cure. The source was simple enough, a dead bird which was trapped in the fireplace which was infested. This was removed and we treated the surrounding areas with a residual insecticide and installed insect monitoring traps. We go back next summer to make sure the problem has been solved.

I think really what it needs is not for people to go in with the 'blitzkreig' idea but to make an agreement with the historic house owner, the National Trust, the museum, etc. for a long term repetitive inspection. I think it is very good business quite honestly.

MR. G. BAKER: Yes, I would agree. Thank you very much.

DR. A. F. BRAVERY (B.R.E.): Thank you for a very entertaining and informative paper. I just wanted to come back on this question of pheremones and *Anobium punctatum*. You may know that for a good number of years F.P.R.L. and more recently at P.R.L. we did a lot of work trying to charactgerise the limits of the effectiveness of smoke treatments against *anobium*. We were specifically interested, of course, in control of *Xestobium* but also we did look at *anobium* and concluded there the reason they were singularly ineffective was indeed, as you said, that the pattern of behaviour of the emerged beetles is such that they do not move about very much. In fact, females have the habit of merging and then returning the other way round into their exit hole and just leaving their rear end out for obvious purposes. The quesiton is, how frequently did you distribute the ferromone traps that you did use?

DRY ROT – NEW METHODS OF DETECTION AND TREATMENT

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1. Introduction

Whilst Dry Rot (*Serpula lacrymans* (Fr.) S. F. Gray) has been recognised as a problem throughout the whole of Europe for many years, there is still a need for discussion and further investigations around the Dry Rot problem. Modern building technology, use of good timber constructions and chemical treatment have not eliminated Dry Rot. In the last couple of years Dry Rot attacks have been found especially in old multi-storey houses during restoration to such an extent that it is a severe problem, achieving big headlines in the newspapers. Traditional repair is expensive and there is an increasing demand from environmental authorities to use less hazardous treatments and lower amounts of chemicals in wood protection. We have to use our knowledge about the nature of attacks in buildings, the necessary requirements for Dry Rot and the limits of these conditions beyond which growth is inhibited or the fungus dies and to use this knowledge in new combinations of prevention and treatment of Dry Rot. Future treatment of Dry Rot will have to include less use of chemicals, lower costs and less inconvenience for the residents while treatment is carried out.

Background and Status

A special laboratory for investigation of decay in timber was established at Technological Institute in 1935. Danish insurance companies introduced a supplement to the general house insurance to cover the repair of severe and unexpected fungal attacks in timber constructions. A mycological expertise was necessary for the identification of fungal attacks, as was consultancy concerning prevention and repair. Research and development programmes were set up in addition to this work and during the years statistical analyses concerning decay in buildings have been carried out, the latest in 1983 (Koch, 1985). It has been stated that type of decay and frequency in relation to construction varies dependent on architectural elaboration, workmanship and maintenance of the houses (*ibid*). The relative occurrence of Dry Rot compared to other decay types has been constant between 20-25 per cent from 1946 to 1983. In the sixties a big increase in building of new detached houses took place. It was often prefabricated houses with flat roofs and double glazing in heavy timber frames. This was reflected with a couple of years delay in the statistics since *Gloeophyllum* sp., *Corticium* sp. and later also *Dacrymyces* sp. became very common. They tolerate high temperature under black roofing felt and black paint, they tolerate desiccation in situations where the construction is only wetted intermittently, *e.g.* after rain and snow. The problems with these constructions are now solved, windows are double-vacuum treated and constructions are improved.

Recently a political decision to restore old multi-storey houses in Denmark instead of pulling them down and building new ones has influenced the statistics in great favour of Dry Rot.

The Dry Rot attacks, found in a building before opening of the construction are mainly found in the cellar where detection is easy. There is no plaster on walls, and beams are partly or fully exposed. But when the restoration programme started a remarkable number of mainly older Dry Rot attacks were found in the floor constructions above ground level, in window frames when they were exchanged and in roof constructions when the roofing was changed. The consequence was that the price and time for a restoration increased to an unacceptable level.

To illustrate the size of the problem an example can be given (personal communication). One multi-storey house situated in the centre of Copenhagen in a street with several severely attacked buildings was planned to be restored. It was known that there was some "minor" attacks in the building. A plan for the restoration was set up. The habited area was 895 m^2 and the restoration costs were set to £580,000 equivalent to £648 per m^2. The work started and when £410,000 had been spent, several Dry Rot attacks were detected to such a severe extent that further work was stopped. A thorough investigation of the whole building was carried out and a new plan was made. An extra £660,000 had to be added on account of the fungal damage detected. The final price was £1,240,000 or £1,385 per m^2.

Therefore thorough investigations are now made before the final plan for a restoration is set up. And even then we find some hidden surprises.

A big restoration is going to take place in an area of Copenhagen named Vesterbro with 22 blocks containing 3,673 flats, with a total habited area of 346,700 m^2 with 6,000 inhabitants. In October 1989 the price for repair of fungal damages mainly Dry Rot was estimated at £110 per m^2 equivalent to £38 million. Today we expect the price to be £150 per m^2 equivalent to £52 million.

The sum allocated for restoration of buildings in Copenhagen was, in 1989, £90 million. For the period 1990-93 £370 million is available in Copenhagen whereas the budget for a neighbour commune with better maintained buildings is £60 million for the same period. Of the £90 million, 50 per cent or £45 million is regarded as loss financed equally by the state and the commune. The remaining 50 per cent is financed by the owner usually in the form of a loan, the cost of which is passed on in the form of an increase in rent.

The individual tenants can obtain state support for a period of 5-10 years depending on income to finance the excess cost. In principle a fungal repair does not enhance the rentable value unless an improvement in the form of new windows, new kitchen or bathroom is achieved. The maximum rent per m^2 is politically laid down by the rent control board.

Buildings can be cleared if they are not specifically worth restoring or protected for architectural, historical or other reasons specially if the cost of renovation exceeds £1,300-£1,400/m^2. However, there is still a political will to preserve the old buildings where possible.

Biology of Dry Rot

The morphology of Dry rot has been described several times (Cockroft, R. 1979). Also the characteristics for identification of Dry Rot in different stages are well described. The fungus has been cultivated in laboratory on different media and exposed to different temperatures and levels of relative humidity. Dry Rot has never grown or decayed wood as well in the laboratory as it does in buildings. Buildings can provide the perfect micro-climate for growth of Dry Rot which nature alone cannot. Dry Rot has according to Danish experiences never been found in wood constructions without a calcium source or other basic material nearby.

It seems to be necessary at least for extensive growth and spread that the oxalic acid produced by the fungus can be neutralised (Bech Andersen, 1985). That can explain the ability of the fungus to grow through brickwork from one floor to the next in different storeys.

The fungus is able to adapt to the surrounding micro-climate not only by buffering acid production *e.g.* by utilisation of calcium but also by transportation of water to where it is needed and exudation of excess water. It certainly does not like draft because it is always found hidden under constructional surfaces. It is an extremely well adapted pest to the buildings.

Only the formation of the fruitbody needs some light and therefore fruitbodies can be seen breaking through skirting boards, window sills and plaster.

Detection Methods

To make a successful restoration of a building all Dry Rot attacks will have to be found before the plan is made. If the attacks are found separately while the work is carried out, the economy- and time-plan for the restoration will be over-run tremendously.

Dry Rot can be detected by break-down of constructions, outbreak of fruitbodies and release of the spores from fruitbodies forming a red-brown layer of "dust". Fresh fruitbodies have a smell of mushrooms, and rotten ones have a very nasty smell. Of course Dry Rot is also detected through restoration or rebuilding where decayed wood or mycelium in brickwork become visible.

If a surveyor is asked to find Dry Rot in a building he can use the above mentioned characteristics, but also he has to use his experience about where the hidden Dry Rot can be found. Dry Rot can be found everywhere if a moisture source is possible. That means in roof-constructions where the roof has been leaking specially at the bottom of the roof where also leakage from the gutters can have an influence, at every floor construciton where beams have contact with wet brickwork around bathrooms and kitchens and of course in the cellar beams. A close look at the facades can give hints about where to find Dry Rot. Leaking downpipes, cracks and frost damage, peeling plaster etc. can start attacks in the timber constructions behind. One can never be sure to find every attack in a building but many constructions will have to be opened before the plan for the whole restoration of a building can be finalised.

There is a big need for development of non-destructive test-methods because the surveys often take place while buildings are still occupied and it can take a couple of years before the restoration actually takes place. Therefore the method of opening constructions, taking up floorboards, making bore-holes to be able to use the eye, awl, hammer and chisel is not very suitable for the residents.

Dogs as an Instrument in Detecting Dry Rot

It is well known that dogs can be trained to find injured people, drugs, plants and animals etc. A dog can also be trained to detect specifically Dry Rot. A training programme was set up in 1988 by The Danish Technological Institute and The Danish Kynological Centre – a dog training centre (Madsen and Adelhøj, 1989; and Madsen, 1989).

There were no restrictions regarding the type of dog and 12 teams, man and dog, were started. The teams started their training on an artificial training-course with small samples of different fungi laid out. During the training the teams had to pass different tests. In 1989 two successful teams who could provide a valuable tool in building investigations were ready. That means they can act as a tool for the professional surveyor who has to verify the results and make the conclusions. The advantages are that non-decayed constructions very rarely will be opened and that a very high percentage of Dry Rot attacks in a given building are found. Comparative analyses show that the two qualified teams can be expected to find 90-100 per cent of all Dry Rot in a building and they will make 0·1-0·5 mistakes per flat, *i.e.* undetected attacks and incorrect positive identifications (Madsen, 1989). In general other types of hidden decay are not found, but most often these wet rot attacks are not important to the planning of a restoration.

A new training programme based on our experiences will be set up late 1990 and this will probably be more efficient and lead to a higher degree of success.

Collimated Photon Scattering, C.P.S.

Decay in electricity and telegraph poles and the economical importance of that has led to development of several instrumental methods of detection, but these can only be used when access is possible from both sides of the decayed timber. This is most often not the case or at least very difficult in buildings.

Equipment developed by Danish Isotope Centre for investigation of the quality of insulation on heating pipes has been modified for detection of decay in buildings (Madsen and Adelhøj, 1989; and Madsen, 1989). The equipment is portable and it is possible to make one-sided measurements. Photons from a gamma source are collimated into a ray which penetrates the material and at a right angle is transmitted back to a detector which counts the photons. The signals from the scattering process depends on the photon energy, the scattering angle and the local electron density. The intensity of reflected photons is proportional to the density within the investigated areas. By changing the distance between the source and the detector, every point in a triangular cross section can be measured. The signals can be transferred to a computer so a complete picture can be obtained. The pilot model developed is able to cover square cross sections of *e.g.* a beam. It is designed as a line detector based on the gamma-camera-principle meaning the measurements are simplified.

The instrument has been demonstrated in practice and the software for practical use of the instrument is being developed. It is a relative expensive instrument so we recognise that only a few specialists will be able to buy and use it. The expected price per instrument is £25,000.

Identification

Higher fungi are traditionally identified by the characteristics of the fruitbody. Dry Rot can easily be identified when fruitbodies are present but that is not always the case in buildings. Surface-mycelium looking like cotton wool or leather can be present. Most often only string-mycelium with thicknesses from thread to pencil are present in brickwork as well as on the surface of decayed wood. Samples of decayed wood including surface-mycelium can be identified by trained personnel using light microscopy only. Even suspicion of Dry Rot in wood samples without surface-mycelium can be detected and more samples will then be asked for. Since it is time consuming, and that means expensive, to wait for the answer from a laboratory analysis, it would be very useful to have a method for identification that can be used by non-skilled people *e.g.* the workers when they restore a building and unexpectedly detect mycelium and/or decayed wood. Such a method should only be used to obtain the answer yes or no. If Dry Rot is present a skilled surveyor is still needed to identify the extent of the attack and give recommendations for repair.

Immunological identification is based on the production of antibodies when an antigene *e.g.* an extract of proteins from Dry Rot is introduced to a mammalian organism *e.g.* a rabbit. The antiserum from the rabbit, containing antibodies against Dry Rot, is tested against Dry Rot and other related fungi, and thereby a great deal of cross-reactions are seen. By eliminating the cross-reactions 1-4 specific antigenes from Dry Rot have been found and introduced to a rabbit for production of a specific antibody. The specific antibody will then be tested against Dry Rot *in situ* and detected by fluorescence with secondary antibodies conjugated to a fluorochrome. The system will then be developed for practical use outside the laboratory.

Treatment of Dry Rot

All over Europe Dry Rot is recognised and repaired in a similar way though there are certain differences (Koch, 1990). All decayed timber is removed as far as the visible extent of attack plus an extra "safety zone" which varies from 30-100 cm. In Denmark it is at least 50 cm and most often 100 cm. Treatment of brickwork is carried out but again the methods and the extent of treatment vary. In Denmark plaster is removed on the inner side of the facades and both sides of inner walls with a "safety zone" at 50-100 cm. Joints are scraped out to a depth of 3 cm, brickwork is burned and chemical treatment carried out twice before new plaster is put up. All load bearing replacement timber has to be pressure treated to class A according to Danish Standard D.S. 2122. Windows, doors etc. must be double-vacuum-treated to class B. Non-load bearing timber can be brushed or sprayed with preservative. In other European countries less impregnated wood is used. Instead, *in situ* treatment by injection or capsules containing fungicide are common or the timber is just surface treated. Compared with other European countries it seems as though Denmark has a very high standard of repair, well described in a widespread and often used standard and with a good quality control. One thing that may have contributed to the high standard of repair is that a detailed prescription was formed very early and experts were asked to give advice. Also nobody wants to take responsibility for a bad repair and be taken to court if the repair fails.

Since Dry Rot is very common in old Danish multi-storey houses and since the attacks are often widespread throughout many floors along the facade it costs an enormous amount of money to restore the houses. The traditional methods of repair also involve use of a fair amount of chemicals and treated timber. In the near future we will probably see the severely attacked houses knocked down for economical reasons and use of chemicals in timber out of ground contact might be restricted for environmental reasons.

On that background we started looking for alterantives in 1986.

The mycelium of Dry Rot is sensitive to high temperatures. According to different laboratory tests (Table 1) the maximum temperature Dry Rot mycelium can resist is 40°C. for 6 hrs. or 50°C. for 1 hr. at 18 per cent moisture content in wood samples (Miric and Willeitner, 1984).

TABLE 1
Lethal temperature for Dry Rot in laboratory tests

Temperature (°C.):	*35*	*37·5*	*40*	*45*	*50*
Time (hrs.)					
Falck (1912)*			1/2		
Liese (1931)*			1/4		
Montgomery (1936)*			1/4		
Langvad and Goksoyr (1967)*	6	4			
Savory (1971)*			1/4		
Miric and Willeitner (1984) (2)	>24		6	3	1

*Hegarty *et al.*

Based on these results a new eradication method using hot air has been developed (Madsen, 1987; and Koch *et al.*, 1989).

To eradicate a Dry Rot attack in a building the mycelium in the timber as well as in brickwork and other materials has to be killed.

The spores will not be killed at these temperatures. According to Hegarty and Schmitt (1988), spores can germinate after heat treatment at 65°C. for 4 hrs. whereas 90°C. for 2 hrs. was lethal. Fruitbodies are not always formed in attacked buildings, but airborne spores from other sources are expected, with a possibility for germination and attack wherever the conditions are right. Form our surveys we know that certain streets in Copenhagen are attacked from one end to the other. The spore concentration might be higher in such areas, so heat treatment of spores in one building would be negated by infection from another. The important thing, therefore, is to pre-

Fig. 1. Full house treatment.

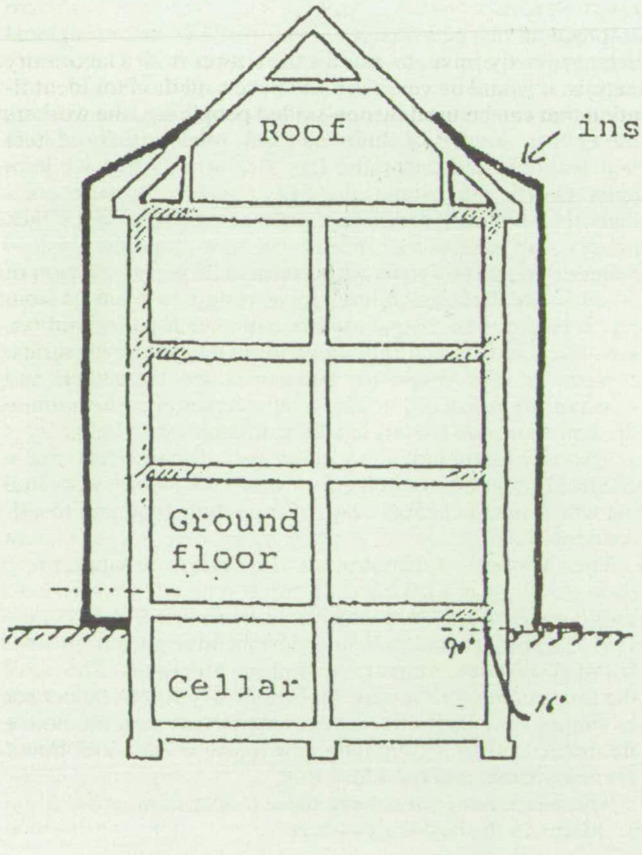
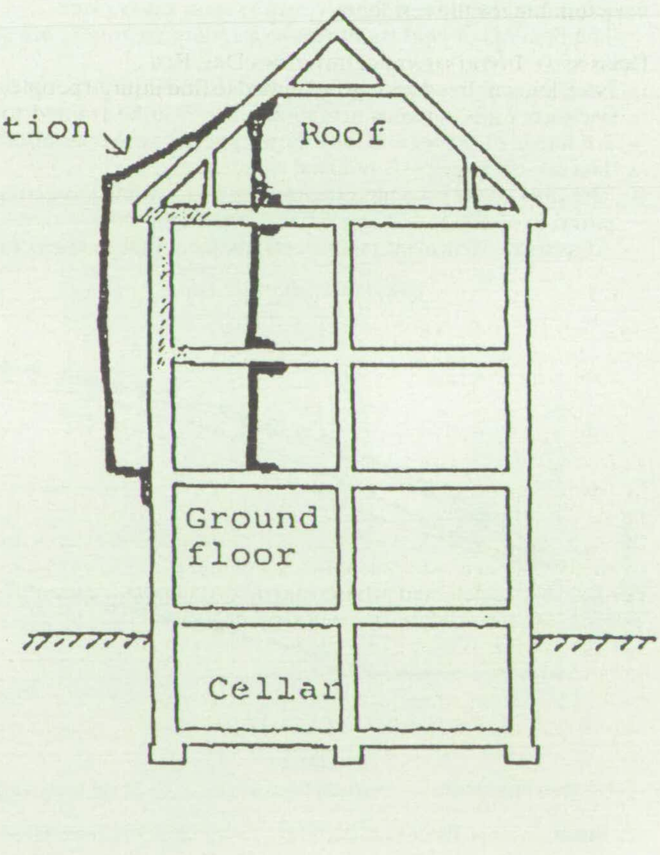


Fig. 2. Partial treatment.



vent germination of the spores, that means re-establish a well-maintained building and maybe make some changes in constructional details so that the risk for access of water to the timber constructions is reduced. In general that must be the main object for every treatment of a building.

The sensitivity of the mycelium to heat is higher when it is active under moist conditions than when it is alive, but maybe dormant under dry conditions. With the result from Miric and Willeitner (1984) obtained at 18 per cent moisture content in wood it was decided to use 40°C. for 24 hrs. as a minimum level for the heat treatment in practice.

The whole building or just the attacked parts of a building can be treated. Before treatment, the moisture sources must be analysed and eliminated and the moisture content is measured. The extent of the attack has to be defined before a partial heat treatment is carried out. The strength of load bearing constructions must be investigated. Constructions which are decayed to an extent where strengthening or exchange of timber is necessary can be opened, but the work is carried out after heat treatment so that desiccation of new/fresh timber is avoided. If there is Dry Rot attack up to an attached neighbouring building a standard chemical treatment of the common wall is necessary since the Dry Rot is able to return from the neighbouring constructions unless a chemical barrier is present.

Insulation material (2 × 50 mm winterbats) is placed along the facade on the scaffold, Fig. 1. Normally, partitions and floors are used as barriers inside the house when partial treatments are carried out, Fig. 2. The whole attack has to be included in the heat treatment. Warm air from an oil or gas burner is led into the construction from two sides through flexible tubes. The amount of heat necessary is calculated by computer, based on measurements of the size of the constructions, Fig. 3. Temperature sensors are placed in all constructions expected to be difficult to heat, *e.g.* in the centre of brickwork and beams. The temperature progress is followed so adjustments of the heat supply can take place in order to keep the costs as low as posible, Fig. 4.

After heat treatment the necessary repair takes place.

The benefits of heat treatment to standard treatment are as follows:

- No chemical treatment of brickwork is necessary except on common walls between neighbours.
- Exchange of timber and the following repairs are minimised.
- The use of chemical is reduced significantly.
- The time spent on a heat treatment is only a few days compared to often several weeks for a standard repair.
- At a partial treatment people can still live in the house compared to the turmoil and dust a standard repair involves.
- The cost of a heat treatment is 10-50 per cent lower than for a standard repair dependent on the degree and situation of attack.

Fig. 3. Calculated temperature rise

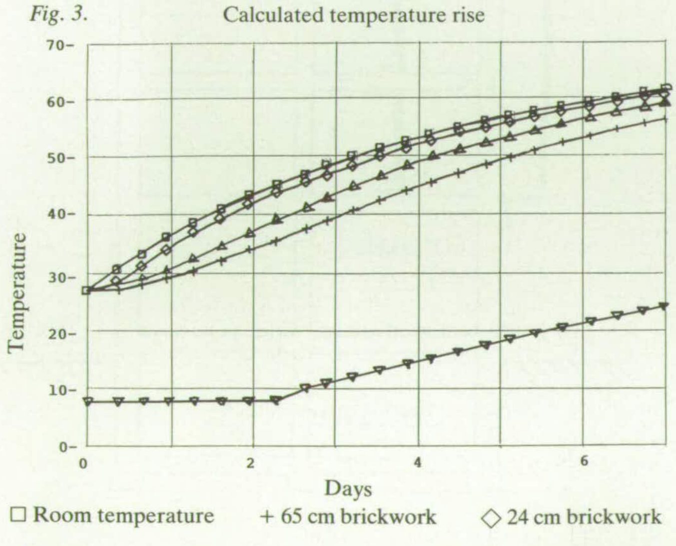
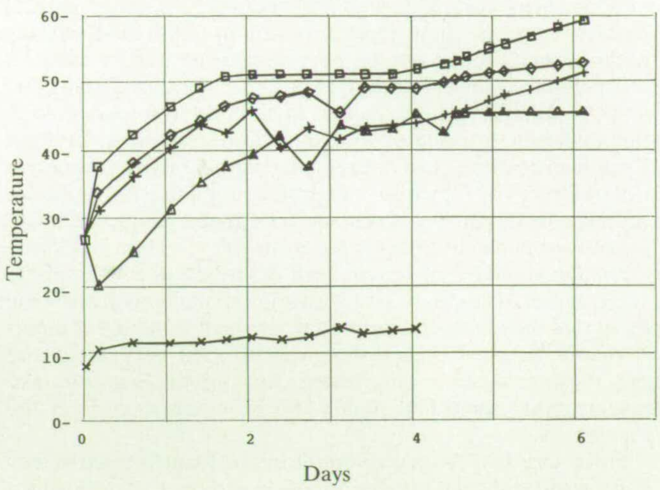


Fig. 4. Measured temperature rise



One building has been fully treated while 25 partial treatments have been carried out. Renewed attacks have not been seen, but since the temperature and time is based on laboratory tests we still need a couple of years before we can regard the method as 100 per cent efficient. In the meantime we are attempting by use of microscopical and chemical analyses to show what is actually happening in the cells and thereby develop a simple staining technique for light microscopy to prove whether the mycelium is dead or alive.

Final Remarks

It is evident that Dry Rot is a severe problem in Danish buildings, specially in older multi-storey houses. It is extremely expensive, partly because it is widespread and common, partly because our standard of repair is very high. We cannot accept the enormous costs of renovating and modernising old buldings without eradicating the Dry Rot attacks that we know exist. On the other hand, the cost of standard repairs are so high that political decisions might be taken to clear these houses and spend the money on new buildings instead. Whereas loans used to be with a term of 20 years they are now 30-50 years. The possibilities for getting new loans covering *e.g.* repair of new fungal attacks within that period are very low. Such repairs will then have to be financed by insurance companies. The insurance companies are meanwhile very reluctant to insure old houses at all even after restoration, so the house owners are left in a very difficult situation.

The environmental authorities will demand less use of chemicals in buildings in the future and the Ministry of Housing will demand cheaper ways of providing good and healthy residences.

The Danish Technological Institute, department of Biotechnology is working on a three year intensive research programme on Dry Rot which is to be finished by the end of 1991. The programme is financed by the insurance companies, building societies, Ministry of Housing and funds. The aim of the programme is to reduce the cost of Dry Rot by 50 per cent by finding new and better detection methods, new methods of treatment and to disseminate new information about how to prevent, detect and treat Dry Rot.

The programme for solving these problems must be:

1. Maintain the buildings we have.

2. Keep the insurance running under preconditions of good maintenance.
3. Make good surveys of buildings before restoration by use of better detection methods.
4. Carry out necessary repairs using the most economical methods and change constructions if possible which have a high risk of fungal attack.
5. Accept that certain old houses are in such a condition that restoration is too expensive.
6. Use all the knowledge we have about prevention of decay when buildings are built or restored.

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DISCUSSION ON PAPER 8

Chairman: Mr. C. H. M. Marsh

MR. C. H. M. MARSH: Thank you very much. Mr. Petersen came over from Berenson with some fascinating contributions to give us and now we have Anne Pia Koch with even more startling thoughts. I guess that has provoked a few interesting questions.

DR. J. KEENLYASIDE (Hutton and Rostron): If I can ask one question and also make one observation if I may.

The organisation I belong to is using dogs to sniff dry rot as well. I do not think we have achieved your 90 to 100 per cent detection rate yet but they are a very useful tool. You mentioned heat treatment to kill fungus. To go back to Bob Child's observations in his talk when he was mentioning the environmental sort of holistic approach if you like, if you kill the fungus with heat treatment but without addressing the fundamental reason why the fungus is in the building in the first place, as in your slide with water coming in, will you not get re-infestation? You have to presumably have a combination of both techniques.

MS. A. PIA KOCH: Of course, you have to make sure that you eliminate the moisture source and you have to make a detailed survey of the building before you start the heat treatment, to spot the moisture sources and to eliminate them. If that is not possible, heat treatment is not to be used in that case. Sometimes in Denmark the lower floor constructions can be placed below ground level where it is continuously wet, and in that case heat treatment cannot be used. These days we have so many attacks above ground level, above the lowest floor construction, especially in the roof constructions and there heat treatment can be used as an effective method.

MR. J. M. BRICKNELL (Private Member): I would like to make one observation. You mentioned the importance of rectifying moisture in resident buildings. In the 30 years I have been working with dry rot I have found that to be probably the hardest thing to do. You may be able to maintain your buildings better in Denmark than we do in London, Birmingham or Manchester but somehow from the pictures which you showed us – which are excellent and I congratulate you on them – I think you have got very similar problems to ours. Elimination of moisture, complete elimination, is very, very difficult to achieve in old buildings.

The question I would like to ask is what thickness of walls and what construction of walls have you tried your heat treatment on? You showed solid brick walls. Have you any equivalent to our rubble-filled cavity walls, may be timbers within a masonry thickness or half a meter.

MS. A. PIA KOCH: I do not think the material or the thickness of the construction means anything. You can treat very thick massive brickwork and you can treat hollow brickwork filled with insulation material. You just have to go along and make a detailed survey of what type of construction you are dealing with in the specific case and to measure the dimensions of the constructions. What you do is to heat the mycellium within the construction. You do not treat the spores. The spores are in the air and they will always be there.

DR. D. J. DICKINSON (Imperial College): Really the point I wanted to make has been lost now but it was just a follow up to the first question. I think Anna Pia was saying the most important aspect of the work is being able to eliminate the need for the use of large amounts of chemical irrigation and massive exposure work and this is where its real strength lies. Of course, you have got to attend to the source of moisture as well but the conventional approach to eliminating the moisture sources and being able to come up with an alternative to using large amounts of chemicals I think offers great prospects, even in this country.

DR. P. FITZSIMMONS (Cementone-Beaver): Anne, thank you very much for your talk. It has been very thought provoking and it is interesting for us all to hear how you think about these things in other countries. There is just one point I would like to make and follow it with a question. The point is that we all know the "be all and end all" of any dry rot eradication work is to dry the building out. If you can do this successfully and well, then probably chemicals are not a necessary extra treatment.

Your talk made me wonder whether in actual fact the heat treatment is working because the heat is killing the fungus and whether all you are actually doing is accelerating the drying out of the building. Anyway, that is just a thought.

My question really involves what you have said about chemical toxicity and leads on quite nicely from what David was saying and that is this: you talk about chemical hazard. I would just like to say that because all chemicals are hazardous the important thing to realise is that ordinary remedial treatment companies, certainly in this country, handle the chemicals in such a way that there should be an extremely low risk of any toxicity to either the people using them or the occupants of buildings. So long as the chemicals, be they hazardous or otherwise, are used in a responsible manner there is absolutely no reason why we should then have such an aversion to the use of chemicals which can do a very good job in buildings whilst they are drying out.

MS. A. PIA KOCH: Can I make a comment on that? It was not a question, was it? No. I think the main purpose for using heat treatment is that in some cases, or in many cases, the cost is lower. You can save from 10 to 50 per cent of the cost for a standard treatment depending on what type of construction you are heat treating. I mean if you have fine decorated ceilings, if you have fine wooden panels and things like that it is very expensive in Denmark to restore these things after you have carried out a standard treatment. Using a heat treatment you do not cause any damage to these constructions. I think that is the main purpose but a great advantage for me is still that we do not need to use so many chemicals. I think that is important too.

MR. R. E. CHILD: What is killing the fungus? Is it the heat or the drying out procedure and if it is the drying out procedure would not dehumidification using just ordinary air dryers be a suitable alternative?

MS. A. PIA KOCH: No we think it is the high temperature that kills the fungus because the heat treatment is carried out in such a short period so that you do not really get any changes in moisture content. Definitely we have many experiences showing that desiccation, I mean repair, bringing the building up to a good standard of maintenance, does not kill the dry rot. It can be dormant for many years and it might go into that stage where it does not decay actively but it will not necessarily die.

MR. G. W. NURSE (Wood Decay Treatment): There are two questions I would like to raise. One is the spore deposits on the fabric in the building and from reading the paper this is very extensive. The author describes whole streets being infected. Therefore, airborne spores must be spread from one building to another. This could account for the dry rot attacks which are occurring in roof areas. The other point is that after heat treatment has been carried out these airborne spores could then be re-deposited on the treated areas and dry rot could develop. The third question is . . .

MR. C. H. M. MARSH: Could we take one at a time, sir, as we might get a little confused because we have a language problem as well? Could you just precis the first quesiton?

MR. G. W. NURSE: The third question I was going to ask is, have you considered the living habits of the tenants? I think a lot of the property is tenanted. Tenants often create condensation problems inside the buildings and this could give suitable conditions for any spore deposits to germinate.

MS. A. PIA KOCH: We have not experienced any re-attack after heat treatment and, as I said before, it is very important that you start before you do your heat treatment to eliminate your moisture source. The moisture content of the constructions has to be below 18 per cent moisture content which we regard as the limit. So we will not have any infection from spores.

MR. G. W. NURSE: Is it possible that the living habits of the occupants give suitable conditions for this to occur in the near future?

MS. A. PIA KOCH: No, not in Danish buildings at least. I do not think so. I can give you an example. When windows are exchanged in an old building the building will be more tight and that can give condensation problems. For example, underneath the windows where the brickwork is thin, especially in bedrooms and kitchens, that gives a problem with moulds and all in all it affects the moisture balance of the whole building, but it is not enough to start a dry rot attack. Our experience is that to start a dry rot attack you need to have a proper moisture source. You have to have a leaking gutter, a leak in the roof or something like that.

A DELEGATE: Anne Pia, can I say congratulations on your paper too. I think you have caused a lot of thought to us here, particularly those of us who are commercially involved in the treatment of buildings against dry rot in particular. It is demanded of us, as the commercial applicators of pesticides and fungicides, to issue a guarantee when we have done our job. In Denmark perhaps the demands are not made on the specialist in such a way. We have to give a 30 year guarantee or a 30 year undertaking that the work we do will have that sort of life. Do you have an answer to that in the way of apportioning treatments at the time of the timber installation or how do you get over that problem?

MS. A. PIA KOCH: I think giving such a guarantee must include a very big risk. In Denmark it is very common to insure your property against fungal decay and it has been a tradition that if you have a dry rot attack in your house you can get the cost of the repair from the insurance companies. Because of all the attacks we see now in Danish buildings the insurance companies tend to step back and say, "We will not insure buildings built before 1920". That means all the buildings with a very high risk of dry rot attack are uninsured.

Also there is a tendency in Denmark if you claim the cost of a dry rot attack from the insurance companies, even though your house is newer than 1920 they will revoke the insurance cover on the grounds that the house presents too large a risk. So owners of old houses in Denmark have a big problem and certainly we have no chemical companies giving any form of guarantee. We do not give any guarantee at all when we do surveys and advice/treatment to the repair of dry rot in buildings.

A sort of guarantee will be given in future on heat treatment. We are making a sort of control organisation with the purpose of ensuring that heat treatment for buildings is conducted under optimum control in order to give the consumer certainty of effective treatment. That organisation is just set up now. It is the companies who carry out the heat treatment which give that control.

MR. D. A. FREEMAN(Guarantee Protection Trust): Since we have got on to commercial questions and not entirely technical questions, I would just like to follow up that last one about the insurance arrangements. First of all, are the insurers in Danish property largely Scandinavian companies, European, British or what are they? Secondly, what is the attitude of the occupants and owners of these pre-1920 buildings to the value of their property? Do they regard them as uninsurable in this respect?

MS. A. PIA KOCH: I do not know the structure of these insurance companies, their backgrounds and their details. Concerning insurance against decay the market is covered by Danish companies. They can be reinsured in Denmark as well as in other countries.

In Denmark a big proportion of the multi-storey houses are owned by individuals and there has been a tendency to neglect the maintenance. It is a problem in the last years there has been a tendency from the single owners to sell the multi-storey houses to the tenants so that everybody gets a share in their own house. There you can see the interest in maintenance of the building is increasing but they do not understand how to maintain a building. They concentrate on the appearance of the building but often neglect the more important things like repairing the roof and keeping the gutters tight and things like that. That is what we try to tell people. We tell them to forget all about decoration, they can do that in their spare time, and employ experts to take care of the more critical problems.

MR. D. G. BUCKLEY (Protectahome): I very much enjoyed your talk. The last slide showed where absorption would occur on a building through cills, through roofs and such like and you mentioned how much rain fell in Denmark. I was wondering, looking at that, if you had done the heat treatment on that specific building would you consider it necessary say within five years, 10 years, 20 years or 30 years to repeat that treatment to avoid the problem occurring again? As I understand it the wood itself will absorb moisture from the surrounding brickwork and in turn may well get up to the moisture contents suitable for fungal decay.

Ms. A. Pia Koch: A heat treatment does not involve any remedial treatment or any protection of the constructions in future but the necessary thing to do is to maintain your buildings. I think these buildings we have in Denmark are remarkably good. If you maintain them they can be kept for many years and you will not get any attack.

Dr. B. Hegarty (Rohm and Hass): Anne, getting back to your C.P.S. apparatus which are £25,000, which is rather expensive, do you think from the feedback you get from the machine you can determine the exact pattern of decay? In other words, can you say whether it is fungal attack or whether perhaps it is insect attack? If you can do that surely it would make it slightly more economically acceptable?

Ms. A. Pia Koch: Maybe we can differentiate between insect attacks and fungal attacks but we cannot define what type of decay it is, and of course we also detect cracks and all sorts of holes in the beams but I think by experience we will be able to detect whether it is decay or not. It certainly needs some experience.

Dr. B. Hegarty: But you will not be able to detect between fungal and insect attack?

Ms. A. Pia Koch: I think so, but cannot be certain. The instrument is too new.

Mr. R. Perriton (R.P. Associates): With the objective of minimising disturbance with your heat treatment methods, therefore, you are not doing exposure, how do you deal with defective *in situ* timbers, timbers that are within the fabric of the building? Do you use one of your instruments in order to identify those timbers that need to be removed because they are structurally weakened or do you leave them all in place?

Ms. A. Pia Koch: We have to exchange timber where the strength is not adequate, and by experience we know where the most severe decay will be.

Mr. R. Perriton: I am surprised you know even with experience exactly where that is.

Ms. A. Pia Koch: The decay will normally be worse, along the facade and in Denmark we have timber in the floor construction. For example, the head, sill and end of beams are more or less surrounded by brickwork and that is likely to be the most severely decayed constructions.

Mr. C. J. Jones (B.W.P.D.A.): A delightful paper and nice to hear the Danish accent augmented by something that I think is derived from Yorkshire and it comes through beautifully and I do thank you for your presentation and we welcome it. I would like to ask one particular question. In view of the magnitude of the industry in this country, I think you were talking mainly about buildings which one can see in Copenhagen, is this a general problem as we have in this country, perhaps in Glasgow, Manchester, Leeds, and big conurbations? Is it an economic proposition which you are going to have to overcome at some time in the future?

Mr. C. H. M. Marsh: Can you just summarise your question, Charles?

Mr. C. J. Jones: Yes, is it a solution to a small or large problem in Denmark as we might have in this country?

Ms. A. Pia Koch: Dry rot is a very big problem in Denmark and we spend a lot of money on repairing these attacks. We do not have a big industry like you have here to treat these attacks. We have a lot of small companies doing the repair of fungal decay.

Mr. C. H. M Marsh: I think, ladies and gentlemen, I must bring it to a conclusion now. The qeustions have gone on for an extraordinarily long time which does indicate the real interest in the subject that Anne Pia has just covered. It is sad really that our industry is suffering so badly that many of our members who would love to be here today to have heard such an interesting talk could not because they are having to "mind the shop" in these difficult times. Perhaps their surveyors are out acting as sniffer dogs and may be dry rot to them smells like freshly iminted five pound notes. Who knows?

It really has been a remarkable achievement and a remarkable talk. I gather there is a reciprocal arrangement whereby one of us (which will be done on a lot basis) will be asked to go back to Denmark and give a talk in Danish! I do not know how you did so well. It was a lovely talk and how you coped with the questions was absolutely marvellous. Thank you very much indeed. *(Applause)*.

CLOSING REMARKS BY THE PRESIDENT

Ladies and gentlemen, when last year's President closed the Convention he considered that the industry needed to strengthen its technological base. He probably was right.

What I am sure of, however, is that on the evidence of the last two days the will is there.

We have heard a first rate selection of papers. During the many conventions I have attended I have been charmed, amused, educated by most of them and chilled by some of them, but I believe that none has been as relevant to our purposes and to our needs as the first Convention of the B.W.P.D.A. The choice and the pattern of the papers reflect great credit upon the small committee responsible.

After a rousing start from B.R.E., each day brought interest of a different kind and yet each had the same balanced feel. We progressed from the status quo to our future needs and on to a glimpse of tomorrow.

Perhaps we can also detect a move away from the long-term-guarantee mania which seems to have gripped us for so long, and there have been one or two catch-phrases that should prove memorable for a year or two. "Product Stewardship" was one of them and "holistic" was another. The term "frontiers of research" can be applied to at least two of the papers.

I would like to pay tribute to the style of both the presenters and the chairmen. It is very often the singer and not only the song that counts.

We need also to remember that not only is presentation important but also timing. One or two papers have over-run the allotted time, denying us the discussion opportunities that I know so many of us come for.

Several of the papers we have heard begged questions, which is healthy. Gavin Hall has clearly implied his intention to return and tell us the answers to the questions he raised this morning. Similarly, with the paper from Bernard King and John Palfreyman yesterday; what are we going to do with the information? To what purpose can we commercially put it?

On the subject of future papers, I am glad that Dr. Keenlyside was present and took part in discussions. Hutton & Rostron are involved in even more esoteric research than we have heard about today and we may well be able to persuade him or one of his colleagues to return to a future Convention and talk to us on their work.

This Convention is now closed but before moving away I have news of a friend of us all. John Levy has been appointed a Fellow of Imperial College and he will be installed in October. This is the highest honour that Imperial College can bestow on anybody and I know you will be as pleased as I am to hear of it.

In concluding I would like to thank not only the presenters who I think have done a tremendous job, but everybody who has taken part. Who can doubt that the presence on this platform of two such ladies as we have heard today have brought to it a charm without which this Convention, and any Convention, would have been diminished. I would like to thank the chairmen who have coped and have stimulated questioning admirably, and finally I would like to say to you, the delegates, it is your participation which has been the mirror of everybody's hard work and which has made it all worthwhile.

Our next Convention is in the same week next year, on 3rd and 4th July and I look forward to seeing you all then, and at dinner tonight.

Thank you very much. *(Applause)*.

THE BRITISH WOOD PRESERVING AND DAMP-PROOFING ASSOCIATION
1990 ANNUAL CONVENTION – 3rd-6th JULY

LIST OF DELEGATES AND VISITORS

Total number attending 169

Name	*Company or Organisation*
	A
Anderson, Dr. D. G.	Hickson World Timber Ltd.
Aston, Dr. D.	Hickson Timber Products Ltd.
Ayris, A.	Cementone-Beaver Ltd.
	B
Baines, Dr. E. F.	Rentokil Ltd.
Baker, J. M.	BRE
Balfour, D.	BSW
Barker, K. J.	Anglia Property Preservation
Belford, Dr. D. S.	Personal member
Belford, Mrs. D. S.	Partner
Bennett, G. A.	T.R.A.D.A.
Berry, R.	BRE
Blow, D. P.	Fosroc Ltd.
Braithwaite, C.	Hickson Timber Products Ltd.
Bravery, Dr. A. F.	Princes Risborough Laboratory
Brennan, D.	Gloster Woodworm
Bricknell, J. M.	Private Consultant
Bromley, M.	B.W.P.D.A.
Brooks, F. W.	Fosroc Ltd.
Buchan, E. M.	Hon. Treasurer B.W.P.D.A.
Buchan, Mrs. E. M.	Partner
Buckley, D. G.	Protectahome
Buijs, A. J.	Flexchemie b.v.
Burgess, Dr. N.	Western European Institute
Byrne, A. C.	North West Electricity
	C
Cahill, D.	Irish Science Agency
Caldwell, I.	South Bucks, Estates
Cardias, Miss F.	University College of North Wales
Carey, Dr. J.	BRE
Chalmers, C. E.	Fosroc Ltd.
Chalmers, I. M.	Calders & Grandidge Ltd.
Chapman, R. G.	Schering Chemicals Ltd.
Chiddle, T. C.	Fosroc Ltd.
Child, R. E.	Welsh Folk Museum
Coffee, Dr. R. A.	ICI Agrochemicals
Coggins, Dr. C. R.	Rentokil Ltd.
Coggins, Mrs. C. R.	Partner
Connell, M.	Hickson Timber Products Ltd.
Cornfield, Mrs. J.	Hickson Timber Products Ltd.
Coyle, P. J.	Protim/Fosroc Ltd.
Crocker, N. E.	Buckman Laboratories
Curran, J.	Rhone-Poulenc/Manchem
	D
Davey, R. N.	Cuprinol Ltd.
David, R. C.	Rentokil Ltd.
Davis, S.	Rentokil Ltd.
de Jong, D.	Bureau of Pesticides
Dickinson, Dr. D. J.	Imperial College
Dyer, R.	Tavistock Woodlands
	E
Eve, A.	Complete Preservation
Ewbank, G.	Rentokil Ltd.
	F
Fitzsimons, Dr. P.	Cementone Beaver Ltd.
Fox, Mrs. R.	Stenographer
Fowlie, I. M.	Calders & Grandidge Ltd.
Freeman, D. A.	Guarantee Protection Trust
Frost, R. A.	Cementone-Beaver Ltd.

Name	*Company or Organisation*
	G
Gilmour, Dr. J.	Rohm & Haas
Goddard, Dr. A.	Fosroc Ltd.
Goslin, H.	Remtox Chemicals
Gough, J.	Timber DPC Surveys Ltd.
Graham, H.	R. H. Campbell Building
Gray, Dr. S.	Imperial College
Grundlinger, Dr. R.	Bayer, A. G.
Gulliver, R. C. P.	Gulliver Timber Treatments Ltd.
	H
Hale, Dr. M.	University College of North Wales
Hall, Dr. G. S.	T.R.A.D.A.
Hanney, R. G.	Rentokil Ltd.
Hanson, R. M.	Hickson Timber Products Ltd.
Harling, D. L.	Mechema Chemicals Ltd.
Hayton, J.	Rentokil Ltd.
Hegarty, Dr. B.	Rohm & Haas
Hilditch, E. A.	Cuprinol Ltd.
Hilditch, Mrs. B. F.	Partner
Hill, L.	B.W.P.D.A.
Holland, Mrs. G.	BRE
Hollis, G.	M.A.F.F.
Hutchison, G. O.	Calders & Grandidge Ltd.
	I
Ince, G.	Troy Chemicals
	J
Jobling, H. A.	Northern Electricity
Jones, C. J.	B.W.P.D.A.
Jones, M. G.	Hickson Timber Products Ltd.
	K
Keenlyside, Dr. J.	Hutton & Rostron
Keeling, S.	S. Keeling & Co.
Keighley, D.	Yorkshire Electricity Board
Kelly, Dr. A.	GORI
King, Prof. B.	Dundee Institute
Kunze, Dr. K.	Schering Chemicals Ltd.
	L
Lamb, K. M.	Cuprinol Ltd.
Lambert, D.	Safeguard Chemicals
Landsiedel, H.	Schering Chemicals Ltd.
Langham, D. A.	Rudders & Payne
Lee, Miss G.	BRE
Lefley, J.	B.W.P.D.A.
Le Grys, P.	Heritage Preservation
Lloyd, H.	Hutton & Rostron
Love, D.	Rhone-Poulenc/Manchem
	M
Margolis, S. D.	British Woodworking Federation
Marsh, C. H. M.	Peter Cox (Preservation) Ltd.
Marshall, R. P.	GPT
Marshall, Mrs. R. P.	Partner
McCullagh, B.	Private Member
McMenemy, P.	Kingfisher Chemicals
Medcalf, P. J.	Cuprinol Ltd.
Metcalf, M.	W. Metcalf Ltd.
Miller, Dr. E. R.	Building Research Establishment
Milne, E. Carmo, A.	Anglo Portuguesa

Name	*Company or Organisation*
Milne, E. Carmo, Ms. J.	Anglo Portuguesa
Moldrup, B.	Danish Wood Treating Co.
Morgan, M. R.	Rentokil Ltd.
Mouzouras, R.	Cuprinol Ltd.
Murphy Dr. R. J.	Imperial College
Murray, K.	Mercian Preservation
	N
Norman Rear Admiral	St. Cartherines College
North, P. D.	Timberwise Consultants Ltd.
North, Mrs. P. D.	Partner
Nubel, D.	British Pest Control Association
Nurse, G. W.	Wood Decay Treatments
Nurse, M. G.	Wood Decay Treatments
	O
Orsler, R. J.	Building Research Establishment
Oxley, J. E.	Sovereign Chemicals Ltd.
	P
Palfreyman, Dr. J. W.	Dundee Institute
Palmein, H.	South Western Electricity
Parker, J.	Calders & Grandidge Ltd.
Parks, A. G.	Burt Boulton (Timber) Ltd.
Payne, B. M.	MacDonald Turner Ltd.
Payne, C. J.	Solignum Ltd.
Pearce, E. M.	Fosroc Ltd.
Perriton, R.	RP Associates
Pia Koch, Ms. A.	Danish Technological Institute
Pierce, A.	Manweb Electricity
Pinion, L. C.	B.W.P.D.A.
Plowman, D	RTZ Chemicals
Pretty, A.	Cementone-Beaver Ltd.
Prins, J. H.	Stichting Keuringsbureau Hout
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