RECORD

of the

1955 ANNUAL CONVENTION

of the

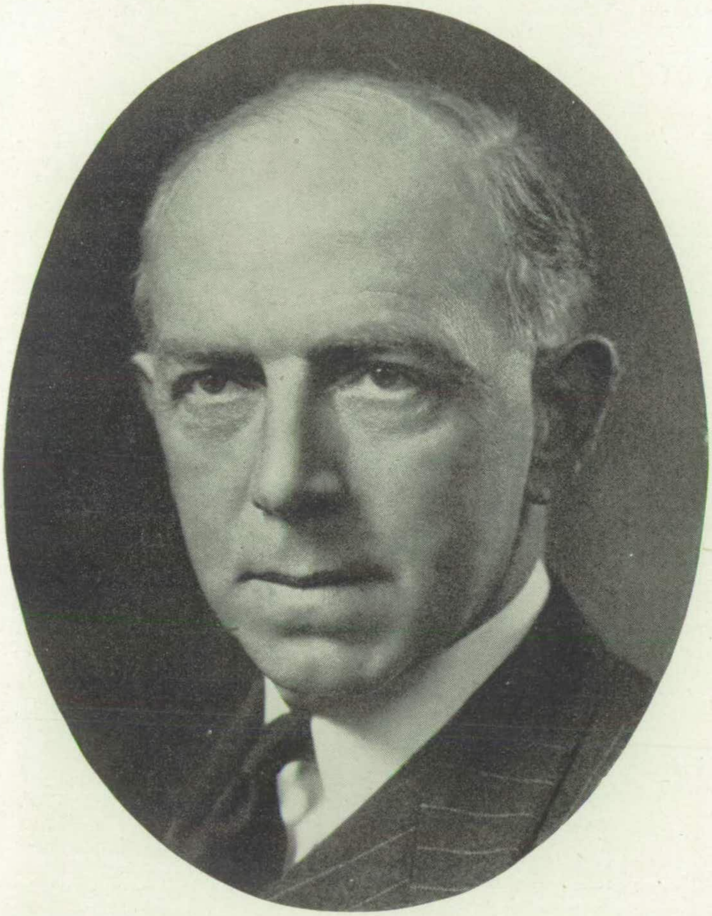
BRITISH WOOD PRESERVING ASSOCIATION

Cambridge,
June 21st—24th, 1955

BRITISH WOOD PRESERVING ASSOCIATION
6, SOUTHAMPTON PLACE, LONDON, W.C.1

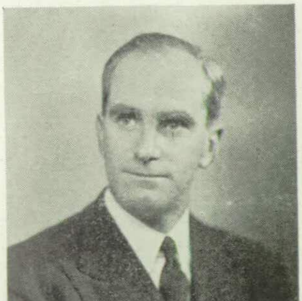
T. G. Robinson

C. S. White



Stanley Robinson,
President of the British Wood Preserving Association

W. E. Vesey



W. K. Hutchison

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THE BRITISH WOOD PRESERVING ASSOCIATION

IT is *not* a trade development association, nor is it a propaganda organization.

It is a body which collects all available information on the preservation and fireproofing of timber and on the methods of applying preservatives and fire retardants ; it sponsors scientific research into the use of preservatives and fire retardants 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. 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 and fire retardants.
Users of timber, e.g., British Transport Commission, Central Electricity Authority, etc.
Firms operating all forms of treating plants.
Specialist timber consultants.
Manufacturers of plants.

COMMITTEES

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

On the Executive Committee there are representatives of learned societies, scientific bodies, principal consumers, architects and consultants, as well as manufacturers and those who specialize in preservative treatment of timber.

Other Committees deal with such matters as service records, specifications, technical problems, membership, publicity, finance, arrangements for the Annual Convention and Library matters.

On several of these Committees there are representatives of Government departments.

SERVICES

a It offers a free advisory service on all problems connected with timber preservation.
b It issues leaflets dealing with practical problems and the latest developments in research.
c It holds an Annual Convention at which specialist papers are presented by experts from all over the world.
d It publishes in book form a Record of the Annual Convention containing copies of the papers and records of the discussions.
e It issues free of charge each month to all members a copy of the journal *Timber Technology*, in which is included the monthly bulletin of the Association.
f It maintains a panel of lecturers whose services are available on request.
g It organizes exhibitions to show the value of preservation.
h It arranges visits to the works of manufacturers and treaters.

FINANCES

It should be appreciated that the Association depends entirely upon 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.

BRITISH WOOD PRESERVING ASSOCIATION

Membership

To: **The British Wood Preserving Association,**
6, Southampton Place, London, W.C.1.

I/We hereby make application for details relating to membership of the British Wood Preserving Association.

Name in full (Block letters) ....

....

Occupation ....

Firm or Organization..

....

Kind of business ....

Address ....

....

....

Date ....

CONTENTS

PRESIDENT'S OPENING ADDRESS

MAY I first say how very glad I am to welcome you all here today. I regret that owing to the timing of the railway strike there are not quite the total number of delegates attending this year as originally anticipated. Nevertheless, there are over 200 delegates and visitors.

It is a particular pleasure to have with us representatives from Belgium, Canada, France, Germany, Holland, Norway, Portugal and Sweden.

Apart from delegates from member firms, the Association welcomes representatives from the Trade and Technical Press, the Admiralty, British Transport Commission, British Standards Institution, Canadian High Commissioner's Office, Edinburgh University, Fire Research Station, Forest Products Research Laboratory, Gas Boards, Heston Borough Council, London County Council, Ministries of Supply, Civil Aviation and Works, departments of the University of Cambridge, Timber Development Association, Timber Trades Federation of the U.K., War Office.

We are sorry that it has not been possible for Dr. Colley and Mr. George Lumsden from the United States of America, Mr. Tack from East Africa and Mr. L. E. Brooker from New Zealand to present papers this year as originally hoped, but we look forward to papers from these gentlemen perhaps even next year.

I would like to remind delegates that during the past year a small panel set up by the Association has been collaborating with the T.D.A. in the revision of the T.D.A. Red Booklet on "Timber Preservation" and it is hoped that when this work is completed it will be possible to issue it as a joint report from the two associations.

It is pleasing to note that there is an increasing awareness of the value of timber preservation, particularly among local authorities and the building industry. One of our Vice-Presidents, Mr. C. S. White, F.R.I.B.A., in the most useful paper he presented last year, provided much helpful guidance on when he considered preservative treatment desirable.

Decay of timber should never be accepted as inevitable, for it is usually an indication that the timber was not adequately protected and preserved. In addition, even when timber is to be used under permanently dry conditions, it is important to assess the possible danger of insect attack. Arguments in favour of preservation will rightly be based on economic considerations. In the days when timber was cheaper than to-day and readily available, such considerations were not always taken into account unless a particularly valuable structure was involved. The treatment of timber for structural purposes should be regarded as an insurance premium paid once at the time of construction in order to prevent decay and insect attack. A most important factor meriting careful thought is the labour costs involved in replacements should untreated timber suffer either fungal or insect attack.

I hope that you will all enjoy your visit to Cambridge and play an active part in the discussions on the various papers. I would ask that anyone in the body of the hall who wishes to speak or ask a question should first state his name and initials clearly. It would also help if the Chairman at the official sessions repeated each questioner's name, to ensure that everyone hears it.

In conclusion I declare the Convention open and I will call upon Mr. David Irvin to take the Chair and Mr. Savory to present his paper.

(1.) THE ROLE OF MICROFUNGI IN THE DECOMPOSITION OF WOOD

BY J. G. SAVORY, B.SC.
(Principal Scientific Officer, Section of Mycology, Forest Products Research Laboratory)

THE Fungi are one of the most important agencies in the breakdown of carbohydrates. It has been accepted that destruction of wood, which is chiefly composed of carbohydrates and lignin, is carried out almost entirely by the wood-boring animals and by a relatively small group of the Basidiomycetes and larger Ascomycetes. The microfungi (Fungi Imperfecti and smaller Ascomycetes) are known to be destroyers of unlignified plant fibres; it is also known that they can grow through wood, living on food materials such as starches and sugars remaining in the sapwood, and that some of the bark-inhabiting Ascomycetes can decay small branches and twigs. Comparatively recently it has been realized that some of the microfungi can decompose timber and that under certain conditions it is they rather than the Basidiomycetes which cause decay of timber in use.

Appearance of Attacked Wood

Wood decayed by the microfungi usually retains its shape and when dry may appear normal though it breaks off with a very brash fracture if an attempt is made to lever up a splinter with the point of a penknife. Whilst still moist, severely decayed wood is very soft and for this reason the decay has been named soft rot or, as Dr. Becker termed it in German, *moderfäule*. Decayed wood is usually discoloured; wood that has remained under water for a number of years is usually markedly darkened on the surface and very soft though depth of penetration of the rot is never very great. When such a piece of submerged wood dries out, cross cracks appear in the darkened decayed surface giving a characteristic appearance which is somewhat similar to that of lightly charred wood. With this exception, soft rot is so completely unlike the white and brown rots that the presence of fungal decay may easily be discounted by one who has experience of Basidiomycete decay only.

In its early stages soft rot is very difficult to detect without the aid of a microscope. Under the microscope it has a characteristic appearance and can be recognized quite easily. The fungal hyphae lie within the thickness of the secondary walls of the wood elements penetrating longitudinally along the wall; in softwoods the path of the hyphae is usually an open spiral. In thicker walled elements the hyphae are seen to lie within cavities formed by enzyme action. In thin longitudinal sections the cavities are best sought for under polarized light when it can be clearly seen that they have characteristically pointed ends.

Historical

The general conclusion reached in published studies of the effects of the growth of microfungi in timber is that none of the really common timber moulds, e.g., *Trichoderma viride*, *Paecilomyces varioti* and *Penicillium* spp., cause decay. Lurie (1931) isolated *Bispora effusa* from wattle (*Acacia decurrens*) and blue gum (*Eucalyptus globulus*) pit props in South Africa and showed that it decayed both sapwood and heartwood of wattle in culture. (Lurie reported penetrations only of the sap-stain type but in studies of the related species *Bispora pusilla* at Princes Risborough, typical sap-stain and soft rot penetrations were observed.) Bailey and Vestal (1937) made an academic study of cavities with pointed ends in timber and deduced that microfungi were the cause.

Barghoorn and Linder (1944) pointed out the role of microfungi in causing decay of timber submerged in the sea and proved that a number of true marine fungi which they isolated caused a decay of the soft rot type. Their work received insufficient attention from those concerned with the preservation of timber on either side of the Atlantic until the discovery at the Forest Products Research Laboratory that microfungi cause decay, not only of timber submerged in *fresh* water but also of timber in the soil. This has led us to recognize the importance of the part microfungi play in the decomposition of wood. The first phase of the work was reported to the International Botanical Congress at Stockholm (Findlay and Savory, 1950). The views then expressed as to the importance of soft rot in water cooling towers were later confirmed and elaborated (Savory 1954) and an appraisal was made of the significance of the microfungi in relation to wood preservatives (Findlay and Savory, 1954).

Methods of Study

Knowledge of the general and microscopic appearance of soft rot has permitted recognition of the examples obtained from the range of situations given in Table 1. Consideration of the nature of these situations has given clues as to the conditions under which soft rot occurs and has suggested profitable lines of laboratory enquiry.

Experimental work began with the isolation of fungi from wood showing soft rot taken from cooling towers. Tests on these fungi in pure culture have shown that the species listed in Table II attack wood. Some fungi which are able to rot non-lignified cellulose are apparently unable to cause soft rot in timber; perhaps the techniques employed are unsuitable for these particular fungi—there is a suspicion that some of them can in fact attack wood.

Further work, some of which is described in detail below, has been done to determine the factors which influence attack of wood by microfungi. *Chaetomium globosum* has been used as a test organism because

TABLE I

SITUATIONS IN WHICH SOFT ROT HAS BEEN FOUND

S = softwood H = hardwood
T = treated with preservatives. U = not treated.

Situation	*Remarks*
In fresh water	
Timber in water-cooling towers	Chiefly S. T. and U.
Boats	Chiefly H.
Piling	S. T. and U.
Mill wheel paddles	H.
In sea water	
Slats in a water-cooling tower	S.
Piling	S. H. T. U.
Boats	Chiefly H.
Test specimens	H.
In soil	
Telegraph poles	S. T. (tar oil and water-soluble)
Railway sleepers	S. T. do.
Fence posts	H.
Piling below buildings	H.
Test specimens	H. S. T. U. do.
In buildings	
Ends of ground floor joists	H. and S. occasionally severe in old timbers.
Floor boards	Fairly common in old S.
Floor blocks	H.
Rainwater gutters	S.
Draining boards	H.
Wood in damp situations	Durable H. in greenhouses, swimming baths, etc.
Exposed, wetted occasionally	
Top end of fence posts	Chiefly H.
Plywood	Chiefly H.
Many old scraps of timber.	Durable H.
Vehicles	
Plywood	H.
Wood in damp situations, floors, etc.	H.
Humidity chamber at 90% r.h.	Beech stored for 2 years.
Imported timbers not in service	Non-durable H. and S.

TABLE II

FUNGI PROVED CAPABLE OF CAUSING SOFT ROT

Fungus	Authority or Isolate Number
Bispora effusa	Lurie
Bispora pusilla	F.P.R.L. S132
Chaetomium cochlioides	,, S109C
Chaetomium elatum	,, S115
Chaetomium funicola	,, S121
Chaetomium globosum	,, S70B
Coniothyrium sp.	,, S603
Stysanus sp.	,, S605
Stysanus sp.	,, S91
Trichurus terrophilus	,, S128
A number of species of true marine fungi	Barghoorn and Linder

it grows well in the laboratory and, since it had been widely used in rot-proofing tests on textiles, information about this fungus was already available. Up to the present only *Chaetomium* spp. have been found to be really suitable for laboratory work and the frequent references to *C. globosum* indicate the limits of our knowledge rather than any strong belief that it is the most important of the wood-destroying microfungi.

Factors Relating to Decay of Wood by Microfungi

Presence of nutrients

In laboratory tests decay of beech by *C. globosum* is very slow unless suitable additional nutrient salts are provided. The rate of decay then becomes comparable with that of the Basidiomycetes. The Basidiomycetes themselves decay wood slightly faster when nutrient salts are provided but the proportional increase is negligible in contrast. Furthermore, the total decay caused by *Chaetomium* (measured as percentage weight loss of test blocks) is roughly proportional to the amount of additional nutrient salts provided. In these tests a mixture of salts suggested by Abrams (1948) was employed. The mixture also greatly stimulated attack of beech by *Trichurus terrophilus* and two species of *Stysanus*.

Following these experiments it was concluded that soft rot would occur more rapidly in wood in contact with well manured soils. Evidence in support of this conclusion is given in Tables III and IV. The results with Vermiculite indicate the rate of decay in the absence of nutrients. The soil samples from Africa were collected by Mr. E. H. Nevard who also made the field observations. The soil analyses were carried out by Mr. M. N. Nicholson of the National Agricultural Advisory Service. The soil analyses may not be strictly applicable to the test soils as it is known that when moist soil is heated more nitrogen becomes available for plant growth; this and possibly other changes are reflected in the altered hydrogen ion concentrations after autoclaving. None the less, there is quite a degree of correlation between the amounts of nutrient present, the field observations and the rate of decay of the test samples. Soil No. 4, which supported no significant decay in the field, gave least decay in the test. The variations in pH do not appear to be significant but the low moisture retaining capacity of soil No. 4 could adversely affect fungal growth under dry climatic conditions.

The experiments with the soil/peat mixture showed that the rate of decay by *Chaetomium* is increased by the addition of suitable amounts of fertilizer though excessive amounts will prevent attack altogether. *Chaetomium* fruited freely on the peat as well as on the test blocks and the lower percentage decay with the plain soil/peat mixture, as compared with that when the soil was employed alone, may arise because some of the nutrients were utilized to rot the peat.

Observations made by Central Electricity Authority on softwoods

TABLE III

SOME OBSERVATIONS ON SOILS

Soil	Field observations on hardwood posts planted in the soil	Calcium carbonate	pH value	Available phosphate	Available potash	Total nitrogen	Organic matter
African soil No. 1 ...	Severe soft rot	Nil	7.3	AD	L	VL	F
African soil No. 2 ...	Severe soft rot	Nil	6.9	F	VL	F	F
African soil No. 3 ...	Severe soft rot	Nil	7.6	AD	F	VL	MD
African soil No. 4 ...	No significant soft rot	Nil	5.8	AD	MD	VL	MD
Princes Risborough soil ...	Soft rot observed	Trace	7.8	AD	F	VL	L

F = fair
L = low
VL = very low
MD = marked deficiency
AD = acute deficiency

TABLE IV

SOIL CONTACT EXPERIMENTS

Soil used		Moisture retaining capacity of soil %	Initial moisture content of soil in the test	Observations after 6 weeks' incubation at 30°C.			
				Soil pH	Average moisture content % of test blocks	Av. wt. loss %*	Range of weight losses
	African soil No. 1	36	46	7.7	Not determined as test blocks had to be washed to remove adhering soil	8.2	7.6—9.2
	No. 2	36	46	7.9		13.0	11.2—14.7
	No. 3	35	45	7.4		11.6	8.5—14.4
	No. 4	16	26	6.0		6.4	3.7—8.5
	Light clay soil from Princes Risborough	33	43	7.2		19.1	17.4—20.2
2 parts light clay soil from Princes Risborough plus one part peat (by volume)		59	59	5.8	52	10.2	8.1—11.2
2 parts light clay soil from Princes Risborough plus one part peat (by volume)	plus 1 gm. National Growmore fertiliser per 300 gm. mixture	—	59	—	69	16.2	12.7—20.5
	plus 5 gm. ditto	—	59	—	55	12.7	9.7—14.3
	plus 10 gm. ditto	—	59	—	53	11.6	10.3—13.0
	plus 20 gm. ditto	—	59	5.2	43	6.1	3.7—7.1
	plus 40 gm. ditto	—	59	5.3	44	Nil	—
	Vermiculite	198	150	—	44	0.36	0 —0.51

* Average of 6 blocks for the soils and of 10 blocks for the soil/peat mixture and the vermiculite.

in water cooling towers have not shown any really clear correlation between rate of decay and the amount of nutrient salts present in the water. Clearly other factors also limit the rate of attack under these conditions for one would expect nutrients to have as great an influence in water as in soil.

Although laboratory tests indicate that little soft rot occurs in timber when no additional nutrients are available, examples of soft rot have been noted in timber which is not likely to have been in contact with nutrients. In a few instances severe decay has been confined to the sapwood and it seems likely that the nutrients present in the sapwood have contributed towards attack by the microfungi. It may be significant that in the laboratory decay by *Chaetomium* is always accompanied by fruit body formation and hence immobilization of nutrients, whereas under natural conditions even severely rotted wood rarely bears fruit bodies.

Temperature

Information about the temperature relations of soft rot is fragmentary. The decay occurs equally at the bottom and top of water cooling towers, that is at temperatures between 25°C. and 35°C. but at 38°C. in laboratory tests *C. globosum* did not decay beech. Maximum decay of cellulose fabrics occurred at 30°C. with *C. globosum* (Abrams) and at 29°C. with a number of other microfungi (Siu and Sinden, 1951). Soft rot in unused sawn timber has chiefly been found in timber imported from the tropics and sub-tropics; it is usually found in temperate zone timber only after the wood has been in service for some years. Probably the general optimum temperature for soft rot is higher than that for Basidiomycete decay and the temperatures of the tropics and sub-tropics may be even more favourable for decay by the microfungi than decay by the Basidiomycetes.

Barghoorn and Linder showed that the optimum temperatures for growth of the marine fungi on agar ranged from 22.5°C. to 30°C. and suggested that "their destructive action on wood and cordage might be more rapid in warm or tropical waters than in cooler northern waters."

Oxygen and moisture relations

The microfungi can attack wood which is too wet or too dry for Basidiomycete decay. The small amount of dissolved oxygen present in well aerated water is sufficient to permit the growth of microfungi on totally immersed wood. It has been shown (Savory, 1954) that the microfungi are the chief cause of deterioration of timber in water-cooling towers in the United Kingdom. If the water is not well aerated, soft rot may be prevented. Barghoorn and Linder observed that in sea water fungi are extremely common on wood under aerobic conditions but totally absent under anaerobic conditions.

Oxygen shortage probably limits the depth of penetration of the microfungi into any piece of wholly submerged wood for decay is always superficial and there is a sharp demarcation between decayed and sound timber, whereas when soft rot occurs in timber exposed, albeit intermittently, to the atmosphere there is no such limit to the depth of penetration.

Basidiomycetes are unable to decay wood when the moisture content lies below about 22 per cent. The limiting moisture content for attack by microfungi is unknown but severe soft rot occurred in beech strips which were exposed at a controlled humidity of 90 per cent. r.h. (equilibrium moisture content 20-21 per cent.) for two years. Soft rot occurs very frequently in situations where rapid drying occurs and the wood probably does not remain wet long enough to permit Basidiomycetes to become established, e.g. tops of fence posts and exposed sheets of plywood.

Erosion

When soft rot occurs under water the depth of penetration is limited but if any form of abrasive action occurs the softened surface is more quickly removed and a new surface is exposed to attack. Barghoorn and Linder have quoted the characteristic reduction in cross section at mud level and at high tide level of wooden piling in the sea as an example, others are to be found in water cooling towers at points where there is a local concentration of flow of the water or when the circulating water contains abrasive materials.

Wood-boring animals

Fresh water worms which do not attack sound wood have been found in softened hull planking of boats. Here again, attack by the fungi permits penetration of the worms which in turn may allow still deeper penetration of the fungus. Deschamps (1952) emphasized the role of fungi and bacteria in aiding attack of wood by marine borers and there are no grounds for rejecting his suggestions that *Limnoria* and *Chelura* only attack wood which has already been decayed.

In freely exposed wood soft rot is sometimes accompanied by insect attack; examples have been noted where presence of slight soft rot in the heartwood of Scots pine building timbers has permitted spread of furniture beetle attack to the heartwood.

Timber species

Soft rot has been observed in hardwoods and softwoods of all durability classes. It is by no means uncommon to find superficial soft rot on very durable hardwoods which have been chosen for use in situations where general conditions are favourable for fungal attack and a high proportion of all decay of these timbers appears to be caused by microfungi. Laboratory tests (Table V) show that there is a striking difference in the resistance of hardwoods and softwoods. The resistance of hardwoods to *C. globosum*, as measured by the accelerated decay test,

TABLE V

RESISTANCE OF TIMBERS TO ATTACK BY *Chaetomium globosum* WHEN EXPOSED AS BLOCKS 10 x 2 x 0.5 CM. BY ABRAMS' MYCELIAL MAT METHOD

Timber	Botanical Name	Degree of resistance to attack by wood-rotting Basidiomycetes	Decay by *Chaetonium globosum*	
			Number of weeks' exposure at 30° C.	Average weight loss
Softwoods				
Bahamas pitch pine	Pinus caribaea	Durable	6	1.6
Scots pine sapwood	Pinus sylvestris	Not durable	6	0.6
Hardwoods				
Greenheart	Ocotea rodiaei	Very durable	6	Negligible
			8	,,
Kokrodua	Afrormosia elata	,, ,,	8	,,
Mchenga	Isoberlinia globiflora	,, ,,	8	5.9
Mjembe	Erythrophleum africanum	,, ,,	8	Negligible
Okan	Cylicodiscus gabunensis	,, ,,	8	,,
Opepe	Sarcocephalus diderrichii	,, ,,	6	,,
			8	,,
Rhodesian teak	Baikiaea plurijuga	,, ,,	8	,,
Tallowwood	Eucalyptus microcorys	,, ,,	6	,,
Wallaba	Eperua falcata	,, ,,	6	,,
Agba	Gossweilerodendron balsamiferum	Durable	8	,,
Albizzia	Albizzia ferruginea	,,	8	,,
Dahoma	Piptadenia africana	,,	8	5.8
Idigbo	Terminalia ivorensis	,,	8	Negligible
Danta	Cistanthera papaverifera	Moderately durable	8	,,
Essia	Combretodendron africanum	,, ,,	8	5.3
Okwen	Brachystegia nigerica	,, ,,	8	4.1
Serrette	Byrsonima spicata	,, ,,	8	Negligible
Beech	Fagus sylvatica	Not durable	6	23.2
			8	33.3
Gaboon plywood	Aucoumea klaineana	,, ,,	6	19.6
Mtondo	Brachystegia spiciformis	,, ,,	8	21.7
Niangon	Tarrietia utilis	,, ,,	6	15.0
Ogea	Daniellia ogea	,, ,,	8	21.7

is roughly proportional to their resistance to attack by the Basidiomycetes but softwood of the lowest durability rating, such as Scots pine sapwood, is as resistant to *Chaetomium* as the very durable hardwoods. It is not practicable as yet to employ softwoods in general laboratory tests because even under optimum conditions decay is slow and very variable.

Plywood

A high proportion of all decay in plywood is caused by the microfungi. Plywood has a high surface/volume ratio and, unlike solid wood, therefore responds quickly to changes in its environment; freely exposed plywood can be quickly wetted and it will dry just as rapidly. The Basidiomycetes, of which *Merulius lacrymans* is an outstanding example, on the whole become established only under relatively stable moisture conditions so it seems that the very nature of plywood favours attack by microfungi. Furthermore, they begin their attack from surfaces. Surface decay on a large-dimension timber may be quite insignificant but decay to an equal depth in plywood is very noticeable because even if there is no mechanical failure through complete loss of strength, delamination usually occurs.

Much of our plywood is made from non-durable hardwoods, the timbers most readily attacked by microfungi, and also when nitrogeneous glues are used they may supply additional nutriments which increase the rate of decay.

Presence of wood preservatives

Soft rot has been found on hardwoods and softwoods impregnated under pressure with creosote and with water-soluble preservatives. Superficial soft rot (to a depth of about 1/16 in.) occurs on the exterior of those portions of creosoted telegraph poles and railway sleepers which lie below ground level and it has caused some failures of poles and sleepers treated with water-soluble preservatives.

Failures of treated timber caused by Basidiomycete decay usually arise through exposure, and attack, of the central core which is not reached by the preservative, that is to say through imperfections of the treatment rather than failure of the preservative. Soft rot, on the other hand, usually begins on the exterior on those parts of the wood which have received treatment. It can at once be inferred that the wood-rotting microfungi, like the sap-staining microfungi, are more resistant to preservatives than the wood-rotting Basidiomycetes.

Laboratory tests of the toxicity of wood preservatives to the microfungi are still experimental in character. Treatment of the wood with preservative can be carried out by the methods laid down in B.S.S. 838 but other methods must be adopted for exposure of the treated wood to the fungus and Abrams' mycelial mat method, first proposed for testing of treated textiles, has been used. The results of such a test of the toxicity of pentachlorophenol to *C. globosum* are given in Table VI.

TABLE VI—TOXICITY OF PENTACHLOROPHENOL TOWARDS *Chaetomium globosum*

Concentration of treating solution weight/weight	Absorption of Pentachlorophenol		Treated veneers after 6 weeks' exposure		Control veneers after 6 weeks' exposure	
	As kg/m³	As lb per cu. ft.	Nature of growth (6 veneers)	Average weight loss %	Nature of growth	Average weight loss % (2 veneers)
5%	32.7	2.04	—	—	Dense on undersurface	67.9
3%	19.2	1.2	—	—	do.	69.9
2%	12.5	0.78	Very slight	—	Sparse—dense. Heavy growth on undersurface	76.9
1%	6.0	0.37	Sparse—moderate	14.6	Dense	76.9
0·5%	2.4	0.15	Moderate	71.3	do.	77.3
0.25%	1.2	0.075	Moderate	74.4	do.	77.1
0.1%	0.47	0.03	Moderate—dense	77.1	do.	75.3

TABLE VII—APPROXIMATE TOXIC LIMITS OF PENTACHLOROPHENOL TO WOOD-DESTROYING FUNGI

Fungus	Species of timber	Method of exposure	Approximate toxic limits		
			As strength of treating solution %	As absorption of pentachlorophenol	
				kg/m³	lb per cu. ft.
Chaetomium globosum	Beech	Abrams' mycelial mat method	1—2	6—12.5	0.37—0.78
Polystictus versicolor	Beech	B.S.S. 838	0.25—0.3	1.12—1.22	0.07—0.076
Coniophora cerebella	Scots pine sapwood	B.S.S. 838	0.15—0.25	0.6—1.13	0.038—0.071
Lentinus lepideus	Scots pine sapwood	B.S.S. 838	Below 0.0375	Below 0.16	Below 0.01
Poria vaporaria	Scots pine sapwood	B.S.S. 838	0.15—0.25	0.6—1.13	0.038—0.071

The test against *C. globosum* was carried out on treated beech veneers 3 x 2 x 0.14 cm. Six veneers were treated with each concentration of preservative. Three treated veneers and one untreated control veneer were exposed in each test container.

In Table IV the approximate toxic limits of pentachlorophenol to *C. globosum* and wood-destroying Basidiomycetes are shown. It may be unwise to compare the results of the two types of test too closely but it is clear that a much higher concentration of pentachlorophenol will be needed to protect beech from *Chaetomium* than from *Polystictus*. Alternatively, timber having an initial retention of preservative sufficient to prevent all forms of decay may eventually, through leaching and other forms of loss of preservative, become subject to attack by microfungi whilst still retaining sufficient preservative to prevent attack by Basidiomycetes.

Interpretation of the Results of Field Trials

With the knowledge available it is possible to give a new interpretation to some of the results of field trials that have already been published.

Natural durability trials

Fig. 1 is reproduced from Smith's (1949) account of field service stake tests of the natural durability of timbers. It shows the percentage of failures at three test sites of all timbers which had completed ten years' trial and had shown failures at least at one site. In the well aerated soils at Princes Risborough and Thetford, softwoods have decayed faster than hardwoods, but in the poorly aerated waterlogged soil at Dolgelley, hardwoods have decayed faster than softwoods. This result is anomalous if interpreted in terms of Basidiomycete attack alone but is explicable if decay by Basidiomycetes *and* by microfungi is postulated. Soil conditions favour attack by Basidiomycetes at Princes Risborough and Thetford. The waterlogged site conditions at Dolgelley are unfavourable for the Basidiomycetes but can be tolerated by the wood-destroying microfungi. If it is assumed that a high proportion of all decay at Dolgelley is soft rot, then it is only to be expected that the softwoods which are inherently resistant to attack by microfungi should decay more slowly than the hardwoods.

Field tests of wood preservatives

Extracts from Bienfait and Hof's (1954) account of field trials in Holland, and Smith's (1954) account of similar tests in the United Kingdom, are given in Tables VIII and IX respectively. In Table IX the total number of failures of full cell, empty cell and open tank treated test stakes planted in equal numbers at Thetford, Princes Risborough and Dolgelley is given. In this test the beech retained slightly more preservative than the Scots pine or Douglas fir while retention by the oak was very much lower. However, if movements of salts subsequent

TABLE VIII

BIENFAIT & HOF. NUMBER OF TEST POSTS BROKEN UP TO FEBRUARY 1954

THE POSTS WERE PLANTED AT THE END OF 1947. THERE WERE 30 IN EACH SERIES

Preservative	Mode of Treatment	Poplar		Willow		Douglas		Pine		Larch		Sitka Spruce	
		Average absorption of salts lb per cu. ft	Number of failures	Average absorption of salts lb per cu. ft	Number of failures	Average absorption of salts lb per cu. ft	Number of failures	Average absorption of salts lb per cu. ft	Number of failures	Average absorption of salts lb per cu. ft	Number of failures	Average Absorption of salts lb per cu. ft	Number of failures
Copper Sulphate	Open tank	0.28	23			0.11	9	0.67	0	0.12	7		
Mercuric chloride	Open tank	0.063	7			0.025	0	0.081	1	0.02	0		
Zinc chloride	Open tank	0.37	18			0.11	4	0.66	1	0.16	4		
Tanalith	Full cell	0.34	29	0.21	30	0.18	5	0.37	3	0.12	2	0.14	4
Tanalith	Open tank	0.21	30	0.17	30	0.08	6	0.33	0	0.08	7	0.05	12
Boliden	Full cell	0.64	13	0.80	11	0.47	0	1.04	0	0.27	2	0.22	0
—	Untreated	—	30	—	30	—	14	—	26	—	9	—	11

TABLE IX

SMITH 1954. RESULTS OF FIELD TRIALS OF WOOD PRESERVATIVES AT 3 SITES

Preservative	90 TREATED SAMPLES No. of failures				90 UNTREATED CONTROLS No. of failures			
	Oak	Beech	Scots	Douglas	Oak	Beech	Scots	Douglas
Ascu 2¼%	1	3	0	4	20	90	61	57
Basalit 2%	8	70	64	51	21	90	75	66
Celcure 2½%	5	28	28	14	18	90	69	54
Chromel 2%	2	12	0	0	18	60	50	51
Tanalith 2%	14	52	7	3	30	90	73	68
Zinc chloride 2%	3	41	30	19	38	90	72	60
All preservatives	33	206	129	91	145	510	400	356

Chromel has been under test 15 years; the remainder 17-23 years.

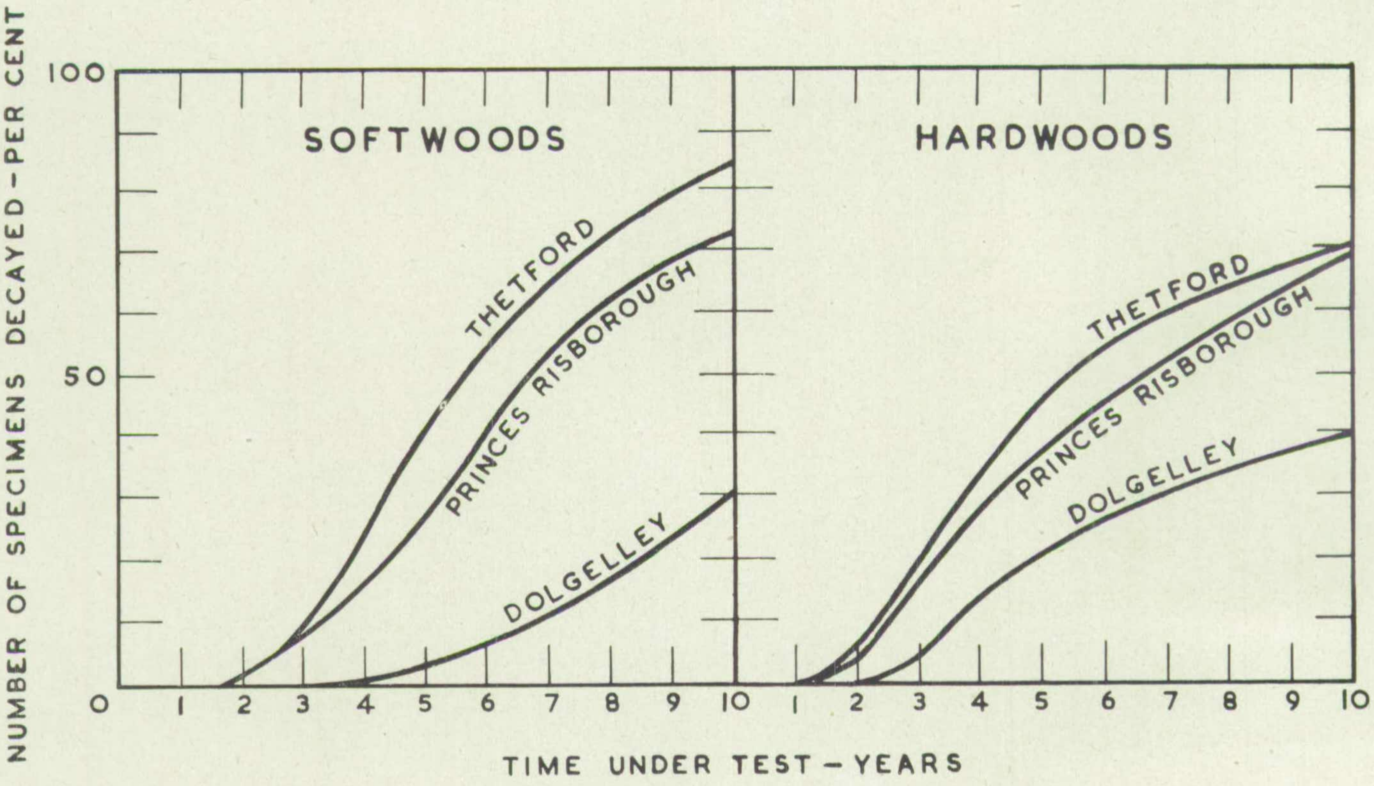

FIG.1 COMPARISON OF THE RATES OF DECAY AT THE DIFFERENT SITES

to treatment are discounted, strength of treating solution (which was the same for all timbers) gives a better measure of the amount of preservative present in those portions of the test specimens which actually received treatment and which are those exposed to superficial soft rot.

In both series of tests the softwoods show fewer failures than the hardwoods. With some of the preservative treatments this difference is very striking. Smith suggested that preservatives might leach more quickly from the beech and oak and commented on the lower resistance of hardwoods to attack by microfungi to account for the difference. Bearing in mind that microfungi are more resistant to preservatives than Basidiomycetes, it seems likely that the more rapid decay of the treated hardwoods, which are inherently more susceptible to soft rot, is indeed the result of attack by microfungi. When a random selection of broken test stakes which had been exposed at Princes Risborough were examined, it was found that nearly all of them showed some degree of soft rot and it was evident (Table X) that soft rot had been the chief cause of failure of the treated hardwoods while, on the other hand, Basidiomycete decay predominated in the softwoods.

TABLE X

CAUSE OF DECAY OF SOME OF THE FIELD TEST SPECIMENS TREATED WITH WATER SOLUBLE SALTS WHICH FAILED AT PRINCES RISBOROUGH PRIOR TO 1953

Timber	Chief cause of failure Basidiomycete decay	Chief cause of failure soft rot	Cause of failure uncertain or both types of decay
Oak	5	1	3
Beech	4	13	3
Scots pine	14	2	4
Douglas fir... ...	23	1	0
Corsican pine ...	0	0	2
Spruce	1	0	0
Hardwoods Total ...	9	14	6
Softwoods Total ...	38	3	6

Although it is believed that soft rot is even more important at Dolgelley than at Princes Risborough, Smith noted that "at Dolgelley the treated failures work out at 5 per cent. of the untreated compared with 14 per cent. at Princes Risborough". This illustrates the essential slowness, except under the most favourable conditions, of soft rot in comparison with Basidiomycete decay.

Neither Bienfait and Hof's nor Smith's results with tar oil treatments have been quoted for very few failures have so far occurred. It is evident that standard tar oil treatments are very effective against the microfungi in ground contact. Whether their ultimate failure will be due to soft rot remains to be seen but soft rot caused the failure of creosoted beech plywood test specimens buried in the ground for only three years.

Conclusions

1. Attack of wood by microfungi, soft rot, is of general occurrence on timber in a wide range of situations. It is often difficult to detect, particularly if the criteria for Basidiomycete decay are applied, hence, though widespread, its importance has been largely overlooked.

2. Under optimum conditions soft rot proceeds rapidly but in most natural situations it is a very slow form of decay.

3. The microfungi are able to tolerate a wider range of conditions than the Basidiomycetes so soft rot may be of importance in any situation in which Basidiomycete growth is reduced or prevented but in which physical conditions are not so severe as to prevent fungal growth altogether.

4. Soft rot is of particular importance on timbers with a large surface/volume ratio because the microfungi are better able than Basidiomycetes to withstand the physical conditions of such an environment, because the attack essentially proceeds inwards from surfaces and because small-dimension, as compared with large-dimension, timbers suffer disproportionate loss of strength when surface weakening occurs.

5. Some of the eventual decay in service of durable hardwoods is soft rot.

6. Much of the ultimate decay of the treated zone of preserved timber is the result of attack by microfungi. This is especially true of treated hardwoods.

7. It is desirable that consideration should be given to the inclusion of microfungi amongst the species of fungi used in laboratory tests of the toxicity of wood preservatives and of the natural durability of timbers.

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Discussion on Paper 1

The CHAIRMAN (Mr. D. B. Irvin): Mr. President, Ladies and Gentlemen, it is indeed for me something of an honour to be the first official Chairman at this Convention. I do sincerely trust that you will enjoy yourselves and go back home considerably richer for the experience.

Talking of being richer for the experience, that happened to Mr. Savory, whom I am about to introduce, a few years ago when I went to Princes Risborough and took with me a little box in which was a very nice fruiting body of Merulius. Dr. Findlay said, "Just a minute, I must get Savory to look at this." So Mr. Savory came in and that was the last I saw of it. Well, not quite actually, because I noticed there was a very pretty picture of Merulius on the front of the book recently produced, and I feel rather proud at having been able to produce something useful in that respect anyway.

Now Mr. Savory is a Cambridge man; he was educated here. I was perhaps a little astonished to find that it took him some ten years at Nottingham University to get a degree, but I found he had had a short holiday of five years in the Royal Navy during the war which probably accounts for the fact.

He is a Principal Scientific Officer at Princes Risborough in the Mycology Department, and he has done a lot of work on boats, which probably accounts for him being in the Royal Navy during the war studying rot in boats and especially the role of the microfungi in the rotting of wood. I feel quite certain that we shall learn something which will perhaps go towards the explaining of the inexplicable in some of the rots that are found today.

May I introduce to you Mr. Savory.

Mr. J. G. SAVORY: Mr. President, Mr. Chairman, Ladies and Gentlemen, I thank you for your kind remarks. I would point out one thing, that my time in the Royal Navy occurred before my interest in boats arose.

My pleasure at being asked to present a paper at the Cambridge Convention of the B.W.P.A. was undiminished when I found that I had not to read the paper, but only to make a few comments upon it. The reading of the paper I am able to leave to you.

We have all seen pieces of wood which have softened on the surface but do not show other signs of breakdown. For a long time some of us have looked at these pieces of wood for signs of breakdown by Basidiomycetes and we have not found them. We concluded, therefore, that the trouble was caused by some form of weathering or chemical attack and not by fungi at all. We dismissed the matter as unimportant, inexplicable, or both unimportant and inexplicable. Very often this surface attack or apparent decay without the presence of fungi is described by the phrase, "the wood has lost its nature." We know now that this is evidence of decay by microfungi and it is a type of decay which we call "soft rot."

Soft rot is easiest to recognize in pieces of wood that have been submerged for some time. There is a skin possibly up to $\frac{1}{4}$-inch thick of brown decayed wood and underneath there is sound, clean and, in the case of Scots pine, quite sweet-smelling timber (Fig. 1 upper).

When the surface of such a piece of wood dries out these extremely characteristic cross cracks appear (Fig. 1 lower). The surface after drying out is now quite hard.

When the pieces of wood that have been freely exposed, or have been buried in the ground, are examined a rather different picture is presented. The soft rot may not be at all easy to recognize. *Here* is a portion of a telegraph pole which broke up with a very brash fracture (Fig. 2). The brash fracture was the only indication of decay. The wood itself was very hard on the surface. It kept its shape and it was only when the wood was sectioned that we were able to determine definitely that decay was present.

This is a portion of a beech plank. Again there is the brash fracture. The wood was apparently quite hard, but when prodded with the point of a penknife it could be broken away quite easily with a very brash fracture, and there was a considerable amount of discoloration.

We have found soft rot in grave-yard specimens which have failed in service. *This* is a beech grave-yard specimen which has failed at ground level. Again very hard, it has kept its shape, but it has failed with a brash fracture and when the wood is prodded with an awl near the point of breakage it can be scraped away in a manner quite uncharacteristic of sound wood.

When the grave-yard specimen was sawn lengthwise, I was very disappointed to find that I could not tell the extent to which decay had penetrated into the wood. In fact, with the exception of a little discoloration and a little bit of blue stain down near the break, it was very difficult to tell by visual inspection that this was not a sound piece of wood. On the other hand, when I started to prod it with an awl I soon found that there was a central area that appeared to be very much more sound, but that, besides the decay down near ground level, there was also decay up at the top end of the post.

I have already said that we very often must rely on examination of the material under the microscope to confirm the presence of soft rot. I intend to show you what soft rot looks like under the microscope, but first of all, for purposes of comparison, I have here a slide showing blue-stain fungus in the wood. This is a longitudinal section. *These* are the wood tracheid walls cut through. *Here* is the brown fungus hypha running across the walls and penetrating through the walls by very fine penetrations.

This is a slide showing a normal wood-destroying Basidiomycete in the wood. Again we have the hypha penetrating through the wood cell walls but making "bore holes" much larger than the hyphae themselves. These bore holes are quite characteristic of the presence of a wood-destroying Basidiomycetes. This clamp connection is another of the characteristics of the Basidiomycetes; this clamp connection is of the particular type that we call a medallion.

Here is the picture presented by soft rot fungus in the wood. This section was taken at a depth of about 6 centimetres in the telegraph pole which I showed you earlier. The fungal hyphae are pursuing a spiral course, and lie entirely within the thickness of the cell wall itself (Fig. 3).

Here we have similar material which has been photographed under polarized light. We can no longer see the actual fungus, but what we can see is the cavity in the cell wall where the fungus has removed the particular layer of cellulose which gives the light refraction which you see here. This is a most valuable method of picking out the presence of soft rot in timber. It is extremely characteristic. The cavities have these very pointed ends. They are quite large in the thicker walled material; in thinner walled material they tend to be much more like tubes than cavities, but nonetheless they still have these pointed ends.

Very often the cavities have quite a characteristic diamond shape.

This is a transverse section of Douglas Fir taken in colour. The cell walls are cut across and you see the fungal hyphae lying within the thickness of the wall.

You can see that even although there are more fungal hyphae in this section they still tend to be concentrated within the wall. There are occasional hyphae that lie within the lumen, but those are usually blue-stain fungus which is very often associated with the soft rot (Fig. 4).

This is pretty well the last stage of attack which it is possible to photograph. Although the central layer of the wall is almost completely disorganized, there is a zone between the two cells which remains unattacked. I would point out that the innermost layer of the wall adjacent to the lumen still appears relatively sound.

This is a transverse section of soft rot in the fibres of beech. This attack was produced by *Chaetomium globosum* in pure culture and it was one of the earliest demonstrations we had that *Chaetomium* was indeed capable of attacking wood.

Here we have the appearance of *Chaetomium* in beech at a later stage. We have had considerable difficulty in sectioning the wood. The section is rather thick so that details of attack on this side are rather difficult to see. *Here*, where the attack has been much more pronounced, we have lost the whole of the inner layers of the cell wall during the process of sectioning.

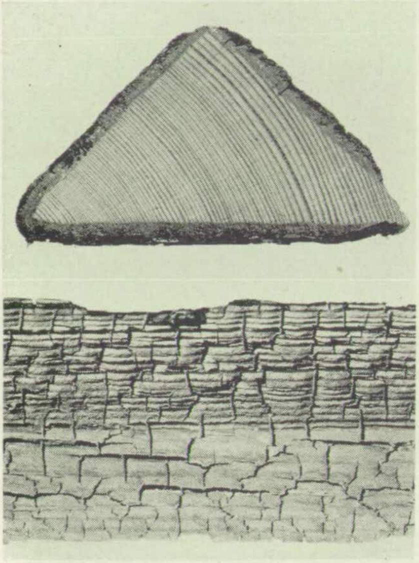

Fig. 1 upper. Softwood slat from a water cooling tower sawn across to show soft rot on the surface and sound wood beneath.
Fig. 1 lower. Surface of a slat from a water cooling tower showing the cross checking which develops when the decayed wood dries out.

Fig. 2. Telegraph pole 8″ in diameter, showing a brash fracture. Soft rot extended to the centre of the pole.

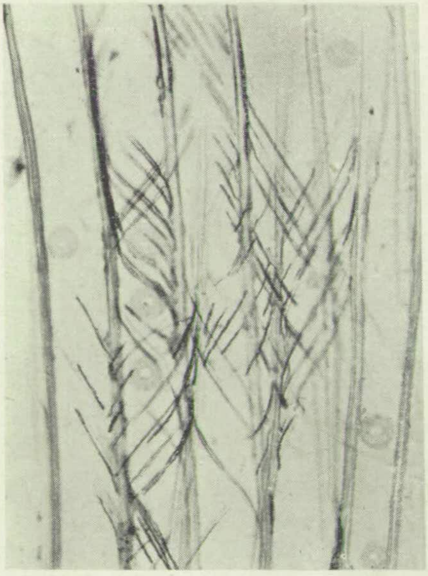

Fig. 3. Radial longitudinal section, highly magnified, of the wood at the depth of 2¼″ from the surface of the telegraph pole. The fungal hyphae run in spirals within the thickness of the walls of the wood cells—typical of soft rot.

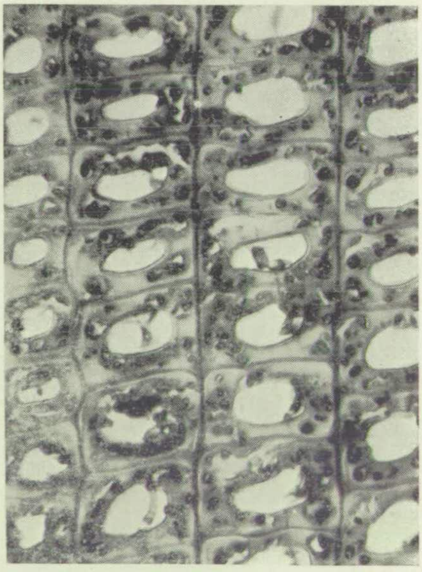

Fig. 4. Transverse section highly magnified, of softwood decayed by soft rot fungi. The dark areas in the walls are fungal hyphae which have been cut across.

I have tried to show you in the time available to me the criteria by which soft rot may be recognized. When more of us can recognize it, then I am quite sure that we shall find out a whole lot more about it.

One last word: besides the Forest Products Research Laboratory, there are two other laboratories in this country that are working on the wood-rotting microfungi, namely, those of the Central Electricity Authority and Messrs. Hickson's Timber Impregnation Company. I have considerable pleasure in acknowledging that there has been a very free interchange of ideas and information between these three laboratories and our present knowledge of soft rot is a result of truly co-operative efforts.

The CHAIRMAN: I would say to Mr. Savory that his photographs are well worth looking at. I would indeed—and I am sure you will agree with me—like to compliment those who sectioned, stained and photographed those particular sections. It is a very unenviable job and I think the photographs are absolutely magnificent.

I am certain, Ladies and Gentlemen, that many of you will have some questions to put to Mr. Savory and I am looking forward to some interesting discussion on this subject of the action of microfungi.

Mr. D. C. BAYNES: My firm are storing some logs for the Government strategic reserve stock. We have had logs in our log pond, which is a salt water pond, for about three or four years now and this soft rot is very noticeable below the water line to a depth at the moment of about an eighth of an inch, which you can scrape off quite easily. I should like to ask Mr. Savory if it is likely that this soft rot will increase in depth as the logs stay in the water.

Mr. J. G. SAVORY: So long as the timber remains in the water and under water, the depth of penetration is not likely to increase at any very rapid rate. I have recently seen timber that has been submerged in the Norwegian fjords for a matter of a hundred and fifty years. I do not know if a lot of surface was lost during transit, but the depth of the penetration was still not much more than a quarter of an inch. Again I have seen material that has been in cooling towers for twenty-five years and the depth of penetration was not very much more than a quarter of an inch.

An entirely different story arises if you wet and infect your wood and then allow it to dry out, and after that only wet it intermittently. You get a much deeper penetration. You may get the same sort of thing arising, as I showed you in the telegraph pole, where the depth of penetration was quite a way through the pole, a depth of 4 inches altogether. But completely submerged in water I do not expect any great depth of penetration. There I think that you have eventually an oxygen shortage which prevents the fungus from going any further into the wood.

It is perhaps a matter of interest that it makes no difference whether you submerge your timber in fresh water or in salt water. The original work on microfungi was done on timber immersed in the sea. In the sea we find there are truly marine fungi not found anywhere else which attack the wood. In fresh water the fungi are not true aquatic fungi at all—so far as we are aware, that is—they are ordinary terrestrial species, the type of fungi that rotted fabrics so very badly when we were in New Guinea during the war.

The CHAIRMAN: Is that satisfactory, Mr. Baynes?

Mr. D. C. BAYNES: Yes, thank you.

Mr. J. A. SCHOFIELD: It appears from this paper and photographs that soft rot is of considerable importance in causing failure of preserved timber in various situations and one rather wonders—at least I do—how many failures in the past have been attributed to Basidiomycetes when, in fact, they were initially caused by Ascomycetes. Would Mr. Savory tell us whether some priority is being given at Princes Risborough to investigating toxic limits and concentrations of major preservatives in use against this type of fungi?

Secondly, I gather from the paper that tar oil preservatives are possibly more effective against the Ascomycetes than certain other types. If there is some foundation for this, would Mr. Savory say in his opinion whether this is because of the permanency of the preservative, the concentration or loading of the preservative or the chemical complexity?

Mr. J. G. SAVORY: Regarding your first question, is priority being given to the testing of the toxicity of proprietary preservatives against soft rot fungi, we find ourselves in an extremely difficult position. In order to carry out a really reliable test of toxicity of a preservative one must test against as wide a range of fungi as possible. Unfortunately we are only able to control one fungus in the laboratory at the moment, the fungus I have mentioned so much, *Chaetomium globosum*. No other fungus is really satisfactory for preservative testing at the moment. That represents a limitation in our knowledge, a limitation in our technique.

Secondly, when it comes to carrying out the test with *Chaetomium globosum* itself, we are still in an exploratory stage of determining the type of tests which should be used. I am more confident now than I was three years ago that I am on the right lines in devising a test, but it may take another three years before I shall be wholly confident that I know enough about *Chaetomium globosum* itself in order to be able to say with certainty, this test will give a reliable result. I think, Sir, that is the situation at the moment regarding your first question.

Your second question regarding the effectiveness of tar oils, I was hoping that the meeting was going to give me some information on that subject.

Mr. P. GRINDELL: This is a quibble, but I rather felt that soft rot was generally referred to in the trade—the timber trade, that is to say—as the "punk" which I believe is a fruiting body. I am no expert in these matters. I thought possibly there was a danger of there being confusion between the one and this other new discovery.

Mr. J. G. SAVORY: I am not aware that soft rot has been used extensively in relation to timber. I know it has been used with regard to fruit like apples; you have soft rot of apples, but I have never heard it referred to timber before.

Regarding confusion, there already is confusion in the terminology of decay. We have terms such as "foxiness", "routiness", "dote", and there are one or two more, all of which add up to the same thing, the early stages of decay—decay by Basidiomycetes. I think we must work hard and suppress any earlier use of soft rot and try to impress our own terminology on the timber trade at large.

Mr. P. GRINDELL: If you will forgive me, I think the term soft rot is so well known in the timber trade that it will take quite a lot to eradicate it.

Mr. E. A. S. PRICE: Mr. Savory has said that we do not know enough about soft rot. I think it is awfully difficult for us at this stage to assess the general economic significance of it, but Mr. Savory should be congratulated on his paper which is going to be invaluable to us in days to come.

Taking up Mr. Schofield's question, it might be of interest that we have had recent reports from Africa that with four creosote treatments on hardwood there you can get a very rapid rate of soft rot which will result in early failure.

In this respect, it is only fair to draw attention to Mr. Savory's Table IX which shows that at least one water-borne preservative is highly efficient in ground contact under conditions of testing.

There is one further point of interest which is a comment, and I hope Mr. Savory will forgive me for bringing it in at this stage, because it is not a question. We have been carrying out service trials in water-cooling towers with the co-operation of the Central Electricity Authority; several points of interest have arisen of which two perhaps might be mentioned at this stage.

One is that we have got conclusive evidence—and I think this is very interesting—that soft rot will attack heartwood every bit as easily as sapwood. This, of course, raises particular problems of preservation, as we have carried out other tests at different levels of treatment which show that what is needed is an adequate treatment of heartwood giving you the same level of treatment that one can so readily achieve in sapwood.

Mr. E. H. B. Boulton: Mr. Chairman, Mr. Savory, some many years ago I had the privilege of going down on the bed of the river Thames when they were taking out the piles upon which the original Waterloo Bridge was built. They consisted of timbers of anything from 4 feet to 16 feet in length; they were anything from 4 inches to about 18 inches in diameter. They were, in fact, what we would have called a nurseryman's job lot of timber. They were not the piles as we know piles today, and after the length of time that Waterloo Bridge stood it only sank $1\frac{1}{2}$ inches in the middle.

Now I have samples of beech and of elm and these have without doubt, from what I have learned today, soft rot to a penetration of up to $\frac{3}{4}$-inch in the larger beech and not so much in the elm. I think many of us know that those logs from Waterloo Bridge were carefully seasoned. What I thought was the water washing away and softening the timber, probably was a soft rot; but those timbers were perfectly sound, were cut into veneers, the logs were sold to America and they all had a wonderful grey colouring on them. Had that grey colour anything at all to do with any of the microfungi's attack in causing the discoloration—attractive discoloration—throughout both the elm and the beech.

Mr. J. G. Savory: Mr. Boulton, you have introduced a terribly difficult aspect of the whole problem. So far I have examined quite a number of samples of buried material, no two of which have been precisely alike. We have a sample of the elm from Waterloo Bridge at the laboratory. I regret to say that I have never got around to going back after five o'clock with a saw and taking a sample from its rightful owner.

Nonetheless, the material we have is, as you say, sound on the inside and deteriorated on the outside. I quite think that is likely to be soft rot. On the other hand, I have examined samples of old buried oak—possibly buried a thousand years—that showed a surface deteriorated zone of perhaps 1 inch in depth. I just could not detect the presence of fungal attack in those at all.

Again I have examined elm from underneath the old Jewel Tower in the City of Westminster, just across the road from the Houses of Parliament. There again there was this very obvious surface softening, but in this case the whole of the timber was very much lighter in weight than it normally should be. I could detect nothing on the surface. Inside I could find areas of soft rot, and other areas which appeared to be sound had, nevertheless, when examined under the polarizing microscope, clearly suffered attack of a type unknown to me. Quite obviously there are other factors that are operating; which particular factor operates will depend on the conditions of environment, such as whether there is aeration or not. I suspect that in many cases bacteria are able to attack the wood, and there again you may have aerobic or anaerobic bacteria.

Yet again there is a possibility that during these long periods of burial the chemicals present in the soil may be able to attack the woods. The situation is that we are aware of these things and many other people are aware of them; people such as Varossieau in Holland and Barghoorn in America have all worked upon the problem and whilst we are able to say the wood is degraded, we are not able to say what organism has been responsible.

I still have not answered your question, what is the cause of the internal greyness? I am sorry, I do not know.

Mr. S. A. RICHARDSON: Have you found any association between the soft rots and the activity of the death-watch beetle? We know that there is an association between the Basidiomycetes and the death-watch beetle attack, but occasionally timber shows no indication of Basidiomycete attack. Yet it is generally thought—and I am one of those who think it—that it is unlikely death-watch will attack timber until it has been attacked by some form of fungi. Have you yet investigated possible association between microfungi and the activity of the death-watch?

Mr. J. G. SAVORY: The short answer to your question, Mr. Richardson, is no, we have not carried out any formal investigation of death-watch/soft rot relation.

On the other hand, we have odd snippets of information which may help to throw some light on the question. In the case of attack of heartwood of a softwood by one of the wood-boring weevils which Mr. Harris of our Entomology section was feeling very concerned about—he was concerned because the wood appeared to be sound and he did not expect weevil attack in sound heartwood. Very much against my inclinations he persuaded me to cut sections of the material and we found soft rot there. Again I have seen soft rot on the surface of softwood, the heartwood of softwood from old buildings, and in the surface-attacked zone we have found furniture beetle attack.

Turning to oak, I have seen quite large samples of oak timbers, wall plates and so on in which the chief form of attack was undoubtedly soft rot. I do not have any doubt whatsoever that there may be quite an association between the microfungi and the death-watch beetle, in that death-watch beetle attack is always quoted as being a scourge of ancient buildings, buildings one hundred and hundred and fifty years old. We say sufficient time has elapsed to permit leakages and hence to permit decay to take place. It is not always very obvious that there has been a leakage in these situations and it is sometimes rather difficult to see that Basidiomycete attack has taken place. From what we know of soft rot, the microfungi are able to attack in less damp situations than the Basidiomycetes. It is quite possible that in many roofs in which conditions are humid rather than damp the fungal attack may be soft rot and not Basidiomycete attack.

Dr. R. C. FISHER: Mr. Chairman, might I break in for a minute now that insects have been raised? There are two statements in Mr. Savory's paper which attracted my attention particularly. One was that in the temperate climates soft rot seems to be associated chiefly with timber which has been in store for a period of years. I should like to ask him, does he think there is any correlation between that fact and the susceptibility of softwood and other timbers to common furniture beetle attack which does not, in this country at least, usually occur until timber has been in service for a period of years? The other, closely related to that, is his comment on the susceptibility of plywood to infestation. Exactly the same thing occurs with furniture beetle damage in plywood. My own feeling, without any proof whatever, is that sometimes there is something present in plywood other than nitrogenous glues which makes it susceptible to attack. We are looking with great interest and anticipation to the mycologists to throw some light on the problem which entomologists have not been able to solve satisfactorily.

Mr. J. G. SAVORY: I think your suggestion is extremely interesting, Dr. Fisher. I do not think I can offer any straight answer to it. Quite obviously you have thought about it more than I have. At the risk of storing up trouble for myself, I suggest that we shall have to look into this more closely in the future.

Mr. J. R. AARON: Does Mr. Savory feel that the secondary cell wall is, to some extent, screened from wood preservatives by the tertiary wall, at least in places? Is he satisfied that the success of soft-rotting fungi is not due to the fact that they are operating in perhaps comparatively poison-free areas?

Mr. J. G. SAVORY: Mr. Aaron, this extremely interesting suggestion of yours, namely that the preservative is not uniformly distributed throughout the thickness of the cell wall, has been raised once or twice before by different people with an enquiring turn of mind. I think again the answer is that we do not know, but so far as I personally am concerned, I have no reason to suppose that the preservative is not fairly uniformly distributed through the cell wall. More than that; there are odd indications that it is, in fact, distributed fairly uniformly throughout the cell wall and that the fungus is not actually, as you suggest, operating in a preservative-free area, but is rather present as a result of its own tolerance for the actual preservative in use.

Mr. H. A. COX: I would like to ask Mr. Savory whether, when he starts to investigate again, he will try and find out whether there is any difference in the different preservatives in the penetration in the different parts of the cell wall? My own idea is that with some preservatives you practically get no penetration in the wall of the cell. I may be wrong. But in others you get deep penetration, and that will be a very important point, I think, in the question of dealing with these microfungi.

Mr. J. G. SAVORY: Thank you, Mr. Cox. I personally have not looked at pieces of wood to try to assess the penetration within the cell wall. I may say it is extremely difficult to see the detailed structure of the walls, in fact we are operating at the limits of resolution with the ordinary light microscope, and in that respect we may have to turn to the electron-microscope. Dr. Liese of Freiborg in Germany is hoping this afternoon to show some of the results of his own investigations with the electron-microscope. I think Mr. Price has made some observations on this subject using a light microscope and he may have some light to throw on the subject.

Mr. E. A. S. PRICE: I have discussed this from time to time with Mr. Savory. I am afraid I cannot help you personally. Our feelings are that you are up against the old, old difficulty of what is real life and what is artificial. The mere physical process of sectioning, one feels, is liable to give a false effect because of the very way in which you cut your section. You might be transporting material from one part of the cell to another. Apart from that, I feel that it is something which has not been tackled basically and I agree with Mr. Cox that it is something which might well be taken up, if not by Forest Products themselves, certainly by some interested university.

Dr. W. P. K. FINDLAY: There is just one point we might remember in discussing this question of distribution of preservatives within the cell wall: that possibility is not so important as we may think, because the fungus has got to get there and, therefore, has got to go over the surface of the cell wall before it can get in the interior of the wall.

Whilst I am on my feet, I would just like to draw attention to number 6 of Mr. Savory's conclusions. I think in the past none of us have given very much thought to the question, what fungi do bring about the eventual breakdown of treated wood? When a piece of treated wood fails, the failure is more often than not due to faulty treatment so that the wood-destroying fungi find their way into untreated wood in the thickness, or within the centre of the pole or whatever it is. Splits occur and hyphae or spores get into the untreated wood. In those cases the decay normally is caused by Basidiomycetes, but where the actual treated zone breaks down, it is my feeling that that breakdown is more often than not the result of attack by microfungi. So I think we must give more thought to this question, what fungi do eventually break down treated wood? We are quite wrong in assuming that they are necessarily the same fungi that would have attacked the wood had it not been treated.

Mr. R. A. BULMAN: May I suggest the possible extension to Dr. Findlay's remarks on the penetration of preservatives. I think this will link up also with Mr. Cox's earlier remarks on penetration. As far as most toxicants are concerned, I think it is clearly acceptable that there are threshold values for the toxicants of preservatives: that is, minimum concentrations below which one must not go if protection is to be achieved.

Now I submit that in attempting to obtain some complete penetration of pieces of timber, it is generally necessary to reduce the concentration of a preservative in the treating solution. It seems to me conceivable that in some cases the dilution may go below the threshold values required. Consequently the gross amount of preservative present might be a very impressive figure, but its concentration in any one section of the wood may well be below what will be required to reject the fungus. It does seem there might well be an optimum concentration covered by an optimum penetration to give the best results.

Mr. S. A. RICHARDSON: Years ago when the electricity authorities were local concerns, I was asked to investigate what was alleged to be the breakdown of creosote-treated poles conveying electricity across an area of Hampshire. I did not need to be a mycologist, or even a timber expert; I think a detective would have done better, because these poles appeared to be perfectly all right except that *Lentinus* was attacking each one of them. The electricity authority had attributed that to the insufficient treatment of the poles.

That was not the case, we found, after detective investigation, because what happened was that the foreman on the job had his holes dug to precisely the same depth and then found the poles were of varying lengths; so he had the bottoms cut off to make them all reach the same height.

Mr. E. H. NEVARD: We have occasionally had samples of the timber in coalmines and tinmines in this country where the wood has been reduced almost to a paste. In the South African goldmines in the Rand I saw quite a lot of it. I wonder if Mr. Savory has yet had an opportunity of examining such material and whether that severe breakdown, which is quite often at a later stage accompanied by an attack by weevils, is a later form of *Chaetomium globosum*, or is it another soft-rotting fungus?

There is one other point. I should have drawn attention to it when the paper was given to me for vetting. I see you have left out the "U" after Tanalith. The Tanalith which was examined in these cases was Tanalith U and it is rather an important point.

Mr. J. G. SAVORY: Thank you, Mr. Nevard, for your last comment.

On your earlier point, I am sorry, I have had no opportunity of examining the material from the mines in Africa. I have read the paper by Lurie in which she describes attack by *Bispora* on mine timber. I think it is more than likely that we have indeed not necessarily *Chaetomium* but another fungus which is more closely related to the white rots causing this white breakdown that you describe.

Regarding the ultimate stages of attack even by *Chaetomium*, we know very little. The wood is extremely difficult to examine, and Dr. Findlay always insists that it is the early stages of attack that are the important ones, and we can let the later stages look after themselves.

Mr. E. H. NEVARD: If you want a specimen of the really spongy stuff, I think Mr. Levy will probably supply you with some. The last specimen I had was about three weeks ago.

Mr. C. W. NICHOL: I think it is true to say that complete penetration of the sapwood of softwoods is not absolutely necessary in order to get protection against *Chaetomium*, but as *Chaetomium* attacks the heartwood equally as much as the sapwood it follows that we have to get complete penetration of the sapwood before we can start getting a sufficiently deep penetration into the heartwood to give the necessary effect. But I can assure Mr. Bulman that in doing this the greatest care is taken by reputable manufacturers and treating firms to ensure that, however much solution has to be put into the timber to achieve that result, the concentration of the solution is never reduced below the toxic point against *Chaetomium*.

That brings me to another point which I would like to make. In your table 9, which sets out the results which have been obtained with various preservatives, the concentrations employed are in some cases far less than those which are used commercially for such purposes as cooling tower timbers, where *Chaetomium* is to be guarded against. For instance, in the case of the third preservative, which is very widely used for cooling tower timbers, the concentration in this table is only one-half of that which is nowadays being used. I would like to ask Mr. Savory whether further tests are being carried out with these various preservatives at higher concentration.

Mr. J. G. SAVORY: Regarding your comment on the lower concentrations, the concentrations in the table, of course, represent the trend of commercial thought some twenty-three years ago; they were the concentrations, I presume, which were in use at that time, and I have no doubt that there are similar tests in progress that reflect the trend of commercial practice at this moment. I would point out to you that the tests are not my tests; they have been lifted *en bloc*, with his approval I hope, from another man's work.

Dr. N. E. HICKIN: You did mention Dr. Varossieau as having worked on this problem. I have always understood that Varossieau, who was working on the softwood piles thrown up from underneath Rotterdam during the bombing, had considered that this curious rot which he found had been caused by bacterial action because of the anaerobic conditions under which this wood must have laid.

Now I have some of that timber and it does look very similar to the picture you portrayed on the slides. Some of these Fungi Imperfecti must be able to oxidize carbohydrates under a very, very low oxygen tension.

My question is, are we to revise our ideas on the bacterial cause of decay? Should we now think that some of what we have thought in the past to be bacterial decay has been caused by Fungi Imperfecti?

Mr. J. G. Savory: I mentioned Varossieau chiefly because some of the material I have examined looked just like the sections, the photographs, that he showed. Quite frankly I think you can reach a stage of decomposition at which it is impossible to tell what organism caused the decomposition; I think Varossieau's material was in that stage. Some of the material I have examined was in a similar state. If we can see the fungal hyphae then we are fairly safe in saying fungi are the cause. At other times we are able to see that the central layer of the secondary wall has entirely disappeared and there are no indications of the presence of fungal hyphae. Are we to say that the fungal hyphae themselves in their turn have disappeared or are we to postulate attack by bacteria or chemicals, or what have we to do? I do not know. We can nearly always see some bacteria in a wood that has been submerged in water, and it is a matter of opinion as to how much the bacteria themselves decay the wood. Personally I find I have more than enough trouble on my hands dealing with the fungi. I prefer to take the bacteria for granted at the moment.

Mr. E. H. Nevard: In view of the complete lack of information from other countries like the States and Australia and so on, are we to infer that soft rot does not occur out there, or is it just a case that we are right in the front of this new knowledge?

Mr. J. G. Savory: Let me restrict myself to published information. I have seen descriptions of the breakdown of timber in water-cooling towers in Australia dated about 1948, and there was included in that description a reference to the fact that the distributing members of the tower—the slats, the louvres—showed surface softening. They tended to mention that point and dismiss it as unimportant and they concentrated on the actual exterior of the tower, the water distributing system, the general structure, and they concluded that Basidiomycete attack was of considerable importance there. We ourselves have looked over water-cooling towers in this country and we have noted the Basidiomycete attack, but only occasionally. We have found that it is not the shell of the tower, but the filling which deteriorates. We have also noted that there was very slight surface softening of the filling and, as a result of our observations, we have finally, after a lot of thought, come to the conclusion that it is important.

I think that the question really is not, does soft rot exist elsewhere, but, is it recognized elsewhere? We find in America that the Californian Redwood Association were and are very concerned about the breakdown of redwood in cooling towers, and I have no doubt from their published work that some at least of the breakdown in their cooling towers is soft rot. On the other hand, some of it very obviously is not soft rot and appears to be various forms of chemical attack. I have seen quite recently a 1954 paper published by the Redwood Association and it is obvious from that that they are starting to take soft rot rather more seriously in their cooling towers. So I think we can be quite assured that interest in the subject is being taken in the States at the moment.

Mr. E. H. NEVARD: You say you restrict your remarks to cooling towers. I was thinking of more general occasions in, say, ground contact. We have examined timbers from South Africa—we know it is very prevalent out there—we have examined timbers from New Zealand and Malaya, and we know it is quite prevalent in ground contact. Again, is it because they have looked for something and not recognized what they have looked at, because even now we are still getting claims that it does not occur out there.

Mr. J. G. SAVORY: I think, Mr. Nevard, when you say, "Are they looking and not recognising what they see?" that you are probably hitting the nail right on the head. Five years ago we also would have looked and we would not have seen.

Mr. B. HICKSON: Mr. Chairman, I think the Association as a whole owe Mr. Savory a very great debt of gratitude in getting this paper over. He has been very modest about the work which he has done and has very truly said that it is still in its infancy. But to the timber trade, to architects and to those of us in the preservation industry who are trying to overcome these difficulties, the future of his work will be quite invaluable. This presentation to us and the discussion we have had today is, I think, very helpful as it gives us a line on what we are aiming at doing.

There is one thing I should like to stress before I sit down: do let us, when this comes from Princes Risborough, stick to the words "Soft Rot" and use capital letters for them. Let it get round the world, let this paper get round the world, so that in any country where there is such a possibility they know what they are talking about and are not like some of us commercial people, not a little bemused by the word "microfungi". I think it is the spreading of this information, this class of paper, which will help the industry to understand causes of decay and damage to timber which have not been understood in the past. I know that nearly twenty years ago I ran into what was called "surface softening" at Piennars River Station which the Pretoria Research Institute looked after. They were putting down tests for preservatives against white ant attack but, as I know now, these tests were confused because, after only two years some of the posts installed had a ring of preserved sapwood into which you could put your fingernail up to a quarter of an inch. This, I am now sure, must have been soft rot. When this had occurred the white ants penetrated the soft rotted sapwood ring easily and then entirely destroyed the untreated core.

The information from Mr. Savory and the other workers on this will be of invaluable help in dealing with this.

Might I answer one question, which I think you threw back on the industry, about creosote and its effect? As far as I know today, purely fortuitously I think creosote has been found to be the most efficient for ground level work in tropical areas against this soft rot attack. I say "fortuitously" because the protection hangs on efficient and controlled application by pressure method of the preservative. The work that is being done in your laboratory and other laboratories will both help the people who are producing and using creosote and other preservatives to obtain better preservative protection which I am sure will give the answer to this when we have some more results from your class of work, because we shall know and recognise the hazard against which we are giving protection.

Mr. E. H. B. Boulton: Mr. Chairman, could we have some idea of the relationship of moisture content in timbers for these various microfungi to develop? I think that is the all-important point as regards seasoning prior to preservation, as to how much development has probably taken place in the timber before the timbers have been subject to any type of treatment or preservation. Is there any information, as with dry rot and wet rot, as to what moisture content the timber must reach before these so-called soft rots develop?

Mr. J. G. Savory: I have given pretty well the whole of my information in the paper, namely that in a relative humidity of 90 per cent.—that is to say, equilibrium moisture content about 20 per cent.—we actually got severe soft rot. That is at a lower moisture content than we would expect to find Basidiomycete attack. I know no more than that, because I have only just instituted tests to try and settle that question more precisely. It is going to take a matter of a couple of years or so before I get a result from my experiments, so we shall just have to wait.

The Chairman: Gentlemen, I am sorry to interrupt what is obviously an extremely interesting discussion, but I am afraid we must keep to our times.

I would like to thank Mr. Savory for the information he has given us and for a very provocative paper which obviously will start something going. Let us hope we may continue the discussion next year, if not before.

(2) "THE DEVELOPMENT AND USE OF NAPHTHENATES FOR TIMBER PRESERVATION."

By R. A. BULMAN, B.SC. HONS.
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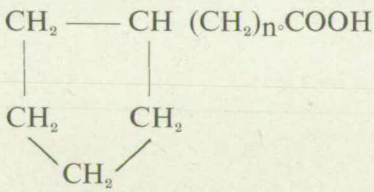
Historical

THE naphthenates as used in timber preservation may be defined as the metal salts of the naphthenic acids. These acids are carboxylic, derived from various crude petroleums or their distillates, and are believed to have been first isolated over one hundred years ago.

Whilst the toxicity of these naphthenic acids to bacteria such as *Staphylococci* had been noted early in their history, it was not until 1889 that von Wolniewicz (1) suggested the metal salts—the naphthenates—as wood preservatives. H. Charitschkow, who carried out a considerable amount of work during the period 1889-1909 on the naphthenic acids and their derivatives, also discussed the use of the metal salts as wood preservatives, with particular reference to the hot and cold soaking of railway sleepers (2).

Although at that time the actual structure and mode of formation of the naphthenic acids had not been elucidated, Markownikow, among others, contributed much on these aspects (3). It was not until the results of further work, such as reported by von Braun (4) that it became accepted that the naphthenic acids are generally of the type:



It was also about this time that evidence was obtained (5) that the naphthenic acids from widely differing sources, exhibited the same characteristics, although the molecular weight and the acid value vary according to the value of "*n*", the number of (CH_2) groups in the side chain of the above formula.

In the meantime, production of metal naphthenates for the preservation of timber and other materials was commenced in Denmark, in 1911, and later in England, where production on a commercial scale commenced in 1933.

Now, after nearly half a century of the successful use of the naphthenate preservatives, it is opportune to survey the field and consider the place of naphthenates in present-day timber preservation.

Manufacture of Metal Naphthenates

For the manufacture of metal naphthenates, two methods are commonly available. One method requires the heating of naphthenic acid directly with a suitable metal compound such as the oxide. Water is driven off as the reaction proceeds, according to the equation given below for copper naphthenate, using the symbol $\bar{N}$ for the naphthenate radicle:—

$2H\bar{N}$	+	CuO	→	$Cu\bar{N}_2$	+	H_2O
naphthenic acid		copper oxide		copper naphthenate		

In the other method, the naphthenic acid is neutralized with alkali such as caustic soda to give sodium naphthenate solution in water. To this solution is then added an aqueous solution of a suitable metal salt in the presence of the organic solvent in which the metal naphthenate is required for use:

$H\bar{N}$	+	$NaOH$	→	NaN	+	H_2O
naphthenic acid		sodium hydroxide		sodium naphthenate		

For the production of copper naphthenate, copper sulphate is the most suitable salt, and the reaction proceeds:

$2\,NaN$	+	$CuSO_4$	→	CuN_2	+	Na_2SO_4
sodium naphthenate		copper sulphate		copper naphthenate		sodium sulphate

The sodium sulphate remains dissolved in the aqueous layer, which can then be completely separated off, together with any impurities resulting from the reaction, to leave copper naphthenate of a high degree of purity dissolved in the appropriate organic solvent. This solution of the naphthenate requires only dilution to the specified concentration and is then ready for use.

Zinc naphthenate may be prepared by the same process, using the appropriate zinc salt.

Regarding the raw materials required, the metal salts such as copper sulphate are normally available in a high degree of purity and need no comment here. It may however, be of some interest to enlarge a little on the naphthenic acids themselves, regarding both their origin and properties. Naphthenic acids are produced from crude petroleums and while these may be roughly divided into three groups according to their content of aromatic, paraffinic and asphaltic fractions, the naphthenic fraction is common to petroleums from most sources (6). The proportion of naphthenic acid present varies considerably however from 0.1 per cent. or less in most American crudes, to approximately 1.0 per cent. in many Russian petroleums, whilst Rumanian oils may contain an even greater proportion (7). In each of these countries, numerous individual sources exist and sources also exist in other countries such as Canada and Japan.

It is, however, interesting to find that regardless of the source of the crude petroleums, the resultant naphthenic acids are essentially the same in character (5).

Extraction of the naphthenic acids from the crude or distilled petroleum may be achieved by treatment of the petroleum with dilute alkali such as aqueous caustic soda solution which results in the formation of sodium naphthenate solution. Acidification then liberates the free naphthenic acid.

More commonly the alkali extraction is carried out after the petroleum distillate has been treated with sulphuric acid for the removal of other impurities.

The alkali wash removes the last traces of acid materials from the petroleum, and naphthenic acids so extracted are recovered in the free state by acidification of the lyes.

It has been shown that the naphthenic acids obtained by either of these methods do not differ in their chemical or physical properties (8).

Of greatest interest here, however, are the toxicity data for the naphthenic acids. In this connection a considerable amount of work has been carried out in Australia (9), using the agar-culture tube technique (10) for the determination of fungal growth-rates for various concentrations of preservative. Results obtained show that the toxicity of the naphthenic acid increases as the acid number of the acid increases, or as the molecular weight decreases. In the same investigation, tests with the corresponding copper naphthenates showed that the toxicity of the copper compound is much less variable than that of the free acid, so that the copper has a "smoothing-out" effect on the toxicity.

Type of Solvents and Methods of Application

Charitschkow reported in 1897 (11) that the copper salt or soap of naphthenic acid dissolves in an organic solvent such as benzene, to give a green solution and this solubility in organic solvents such as benzene, white spirit and other petroleum distillates is one of the outstanding features of the naphthenates resulting in the advantages for this type of preservative, as listed below (12):

(1) The toxic substance, being insoluble in water is not liable to be leached out of the wood.

(2) Since the preservatives contain no water, they do not cause the wood to swell and there is therefore no risk of distortion when

treating wooden parts that have been machined to an exact size or shape.

(3) They can be used on horticultural timber with little risk of injuring the plants.

(4) The treated wood can subsequently be painted.

(5) They will penetrate well if the solvent be a light oil and are therefore particularly suitable for application by brushing or dipping

The solvent used may be varied according to the type of wood structures to be treated; thus in some instances, a solvent which dries off quickly is required in order to avoid interruption of production schedules.

The solvent also varies according to the method of application to be used and with a suitable solvent, the metallic naphthenates may be applied by any of the preservation methods commonly used in this country. These include brush, spray, cold soak, hot and cold soak, and pressure treatments.

For the first three methods, moderately volatile solvents such as white spirit are applicable whilst for hot and cold soaking, the solvent recommended should be somewhat less volatile. For pressure treatment, a low priced solvent—generally of low volatility—is desirable unless a solvent recovery process, as put forward by Hudson (13), is applied. In this process, the solvent is withdrawn from the timber after treatment in such a manner that whilst the preservative is left in the timber, the solvent is taken off by the combined effects of heat and vacuum, to be recovered for further use. Under such circumstances, a more volatile and more expensive solvent such as xylene, can be used without unduly affecting the cost of the treatment.

Properties of the Naphthenates

Various properties of copper naphthenate such as its low solubility in water, satisfactory electrical insulating properties, its lack of any vapour pressure at ordinary temperatures, and its complete solubility in a wide variety of organic solvents, have been presented at length by Minich and Goll (14), and advantage will be taken of the space available here to indicate somewhat more fully the toxicity to the various wood-destroying agencies.

Toxicity to Fungi

Whilst the search for improvements in laboratory tests for wood preservatives continues (15) it is of interest to consider the information already available.

For many years it was believed that the naphthenic acids could be replaced, sometimes with advantage, by others such as stearic, oleic or lanoleic acids. Unpublished information from the Forest Products Research Laboratory (Table 1) shows beyond all doubt that copper naphthenate is far superior to the copper soaps of these other acids, regarding their toxicity to the common wood destroying fungi.

TABLE 1

TOXIC LIMITS OF 4 FUNGI FOR 4 COPPER SOAPS AS DETERMINED BY THE AGAR TEST
(Expressed as percentage of preservative in 2% malt agar)

Fungus	Preservative			
	Copper lanolate	Copper naphthenate	Copper oleate	Copper stearate
Fomes annosus	0.80 — 0.96	0.32 — 0.48	0.32 — 0.48	1.01 — 1.28
Poria vaporaria	More than 1.6	Less than 0.16	0.32 — 0.48	1.28 — 1.6
Polystictus versicolor	More than 1.6	0.64 — 0.80	0.64 — 0.80	More than 1.31
Coniophora cerebella	More than 1.6	Less than 0.16	More than 1.6	More than 1.31

It will be noticed that in this test, *Poria vaporaria* was no more resistant to copper naphthenate than was *Coniophora cerebella*. This suggests that copper naphthenate should be excluded from those copper compounds to which *Poria vaporaria* is described as resistant in British Standard 838 (16).

Toxicity tests, also carried out by the Forest Products Research Laboratory (Note 1) using the British Standard wood block test (16) show the following toxic limits (Table 1a) for copper naphthenate (expressed as copper) and pentachlorophenol, with respect to various fungi.

TABLE 1a

TOXIC LIMITS OF 3 FUNGI FOR COPPER NAPHTHENATE AND PENTACHLOROPHENOL
(lb./cu. ft.)

Preservative	Fungus		
	Lentinus lepideus	Coniophora cerebella	Polystictus versicolor
Copper naphthenate (as copper)	about 0.0036	about 0.018	0.036 — 0.045
Pentachlorophenol	0.030	0.042 — 0.072	0.078

Note 1—The data for Tables 1 and 1a are used by the kind permission of the Forest Products Research Laboratory. Princes Risborough.

Other data have been previously quoted (17) and show somewhat greater differences between the toxicities of pentachlorophenol and copper naphthenate, but it should be noted that the tests from which these data were obtained did not extend to the actual toxic limits and also were carried out on a qualitative basis only (18).

Other tests (14) using the Leutritz wood block-soil technique (19) show the very low concentrations of copper naphthenate which completely prevent decay by various fungi (Table 2).

TABLE 2

EFFECTIVENESS OF COPPER NAPHTHENATE AGAINST WOOD DECAY FUNGI

Fungus	Concentration of Preservative (lb./cu. ft. as copper) which completely prevent decay
Lenzites trabea	0.01
Poria microspora	0.019
Lentinus lepideus	0.019

The effects of leaching on the toxicity limits are illustrated by the tests carried out by Harkom and Sedziak (20) in which it was shown that after passing through both heating and leaching cycles, the blocks treated with copper naphthenate showed more resistance to decay than those treated with pentachlorophenol.

Stake tests carried out under severe service conditions confirm the good protection against severe decay by copper naphthenate (21).

Likewise, in similar tests using Douglas Fir plywood stakes treated after glueing, good results (Table 3) are being shown, despite the presence of termite attack as well as decay (21). Especially noteworthy is the high degree of protection given by a 10 second immersion in a copper naphthenate solution containing the equivalent of only 2 per cent. copper.

In tests against decay, Verrall (22) also found that satisfactory protection was given even by somewhat dilute solutions of copper naphthenate as shown in Table 4.

Insects

Schulze and Becker (23) carried out tests with copper and zinc naphthenates against the larvae of *Hylotrupes* and *Anobium* and are reported (24) to have found that although they act somewhat more slowly on *Anobium* than on *Hylotrupes* larvae, they are undoubtedly effective insecticides.

Kelsey (25) also conducted tests with wood treated with a solution containing zinc naphthenate as the principal ingredient and *Anobium* as the test insect.

TABLE 3

PLYWOOD STAKE TESTS (21)

Condition of Douglas Fir Stakes (½" x 4" x 18") treated after glueing and exposed for 6 years at the Harrison Experimental Forest, Mississippi.

Preservative	Treatment (Note 2)	Absorption lb./cu.ft. Soln:	Absorption lb./cu.ft. Preservative	Condition after 6 years Good %	Condition after 6 years Serviceable %	Condition after 6 years destroyed %	Average life in years
Creosote	D	1.0	—	—	32.5	67.5	(6) Note 1
	CS	5.3	—	10	80	10	—
	HCS	2.0	—	90	10	—	—
	P	19.6	—	100	—	—	—
Copper naphthenate 2% copper	D	0.4	0.008 Cu.	10	90	—	—
	CS	1.1	0.022 ,,	50	50	—	—
	HCS	1.2	0.024 ,,	70	20	10	—
	P	2.9	0.058 ,,	60	30	10	—
5% Pentachlorophenol solution	D	0.7	0.035 PCP	—	60	40	—
	CS	2.0	0.100 ,,	—	90	10	—
	HCS	2.1	0.105 ,,	—	80	20	—
	P	12.5	0.625 ,,	80	20	—	—
Chromated Zinc Chloride	D		0.03	—	—	100	4.0
	CS		0.35	10	70	20	—
	P		0.62	80	20	—	—
Untreated	—	—	—	—	—	100	3.6

Note 1.—Estimated figure.

Note 2.—Key to treatments: D = dip for 10 seconds.
HCS = { hot soak for 1 hr. cold soak for 1 hr. }
CS = Cold soak for 24 hrs.
P = Pressure.

TABLE 4

SOAK AND BRUSH TREATMENTS FOR WOOD OFF THE GROUND (22) AFTER NEARLY 4 YEARS' EXPOSURE

Decay ratings of test units based on decay exposed by longitudinal sawing (0% = completely sound: 100% = completely decayed)

Treatment	Preservative solution	Average Decay Rating (%) after nearly 4 yrs. test
Brush—2 coats	5% Pentachlorophenol	0.8
	18% Copper Naphthenate (2% copper)	0.3
Soak 30 mins.	5% Pentachlorophenol	0.8
	0.2% Phenyl Mercuric Oleate	1.0
	4.5 Copper Naphthenate (0.5% copper)	0.4
Soak 60 mins.	5% Pentachlorophenol	1.2
Untreated	—	43.5

It was found that in no case were any eggs laid on the treated wood, whilst of several water-borne preservatives similarly tested, none showed any deterrent effect so far as oviposition was concerned. The zinc naphthenate solution used also gave highly effective results against *Anobium* larvae transferred to the treated wood, death of the larvae being caused in less than two months.

Against termites, successful results have been obtained in similar laboratory tests. Thus, Kelsey also found (25) that the zinc naphthenate solution used gave satisfactory eradication of *Calotermes brouni* from infested timber and even with one or two brush coats, any surviving termites were in a shrivelled condition and probably would not have lived much longer.

In the tests (21) on which Table 3 is based, termite attack was present but, nevertheless, satisfactory protection was given, whilst in other tests (21) a simple brush coating with a solution containing only 2 per cent. copper as the naphthenate, more than doubled the life of the timber under most severe conditions of both termite attack and decay.

Wolcott reports (26) that timber, after a ten minute submergence in a solution containing 12 per cent. copper naphthenate (equivalent to only 1.2 per cent. copper approximately) showed no attack after two years' exposure of the treated wood to attack by the dry-wood termite *Cryptotermes brevis*. With some inadequate treatments, the wood was attacked after only eight days. Normally, however, the concentration of copper recommended for such exposure would be appreciably higher. Other references (27, 28) have also been made to the satisfactory results given by copper naphthenate against termites.

Marine Borers

Published results of tests using copper naphthenate for protection against marine borers are relatively few. In tests for comparing different preservatives by the floating collar method, copper naphthenate in kerosene solution was found to be extremely effective in killing off the marine borers present in the heavily attacked wood used in the tests.

Similar results were obtained with immersion and brush treatments whilst other small scale tests with pretreated timber have given such good results as to justify further organized trials on a larger scale.

Geographical Distribution and Specifications

In 1911 application of naphthenates for timber preservation was restricted to Denmark. Since then, however, the adaptability of these highly effective preservatives, together with their ease of application and safety in handling, has led to their wide use throughout the world. Some forty different countries are in fact supplied from England alone, whilst many others are supplied from Denmark or from the United

States where production of these preservatives is also proceeding on a large scale.

It is not surprising therefore to find a number of specifications referring to the application of naphthenates, especially of copper, for the preservative treatment of timber. Typical examples of such specifications are those for Great Britain (29, 30, 31), Australia (32,33), New Zealand (34), South Africa (35, 36), Canada (37), and the United States (38).

Types of Wooden Structures Treated

It may well be said that with the introduction of the "spirit soluble" preservatives in the form of naphthenates, non-pressure treatments became generally accepted as methods of wood preservation filling a wide gap between pressure treatments on the one hand and surface treatments with tar-oil preservatives on the other.

During the last war, vast quantities of timber in a wide variety of forms would have been completely unprotected had the naphthenate preservatives not been available for non-pressure treatments. This applied particularly, for instance, when small factories and workshops were brought into use for the manufacture of the individual parts for larger structures.

Examples of these include field telegraph poles and wooden components of telegraph apparatus, shelter bunks and folding beds, prefabricated buildings, tool boxes, instrument cases, and packing cases for a variety of purposes.

Regarding peace-time conditions, it is perhaps not fully realized how much timber is wasted through its use in repair and maintenance work without preservative treatment of any kind whatsoever.

For work of this kind, carried out on the site with timber drawn from stock in a carpenter's shop, maintenance depots and the like, the naphthenates in their "ready-for-use" solutions are admirably suited and have an enormous field of application. By means of such treatments on site, the unique position of timber as an adaptable material can all the more readily be maintained against competition from other materials.

There are many examples of this type of work but space permits mention of only a few of the buildings, such as schools (39), horticultural woodwork such as for greenhouses, seedboxes, garden stakes and posts (40, 41 and 49,) and, of course, packaging (42). Solvent type preservatives are mentioned as the most suitable for general use on wooden craft (43) whilst the use of copper naphthenate for mining timbers is also recorded (44, 45). Pole butts of various species can be satisfactorily treated either by cold soaking prior to installation (46) or by ground-line treatments after a period in service (47).

Recent Developments

Whilst the naphthenates themselves have a considerable degree of water repellency as measured by a standard test (48), this valuable property can be improved still further by the addition of specific water repellents which are easily compatible with this type of preservative. By this means, added dimensional stability of treated timber can be achieved in a single operation.

It will no doubt be of interest to note that between the three originators of the large scale production of naphthenates for preservation in Denmark, England and the United States respectively, there is a systematic exchange of technical information, especially regarding research and development work.

Conclusion

In conclusion, naphthenates have been widely used for nearly half a century for the treatment of many different kinds of wood structures. Throughout this time their use has spread to many different wood products in many countries of the world, and even greater scope for them can be confidently predicted.

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Discussion on Paper 2

The CHAIRMAN (Mr. C. S. White): Ladies and Gentlemen, last year I was privileged and rather embarrassed in presenting a paper here. This year I am in the happy position of listening to others, but having an additional pleasure this morning in introducing Mr. Bulman. Some of you may not be fully aware of his recent experience in this field, but having graduated in chemistry at Liverpool fifteen years ago he did not begin, I gather, straight away in the field of timber preservation. For some five years he had experience in the manufacture of chemicals. He then had five years' experience of timber preservation, from 1945 to 1950, followed by two years dealing with the manufacture of plywood in West Africa.

On this latter subject I found myself asking him a number of questions half an hour ago because I should like to hear more during the discussion, if time permits, about plywood manufacture and in particular about certain timbers from West Africa in this connection.

His paper, as you know, is concerned with naphthenates and particular types of preservation. Mr. Bulman is in charge of the Research Department of Cuprinol, which we all know. We look forward very much to hearing what he has to say. I do not think you have any slides, Mr. Bulman?

Mr. R. A. BULMAN: No, Sir.

The CHAIRMAN: We do hope that people will take part in the discussion. Well, Ladies and Gentlemen, I have great pleasure in calling upon Mr. Bulman to present his paper on "Naphthenates for timber preservation."

Mr. R. A. BULMAN: Mr. Chairman, Ladies and Gentlemen, first I must thank our Chairman for those few kind words and then I really must express my appreciation of the privilege granted by the Association of being able to address you this morning. I must also sincerely acknowledge the advice and assistance both from my colleagues and from the Officers of Princes Risborough.

The paper itself was not set out to be, shall we say, controversial; I heard a comment recently to the effect that it is not controversial. Nevertheless I feel there will be quite a number of questions arising from it; and in point of fact, after having written the paper and then put it aside for a few weeks, I began to go over it and find quite a few queries myself. Before going on to those queries, however, I would like to make one extremely small correction for the sake of any chemists present: on page 2 in the first and third equations, there should be a little stroke above the "N" of the $Cu\overline{N}_2$ to show that it is a symbol for the naphthenic acid radical and has no relation to the nitrogen of the air.

As far as the questions are concerned, one concerns the acid values of the naphthenic acid itself and these equations as they stand do not take into account the varying acid value. But as is mentioned in the paper, the toxicity of the acid does vary with its acid value and I would mention that a common range of acid values is from a figure of 100 up to between 300 and 400 units; so you will appreciate that there is quite a range between those various grades of acid and there is quite a range of toxicity values.

Some people might say, "Why not use the most toxic acid?" I should at this point mention that the higher acid value means that the molecule itself is smaller. One would think at first that that would also be a great asset to penetration into the timber, which is probably very true, so that we have the rather anomalous position of the most toxic and the most penetrating types of material, shall we say, not being commonly used. The reason for that is that the solubility of these acids does vary and as one gets up to the higher acid values, the acids themselves and their metal salts, or metal compounds, do become somewhat more soluble in water. Consequently commercial practice tends to steer away from those extremely toxic but possibly leachable materials and keep more to the middle road where we find the best of both worlds.

There has been quite a lot of work done with regard to insects and I think Dr. Becker of Germany has been most prolific with the number of papers and experiments he has carried out on this subject. Opinion seems to be divided as to the ultimate value of these tests inasmuch as they are carried out over somewhat limited periods, but I think it is generally agreed that they do serve as quite a useful sifting method, sorting out the wheat from the chaff, and give one something to work on for more extended tests.

In the papers, reference has been made to an earlier paper written by Minich and Goll of America and I was perhaps rather brief in my references to that paper. Some people may be interested in having a few more of the actual data and I have picked out a few which seemed to be very relevant. One of these is the solubility of copper naphthenate. In boiling water the solubility is as low as 0.0002 per cent. by weight; at ordinary room temperatures it is actually about half of that, so you will see that the material is very unlikely to be leached out by water. Vapour pressure at a temperature of 100°C.—the boiling point of water—is actually zero, and appreciably higher temperatures have to be reached before any vapour pressure becomes measurable, so the material is clearly non-volatile.

As a matter of interest some electrical data were given in the same paper. If I remember rightly, the authors at the time expressed the view that they were not very expert in electrical matters and I must make the same plea, but for those who are specifically interested in this aspect the dielectric content of copper naphthenate is given as 2.9 at one kilocycle and its resistivity is given as 8×10^{11} ohms per cubic centimetre; it has a very high resistance electrically and seems therefore to be very suitable for any timbers used in connection with electrical installations.

The paper has dealt rather more with preventive treatment of timbers and I wonder perhaps if it was an oversight not to mention eradication and disinfestation for which, of course, the naphthenates find a very great use indeed. One particular advantage is that they can be used in practically all circumstances and are completely harmless to human beings and animals.

There is one other point which I feel is an omission from the paper and that is, I always think it is very useful to emphasize to any users of wood preservatives that when the treatment has been applied and the treated timber is then sawn or planed or machined in any way, it is imperative to re-treat the newly exposed surfaces. I think that applies to any preservative and to any method of treatment.

Some people claim that by putting wood preservatives into tins people purchasing them are likely to misapply them, and whilst I think that generally for such preservatives the instructions given are quite clear, people do sometimes forget to read them. It reminds me of a story I read in a newspaper recently of an ice-cream machine used in America: one put a nickel in one slot for strawberry flavour or in another slot for vanilla flavour and so on and each little slot has its directions for operating. Over the top of the machine however was printed a large notice which read: "If all else fails, try reading the directions". Well, I think much the same applies to timber preservation generally.

I have no doubt there is room for many more questions and perhaps now we might ask if any such questions are forthcoming.

The CHAIRMAN: Well, Ladies and Gentlemen, I hope you will not hesitate to come forward with whatever questions now occur to you; the Meeting is open for discussion.

Mr. C. D. COOK: I think we should congratulate Mr. Bulman on his very interesting and comprehensive paper and his very full references. I am particularly interested in Table 1; I think it would be of interest to know the copper content of the various soaps tested. I would, however, point out that agar petri dish tests on these soaps cannot be regarded as a sufficient guide to the usefulness of these compounds.

Mr. Bulman has quite rightly pointed out the effect of the acid value on the toxicity of the copper naphthenate. Mr. Tamblyn has suggested that the important ingredient in copper naphthenate below an acid value of 250 is the copper content. In view of this it is a little surprising that copper naphthenate should show such relatively high toxic limits towards such well-known copper resistant fungi as *Poria vaporaria* and *Coniophora cerebella*. May this be due to the influence of the naphthenic acid group?

Data supplied as to the toxic limits of copper naphthenate are very often conflicting. If one compares data supplied by Mr. Hatfield at last year's Convention, the data supplied in Table 1A, and 2, we have a good illustration of this point. Could this be due to the differences in acid value?

I consider that when researchers publish toxic limits of copper naphthenate they should report their results in terms of the total copper naphthenate content and reference should be made to either the acid value or its interrelated copper content.

Mr. Bulman and Mr. Hatfield refer to Minich and Goll's statement that copper naphthenate does not possess any measurable vapour pressure at room temperature. At a recent meeting of the Society of Chemistry & Industry, held in Manchester, statements were made that certain paint manufacturers were faced with the problem of loss of toxicity of copper naphthenate from paints containing this preservative. If this is true it would suggest that either losses by volatility or breakdown in the copper naphthenate had occurred. There is some evidence to suggest that the latter is more likely, since it is known that when copper naphthenate treated blocks are weathered there is a breakdown resulting in an increase in the oil insoluble copper content of the timber. It is likely that free naphthenic acid may be formed which is capable of being lost from the timber as a result of evaporation. Should this occur, then the effectiveness of the preservative towards *Coniophora cerebella* and *Poria vaporaria* may be reduced.

I refer you now to page 41. Reference is made on page 41 to high degrees of protection against termite and fungal attack afforded to laminated stakes treated with 10-second immersion using copper naphthenate. Supporting evidence is given in Table 3. On the other hand similar tests, instituted by the same organization in the same area where termite attack was significant and using Southern Yellow Pine stakes, indicated an average life for brush-applied coatings of four years, three-minute dip treatments of five years, pressure treatments of greater than eleven years compared with a control of two years. Do these results justify the statement that a dip or brush treatment can give a high degree of protection against termite, particularly when the results are compared with pressure treatments using the same preservative?

I would now refer you to page eight; reference is made on page eight to the protection afforded by copper naphthenate towards Marine borer attack. On the other hand if reference were made to the Madison Report D 1773, dated June, 1950, the results are rather disappointing in regard to copper naphthenate protection. For pressure-creosoted timber an average life of over 13 years was reported compared with less than 2 years for one-brush coating, about 2 years for empty cell pressure treatments, and less than 3 years for the full cell treatments using copper naphthenate.

Mr. R. A. Bulman: Mr. Chairman, I think we ought to thank Mr. Cook for that remarkable exposition. I think there are four questions arising and I will try to deal with them.

The first one related to the influence of the naphthenic acid as a contribution to the toxicity of copper naphthenate. I think we can refer back to our friends in Australia, including Tamblyn & Company, who do find extremely high toxicity for the free naphthenic acid itself. There seems to be absolutely no doubt that the acid does play an important part in preserving the timber.

Secondly, I have heard it stated by an authority that in some experiments carried out in America some timber was leached "ad infinitum". That means it was leached, under laboratory conditions of course, until no copper remained in the wood. The timber, nevertheless, still had a high degree of protection against fungi, indicating that the naphthenic radicle was still present and active. I think Tamblyn's work did suggest that at various acid levels the relative importance, or relative toxicity of the copper on the one hand and of the naphthenic acid on the other, does vary according to which end of the scale of acid values is being considered.

I cannot quite understand the question of copper naphthenate in paints because to the best of my knowledge copper naphthenate is not normally used in paints and it is not counted as an effective paint drier. So far as I know it is not used, so I cannot quite see that that point is important except that I would refute any suggestion that that contradicts the low volatility or permanence of copper naphthenate as such. I suspect that a simple analysis would verify that point.

There was the question of the evaporation of naphthenic acid and I think that is covered by my previous remarks regarding removal of the copper leaving only the naphthenic acid in the wood. Unfortunately I have not got the boiling ranges of the naphthenic acid as such, but they are very high and I think we need have no fear of any evaporation of the acid.

Now the comments on termite resistance. I will say that the mention made in the paper was merely to indicate the scope of naphthenates in that field and was not a recommendation that for long-term protection of railway sleepers, telegraph poles and the like from termites, a single brush or ten-second immersion treatment should be used.

The other question arose in connection with Marine borers. Mr. Cook did not mention the concentration of the copper or copper naphthenate in the solution or in the wood. Perhaps he might be able to amplify that some more. However, do you find your points otherwise covered Mr. Cook?

The CHAIRMAN: Are there any other questions?

Mr. L. A. BATES: Whilst the widespread practice in the electricity supply industry is to cut off poles to adjust sinking depth, there are occasions when we have to do fabrication in drilling and cutting poles on site after they have been pressure creosoted.

I should like to ask Mr. Bulman whether such fabrication on site should receive some local treatment and I should like to ask him whether he contends the treatment by one of these spirit solvents, I think he calls them, is likely to be more effective than brush treatment by creosote on poles that have fundamentally creosote treatment.

Mr. R. A. Bulman: I think the question really relates to the compatibility of naphthenates with creosote and the two liquids are of course, completely compatible.

I would not see any difficulty whatsoever in applying a naphthenate solution that is a spirit solution, to the cut ends of telegraph poles. In fact, the ease of penetration resulting from the solutions would be quite an asset. I think it is, or should be, common practice to treat any cut ends and I think these solutions are admirable for the job.

Mr. L. A. Bates: You did not quite answer my questions. Do you treat them normally with creosote brush treatment? Is it contended that these solvents are likely to be more effective than creosote with such local treatments, and would it depend upon whether the pole was going to be below ground or normally above ground?

Mr. R. A. Bulman: I am sorry if I misunderstood you. There is the point about the penetration factor which is considerably easier and better with the lighter solvent solutions than with creosote. From that point of view there would be a definite advantage and there would be no trouble in using the material either underground or above ground. Does that cover the point?

Mr. L. A. Bates: Yes, thank you.

Dr. D. McNeil: I have been extremely interested in this paper by Mr. Bulman. I have quite a number of questions, particularly on the extraction of naphthenic acids and their conversion to metallic salts. However, I will take most of them up privately. This morning I will confine my questions to two points.

First of all Mr. Bulman states that the acids extracted from various types of petroleum are basically the same. Does that mean that they are the same chemically? In other words that they are carboxylic, or does he mean that the value of "n" in his formula is of the same order for various petroleums?

I would, incidentally, be interested to learn what the range of the value of "n" normally is.

The second point I would like to ask Mr. Bulman refers to corrosion. Naphthenic acids themselves, I understand, are very corrosive materials and in the refining stainless steel equipment must be used. Are these metal naphthenates similarly corrosive and is there any danger of excessive corrosion of metals particularly with steel in contact with wood treated with metal naphthenates either chemically or electrolytically?

Mr. R. A. BULMAN: Referring to the naphthenic acids themselves and their origin, the similarity lies in their chemical formulae. They all follow the pattern illustrated in the paper and the "n" figure can vary from zero up to values of about 24. It is that variation of the figure "n" which controls the size of the molecule, the molecular weight and hence its acid value.

Regarding the corrosion aspects, I think one has to bear in mind that in the extraction of naphthenic acids other chemicals are used: for instance, sulphuric acid itself features largely, so it is quite understandable that stainless steel would be used in those processes.

When it comes to naphthenic acid combined with the metal, naphthenic acid itself is not nearly so reactive as its name "acid" would, or might, imply. Hence the rather roundabout way of producing the chemical compounds by indirect reactions. When the metal compounds are obtained they are almost completely non-corrosive, but there is a suggestion that, since aluminium is extremely susceptible to minute traces of copper, some precaution should be taken when using aluminium; all that is needed is to paint the treated wood before putting the metal in contact with it. Apart from that there is no difficulty whatsoever. In fact, there is quite a lot of evidence to suggest that iron nails in copper naphthenate treated wood are protected.

Mr. D. J. EVANS: Arising out of that last query, I think it ought to be a little more emphasised that there is a danger when you have aluminium and light alloys in contact with copper naphthenate treated materials. Certainly the Air Ministry avoid the use of copper naphthenate because of their extended use of light alloys. Particularly does this apply to application of anything which has to be transported by plane, or is in contact with any fittings.

Further, though it is not metallic, it ought to be remembered that rubber can be attacked by copper naphthenate seriously, particularly in long storage. I think those points should be remembered.

Might I make one small point now that we are on a matter which affects packaging? In a sentence on page 44 in the last paragraph, in which examples of work for which copper naphthenate can be used are given, the phrase, ". . . and, of course, packaging . . ." is mentioned. Recently the B.S.I. considered the need for a code of practice in applying preservatives to packages made of timber. They found that there was no demand whatsoever from commerce, either from the user or the supplier angle for a code of practice relating to packaging preservation. I think they are probably right. In the Services there is a slight need, but the view is that a package made from timber is, on the whole, a short-lived item, and that the preservation of packaging is scarcely worth the money spent on it. I am not suggesting for a moment that we deprecate the use of copper naphthenate as a preservative; we are fully aware of its value, but what we try and do is to use it in the right place and in the right way rather than suggest that it should be used everywhere in all circumstances.

I would like to emphasize this light alloy and rubber danger. Following the crack about reading the instructions, it might be advisable to add that to any instructions that may be issued: in the use of copper naphthenate the contact of rubber and light alloys is of course a danger.

Mr. R. A. BULMAN: I thank Mr. Evans for the points he has mentioned. He has brought to my mind at least one point, and that is a sense of proportion in referring to this corrosion aspect. I believe data can be produced to indicate that the corrosive powers of copper do not depend on it being associated with the naphthenates. The corrosive aspects will apply to probably any other copper containing preservative, and to the best of my recollection in some comparative tests the copper naphthenate came out the best of several preservatives tested in that respect. It is probably a point to bear in mind in considering the instructions for use that might well be applied to all copper containing preservatives.

Mr. S. A. RICHARDSON: It seems that copper naphthenate is a general panacea of all troubles in connection with timber decay, but I should like to refer to paragraph 2 on page 8: "Against termites, successful . . ."—that is the key word—". . . results have been obtained in similar laboratory tests." But on the last line we read, ". . . any surviving termites were in a shrivelled condition and probably would not have lived much longer."

That does not convince me as to the thoroughness of the test, when things are "probably" going to die. We do not draw conclusions from them usually, and the fact that they have had one or two brush coats suggests to me that only one test has been carried out to prove that the material is successful against termites.

The next paragraph says that copper naphthenate, 2 per cent., more than doubled the life of the timber under most severe conditions of both termite attack and decay. When I lived in West Africa we found that termites could destroy the timber in a matter of twenty-four hours and if you can prolong the life to forty-eight hours I do not think you have succeeded in doing anything very much.

I wonder if you could answer those questions?

Mr. R. A. BULMAN: They hardly seem to be questions, but if I remember rightly the comment about the termites which would probably not have lived much longer was really taken as a quotation from the paper itself which was actually written by Kelsey of New

Zealand, who is, I believe, held in quite high regard in the entomological world and is quite conscientious in his tests.

It is difficult to give an answer to the very good point about increasing the life of the timber to two days. That is not a very difficult thing to achieve with or without preservatives, but possibly Mr. Richardson could help the community generally by suggesting a simple means of expressing the efficiency of a preservative. It seems to me that some simple ratio between the life of the untreated timber and the life of the treated timber would be a useful means of doing that, but it has its limitations. Perhaps we might be able to get some better suggestions for it.

Mr. S. A. RICHARDSON: I will write a paper on that one of these days, but at the moment I think we will leave it as just a question on my side and not a statement.

Mr. D. H. SPRANKLIN: Can Mr. Bulman give us any information about the effect of a solvent in which copper naphthenate is dissolved and has he any information about the use of copper naphthenate in emulsion?

I have one other question concerning the manufacture, is it not usually the case that copper naphthenate manufactured by the method he suggests contains a considerable proportion of free naphthenic acid when it is finally dissolved in a solvent?

Mr. R. A. BULMAN: I am not quite clear, Mr. Chairman, on the first part of Mr. Spranklin's questions regarding the solvents.

Mr. D. H. SPRANKLIN: Could you tell us the effect of different solvents, whether different solvents have any effect on the toxicity of copper naphthenate?

Mr. R. A. BULMAN: To the best of my knowledge complete data are not available specifically on copper naphthenate in that respect, but there is evidence with other preservatives that a simple solvent such as acetone, which would not of course be used commercially, whilst it does not affect the toxicity of the chemical, it does not add anything to it; but a heavier solvent, such as a fuel oil, may well add a little toxicity from its own point of view and could assist in a type of water-proofing effect on the timber if the solvent is of such a low volatility that it will stay in the wood and not evaporate. Other solvents, of course, evaporate and leave the wood and, therefore, have no effect whatsoever.

As far as emulsions are concerned, copper naphthenate emulsions can be prepared and are used very extensively in connection with textiles. But I am not aware of them ever having been used in timber, and at this juncture it is not a thing that I would recommend. A lot of work has been done with emulsions for timber preservation and yet I do not think any such method has survived.

As far as the free naphthenic acid in copper naphthenate materials is concerned, I do not think any copper naphthenate manufacturers are philanthropists. Naphthenic acid does cost money and I am quite sure they would not throw away any more than necessary. It can be taken that there is no free naphthenic acid present in a properly prepared copper naphthenate solution; that is, solutions prepared under the good standards of quality control.

Dr. W. P. K. FINDLAY: We are generally told that it is quite reasonable to apply paint to wood that has been treated with copper naphthenate solutions, but occasionally staining of light-coloured paint occurs. Could the speaker indicate the precautions that should be taken to avoid damage to paint applied after treatment with copper naphthenate?

Mr. R. A. BULMAN: First I might take this opportunity of mentioning one or two of the basic reasons for this staining occurring. It can occur with certain inferior products because of lack of penetration due to the type of acid used in preparation, with the consequence that a heavy layer of naphthenate would stay on the surface of the wood and behave almost like a film of paint itself. Otherwise when the penetration is normal in the prepared product, the trouble is less likely to occur, although it is a difficulty which sometimes does occur with heavily treated timber from which the solvent has not had a good chance to evaporate.

In the instances where any difficulty might occur, aluminium priming paints are quite useful in overcoming that difficulty when one wishes to produce a completely white finish; but there are also types of paints on the market which can be applied without that difficulty. I did intend to bring a sample treated with such a paint to show what can be achieved.

Dr. R. C. FISHER: Mr. Chairman, I noticed that Mr. Bulman did not make any mention of a recent paper; he has probably not had an opportunity of seeing this. There has been published in South Africa a recent account of work on the control of that old friend we have discussed at this Convention, the house long-horn beetle; it is a paper by a man called Dürr. Now Dürr has carried out a series of experiments with many preservatives and he deals quite exhaustively with copper and zinc naphthenate. I should like to hear the speaker's comment on the comparative toxicity of copper naphthenate and zinc naphthenate.

In South Africa the conclusion is that copper naphthenate is more toxic to young larvae introduced into impregnated timber than zinc naphthenate. He goes on further to say that zinc naphthenate is more toxic than PCP; that is bringing in another preservative altogether. Their final recommendation is the use of 3 per cent. zinc naphthenate plus 2 per cent. PCP, as one of the most suitable preservatives for the prevention of house long-horn beetle attack in South Africa.

One other point that this author makes is the difference in the effect of these preservatives in so far as prevention of attack is concerned—that is preventing egg laying—in which copper naphthenate was less effective than PCP. On the other hand, by comparing impregnated materials, on the one hand the naphthenate and on the other hand the PCP, the naphthenate is more effective. Have you any comments on these rather interesting preservatives?

Mr. R. A. BULMAN: Thank you, Dr. Fisher. I will say that I have not had an opportunity to study this paper. In general the results quoted are not surprising, although I do believe that Becker makes a report to the effect that zinc naphthenate is somewhat more effective than the copper naphthenate against Hylotrupes. I think it would be necessary to put those two papers side by side to see how they do tie up. Otherwise the copper product is generally accepted as being superior to the zinc product, both in regard to insects and fungi. However, we all know there is still quite a lot of work to be done, especially in connection with the house long-horn beetle, and it certainly will be interesting to get hold of this paper and see the results.

Regarding the mixture of zinc naphthenate and pentachlorophenol, I do not know whether we have anticipated the Colonies, but there is a composition like that available on the market in England and has been for some considerable time. If I remember rightly, it was put forward something over five years ago and is now available. One reason for that composition being effective, I suggest, is the possibility of the formation of zinc pentachlorophenate, and possibly that is slightly more toxic than either the pentachlorophenol or naphthenate by *itself*.

Mr. S. A. RICHARDSON: I want to ask a question which might be solved by the joint efforts of Dr. Findlay and yourself, Mr. Chairman, and that is, one occasionally finds *Merulius lacrymans* growing over timber which has been treated with copper naphthenate and is very obviously green in colour except at the point where the *Merulius* has grown on it and then the colour has been extracted. On analysis you find that not only has the naphthenic acid disappeared, but also the metallic radical as well. Can you explain that, or have you anything to add to the general knowledge on the subject?

Mr. R. A. BULMAN: Perhaps Dr. Findlay would like to tackle that one directly and make his comments first. I am sure I will have nothing to add to what he can say on the subject.

Dr. W. P. K. FINDLAY: I would like to prove there is no copper there. I frankly doubt Mr. Richardson's analysis. I cannot think the copper has evaporated in the air; it must be somewhere. I would like to know what the chemical reaction is which discolours it, and I hand that back to Mr. Bulman.

Mr. R. A. BULMAN: Perhaps I should say at the outset that I rather expected Dr. Findlay to speak on the enzymes that fungi seem to carry about with them and use for various purposes in the breakdown of wood itself, and probably in breaking down numerous chemicals and wood preservatives. I suggest that any peculiarities on the lines mentioned by Mr. Richardson probably originate from some kind of enzymic action.

Mr. S. A. RICHARDSON: Thank you.

Mr. J. G. SAVORY: I would like to point out in relation to the last question that, firstly, you have to be certain that the wood has indeed been treated by copper naphthenate; a green colour does not necessarily mean that it has been treated by copper naphthenate. Secondly, in the tests referred to on page 40 of Mr. Bulman's paper we noticed just this discoloration. There was a zone around the *Coniophora* and *Poria vaporaria*, where the agar was completely decolorized. When someone carried out the ordinary spot copper test it gave no copper reaction. There was no doubt that something was happening in that particular test.

Dr. W. P. K. FINDLAY: The copper must have been there.

Mr. J. G. SAVORY: Yes, the copper must have been there.

Mr. R. A. BULMAN: I am going to pass that one back to those enzymes again.

I would like to thank Mr. Savory for those comments as he has brought to my mind a specific instance when somebody brought along a sample of wood to me and said, "Here's your copper naphthenate; see what's happened—the wood's decaying." I took one look at the colour and said, "I know it's green but it isn't the green of copper naphthenate." Actually there was no copper there whatsoever and no naphthenate either. It was just some kind of paint. Sometimes I think the colour of copper naphthenate ought to be changed to another colour so that there is no confusion with green paints and the colour of copper naphthenate.

Mr. N. A. RICHARDSON: Regarding the last few points in the discussion. It is of course a well-known fact that copper is capable of forming a complex ion and as such would not respond to the normal test for copper. I do not know very much about the biochemistry of reactions that take place under fungal growth, but I would imagine that the explanation of the decoloration could well be the formation of complex ions. Dr. Findlay is quite right in that copper would not disappear from the wood, and it would be included in any complex ion which would not react to the normal chemical tests for copper.

In his paper Mr. Bulman has stressed the surface applications as treatments with copper naphthenate solution, and undoubtedly the reason for this is the relatively high cost of these preservatives due in turn to the high cost of the solvents. Any method by which the solvents could be recovered from treated wood would, I feel sure, encourage the better use of copper naphthenate solutions in impregnation treatments and this gives added interest to the work which Monie Hudson has been doing in the U.S.A. on his solvent recovery process.

In this connection I would like to ask Mr. Bulman whether he has any information on the lowest temperature at which copper naphthenate might be decomposed. The temperatures he uses in his solvent recovery are such that the treated wood is often no longer green. I have seen samples of vapour-dried timber treated with copper naphthenate solutions and they were quite brown in appearance. I suspect the copper naphthenate may have been decomposed and I would like to ask Mr. Bulman whether he has any information on the temperature at which the copper naphthenate would decompose.

There is one figure in the paper which seems to need correction. I notice in Table 3, where you give the absorptions for various forms of treatment, there is something a little odd about the results of the pressure treatment with the copper naphthenate solutions. You will note that the creosote and the pentachlorophenol solutions follow the normal pattern, 19.6 lb./cu. ft. in one and 12.5 lb./cu. ft. in the other, whereas you give only 2.9 lb./cu. ft. for treatment with copper naphthenate solution. In view of the fact that it is claimed that this penetrates wood so well, there is something queer about that. It is not your fault however. I have checked the figures in the original paper and I think there is something odd about this particular one.

The only other observation I have is this and I do not know whether my colleague, Dr. Findlay, would also like to comment on it. When the old British Standard 1282 was operative it included a test which I know he regards as quite a useful one. It was an acceptance test for wood preservatives, which consisted of a fungal test using a dip treatment for the test samples. I remember very clearly that solutions of copper naphthenate containing below 3 per cent. of copper—that is with the average copper naphthenate solutions of less than 25 per cent. in strength—failed to pass the test, whereas the normal 3 per cent. copper solutions were quite satisfactory. I think it would be a good thing to bring forward the point that for these dipping treatments you should not use solutions containing less than about 25 per cent. of copper naphthenate.

Mr. R. A. Bulman: Thank you, Mr. Richardson. Taking your points in turn and referring first to the solvent recovery process, I hesitate to give any specific temperature for decomposition of copper naphthenate, because of course conditions are likely to vary so much.

It is high, and I believe I am right in saying it is well above the boiling point of water even under the most adverse conditions.

As for the brown colour of the timber treated by the solvent recovery process, I have not actually seen the sample myself. It may possibly tie up with the solvent used which, although being essentially colourless, may collect types of impurities on its route round the recovery plant.

Now going on to Table 3 and the comment that these heavier treatments by the hot and cold soaking and the pressure methods show inferior results to the dipping and cold soaking, it has brought to my mind a very interesting point: namely, that these heavier treatments do tend to pick out the more permeable parts of the timber; one would see from the volumetric absorption that they are somewhat on the low side and it seems all the preservative has gone into some localized area. From that point of view, therefore, the pressure has been disadvantageous rather than otherwise.

Regarding the copper content, I quite agree with Mr. Richardson that for general purposes the 3 per cent. copper solution is by far the most satisfactory and should be insisted upon. Nevertheless, I will mention that various people have tried lower concentrations and I believe some fairly authoritative people even tend to recommend them. But to the best of our knowledge, it is certainly safer to use 3 per cent. solution for these kinds of usages.

The CHAIRMAN: I should like to ask a question about this question of staining, when the wood is subsequently to be painted. Mention was made of the use of aluminium primer as a precaution against subsequent staining. There is also a possibility that with certain types of preservative, or at least using copper naphthenate, certain methods of application might leave a skin or scum or layer of preservative almost like an opaque film. The question is, I take it that certain timbers would be better than others from the point of view of the risk of subsequent staining? For example, a very absorbent wood would probably take the preservative and you get no skin or scum on the surface. But I imagine with some woods the penetration would be sluggish and perhaps incomplete with copper naphthenate and any other preservative, and you stand more risk of staining because of that.

My second question is, is aluminium priming necessarily the only method of killing staining which it is suspected might come through using copper naphthenate? Is that the best primer? First of all, does not the type of timber influence whether or not you are going to get the staining? Secondly, if you suspect it, is aluminium primer the best type of sealer?

Mr. R. A. BULMAN: Mr. Chairman, I must thank you for raising those points, especially the first, which suggests that I did not quite make myself clear earlier. I was really dividing the staining or its causes into two halves. The "superficial effect" has arisen in one case from an inferior product—an inferior type of copper naphthenate—which when applied to the timber was so viscous that it did not penetrate the wood and tended to stay on the surface. All I can say is that the people who made the copper naphthenate did not know much about the properties of naphthenic acids and the correct ones to use. That was one half of the problem, purely the property of the preservative—a low grade preservative.

The other half of the problem is the penetration and in this respect a more permeable timber may give more trouble because it will, of course, absorb the solution more readily and the solvent will take somewhat longer to dry out from the innermost parts of the wood than if it were on the surface.

Regarding the primer, aluminium priming paint is not the only material, although I believe that is the subject of a British Standard, or one that is being drafted, specifically in connection with Douglas fir, as being probably the more common timber to give any staining. I have mentioned other types of paints and it does seem that a rubberized paint could be used as an under-coating or primer.

The CHAIRMAN: Thank you, Mr. Bulman.

Mr. D. J. EVANS: Might I ask Mr. Bulman if he thinks it is surprising that the aluminium primer is the most promising? Presumably it is contrasted with a lead-containing primer because the difference in electrical chemical table between aluminium and copper is the reason that aluminium and light alloys are dangerous materials to put together. I should have thought that the closeness of lead and copper would have led us to suppose that a lead paint primer would be more efficient. Can you say who has worked on this and where the results are published?

Mr. R. A. BULMAN: I believe I made a reference in connection with the aluminium primer to a British Standard which is being drafted. Now who is working on that I am afraid I do not know at the moment. I could probably find out and probably find what data they are working on. But I suggest it is not quite so surprising to find the aluminium paint used, the difference being that in such a paint the aluminium is in a metallic state, whereas in lead paint the lead is combined and is not present as free lead. So really the two types of paint are not related.

I suggest that the real point at issue is whether there might be corrosion of the aluminium paint. Firstly, I do not think that would be of any importance if it did occur. Secondly, if there is another coating of paint on top I feel sure that might keep out any moisture that might lead to corrosion. Does that cover your point?

Mr. D. J. EVANS: Yes, thank you, but it has not said why a lead primer is not a satisfactory one which is implied in the remark that an aluminium primer is a better one.

Mr. N. A. RICHARDSON: I think a lot of these problems have nothing to do with the copper naphthenate at all; it is a matter of the solvents used. We have carried out some impregnation tests with copper naphthenate and other solvent-type preservatives, and with high absorptions it has taken several months for the solvent to evaporate from the interior of the wood. It is the slow rate of evaporation of the solvent which is the cause of the trouble, and one would expect more trouble with lead paint than with a good leafing aluminium paint.

This question of solvent recovery is one, I think, you manufacturers of copper naphthenate could well bring to the notice of users. Where painting is important I think a grade with a quick-drying solvent has very special advantages and could be offered for those particular purposes.

We had a similar case a year or two back, which was another aspect of this problem, when one of the Agricultural Executive Committees had some glasshouses which they treated with copper naphthenate solution and they lost all their tomato and lettuce seedlings. There again it was nothing to do with the copper naphthenate, it was due to the fact that the plants were put in the glasshouse before the solvent had evaporated from the timber. I was in time to suggest to them that the other glasshouses, which had been similarly treated, should be left with the heat on and well ventilated for a few days. I am glad to say that this proved to be the right thing to do and no further trouble was experienced.

I think a lot of your trouble with copper naphthenate solutions, as with other solvent-type preservatives—pentachlorophenol and so forth—is not due to the material itself, but to the solvents used, and where questions of painting or injury to plant life and so on are important, it would be a big advantage to use a readily volatile solvent.

Mr. R. A. BULMAN: Thank you, Mr. Richardson. I can only agree with what you say, that reasonable time must be allowed for the solvent to evaporate. I would add that there are, for that reason, various industrial grades of copper naphthenate available, prepared in a solvent chosen to suit the particular application of the treated wood.

The CHAIRMAN: Ladies and Gentlemen, we have had an interesting discussion and the time is passing.

I was personally grateful to Mr. Evans for mentioning this question of aluminium following up my question about aluminium primer because, although I do not know much about the subject, I seem to recall there was some inter-action sometimes between copper and aluminium—electrolytic action of some kind. I wondered whether it was serious in this particular case. Apparently it is not. It is well known in the building trade that aluminium primer is of considerable value in sealing certain types of wood upon which stain has been applied in the past; it may be twenty years before. But some types of stain and some types of preservative will still come through a certain type of paint after many years unless aluminium primer or some kind of primer is applied. The problem of preserving, which most of us would like to do in my profession where it is necessary, is handicapped occasionally by the requirements that a particular timber must, by the instructions of the client, be painted as well as preserved in a colour practically dead-white, or nearly so, and that is a very exacting requirement. That is why I raised that point, and I was very interested to hear some of the discussion about it.

Now we have had a most interesting meeting. I personally have been interested although it has been miles above my head. I should like particularly to thank Mr. Bulman, whose firm is so well known and whose products are so well known, and also the people who took part, not least the bombardment from Winchester, which is always enlivening and always welcome. I enjoyed the clever way in which—I suppose it is Wimbledon week—Dr. Findlay volleyed back from the baseline skilfully and there was a sort of lob which followed. I am not sure what happened after that, I do not think there was any finality in that particular set, but it was extremely entertaining to watch and listen to.

I would like to thank Mr. Bulman very much for this paper on which he most obviously spent a great deal of time. He was provocative in places. I do not know whether it was deliberate or not; if it was, he has every excuse because it produced a most interesting discussion. I hope you will join me in thanking Mr. Bulman very much indeed for the trouble he has taken and the most interesting paper.

(3.) "MINING TIMBER AND ITS PRESERVATION."

By B. C. Hollingsworth
(Timber Branch, National Coal Board)

1. Introduction

Coal Mining requires timber for so many of its operations that some explanation of the scope of this paper is advisable. There is, for instance, no necessity here to deal with the joinery and constructional timbers which, like other great industrial undertakings, coal mining demands in large quantities. What is peculiar to the mining industry is another timber demand altogether, a demand for the support and maintenance of workings below the surface of the earth, and this is defined in government publications as "timber required for propping and shoring purposes underground". It is with this "mining timber", to give it its usual title, that this paper is concerned.

Until recent years, little regard was paid to the treatment of mining timber with preservatives before use. The low price of timber supports during the greater part of mining history and inadequate appreciation in mining circles—as in other industries—of the full possibilities of timber preservation probably explain this neglect. To-day, however, there is a widespread realization among mining engineers and others responsible for the equipment and maintenance of colliery undertakings that conditions in many underground workings encourage fungal attack on the timbers used. Preservation, it is realized, may well increase safety and lower costs in those places where mining timber is particularly liable to decay.

The field, therefore, for the treatment of timber used underground in collieries is a wide one, but it should not be assumed it is unlimited. There are important factors which restrict the use of treated timber in the mines and these the paper proposes to discuss in some detail.

2. The Use of Timber in Mining

Before dealing with the field for preservation, a brief survey of coal mining operations, of timbering methods and of the species and specification of wooden supports, etc., used in coal mines may be helpful.

(a) Coal Mining Operations

The necessity for supports in mines arises, of course, directly from the nature of mining operations. Coal seams lie at various levels and inclinations below the earth's surface, and they can be approached either by inclined roadways when shallow or by vertical shafts when deep. The removal of coal from these seams creates a void and upsets the equilibrium of the surrounding strata so that movement occurs and some form of artificial support becomes necessary. This support can be provided in various ways and by using different materials, steel or timber being the commonest, but it is with the use of timber supports that we are directly concerned here.

The mining engineer divides support problems into two parts, those he encounters in the underground roadways of the mine and those he has to solve at the working-place or face. The roadways, which are used for ventilation, for the transport of coal to the pit bottom, and for the carriage of men, tools and materials to the face, vary greatly in size. There are wide and lofty main roads and narrower "gate" roads which connect the main haulage with the various faces of the pit, but all require support if they are to remain both safe and efficient channels of communication. At one time, timber was almost universally used for roadway support, but during the past 30 years steel arches have gradually replaced it for main road work. Timber,

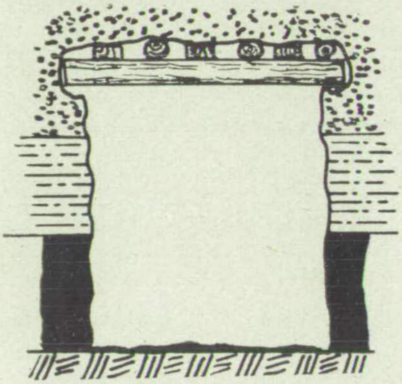

FIG. 1.

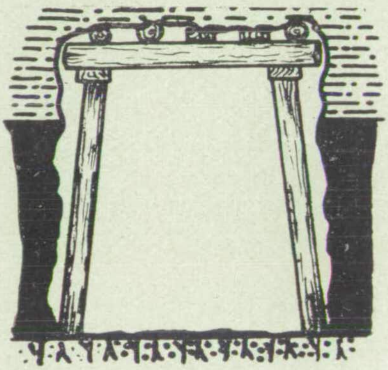

FIG. 2.

nevertheless, is still used in places where the life of a road is not likely to be extensive and for lining behind the steel arches and for sleepering the extensive mine car or hutch haulage systems.

At the working place or face of a colliery, there are two main methods of extracting coal from the seam, and each of these calls for a plentiful supply of supports. In thick or moderately thick seams, the Pillar and Stall system may be used, under which places are driven into the solid coal and the area to be worked is divided into rectangular pillars by narrow places known as "stalls". In most British seams, however, the Longwall system of working is preferred. Under this method, the coal is extracted in one operation by working one or more straight faces, each of approximately 100 yards or longer in length.

(*b*) *Timbering in Roadways*

There are numerous variations in the use of timber as a roadway support. One of the simplest forms is the crossbar or crowntree which is used in "drawing roads" or "gate roads" near to the coal face. This consists of round, half-round or rectangular sections of coniferous timber stretched transversely across the roof of the roadway (Fig. 1) and it may be used with or without upright supports according to the nature of the pressures encountered. Where it is used with upright wooden supports, the crowntree rests on a round pitprop at each end, these props frequently being set at an angle to strengthen the whole erection. (Fig. 2) Other and more elaborate methods of support, such as "herringbone" timbering, do not call for comment here but it should be mentioned that small rectangular pieces of timber called lids are used at the base of the props as sole pieces or placed between the upright and the crowntree to provide for initial crush and thus to extend the life of the timber. The round pitprops, used as uprights both in roadways and at the face, should be of coniferous timber, well seasoned, normally with the bark removed. They should be straight, free from coarse knots, square cut at the ends, and the ratio of length to diameter for short props should be approximately 12 to 1, although with long lengths a higher ratio is allowed.

Above the crowntrees or between the pitprops and the roadsides lagging pieces may be used, and these lagging timbers are also required for lining those roadways where steel arches are installed. Short round props of $2\frac{1}{2}$ in.-3 in. diameter are sometimes used for laggings but in addition there is a demand in many coalfields for sawn timber, either hard or softwood, usually in $1\frac{1}{4}$ in.-$1\frac{1}{2}$ in. thicknesses and varying widths and lengths for this purpose. These Coverboards, as they are called, can be either edged or unedged, according to colliery demand, and they form an appreciable percentage of the volume of timber used in roadway-work.

Another kind of timber used extensively in roadways is the pit sleeper which carries the flat bottom or bridge rails of the mine car or hutch haulage systems. It varies in length and section to suit the rail gauge in use and preferably it is made of softwood, as many hardwoods used for this purpose and in small sizes are liable to split.

The ideal species of coniferous timber for use in roadways is European Larch (*Larix decidua* Mill) which gives a combination of light weight, strength and durability found in no other softwood. Unfortunately, it is now impossible to obtain sufficient supplies of this species to satisfy colliery needs and for ordinary timbering, Scots Pine (*Pinus sylvestris* L) and Norway Spruce (*Picea abies* Karst) give excellent results as also do several other species of conifer such as Maritime Pine, Corsican Pine, Sitka Spruce, Douglas Fir, and Japanese Larch, always provided these are well grown and well seasoned.

(*c*) *Timbering at the Face*

It has already been mentioned that complete extraction of coal inevitably results in a downward movement by the strata over the whole area which is being worked. The mining engineer controls this subsidence in Longwall Working by erecting stone packs at intervals along the face, and by temporarily supporting the corridor between such packs and the face with a double row of pitprops, each set of two opposite props being bridged by a crossbar or crowntree. Here again, as in roadway work, the principal categories of timber support used are the crowntree and the round pitprop, both of coniferous timber, and lids are also employed as sole and crown pieces to absorb initial stress. Various other mining timbers are used at the face, such as the small props and blocks which support the undercut during the first operation of longwall working, but the only category which calls

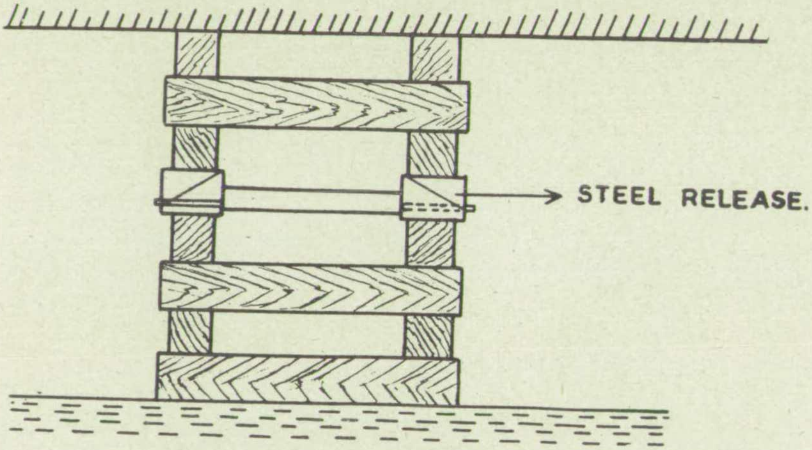

FIG. 3.

for detailed mention here is the chock. (Fig. 3) This is a short piece of hardwood, square in section (typical specifications are 2 ft. x 5 in. x 5 in. and 3 ft. x 6 in. x 6 in.), which is used in association with packs to build up rigid pillars at the edge of the waste area opposite the working face.

3. The Field for Preservation

It is well known that the four conditions necessary for decay of timber are warmth, air, moisture and wholesome food for fungus. These conditions are frequently found together in British collieries, particularly in return airways where temperature and humidity are often favourable to fungal infection. The species of fungus which can flourish in favourable conditions underground are numerous, including *Coniophora cerebella*, *Paxillus panuoides*, *Fomes annosus*, *Polystictus versicolor* and *Lentinus lepideus*, but the chief species encountered are the well-known *Merulius lacrymans* and *Poria vaporaria*.

Underground conditions likely to encourage fungal infection vary greatly between collieries, between sections of individual pits and even between levels in a single situation. Thus, many collieries enjoy throughout their workings remarkably dry conditions where risks of decay are slight, whilst in others temperature and humidity vary significantly between different sections and different roadways. Again, it is not unusual to find at a particular point underground conditions favourable to decay at ground level yet unfavourable at roof level. Nor does the variation in the incidence of fungal infection end here, since it is obvious fully seasoned timber installed below ground will offer more resistance to infection than timber used in a green or semi-seasoned state. The mining engineer, facing the question "to treat or not to treat" mining timber with preservatives, must bear all these points in mind but he must do something else. He must consider whether the length of time he expects to use his installation of timber is sufficient either to risk infection or to warrant preservative treatment.

One thing is certain, where in underground operations the useful life of mining timber is shortened by decay, the costs involved may not be purely economic. Fungal decay, even incipient decay, can cause serious reduction in the strength of a support and may conceivably lead to failure under stresses which the species and specification of timber concerned should normally accept. To this risk of failure must be added the fact that infected timber is known to be more inflammable than sound timber; consequently the influence of decay on safety must be acknowledged.

In Britain, investigation into the useful life periods of treated and untreated mining timber was, until recent years, spasmodic and largely unrecorded. The best known pre-war experiments were conducted for the Department of Scientific and Industrial Research by Mr. J. Bryan and Mr. N. A. Richardson who issued reports in 1935 and 1949 on results obtained over a period of 16 years.*

The pits chosen in 1930 for these tests were the Langton Pit at Pinxton, near Nottingham and Woolmet Pit, Portobello, near Edinburgh, both being collieries where fungus growth was known to flourish in the underground workings. Seasoned Scots Pine pitprops both imported and home grown, were used and whilst a proportion were left untreated as controls, equal quantities of others at Langton Pit were treated with Wolman Salts, Zinc chloride, Sodium fluoride, common salt, and coal tar creosote. At Woolmet pit, similar installations were made but the creosote treatment was omitted. In all cases, the treatment was carried out at the pithead and consisted of the hot and cold open tank impregnation process, each prop being

* Department of Scientific and Industrial Research, Forest Products Research Records No. 3 (Wood Preservation Series No. 1) Experiments on the Preservation of Mine Timber, Progress Report No. 1, Published by H.M. Stationery Office, 1935. Final Report, Published by H.M. Stationery Office, 1949.

identified with a zinc label stamped with a serial number. The props were set up in various parts of the Langton Pit but installed in only one roadway at Woolmet, and inspections were carried out in both pits at half-yearly intervals for the first five years, annually between 1935 and 1940, and thereafter stopped altogether until a final examination was made in 1947. An extract from the 1949 report may be quoted to indicate the results:

"Many of the untreated props showed signs of decay at the first inspection and some were completely destroyed after 18 months. On the other hand, a few have remained sound up to the time of the last inspection, these having been in drier places where conditions were less favourable to decay. Not one of the treated props showed any signs of attack at the first inspection, after which a few isolated ones, chiefly those treated with sodium chloride, began to decay."

In its summary of conclusions, the 1949 report uses these words:

"The recognized wood preservatives, as to be expected, have given the best results, but even the common salt treatment has had quite an appreciable effect. Creosote has proved the best, no decay whatever having been observed in any of the props treated with it after 16 years."

Since the nationalization of the collieries in 1947, the National Coal Board's Scientific Department has been carrying out experiments at Ashington Colliery in the Northern (N. & C.) Division. The situation chosen, the Bothal High Main return airway, has conditions favourable to fungal decay, with average air quantity, temperature and humidity as follows:

Average air quantity	Up to 1951	14,000 cu. ft./min.
	1952	12,000 cu. ft./min.
	1953	4,000 cu. ft./min.
	1954	3,000 cu. ft./min.
Average hygrometer reading	Dry bulb 56/59 deg. F.	
	Wet bulb 56/59 deg. F.	
	Relative humidity 100.0 per cent.	

The size of prop used for test was 5 ft. long by 5 in. diameter, and tests were commenced on untreated, creosoted, and props treated with a water soluble in the summer of 1948, props treated with another water soluble preservative being set up in March 1949. Fifty props of each type were installed, being placed in rotation along each side of the roadway at one yard intervals. They were set up with wooden lids and steel bars.

Each month the props are examined visually, penetration with a sharp instrument is measured, and general qualitative observations are made. Every six months one prop of each type is withdrawn and these are examined in the laboratory, the tests including the total compressive load at failure; the prop withdrawn is replaced by a steel support. The results of these tests to date are shown in the Table.

SIX-MONTHLY TESTS ON PROPS

Period	Untreated		Creosoted		Water Soluble A		Water Soluble B	
	Wt. per cu. ft.	Total C.L.	Wt. per cu. ft.	Total C.L.	Wt. per cu. ft.	Total C.L.	Wt. per cu. ft.	Total C.L.
After	*lb.*	*tons*	*lb.*	*tons*	*lb.*	*tons*	*lb.*	*tons*
6 months	29.0	17.8	42.4	33.6	42.5	35.6	31.4	19.32
12 ,,	29.27	18.0	44.26	36.1	43.21	28.5	34.5	28.4
18 ,,	23.50	7.88	42.4	33.45	36.8	32.4		
24 ,,	30.56	8.3	39.9	28.1	40.15	32.5	42.42	29.18
30 ,,	26.45	5.6	43.25	27.6	47.31	33.5	38.5	24.5
36 ,,	All withdrawn		37.5	26.3	44.2	26.35		
42 ,,			42.9	33.15	30.35	27.85	42.8	28.2
48 ,,			37.8	23.6	37.6	33.4	46.1	25.8
54 ,,			36.9	27.8	40.3	36.9	34.9	25.5
60 ,,			44.4	27.4	43.6	24.7	35.9	27.2
66 ,,			39.9	25.2	39.4	27.3	39.2	24.0
72 ,,			36.1	28.0	42.5	25.7		
79 ,,			43.1	34.5	38.7	24.0		

C.L.=Compressive load at failure.

The tests have shown that under the conditions prevailing in this return airway, the useful life of untreated timber is eighteen months. Fungi have appeared on several of the creosoted props from time to time but the growths have been patchy and no serious decay is evident as yet. The Water Soluble A props have resisted fungal growth and there is no evidence of attack after 6½ years. In the case of the props treated with another water soluble, no appreciable fungal attack has been observed after a period of over five years. The values of compressive load at failure show a rather wide variation but in dealing with round timber it is difficult to select props for tests which are of exactly equal size and performance. The tests are to be continued.

From this brief review of experimental work on the liability of untreated mining timber to decay, it is obvious that beneficial results can be expected to follow treatment with preservatives of timber which is to be employed underground on work of a permanent or semi-permanent nature in conditions favourable to fungal infection. In any particular colliery or part of a colliery, managements know from observation of temperature and humidity and also from experience where infection is most likely to occur. Equipped with this knowledge, their decision to use treated timber will be influenced by considerations of safety and cost, and in most cases the first question asked will be, "What is the potential useful life of the timber installed?" If only a short life of a few weeks or, at most, one or two months is anticipated, then even in conditions favourable to fungal decay, treatment may be considered unnecessary.

With this question of useful life in mind, the position of face supports merits special attention. These timbers are, from the very nature of their work, more liable to early loss than those used in other parts of colliery workings. They are repeatedly withdrawn and re-set as the coalface advances and, however carefully they are handled, eventually become crushed or broken or are buried in the waste. Consequently, their expectation of life can seldom be long enough to justify the expense of preservative treatment.

In the case of roadway timbering, it is often taken for granted that preservative treatment is essential wherever conditions favour decay. Yet even here, the temporary nature of many underground roadways may make the use of treated timber unnecessary. Given the expectation of permanent or semi-permanent installation, however, roadway timbers do offer a wide field for preservation where fungal infection is likely to occur and roadway props, crowntrees, track sleepers, coverboards and other lagging material may all call for treatment.

Apart from questions of extended life and maintained strength, the fire-retardent effect of some preservatives on roadway timbers calls for comment, although the scope of this paper does not allow detailed examination of this subject. Reference has already been made to the inflammable nature of decayed timber, so that naturally any steps taken to avoid decay have some fire precaution value. Additional to this, it is claimed for the water-soluble type preservatives that they have some fire-retardent action which would, at the least, delay flame spread along the timbers of an underground roadway in the event of a serious conflagration. More effective fireproofing of roadway timbers can be secured by the application of a surface coating of incombustible material to the wood after erection or by impregnation with suitable salts before use, ammonium phosphates being especially recommended by some authorities. The decision to treat timber against decay, against fire or with salts which give protection against both risks at once must be taken by managements after study of the risks involved in making any particular installation. In this connection the section on Fire Hazard of the 1953 Report of the Safety in Mines Research Establishment, page 38, may be quoted as follows:

> "Untreated timber, particularly the timber lagging of roadways, provided the main fuel in at least four serious fires during 1953. These fires stress the need for the fire-retardant treatment of timber, discussed by Eisner (1951), not only for the lagging of mine roadways and for ventilation doors but also for surface structures such as the timber supports of winding gear."

4. Preservatives and Methods of Treatment

For all practical purposes, the preservatives which are used to prevent decay in mining timber can be divided into two groups; (a) creosotes and (b) water solubles. No detailed description of these preservatives is required in a paper presented to members of the British Wood Preserving Association, and it may be said at once that the effectiveness of either group in preventing decay is generally recognized by mining engineers and is borne out by the experimental work already described under Section 3.

In choosing a preservative for mining timber, however, effectiveness in preventing decay is not the sole consideration. Fire precautions are of such prime importance in underground workings that any preservative which tends to increase rather than to retard the inflammability of timber must, to that extent, be suspect. Some colliery managements, for instance, avoid the use of creosotes as tending to increase the inflammability of timber, but this is a view which has been challenged.*

Another point which merits consideration is excess of water at certain points in colliery workings. Under seriously wet conditions, leaching of chemicals out of water soluble treated timber is a possibility which managements should study when choosing a preservative, so as to discover the most effective solution to employ.

On methods of treatment, although the open tank process used in the pre-war experiments on mining timber appeared to give satisfactory results, it is generally recognized in the mining industry to-day that deep penetration of timber with preservatives is preferable and can best be secured by injection under pressure. The Full-cell or Bethell process of pressure treatment is the one almost universally adopted, and a large proportion of mining timber impregnated before use is nowadays treated by this method.

One of the problems in treating mining timber—and this refers especially to home-grown material—is that it sometimes reaches the preservation plants insufficiently seasoned and, in the case of round pitprops, insufficiently barked for the best results to be obtained. This is a question which is increasingly receiving the attention of those responsible for purchasing mining timber.

5. The Economy of Preserving Mining Timber

From time to time, exaggerated claims, based upon the total consumption in Britain of mining timber, have been made for the economies to be gained by preservative treatment. This paper has endeavoured to show that, apart altogether from the threat of fungal infection, the

* "Impregnated timber is not a fire-hazard"
By: D. H. Broese Van Groenou, Wood Preservation Laboratory of Rütgerswerke A.G., Frankfurt.
From: Strassenblau u. Bautenschutz m. Steinkohlenteer, March, 1954, 3, 2-4.

expectation of life in mining timber installed on the working face—and even in some roadways—is comparatively short. The field for economy by preservative treatment is thus narrowed down to those underground places, mostly roadways, where conditions favour decay and where a useful life of more than a few months is expected of the timber installed.

In these places, experiment has shown that preservative treatment can extend the life of mining timber from a few months (the life-period of untreated wood subjected to serious infection), to as long as 10 years. This is not to assume, as some over-enthusiastic people have done, that every support, sleeper or coverboard treated with preservatives will be in use 10 years from the date of installation. Even in roadways, varying degrees of stress cause breakages and crushing of props, whilst the wear and tear of haulage systems continually splits and damages track sleepers. Nevertheless, a useful life several times longer than that of untreated timber is possible for those supports which survive damage and loss. And to the savings in actual timber cost which this entails must be added the savings in re-installation, since replacement of track due to decayed sleepers or of supports due to decayed props or coverboards is an expensive operation.

The cost of preservative treatment, where this is carried out at pressure plants owned outside the mining industry usually adds 25 per cent. to 35 per cent. to the current free on conveyance cost of mining timber but, in addition, some extra carriage costs are involved if the material is substantially diverted from its normal route from supplier to colliery.

How far these costs are reduced in those places where the mining industry maintains its own pressure cylinders is a subject at present under investigation and subject to experiment. Normally, the demand for treated timber at any one colliery is insufficient to merit the expenses of individual pithead equipment but with the development of central stores and workshops serving groups of collieries with supplies, the advantages of erecting preservation plants at central points in the coalfields may become apparent.

In conclusion, it must be recognized that there is a proven if limited field for mining timber preservation. Treatment of such timber is not, as this paper has shown, an entirely new practice but it is one which, owing to the untiring efforts of its advocates, has developed rapidly over recent years and has now reached a fruitful stage. It promises increased safety and valuable economies to the mining industry and it is, therefore, a development which deserves encouragement.

This paper is presented by permission of the National Coal Board but it represents the author's personal opinions and not necessarily those of the Board.

Discussion on Paper 3

The CHAIRMAN (Brigadier H. C. J. Yeo, D.S.O.): Gentlemen, I was honoured and a little astonished when the Association asked me to take the Chair at the discussion on mining timbers and their preservation because, as you may know, I know very little about mining timbers. Since I have read Mr. Hollingsworth's paper I am, of course, considerably better informed.

Mr. Hollingsworth is a product of the timber trade having spent twenty years with the well-known Scottish importers, James Kennedy and Company, when he was assistant manager of their pitwood department. In 1939 he went over to Timber Control and became the pitwood officer for the Scottish region; that was 1939 to 1947. In 1947 he went to the National Coal Board and is now the head of the Distribution and Home Grown Timber Section of the National Coal Board's Timber Branch.

I believe, Mr. President, that this is the first occasion on which we have had the privilege of welcoming the members of the National Coal Board. I am sure, Gentlemen, we have all wished to meet members of the National Coal Board at times, either for professional or domestic reasons! Mr. Hollingsworth has told me of the really enormous quantity of timber that is sent down the mines, and the thought occurred to me that perhaps this is not the place to discuss what we get in return!

I have great pleasure in introducing Mr. Hollingsworth.

Mr. B. C. HOLLINGSWORTH: This is the first time, I believe, that the Convention has had before it a paper on mining timber. It is quite frankly a branch of the timber trade which, probably owing to the shy and retiring nature of its practitioners, has very little written record. But it is not without its importance.

As your Chairman has indicated, a lot of timber is used in the mines for support and other purposes—something approaching two million tons a year, and that is quite a considerable part of our country's total timber consumption; some years it must approach twenty-five per cent.

You may feel the paper deals rather exhaustively with mining and with the use of timber in mining before it gets down to what might be called the sixty-four dollar question, the question of preservation. This approach was felt necessary because the specifications of mining timber and the way it is used are not very familiar even to timber people; also because mining timber is comparatively a latecomer to the field of preservation.

One of the main objects of the paper is to show that, although support problems in collieries are divided into two parts—there is the problem of supporting the roof at the working-place or face of the colliery where the coal is actually taken out of the seam, and there is the problem of supporting the network of underground roadways in the collieries—the field for preservation is mainly in roadway timbering. Nowadays, of course, the main underground roadways of collieries are not supported by timber at all; they are supported by other means, mostly by steel arches. But there is a large and constant demand for timber supports in some—not all—of the subsidiary roadways, what are called the gate or drawing roads. These are the roadways which connect the main haulages underground with the various faces where the coal is actually being got.

However, apart from this altogether, whether a roadway is main or subsidiary, and whether it is supported by steel or by timber supports, there are other timber demands for lining behind the supports of the roadways, what are called "lagging timbers". There is also another demand for sleepering the haulage systems underground, the hutch and mine car haulage systems.

Given then that there is a field for preservation, the paper next goes on to examine the question, when and to what extent preservation is necessary. Conditions which favour fungal infection are not present in every colliery, nor are they necessarily present in every roadway of an infected pit, but they are sufficiently prevalent to warrant investigation of what effect those conditions have on mining timber. Here we are very fortunate in having two main sources of information. There has been a lot of work on this at various times, but in this country we have two main sources of information: there is first of all the work carried out by the Department of Scientific and Industrial Research which was initiated as long ago as 1930 and which was finally reported upon in 1949. There are also a series of tests which have been carried out since nationalisation by the Scientific Department of the Coal Board at Ashington Colliery in the Northumberland and Cumberland Division of the Board. Those tests were first started nearly seven years ago and they are still going on.

All this experimental work shows that untreated timber, when it is set up in bad conditions which favour fungal decay, normally speaking is useless as a support in eighteen months, sometimes considerably less, but that timber which is treated with suitable preservatives can have a useful life of several years, always provided of course that it is not in the meantime damaged or lost under all the stresses and strains to which almost any kind of timber is subjected in underground workings.

The paper mentions another subject which I have not dealt with in detail but which we felt ought to be included. This is the fire-retardent effect of some wood preservatives on mining timber. This is a subject that is of great interest to those who are responsible for fire precautions underground in our collieries, particularly in roadways. Untreated timber and timber that is partially rotten or very rotten can be a very serious fire risk especially in certain localised roadway situations.

There are various alternative methods of fire-proofing which can be used in that case.

The next question is, what kind of preservative should be used to treat mining timber against decay? Inevitably this question introduces the rival claims of different kinds of wood preservatives, mainly, in the case of mining timber, the creosotes and the water solubles. Inflammability on the one hand or a tendency to leach out of the timber on the other by another are things that have to be taken into account. In the long run it is the man on the spot, the mining engineer, who has to decide what kind of preservative should be used, and the paper tries to show the kind of considerations which will influence him in coming to a decision.

On the method of treatment which should be used for mining timber, I think probably most of you know that the full cell or Bethell pressure process is generally used for treating mining timber in this country. But since the paper was prepared some interesting information has come to hand and has been published on the treatment of mining timber in Canada by the hot and cold steeping process. Mr. Honour and Mr. Davies—I think they are mining engineers—writing in the March issue of the *Canadian Mining Journal* have been describing work carried out during the past year or two at the Dome Mines in Canada with a plant which is capable of treating 3½ million board feet annually. They describe a method which adopts zinc chloride as the preservative and uses a rather higher temperature in the hot solution than I understand is normal with the hot and cold steeping process. They claim that by the method they describe they are managing to attain a retention of the preservative and a penetration which is equivalent to what is secured by the full cell pressure process. What is particularly interesting in their account is that they describe the results of tests carried out at the National Testing Laboratory at Toronto University, which show, according to them, that when they use as high a solution as ten per cent. of their preservative, they get no loss of strength in compression parallel to grain, whereas they say that with timber tested at the same time treated by the full cell process there was some loss of strength even with a weaker solution of only about five per cent.

I should say, by the way, that none of the timber they tell us about in this article has been in position more than three years at the Dome Mines so that their results cannot be considered as very conclusive yet; but they claim that so far timber treated by their method has shown no signs of decay.

I thought it would be interesting in passing to mention this as something that has come to my notice since the paper was prepared, but I do not want to take too much of your time introducing the paper.

The only final point I should like to mention is the question of the economies of mining timber preservation. To those who are unfamiliar with deep mining operations, it usually comes as a sharp surprise to find what a short working life most mining timber has. In the working places of British collieries where the Longwall system of mining is usually in operation, very little timber used for support work has a life that is long enough to put it in any danger of decay from fungal attack. Even in the subsidiary roadways which I have referred to the life of the timber, its expectation of life when it is set up, is very often something that is measured in months rather than in years. Consequently, the field for preservation is considerably narrowed; it is narrowed down, one would say, to situations where the timber has to be in position and used for about a year or longer and situations where, at the same time, there are conditions which favour decay. In those situations—and there are very many—there can be no question that valuable economies in cost can and are being achieved. Increasingly mining engineers in this country are becoming aware of the possibilities of making roadways safer and maintaining them at a cheaper cost by the use of treated timber. One can have no doubt that there is a permanent and a place of growing importance for wood preservation in the mining industry in this country today.

The CHAIRMAN: Before I ask Mr. Hollingsworth to answer your questions and open the paper for discussion, I would like to issue a word of warning to the various interests represented here, and that is that Mr. Hollingsworth is a potential customer unlike most of the speakers!

Mr. B. C. HOLLINGSWORTH: There are two things I should also say: one is that I am not a mining engineer, although I have a little knowledge of how timber is used in mining; and any opinions that I express are purely my own and not necessarily those of the Coal Board.

Mr. R. A. BULMAN: I wonder if I may ask in connection with the chloride used in the Canadian test whether the normally accepted fire-retardent properties of zinc chloride itself would play a big part in choosing that preservative for mining timbers?

Mr. B. C. HOLLINGSWORTH: No, Sir, that was not mentioned in the article. The main reason for this plant being set up, as far as I understand it, was that it was very cheap to run and it gave a very effective protection against decay; but the article, as far as I remember, did not mention the question of fire-retardent properties of the preservative.

Mr. C. H. D'AMBRUMENIL: You mentioned in your paper that home-grown mining timber on many occasions receives insufficient preparation before being forwarded for treatment. Could you enlarge upon that point?

Mr. B. C. HOLLINGSWORTH: Yes. We are using a lot of home-grown timber now in the collieries. Last year 45 per cent. or 46 per cent. of the timber used in British collieries was native timber and that percentage will probably increase in the future. The interesting thing to us is that, as far as we can take the figures out (it is very difficult for us to know exactly what kind of timber is going through preservation plants) about 45 per cent. of the timber actually treated in 1954 was of home-grown origin, so that we do get a lot of home-grown timber which is treated with preservatives, and we do get complaints that some of it is insufficiently seasoned, since it is too green, when it comes to the plant. I am not an expert on the treatment of timber, but I understand this means it is a more difficult job for the pressure plant people to get the timber impregnated with a preservative.

Another complaint we get is that some of the home-grown props are not cleanly enough barked. Consequently if there is bark adhering to the timber, some part of it is insufficiently treated. I may say that a great many people concerned with home-grown timber are experimenting with mechanical peeling machines at the present moment for pitprops. There are two or three different machines on the market and we do hope that, as time goes on, we shall get practically all our props from home-grown sources peeled, and, what is more, well peeled, thoroughly peeled. This question of insufficient peeling and insufficient seasoning is a difficult problem.

The CHAIRMAN: Could I ask Mr. Hollingsworth—you said it was roughly 700,000 standards a year of timber go down the mines . . .?

Mr. B. C. HOLLINGSWORTH: Yes.

The CHAIRMAN: How much of that do you reckon is worthy of treatment with preservatives—an approximate figure? Main roadways, gate roadways, sleepers on the various lines, you probably could call those permanent or semi-permanent. I wonder if you could give us any idea of the amount of that which you think is justified in being put through preservation and how much is at present.

Mr. B. C. HOLLINGSWORTH: Any opinion I gave on this would be purely my own because it is naturally a very ticklish subject. First of all a large proportion of timber which goes down the mines is used on actual support work on the face, and of the timber used in roadways there is quite a lot which does not need preserving even in certain gate roads. But at a conservative estimate I would say that perhaps ten per cent. of mining timber might be in the field for preservation. I do not say all of this percentage would necessarily need to be preserved; some of it might be used in dry pits where that was unnecessary. Once or twice we have seen publications which point out the tremendous field for preservation in pit sleepers, the little sleepers that carry the haulage system. We agree that is a very good field for preservation, but it must be remembered that all collieries do not use timber sleepers; they use other kinds of sleepers, metal and so forth. Actually less than three per cent. of the timber which goes down British collieries is used for sleepering purposes. Last year it was 2.7 per cent. so there is not a tremendously big field in sleepers. There is probably a bigger field in lagging timbers.

The CHAIRMAN: That was the first part. My last question was, can you give us any idea of how much is at present treated. Do you think ten per cent. is reasonable?

Mr. B. C. HOLLINGSWORTH: We have no up-to-date figures on that and I do not know, even if I had them, whether I could tell you.

Mr. J. A. SCHOFIELD: Mr. Chairman, I believe that various forms or species of wood-destroying fungi are found in mines and that such fungi can vary in their resistance to certain types of chemicals. I wonder if Mr. Hollingsworth could tell me whether any investigations have been carried out to classify the mines according to the predominant amount of fungus encountered in order to select the most appropriate type of preservative?

On page 10 he states that the cost of preservative treatment alone adds 25 per cent. to 30 per cent. to the cost of timber; this is free on conveyance cost. This, to me, seems very high as the normal preservative treatment for this kind of hazard would be in the region of 12½ per cent. to 15 per cent. of the cost of the timber. That is on imported timber. The other alternative would be that the N.C.B. are buying mining timber, a large proportion of which is imported, at a very low cost.

Mr. B. C. HOLLINGSWORTH: With regard to the first part of Mr. Schofield's question, as far as I know in this country there has been no investigation of the kind he mentioned, except for the reports that were made by Mr. Richardson and Mr. Bryan when they issued their two publications on the pre-war investigation. They mentioned there the various types of fungi which were encountered in collieries. I do not know whether that was based on investigation by the Department of Industrial and Scientific Research or not. So far as I know the Coal Board have not gone into that. Mr. Gold is here from our Scientific Department; he may be able to say something about it.

About the cost question, my figures are accurate for the various prices of mining timber. The answer is quite briefly that mining timber is much cheaper than ordinary sawn timber, DBB and so on; it is at the bottom end of the price scale in the timber market, and we can only say we thank you for the compliment, Sir, that we are buying our mining timber as cheaply as we are. We buy, for instance, cover boards at something like 5s. 9d. per cubic foot free on truck with some carriage over and above that. I think you will find that if you apply your cost of preservatives to that, it is within the percentages I have mentioned.

The CHAIRMAN: Could Mr. Gold add anything to that?

Mr. J. H. GOLD: As far as I know there has been no general classification or investigation of the type of fungus which might be encountered. Certainly nothing has been done by the Scientific Department of the Board. There may be some indication by investigation at our collieries by the people on the spot, but nothing has been published on that matter.

Dr. W. P. K. FINDLAY: With reference to that last point Mr. Gold mentioned, I think we can take it that there will be a risk of similar fungi turning up in all mines. Therefore there would never be any question of formulating a preservative to fit a particular mine in this country. I emphasise "in this country" because in South Africa you have again quite different florae. So far as this country is concerned, the species which Mr. Hollingsworth has mentioned are the common species that one finds.

Incidentally he mentioned *Merulius lacrymans* as being common. In our experience that is rather rare in mines, and *Poria vaillantii* and *Lentinus lepideus* are more frequent.

While I am on my feet I would like to say how very glad I am this subject has been brought before this Association. It is one I have been interested in for many years. Some of these damp mines are a delight for mycologists. We find all sorts of luxuriant and magnificent specimens. I always welcome an opportunity to visit them.

Mr. N. A. RICHARDSON: I should like to add my congratulations to those of Dr. Findlay to Mr. Hollingsworth for what I think is a very enjoyable paper. It very fairly and very well describes the use of timber in mining. I know when we tried our experiments we had not as much information as that to start on; we may even have done them in a slightly different way; but it is a rather disturbing thought to be reminded of those stresses.

I have only one observation: it is probably a question of wording; Mr. Hollingsworth probably has not written it in the way I read it. It is on page 9 where he is speaking of the methods of treatment; I take it in line with this question of cost. I think Mr. Hollingsworth's view that treatment is only desirable or necessary in certain circumstances, and that in some areas or in some isolated collieries only relatively small amounts of timber are involved, suggests that we cannot get penetration or absorption by the open tank method comparable with those of pressure. I should just like to put that point right, because actually those tests which you so kindly referred to earlier, the absorption in those open tank tests is two or three times that which you are getting under pressure at the present moment, especially with Scots

Pine. It is one of those woods which is particularly amenable to open-tank treatment. It is a very simple form of apparatus. I put it forward that in cases where only a small quantity of timber is involved, it may well be worth the colliery manager doing a little treatment on his own. It would be well worth while and it would save what is undoubtedly a high proportion of cost—that of the timber and transport to and from the treatment plant.

Mr. B. C. HOLLINGSWORTH: Yes, I must admit that when this paper was prepared, from what I had heard of the subject and read of the subject I was under the impression that one could not obtain the necessary penetration by the hot and cold method, but the later information which came to my hands from Canada certainly surprised me, when I read the results these people had got.

Mr. N. A. RICHARDSON: It depends on the species.

Mr. B. C. HOLLINGSWORTH: Yes, I can well believe that.

Mr. T. G. ROBINSON: Mr. Hollingsworth has mentioned prices. I am not interested in that; I do not want to flog it. But there is no doubt at all about the point Mr. D'Ambrumenil made of material coming into the treating plants insufficiently prepared for treatment; it is one of the difficulties we have got to contend with. Very often the home timber sent in is not properly barked whether in round or square-sawn, and very often it is wringing wet.

Mr. B. C. HOLLINGSWORTH: I am afraid we have heard that complaint several times. I do not think it makes a great deal of difference to the price paid.

Mr. B. HICKSON: I should like to confirm exactly what Mr. Robinson said. In relation to what Mr. Richardson was saying just now, I fully agree that with a dry, suitable timber you can get absorptions up to $2\frac{1}{2}$ gallons a cubic foot. But with the commercial throughput you are never sure whether you are going to have timber completely seasoned. Secondly, if you have thoroughly seasoned timber your economics go up because you absorb too much preservative—more than you need—and the control system of pressure and impregnation does give you a wider spread in my opinion.

There is one other point I would like to ask our speaker today. He did mention on the question of sleepers that there have been an increasing number of steel sleepers as well as timber ones. Of course those of us who have been associated with preserving as long as I have have known of the strong drift from timber to steel for roadways and many other purposes. I wondered whether, in the interests of the timber trade, the use of preservation on a well-known product would be likely to cause the introduction—or re-introduction shall I say?—of timber in places where steel is now being used probably at twice the cost of even treated timber. I do not mean replacing a steel arch, but timber could be used in many of these borderline cases where steel has become rather an engineer's product and where timber might now be used more efficiently and more cheaply than steel.

Mr. B. C. Hollingsworth: I certainly agree with Mr. Hickson that even timbers that have been subjected to treatment at the costs which have been mentioned would still be considerably cheaper than steel supports, either steel arches in roadways or steel props. That could be taken as certain. But the decision to use steel or timber is one which rests in the Board very largely with the production people in the areas and divisions of the organisation. It does not even always rest with the colliery manager. I should make it quite clear that this is a thing which is subject to fairly high-level planning for a group of pits. I do not know whether you are aware that the Coal Board is organised into nine divisions, and the nine divisions each have, say, five or six areas, and in every area (which may have quite a number of pits in it), there is a production manager. There are still colliery agents of groups of pits and the production manager and his agents are constantly dealing with matters of policy, with questions such as supporting roadways and faces on steel or timber. Various factors—safety, good recovery rates of the steel when it is being used and the costs involved—are taken into consideration before they come to a decision. But I have no doubt that all the work that has been done on treated timber during the past year or two may, in some cases, lead to the use of, say, treated sleepers instead of metal sleepers. That may well be the case.

Mr. S. H. Hollick: Some time ago we required some photographs of underground mining timber. It was found when these photographs arrived that the props had been pointed after treatment. Is it necessary to fabricate timbers after treatment, because if such a practice becomes general then it is likely to lead to failure?

Mr. B. C. Hollingsworth: Yes, that is quite true. The pointing of props before they are used in the pit—and it is usually done in the pit—is something that was far more prevalent twenty or thirty years ago than it is today. The theory was the prop which had been pointed took the first crush of the roof more safely than the prop that was left untreated in that way. But the ideal thing is that the prop, if it has to be pointed for the engineer's job, should be prepared in that way before it goes to the preservation plant. It is most unsuitable that it should be done after preservation because naturally that is destroying a lot of the precautions that have been taken. There are not a great many pointed props used nowadays.

Mr. J. St. G. Sproule: Mr. Chairman, Mr. Hollingsworth's paper quite accurately puts the emphasis on protection against fungal attack, but it should be mentioned that in some countries the danger is almost entirely of insects. I know in Australia I have seen sugar gum pitprops reduced almost to powder in under two years by insect attack. It is rather interesting that this was re-growth timber, 80 per cent. sapwood and before the supply of timber ran out the average life was probably about eight years.

Mr. B. C. HOLLINGSWORTH: The information I have is that we have no records of any serious insect attack on mining timber in this country. It does not seem to be one of the dangers that we have to face. I do not know whether Mr. Gold has any records of it in his part of the world.

Mr. J. H. GOLD: We have had occasional insects that have come into the timber, but we have no evidence of any multiplication in the roadways.

Mr. L. A. BATES: Mr. Chairman, in the experiments in 1930 and in those carried out since the war, treatment by creosote in the tank method and by the full cell process is mentioned. I would like to know why the N.C.B. prefer the full cell process to the empty cell process which would seem to be the treatment which would give you sufficient life for uses down the pit. It would be rather easier to handle, I should think, and it would also reduce the fire risk if there were an appreciable fire risk from the use of creosote.

There is a further point: in the Ashington experiments I do not think any mention is made of the species of timber used for the pit-props, and perhaps some information on that point would be interesting.

Mr. B. C. HOLLINGSWORTH: Answering your second question first, Sir—I am subject to correction here by my friend, Mr. Gold—I think it was Scots Pine.

Mr. J. H. GOLD: I am afraid I do not know.

Mr. B. C. HOLLINGSWORTH: As far as I know, the species used was Scots Pine at Ashington.

On your first question, I think the reason we have used the full cell process is that very few collieries were equipped to treat timber. Consequently we had the timber treated by various firms which offered to do the work with pressure cylinders. It is not that we have any prejudice against the method you describe; it is just that collieries had not got the apparatus themselves and they bought the timber with instructions to their suppliers to send it via the preservation plant. It is because the preservation plants were there in various parts of the country, prepared to do the job, that the full cell process was used. I think that is the simple answer to the question.

Mr. L. A. BATES: On that point, and speaking on behalf of the users who expect considerably longer life from poles than one would want from mining timber, and looking upon these tests such as are being carried out at Ashington as life tests, it would be very interesting to include some pitprops treated by the Rueping process in order to get a direct comparison with others.

The CHAIRMAN: Gentlemen, on your behalf I would like to thank Mr. Hollingsworth for his very instructive and informative paper, and for the very clear and forthright way in which he has answered your questions. I think we must accept his answer to the question as to whether they are likely to substitute steel for timber, for like a good timber man he is compelled to sit on the fence, but I am glad to say he has not allowed the iron to enter his soul.

I thank you very much, Mr. Hollingsworth, on behalf of the Association.

(4) PRESSURE CREOSOTING AND THE REQUIREMENTS FOR TREATING PRACTICE.

By Philip Grindell

Burt, Boulton & Haywood Ltd.

THE problem can be divided into five elements, each of which is essential to the satisfactory service life of the treated material. These are as follows :—

(a) The timber and its preparation.

(*b*) The Treating Medium.

(*c*) The Plant.

(*d*) The Treatment.

(*e*) Installation of the treated material.

The main species treated commercially in large quantities, Douglas Fir, Western Hemlock and Balsam, Yellow or Red Deal, European Whitewood, Spruce, Maritime Pine, are used chiefly by reason of cost and availability and not necessarily because of their capacity for penetration with a preservative. Of the above species, the most easy to treat are Red Deal and Maritime Pine, the sapwood of both of which can be completely impregnated. The heartwood of these timbers is difficult to impregnate and it is general for the depth of penetration to be slight. Douglas Fir and Hemlock, Baltic Whitewood and Canadian Spruce will not take large quantities of preservative, but it is possible to give adequate protection and to ensure a reasonable length of life in service.

For heavy construction work, Douglas Fir has taken the place of Pitch Pine, now in very short supply. The size of the Douglas Fir permits us to use it for square piling, decking, bridge timbers, Sleepers and Crossings. In order to ensure the length of life which is required for such purposes, it has been found necessary to incise to enable us to obtain adequate penetration of preservative. At this point I should like to add weight to the representations made by both Mr. N. A. Richardson and also Mr. Woods at previous conferences in regard to the use of round piling both for jetty work and for sea defence purposes. It is agreed that the use of round timber presents certain problems to the constructional Engineer, but the length of life which can be obtained by the deeper penetration will justify an addition to the initial cost.

The sap ring on the round pile is completely impregnated to a depth of some inches, and provides a most effective barrier against decay or marine borer attack.

The use of round piling is accepted Civil Engineering practice both in Canada and the United States, and the construction problems have been overcome there.

The reference to preparation means that the timber should be cross-cut, drilled, morticed, notched, etc., before it is brought to the Treatment Plant.

A most important aspect of preparation is that which deals with the proper seasoning of the material before treatment. A great deal of thought and attention is given to both the treating medium and the process, but all this work can be brought to nothing if the moisture content of the timber is too high.

Although certain specifications stipulate that the moisture content of timber should not exceed 25 per cent. of the oven dry weight, it is by no means certain that timber of a higher moisture content, say 30/35 per cent. is not just as suitable. In addition, timber which is too dry or which has been dried down to a low moisture content too quickly, can also present problems. Bleeding can be caused by over rapid drying and is a serious problem with telegraph and transmission poles.

Determination of moisture content is carried out in three ways :—

(a) Oven Test. The prepared samples are weighed immediately after they have been taken. They are then dried in the oven until the weight remains constant. The moisture content is determined by the difference between the wet and dry weights expressed as a percentage of the dry weight.

(b) Dean & Stark Method. The sample (in the form of borings) is weighed, before being transferred to a flask, which is linked to a condenser and a Dean & Stark receiver. Xylole is added to the borings in the flask, and the flask is then heated and distillation is continued until condensed water is visible only in the bottom of the receiver, and the volume of water remains constant. The moisture content is then determined, as a percentage of the dry weight of the sample.

(c) Moisture Meter. This method, uses the principle that water is a good conductor of electricity. Increased resistance to the passage of the current of electricity proves reduction in moisture content.

These methods can be further sub-divided by the method of sampling. The most effective is that which requires a section to be cross-cut from the piece at a distance of 9 inches from the end. This segment will be about $\frac{1}{4}$ inch in thickness. Moisture Content may then be determined by using any of the three methods mentioned above. The limitation to the cutting of segments is that it is generally undesirable that the length of the piece shall be reduced by 9 inches. It would be very uneconomical where timber of large section was involved. For this reason, it has become general practice to use borings taken by an increment borer to a total weight of 8 gm.

The taking of borings as a method of determination of moisture content, although the best available, is by no means as accurate as that of the sample cross-section. Furthermore, any heat generated by friction of the increment borer can cause loss of surface moisture of the boring and thereby an incorrect reading.

The moisture pattern within a piece of timber varies considerably, and is very often star shaped. This would mean that borings taken into the end of one of the rays of the star could give a high moisture content, and a boring taken within the rays will result in a relatively low reading.

The borings are then tested by methods 1 or 2.

Since laboratory equipment is not always available, the usual practice is for the Oven test to be applied. This method usually requires drying over a period of at least two hours.

Experiments have been carried out by our own Company with a view to the use of the Moisture Meter for producing the moisture content of borings, but the results to date have not been promising. It will be remembered that the Moisture Meter is limited in its range, and that the margin of error in the higher range of moisture content becomes progressively greater.

Observations of the rate of drying taken over a number of years have shown very little uniformity between one piece and the next. It is perhaps of interest to state that our experience in regard to Telegraph and Transmission Poles has been that the pole which has been floated for a short period will dry out quickly and will take treatment readily. On the other hand, the pole which has been floated for a long period will become water logged very rapidly, and will take many months to dry out satisfactorily. One other curious factor has been that the unfloated pole is more difficult to impregnate than the floated. Whether this is due to the presence of material in the wood cells which is removed by floating, has not been proved. The speed of drying also appears to have an effect of slowing injection of preservative.

The stowage of the timber is most important to the speedy drying of the timber. The site should be well drained, and the dunnage timbers sufficiently high to allow air circulation through from the bottom of the stack. The only effective method of stacking is that which allows for good ventilation. Experiments carried out with poles in the rough, and machine dressed have not been conclusive. It would appear that the location of the storage area can make a marked difference to the speed of drying or of reduction in moisture content after it has been increased by a prolonged rainy period.

The sheeting of stock can be a very mixed blessing, particularly when the atmospheric humidity is high, since the reduction in air circulation so brought about can cause moulds to develop.

The time taken for timber to reach a satisfactory moisture content to ensure proper impregnation has been a source of concern to many. Capital tied up in stock, and the rental cost of the area occupied are the problems which have to be faced.

Some of the methods which have been adopted to reduce seasoning time are as follows :—

(1) The Boulton or boiling under vacuum process is used with great success for the rapid reduction of the moisture content of green timber. This process can be followed by one of the accepted pressure treatment processes in the same pressure vessel without further handling.

(2) Steam drying has been used for the same purpose.

(3) Vapour drying has been used, the medium usually being Xylole.

(4) Kiln drying in a Kiln of conventional pattern.

(5) Controlled Air Seasoning. This process has been developed by the Southern Wood Preserving Co. of Atlanta, Georgia, and U.S.

In operation it uses the principle of the circulation of warm moist air, and would seem to follow the method of the progressive Kiln.

(6) Estrade process. It is known that any telegraph or transmission pole which is exposed to the elements will check, and may even develop deep shakes. These deep shakes may allow the development of fungal growths if the preservative has not penetrated sufficiently deeply. For this reason, the Estrade process, using the Estrade oven or Kiln sets out to produce this effect by the circulation of a current of hot air. (100°C.).

After this treatment the poles are pressure creosoted.

The method has been used with Whitewood (Sapin) which is otherwise difficult to treat with vacuum and pressure impregnation, without the use of steaming treatment or air seasoning for a period.

The Treating Medium

I shall not attempt to deal with the Chemical aspect of the treating medium since I have no chemical knowledge, but shall confine my remarks to the state of the oil during use.

All oil is tested for specific gravity, water content and distillation when it is received at the Plant. At frequent intervals a water content test is taken to maintain the requirement of B.S. 144. If the water content is above normal, the surplus water can be removed by one of the following methods : (a) Syphoning after settlement ; (b) Boiling ; (c) Return to the tar distiller for cleaning ; (d) Boiling under vacuum.

In plants which are equipped for Boulton treatment, it is possible to keep the oil free of water. In so doing, some of the low boiling ractions of the oil can be drawn off at the same time as the water.

It is essential that these should be recovered and returned to the storage.

Water in the oil also absorbs sugars, and other water soluble substances from the wood. In time, the specific gravity of this "water" increases and, with the addition of insoluble matter, forms an emulsion which is very difficult to separate.

In the course of a long period of operation, small quantities of sawdust, grit, and other solids tend to accumulate in the oil, and will cause the amount of "matter insoluble in Toluole" to rise above the permitted limit. At this stage, the settlement of the oil followed by the cleaning of storage vessels and the removal of deposits from the heating coils will take place. In modern treating Plants there are filters which require cleaning each week, but it is only practicable to take out the larger particles—(1/16 inch and above).

The Plant

The modern plant will be able to draw and maintain a vacuum 25 in. of mercury or maintain a cylinder pressure of 200 p.s.i., and a temperature of 200°F. This latter requirement can only be obtained by adequate lagging of containers, pipe lines and the pressure vessel. The loss of temperature during movement from container to pressure vessel can be as high as 30°F., with unlagged surfaces.

Storage of preservative must be in enclosed tanks. Unless this requirement is met, the rain water and solid matter carried in the air will be mixed with the oil. If storage tanks are below ground, the maintenance problems are likely to be considerable.

At the same time as we demand a satisfactory storage for the preservative, we require also that the measurement should be accurate. A number of methods have been used, but most depend on the "U" tube principle, employing a float device (which rises and falls with the movement of the liquid) attached by some form of linkage to a pointer on a graduated scale.

A weigh bridge is available for the purpose of comparing the weight of the test pieces, before and after treatment. In some Plants it is possible to weigh the treating cylinder, and in others, the trolley on which the timber is loaded passes over a weigh bridge.

The charge record should give the inspecting Engineer full details of the treatment cycle, and to it should be attached the relative temperature and pressure chart.

A new development found in some modern plants is the heat exchanger. This is a multitubular heater of the conventional type placed alongside the cylinder. The creosote oil is circulated from the bottom of the cylinder, through the heat exchanger and back into the cylinder. The flow can be increased mechanically by pump or other circulating device if the convection currents are not considered to be sufficient. This equipment is likely to make peak demands on the steam producing plant.

It has been felt that this method will ensure a more even temperature over the whole of the charge. The present method, depending as it does on convection currents, does not give the same turbulence to the oil, and there is a danger that there may be a settlement of water on the top of the oil during the pressure period.

Still dealing with the problem of temperature, our experience has been that the position of the thermometer can have a very big effect on its recording. From experience over all of the plants, we have now placed it in a pocket situated centrally and at 3 ft. from bottom of cylinder. This position has been determined by experiments with maximum and minimum thermometer to give the best average reading.

All of the pressure vessels have a safety device. There is a 60 lbs. relief valve and return line which will enable us to exhaust the air pressure as we introduce the preservative medium. This return line to a measure tank gives us an indication of the level of the preservative in the pressure vessel.

Some plants have a tell-tale or sight glass, but with such a preservative as creosote oil, it is particularly difficult to be able to keep this clear. One other problem is brought about by the foaming of the liquid caused by the transfer pump and the vortex formed on rapid emptying.

As soon as the cylinder is full (in the case of the Rueping Process), the 60 lb. relief valve is isolated when the oil pressure pump is started. A 200 p.s.i. safety valve is fitted to the plant.

The form of construction of the pressure vessel varies, the riveted vessel falling out of favour and the welded vessel taking its place. The problem of the riveted vessel lies in keeping the seams tight. This necessitates the periodic removal of the lagging from these areas.

The pressure vessel is a difficult piece of equipment for which to provide foundations which will spread the load of the heavy door adequately. The weight of the door tends to buckle the cylinder and, therefore, the foundations must be very substantial. It is most essential that the cylinder should be well clear of the ground and situated over a drainage pit to enable any spilled preservative to be recovered to the settling tank before being returned to the storage. Many types of closure are in use, from the bolted door, and the Haskin door, to the Leeds and Bradford quick closing door, and the other types of quick closing door which depend on the inserted copper tube, inflated with oil or air for making a closure between the cylinder shell and the door face. Some plants have given a "new look" to the screwed door, by using a compressed air wrench for rapid tightening of the screws. The choice of pressure pumps varies with the individual engineer and other circumstances, such as the relative cost of steam and electricity, but our experience has led us to standardize on the steam driven vertical reciprocating pump, because of its flexibility. This gives us steady, unlaboured pressure at a most economical cost.

There are, however, many other equipments which are in use, the electric pump being one of them. Some plants are fitted with turbine pumps. Pressure variations are obtained by manipulation of the delivery valve. Here again, the flexibility is a great advantage. There is one disadvantage to this equipment in that it calls for a greater degree of skill for its maintenance.

With regard to the vacuum Engine, we still prefer steam for inexpensive operation. In plants where there are higher pressures of steam available, a steam ejector system is used with success. Of the economics of the use of steam ejectors, I have no experience.

The trolleys in use should be of very robust construction, since with crane loading, "wear and tear" is considerable. Many methods of handling into and out of the cylinder are in use.

The Treatment

I shall not attempt to deal with the B.S. 913 in detail, but rather to discuss certain aspects of it.

During one of the recent conferences, reference was made to the plant operator. I should like to add my own observations in this respect. I would go so far as to say that a conscientious well-trained operator is one of the most important requirements in satisfactory pressure creosoting. The capable operator, with many years of experience of the practical application of the B.S. 913 develops a "feel" or "sense" of the type of timber which is being treated. This enables him to make small variations to suit. These variations result in treatment of a very high order, and which could not be obtained by slavish adherence to "the book."

This question of the "feel" of the timber is particularly noticeable in the case of telegraph poles, and the variation in treatability of poles from various regions is a study in itself. The problem of mixed specie charges has been dealt with on previous occasions, during which the speaker referred to the difficulties experienced by the commercial treatment plant in "making up a charge." Whilst it is obviously undesirable that species should be mixed within the charge, this difficulty can be overcome if the material is treated to the schedule of the most resistant species in the charge (using the prolonged pressure periods set out in the B.S.). By this I mean that there is a limit to the amount which the sapwood of timber will absorb; this point once reached the absorption into heartwood of the receptive species will be less than the absorption into the surfaces of the resistant timbers if these are incised. There is one point of objection to the above, and that is that the receptive material should *NOT* form the greater part of the charge.

One method which could be adopted for mixed charges, would be to use the maximum gross absorption figure for each species, and to multiply by the number of cubic feet of each variety in the charge.

The main disadvantage to this solution of the problem is that the maximum absorption figures for different species cannot be more than rule of thumb averages. If the mixed charges are not running true to form, the receptive material may get more of the absorption than it should.

Initial absorption, and the kick-back (or return of preservative on pressure release) are matters of considerable interest to pressure creosoters. It is generally accepted that initial absorption shall form part of the injection, and that the required volume of oil according to the schedule in B.S. shall then be injected under pressure. The kick-back on an "empty cell" charge is quite astonishing since in many cases the whole of the preservative pressed in will be returned through the relief line, and the net retention will be represented by the initial absorption. With full-cell treatment, it is not anticipated that there would be any kick-back, since we commence with an initial vacuum. But in spite of this, it can and does happen.

It must be remembered that both the cylinder and the timber are elastic, and that under pressure, distortion takes place. The kick-back of oil after release of pressure is due to the return of the stressed materials to their normal condition.

In dealing with the installation of the treated material, the following factors should be remembered:

1. That cutting should have been done before treatment, in the case of pile shoes, pile heads, drilling of Sleepers, drilling of Transmission poles, etc.

2. If due to the set of the pile it has been necessary to cut after driving, the exposed head should be brush-treated and capped.

3. If it is necessary to bore after treatment, a pressure bolt hole treating tool has been put on the market.

4. Care should be taken in the handling to avoid damage by hooks etc., which may break the preservative barrier.

5. It is not desirable that timber shall be cut after treatment, as untreated surfaces are likely to be exposed. The brush application of preservative to these surfaces has a limited value.

Discussion on Paper 4.

The CHAIRMAN (Mr. G. S. Wade): Ladies and Gentlemen, it gives me particular pleasure to take the Chair at this session for Mr. Philip Grindell. Like so many in the trade I had the great pleasure of knowing his father, and like so many I had a great regard and admiration for him. I gather that Mr. Grindell is the third generation and the fifth member of his family to interest himself in timber. I think one always admires the family connections; they are a pleasant aspect of private industry.

Mr. Grindell's experience is very wide, as one can see from his paper. He has not only been in the firm of Burt, Boulton & Haywood for a number of years, but he has also worked with agents and brokers, and he made a study tour in Canada of the mills and preserving plants. He is now the manager of Burt, Boulton & Haywood's Belvedere works and with his experience I have no doubt he is a most valuable asset to them.

This is rather a short session so I do not propose to say much more, except to introduce Mr. Grindell and ask him to add any further remarks which he may have to make.

Mr. P. GRINDELL: Mr. Chairman, Ladies and Gentlemen, I should like first of all to take the opportunity of thanking our Chairman for the kind things which he has said and to thank the British Wood Preserving Association's committee for allowing me to present this paper.

I do not think you want to hear very much of my voice, but I would like to show you a few photographs which will tend to underline the points which I have raised.

This first photograph gives you a very clear picture of the complete impregnation of sapwood in a telegraph pole. I should like to draw your attention also to these radial patterns of impregnation into the heartwood. This emphasises the necessity for thorough seasoning of your material before you treat it. Bear in mind that had this pole not been properly seasoned you would have had, due to climatic conditions —the heat and so on—a fissure developing just where that impregnation is; it would have given an opportunity for fungi or insects to enter through that channel. I think that illustrates the point fairly well.

This I have put on because I feel it illustrates very well the reason why the creosoters recommend to their customers that they should have incising. Look at the penetration on this unincised sample of Douglas Fir. See how irregular the pattern is; see too around the heart centre how you have had the seasoning checks and how the preservative has found its way in through those seasoning checks, giving you that added life that you require.

In contrast the next photograph shows what you can get with incising. You will notice the perfectly regular impregnation all the way round the section. In a few moments, after you have seen the last few of these sections, I am going to show you pictures of the incising machine.

This is rather a freak in that you have got areas of creosote impregnation in the summer wood right in the centre. I am not very well up in these things, but I am told that it has to do with the presence of unaspirated pits in the summer wood.

This again is rather a freak. This again is Douglas Fir and here you have got interior sapwood. I was very much concerned when I saw on the ends of Douglas Fir what appeared to be a corona of a different colour. There was the usual pinky colour of Douglas Fir and then there was this band of yellowish colour. I enquired about it and I was told that it was this internal sapwood. So I wondered whether treatment of internal sapwood would have the same effect as with normal sapwood; that is to say, that it would take a lot of impregnation. As you can see from the photograph, there is little doubt that it does.

This is not an advertisement for super creosoting; it is purely one of those things that you can get with certain types of timber. This piece of elm is creosoted right through, but it is only with certain timbers that you can get this rather amazing result. I think it is widely known that sapwood will accept preservation very readily, but that heartwood is pretty difficult to treat.

That is a piece of beech and the little spot at the top is the only bit that has not received the treatment. With beech, there are slight variations but I would say you can hope to treat very nearly through and through, certainly some 80 per cent. to 100 per cent. treatment.

That is all of the sections.

One of the things I should like to mention at this time is this question of checking in large sizes. With large sized timbers—12 by 12, 14 by 14—and with sleepers and crossing timbers it is impossible to season satisfactorily without this checking developing. I would like to make a case that, because you see a shake either in a piece of sawn timber or in a pole, it is not a defect. In those sizes and with the purpose of subsequent impregnation it is highly desirable that you should have that checking.

I should like to deal with a rather interesting point in regard to Douglas Fir, and that is in regard to the Inter-mountain fir, of which we occasionally get consignments. The photographs which you saw of Douglas Fir were Coast Fir and although those were fairly difficult to impregnate they were relatively simple by comparison with the Inter-mountain fir. I am given to understand that at the moment no real solution has been found for this problem, and the depth of impregnation is quite slight.

This is the incising machine. You have top and bottom rollers with knives $\frac{3}{4}$ inch long. I do not think you can quite make out the side rollers, but you will see them in the next slide. So you can make these cuts all at the same time. All four sides are incised when the piece passes through the machine.

You can see the piece coming out from between the rollers of the incising machine. The pattern is staggered on the timber so that you do not get checking right along the piece. One other interesting thing is that there is a tendency with this incising to reduce the surface tension and to prevent very deep checking subsequently.

I am particularly interested in the matter of round timber for piling and sea defence work.

This is a small photograph which illustrates the use of round piling. This is actually in Canada. If you will cast your minds back to the first photograph which I showed you, that of the round timber, the pole, you will see that you have a band of impregnation of some 2 inches which gives you a very good protection, not only against the fungus and insect attack, but also against the problem, particularly in sea defence work, of abrasion. You can see that with 2 inches of preservation on the outside you are going to have a much longer life before the seal breaks than you will with the Douglas Fir with its thinner preservative walls.

Going on from that, I would like to show you just a few plant photographs which may be of interest.

This is the preparation of the timber. I am sure you are going to say, "This is a most confused picture. What does it mean?" In point of fact it is the business end of the pre-cutting machine which is used in the preparation of poles before treatment. At the top left you have got a cutter block which is preparing a flat surface which you can see *here* on the pole. A little further along on the right you can see two augers, and those two augers drill the holes through the pole. Finally, you can see *here* the cross-cut saw which angles to cut the tip of the pole so that you have got the run-off of weather and so on.

Here again, to illustrate the preparation of timber before treatment, you have got all these rather fancy notches and drillings done on the timber prior to treatment. That is most desirable, because if you do subsequently cut or gain or do anything like that, you are breaking that preservative seal.

In this photograph at the top you can see the condenser used with the Boulton process, the boiling under vacuum process. The cylinder door—it is a very old pattern—but it still does the job. I think of all the doors probably the dogged door is still the best although it is the slowest. In the left foreground is the robust type of trolley which is so essential for plant working, otherwise the amount of wear and tear that you get with crane loading is very considerable.

This is the interior of one of the pump houses, just to give you an idea of what the engineroom looks like. On the right-hand side there are pressure pumps, steam actuated, and on the left the vacuum pump or air compressor. For ease of operation we work a colour code system on our pipe lines for the preservative, the live steam, the exhaust steam and so on and so forth.

This is another pump house photograph. I think the interesting thing here is that you have got all the controls within the pump house. It does ensure that your operator does not have to dash in and out all the time, and he has a very thorough control of the operations. The transfer pump is below the grille there for transferring the oil from the storage to the pressure vessel and *vice versa.*

There again is another view of the same pump house with the recording dials on the wall on the left, showing the volume of preservative before and after the charge.

This one I put in to show the Rueping tank. *This* is rather an older plant. The Rueping tank is on top of the cylinder. But nowadays we do not work with the Rueping tank as I believe the French do; we work on the principle of pushing our oil over from another storage rather than air pressure into the Rueping tank.

I hope you can see at the rear end of these lagged vessels that there is a draw-off tap so that we can test the preservative whilst the charge is in course of operation. That is all I really put that photograph in for.

This is just to show you the type of Haskin door. This is not a new door by any means, but it is still very efficient; it works rather on the umbrella principle of these spokes being drawn in or pushed out and the ends of these spokes engage in lugs on the face of the doors.

This one shows the type of cylinder trolley with the retaining lugs. There is quite a big danger of the timber and trolley floating off the tracks if you do not have some form of holding down. Again, of course, you have to retain your load by chaining it. Over on the left—it is not a very good photograph, I am afraid; I think I have got one later which is rather better—is the Leeds and Bradford door where you have got these lugs which engage over the front of the door. They are actually worked on a cam-ring principle so that when you engage a lever on the right-hand side of the cylinder *there* these cams or lugs, whichever you like to call them, retract back into the shell *here* and allow you to open the door.

This is the same treatment plant with this door. Again it is not particularly clear, I am afraid. *There* is safety valve gear. The plant is covered with a shed.

I think this gives you a fairly good idea of plant layout. There are two double-ended cylinders. There is a charge entering one here;

I am afraid you have lost part of it on the left. There is another charge *here* waiting to go into the other cylinder. I am afraid we cannot see it, but there is a weighbridge *here*.

Again I am afraid we are rather cut off in this picture, but this is one of the latest cylinders, 120 feet long. It is well raised from the general level of the ground in this concrete well; it enables you to get at the underside of your cylinder to deal with any problems that may arise. You have got the lagged storage vessel; again the vertical above ground level to which I have referred.

These are really to show you the sort of results that can be obtained with poles. You can see they are perfectly dry and they are still on the cylinder trolley as they are withdrawn from the cylinder.

The operator is turning the pole just to give you an illustration.

Here again he is turning the pole.

As you can see, his hands are clean. This is not a conjuring trick. It is not a thing, of course, that can be done every time; it is just not possible to give you that complete one hundred per cent. freedom from bleeding on poles, but you can get reasonably good results and consistent results.

I do not think there is anything more I want to say about the photographs.

In conclusion I would like to draw your attention to two samples, which are not necessarily representative—but I think you will find them exceptionally interesting—of Post Office poles, one creosoted in 1896 and one creosoted in 1899. They are not necessarily representative, as there are many hundreds of such poles to be found throughout the country. These are exhibited by kind permission of the Post Office Supplies Department. Perhaps Mr. Carr would like to refer to them later on.

Thank you very much indeed.

The CHAIRMAN: May we have any questions or points for discussion?

Mr. R. G. G. ENGLISH: Mr. Chairman, I was particularly interested in Mr. Grindell's remarks about the pre-drying of timber. I would like to ask him about various methods which he outlined in his paper. Would he enlarge a little upon them and tell us particularly if he does see any evidence of damage to timber by those different methods, except the kiln drying. It seems the kiln drying is the only safe way. Are there many kilns, if any, in this country which are long enough to take poles?

Mr. P. GRINDELL: I have put forward these six possibles because they are methods which, from reading through various literature, have been used. I would not say necessarily that the Boulton process is used; it certainly is not used in this country with poles, as far as I know. But I had a very interesting discussion last night with a Norwegian gentleman and he told me that he was using the Boulton process with poles and quite satisfactorily.

Steam drying and vapour drying are not used in this country yet, as far as I know, but kiln drying is used. I am sorry to use the word "we", but we have kilns which are sufficiently long to do 30-feet poles. It is rather a pity that they do not just go that extra 4 feet which would give us the complete range of poles which are in general demand, but they do not. The results which we have obtained from straight kiln drying over about a 4- to 6-day cycle are reasonably good. The only thing is that you are dealing with accelerated drying and in all cases where you have got accelerated drying you tend to get checking, which may be rather deeper than with air seasoning. I am not going to say that the checks will not close to some limited degree after you have treated the timber.

I was pleased to be able to discuss controlled air seasoning with a representative of the Southern Wood Preserving Company and he was very satisfied with the results that they were getting. My impression is that this controlled air seasoning rather follows the lines of the progressive kiln. I think they have put in a great deal of spade work on it to produce the answer. The Estrade process is used in France. For our purposes to circulate hot air would be rather drastic.

Does that answer your question?

Mr. R. G. G. English: Yes, Sir.

Mr. E. Carr: I should like to congratulate Mr. Grindell on the skilful way in which he has done the delicate operation of compressing several gallons into a proverbial pint pot in this paper. The application is very satisfactory.

I think you will find the specimens on the table very interesting, to see what can be done with preservation; but they are comparative youngsters. We have in our records now details of over 7,000 poles which have been erected over seventy-five years and are still in service. They were treated by the full cell process and they are still going strong. We went over to the Rueping process in 1913, so that we have still to see whether any of the poles that were creosoted by that method will stand the test of time as the others did.

Mr. J. Thornton: I too would like to congratulate Mr. Grindell on his paper. I feel that to attempt to outline the problems that confront the plant operator in a paper is almost trying to do the impossible. There are so many variables we have to take into account.

Mr. Grindell, I think, does very well in covering practically every phase of treatment although admittedly he could not go into every detail. I particularly like the paragraph where he refers to the qualities required of the plant operator to carry out good treatment. This was mentioned, as he pointed out, two years ago and I think at that time it was the intention of the B.W.P.A. to try and help the plant operators and give them more encouragement and advice. I would still like that to be kept under consideration. It is essential in any treatment plant to have the very best type of plant operators, those who not only know the plant, but also know the timber and what they are doing.

I would like Mr. Grindell to go a little further into the problem he poses about mixed charges.

Mr. P. GRINDELL: That is a hardy annual!

Mr. J. THORNTON: It is a hardy annual. There are so many variations in species, in section sizes, in moisture content and in the density of the timber that there are times when it is very dangerous to mix charges. I should like the speaker to enlarge a little on the problem of mixed charges.

Mr. P. GRINDELL: As Mr. Thornton has said, the question of mixed charges is a particularly vexed one. I would say that it comes back to the skill of the man who knows his timbers. After many years of observing plant operation, I think one would say that enthusiasm, plus experience, is the key-note to a satisfactory and well-trained operator; after those years of training he gets to know the timbers which are in general use commercially.

What I would say to you is that you can almost make a dividing line, and a very, very broad one, between what you might term a "hard" charge and a "soft" charge; that is to say a charge which has permeable timbers on the one hand and a charge which has resistant timbers on the other. Without going into a great deal of detail, I do not think I can at this stage give you more differentiation than that.

Mr. H. A. COX: I should like to ask Mr. Grindell if, generally speaking, he thinks the operators know sufficient about the nature of timber. Much depends on the satisfactory treatment of timber and an operator being able to look at it and say, "That is refractory; it is not uniformly grown; it has got this, that and the other the matter with it." Are any steps being taken in these days to try and give the operators an opportunity of learning more about the timbers?

Mr. P. GRINDELL: I am sorry to say that I can only speak from personal knowledge, and it is difficult for me to comment; but I can say that, as far as our operators are concerned, they do know a piece of timber when they see it. They have been in the trade, some of them, nearly as long as the family have. There are only certain species that come into the treating plants anyway; you get the odd stray that comes in, but mainly the treating plants deal with Douglas Fir and those timbers which I have mentioned specifically. If he hits a rock in something that he does not know, naturally he seeks guidance and that is what people like ourselves are here for, to give them the guidance on what we think is the right thing to do with a piece of refractory timber or an unknown timber. If we do not know, as is often the case with me, then we ask the experts at Princes Risborough. Does that answer your questions?

Mr. H. A. Cox: I think so.

Mr. D. C. Baynes: Mr. Chairman, this is not, I am afraid, a question, but I thought the Convention might like to hear of some experience which I had a month or two ago when we had to preserve, using a water soluble in this case, about six standards of 3 by 9 Douglas Fir. It all came off the same pile and it was off the same shipment. Presumably, therefore, it came from the same forests. We put the first charge in of about three standards and we gave it two hours vacuum. We got a little over the required liquid in after a further two hours pressing. The remaining three standards went into the cylinder at about 4 o'clock in the afternoon and the operator put the vacuum on. At 5 o'clock it was time to go home, and so he left the vacuum on as high as he could get it, shut all the valves and turned the air pump off. When he came back the next morning he turned his valves on again and was delighted to find that his vacuum gauge went up to about 28 inches. It is a very modern plant and everything seems to work. He then proceeded to press and in three-quarters of an hour he had got his full gallon per cubic foot into the wood. I thought that you might be interested to hear that, because we had a very interesting paper last year on the prolonged vacuums. This one does seem to prove the point.

Mr. P. Grindell: That is a very interesting point indeed, Mr. Baynes, thank you very much.

Mr. F. M. Potter: May I raise just a few points. One thing I do feel that we have had at these Conventions, and this one adds to it, is some down-to-earth papers on practical creosoting. I think this paper fits in very well with the papers by Rothwell and Cosgrove in the past.

On the question of treating Inter-mountain Douglas Fir; are improved results obtained by the Boulton process much used on the west coast of Canada and the north-west coast of the United States?

On the problem of marine work, may I ask whether, in these days when the application of a paint by spraying is such a relatively simple job, to achieve finality and the absolute maximum life of timber in sea waters, it would not be a good thing to spray the dangerous area of the treated timber with a coal tar solution? As far as I can see from the literature, the one thing the marine beastie does not like is scratching its soft skin; it does not like going through a hard coating of pitch on the timber surface. In fact, I think in America they are largely using coal tar creosote solutions as distinct from a straight creosote.

Another matter that I might raise is to draw attention to the work that has been done in the United States on insoluble matter. You may have found that consumers' inspectors are tending to sample the creosote at the works—your used creosote, not the creosote as delivered by the producer—and raising questions on the insoluble matter. I would draw attention to the fact that the test for insoluble matter by dissolving the creosote in toluole was designed for the analysis of fresh creosote and the only matter thrown out is the real free carbon matter and dirt. But when this solvent is applied to used creosotes, depending upon the type of timber for which they have been used, sugars, if present, are thrown out and extractives from the timber which are, in fact, soluble in the original creosote. I cannot see that those resins and other bodies which are soluble in the creosote do, in fact, any harm to the preserving process. It is a matter that wants looking into, and an A.W.P.A. Committee is so doing. The first sample examined threw some light on the problem, but since then I have not been able to obtain a creosote which gives a different soluble matter after filtration than before, using toluene as the solvent. There is some work by Mayfield, who shows in his particular case, recently published, that of the insoluble matter 51 per cent. is sugar and only 12 per cent. is ash and dirt.

Mr. P. Grindell: There are a number of very interesting points raised here. The first one in regard to the west coast of Canada and the States, dealing only with Boultonising, is not quite correct, Sir, in that for green timber, both piling and sleepers, they do Boultonise but there are some yards which deal only with sleepers. I think they are 7 by 8 sleepers that are used and those that are air-seasoned do not receive the Boulton process.

In regard to the marine work and the application of coal tar solution with a spray, I should like to join issue with you on that one. I think you might have a difficulty of application when you have got tidal work on sea defences or jetties. If I may, I would like to re-emphasise the case for using round piling which will give you that first-class protection from the very beginning.

You deal with the question of sampling of creosote and this question of insolubles. I am sorry, I am no chemist, but I agree with you that some very interesting work has been done on it by Mayfield. I think that the work you are commencing on will be very valuable to us.

Mr. W. R. Saunders: Some time ago I was called upon to investigate a complaint in connection with creosote used at a small pressure plant. When I visited the plant I found that the complaint was concerned with the bleeding of timber; the timber was Douglas Fir fillings of about 6 inches in diameter, well peeled, had been treated by the Full Cell process and had been cut more or less at the same time and stored in exactly the same way. After treatment it was found that about 10 per cent. only of these poles were bleeding; the rest seemed to be comparatively free from the trouble. There are obvious reasons for bleeding associated with injury to the timber, but it does seem strange to me that we have timber here which is more or less identical of which a certain percentage is bleeding and the rest is not.

I also have in my garden a certain fence which was treated in exactly the same way. I believe the main posts are 6 by 3 and about three of those posts are still bleeding after three years' use. The remainder are entirely dry and have been dry ever since I put them in.

Has Mr. Grindell any explanation for this particular bleeding trouble?

I have another point: on one of his excellent slides I noticed the timber going into the plant; it was 6 by 2. There seemed to be no distance pieces, shall we say, on that timber going in. Would he suggest, or would he recommend, that additional pieces be used or not?

My other question—I do hope you will forgive me for asking this one—you did say you thought doors with dogs, etcetera were far better than other types. Would you be good enough, please, to give us your reasons for that?

Mr. P. Grindell: I will deal first of all with this question of bleeding. It is a very vexed one and a lot of work is being done on it, not only here, but all over the world. If I have given the impression that bleeding can be prevented in anything other than poles, then please may I correct that impression now. With the Red Fir poles, *Pinus sylvestris*, we can get pretty good results, as I said earlier; but let me tell you that your case of certain poles being wet and certain poles being dry is by no means unusual. In fact, I can give you instances when a pole for two-thirds of its length will be perfectly dry and the other third will be wet.

I have rather made a comparison between poles and humans. We are all very different in our make-up and I think that must be the answer to it. Furthermore I would say that poles from different areas of the Baltic react differently when we treat them. Some will take the preservative readily and will not bleed; others will take the preservative with difficulty and then they do bleed. So there is really no hard and fast line on that. Again I fall back on my stand-by—which I think you will agree is a good one—that the operator knows what he is treating and works accordingly. There are, naturally, techniques for dealing with structural variations in timber, resulting from differing growth factors.

Now on the garden fence question, the 6 by 3, as far as I know you have no sapwood on them; I rather think that it was treated with the Full Cell process. I would think with the Full Cell process you stand a pretty good chance of bleeding anyway. The poles are normally treated by the Rueping process where you can, with your vacuum, remove the surplus oil and there is not that concentration of preservative on the outside. Concentration of the preservative on the outside, air in the pole, climatic conditions, origin of the pole, there are any number of causes behind this question of bleeding. It is not by any means simple.

On the question of distance pieces, I would say that unless you are dealing with planed material where the surfaces are very, very close together and tend to stick almost, it is not generally necessary. But there again your own experience will tell you how you get on. You probably notice that the chains on the cylinder trolleys were not particularly tight. As I mentioned earlier also, the whole thing is afloat more or less inside the vessel.

The "dogged door" was your final point: it is rather a question of the seal which is used with the door as much as anything. With some of the more modern doors the seal has not yet got to that state of perfection that has been reached with the graphited asbestos packings that are used with the dogged doors. That is really my reason for preference.

Mr. G. Gobert: We have trouble with incising machines and I should like to ask Mr. Grindell if he would be kind enough to advise us whether in his opinion blunt incising machines do increase the porosity on the wood. What is the maintenance cost and what, in his opinion, is the life of the cutter in the different types of woods?

Mr. P. Grindell: I am afraid, Sir, that you have me at a disadvantage. I cannot really tell you the life of the cutters. I know that they do not last over long. I should think probably with the blunt cutter you get even less life, but I really do not know the answer to that one.

Mr. G. Gobert: Does it in fact increase the porosity of the wood?

Mr. P. Grindell: I could not tell you. I think that is one of those questions where I should consult the experts.

Mr. J. T. Cosgrove: I would like to congratulate Mr. Grindell on his most interesting paper, particularly on one of his remarks regarding the importance of the plant operator.

There is just one question I would like to ask him today. He stressed seasoning during his introductory remarks and referred to the checking of Douglas Fir in seasoning. I should like to ask him whether, when seasoning a standard product—I have in mind particularly railway sleepers and crossing timbers—there would be, in his opinion, an advantage in incising before seasoning, and also whether his answer would be influenced by the climate at the yard, because I have in mind a yard with a comparatively damp climate where there might be a difficulty with the water lying on the timber after it had been incised.

Mr. P. Grindell: That is very interesting indeed. I do not think there is an answer straight out of the book for that one. I should imagine incising before seasoning would have the effect of reducing the deep checks, but whether incising, done many months before the treatment took place, would be as effective when you came to treat, I do not know, whatever the climate in this country. I think the answer is, try it and see.

Mr. S. H. HOLLICK: Just a little while ago I had a discussion with Mr. Potter on the treatment of pine *in situ*. Some years ago I met Mr. Tamlyn and he told me of a method which had been used with great success in Australia, utilising the fact that creosote will float. He had a contraption which one could imagine as a biscuit tin with the bottom knocked out and with float attachments. One poured the creosote between the frame and the pile, which kept it from dispersing over the face of the water. The floats enabled the contraption to rise and fall with the tides. He said it was a great success in Australia.

Mr. P. GRINDELL: Thank you, Mr. Hollick.

Mr. R. A. BULMAN: First may I add my thanks to Mr. Grindell for an extremely interesting paper, and just raise a question regarding the elm and beech for complete preservation. May I ask details of sizes of timbers concerned and the treating schedules used?

Mr. P. GRINDELL: The elm, as far as I can recollect, was about 3 by 12. It was taken from a length; it was not an end section. I think I am right in saying that the pressure period would be of the order of three-quarters of an hour to one hour.

As regards the beech, that was only about 3 by 4; again it was cut from a length and the time cycle was similar. If your timber is at the right seasoning degree, neither of those timbers presents a great deal of difficulty. However, if you are going to obtain one hundred per cent. impregnation, or aim at one hundred per cent. impregnation with beech, I think first of all you have got to have it down in the moisture content range of about 8 to 12. (You have then got to be sure of this one hundred per cent.) You have got to do a cycle of vacuum plus pressure plus steeping of anything up to twenty-four hours. Those are special cases; please do not imagine that they are normal. As I mentioned, I was showing one or two freaks as a matter of interest.

Mr. A. M. CARMO: I would like to ask you a small question about incising. In our country we do not practise incising at all. We have a very soft wood which is Maritime pine. We have been having good treatment in round timber such as poles where a large band of treatment is allowed. However, in half-round timber and square timber, such as a sleeper, where the tree is cut in the middle, we have a lot of heartwood in the centre. Our heartwood is very difficult to treat, difficult to impregnate. It happens on our railways that the heartwood becomes very, very severely decayed whilst the sapwood stays sound.

Is there a practical means of making a machine for incising only one side of the timber, because the other three sides or the round edge of the timber do not need incising? Have you any experience of this in England since you have imported a lot of Maritime pine sleepers from Portugal?

Mr. P. GRINDELL: I think I can answer the question to a small degree. I think it is a practice to incise some Maritime pine sleepers. I rather think I must leave it to the big sleeper users to answer that, but we do actually incise on four sides.

As a matter of interest on this question of incising on one side, one edge, I know that there is an incising machine that does top and bottom only, but that and the four-side machine are the only machines I know of.

Mr. N. A. RICHARDSON: On that particular observation, about twenty years ago we did some experiments with railway sleepers and that particular problem arose with the standard treatment of redwood, where you have three sapwood faces and a heartwood face. We had noticed that where decay did occur with sleepers it was on the poorly treated heartwood face. In those experiments we did include Baltic redwood which had been incised. It was naturally much easier to use existing incising equipment so that all four sides were treated, but that does not really affect the issue. To economise in the use of creosote, to get re-distribution of creosote used instead of using standard Full Cell treatment, we used Empty Cell treatment with slightly less retention than the normal Full Cell treatment for sleepers, and over a matter of twenty years those sleepers have given extraordinarily good results, much better than standard Full Cell treatment. That is the only experience in this country I have of that. Mr. Rothwell may want to add to that. He has been thinking on those lines, I know.

Mr. W. ROTHWELL: It is our practice to incise all sleepers, whether Douglas Fir, Maritime pine or Baltic redwood. You get better penetration in the heartwood and you get a big reduction in the surface checking in sapwood in use. The only disadvantage is the heavy retention of creosote which, when we are short of creosote, we get over by using the Lowry Empty Cell process.

With regard to designing a machine which would incise one face only, it would be a bit difficult with a standard design, but it would be quite easy to design one which would do one face and two edges. You see, the driving force of the sleeper through the incising machine is the knives, and if you only have one face the knives will be apt to tear through the timber rather than push it through. There should not be any difficulty in designing two edges and one face; there is a difficulty in designing one edge at the moment.

The CHAIRMAN: Ladies and Gentlemen, I am sorry to call a halt to this very interesting discussion, but it only remains for me to thank Mr. Grindell on your behalf for a most interesting paper and for what has developed into an extremely informative discussion. I am sure you will all join me in expressing our appreciation of his effort.

(5) RECENT DEVELOPMENTS IN THE EVALUATION OF THE PERMANENCE AND TOXICITY OF WOOD PRESERVATIVES.

By E. A. S. PRICE, B.A., & C. D. COOK, B.SC., F.R.I.C.
(Hickson's Timber Impregnation Co. (G.B.) Ltd.,)

1. Introduction

TIMBER preservation is a rapidly expanding industry throughout the world and there is evidence to suggest that the scientific study of its problems is increasing proportionately. During the last few years considerable efforts have been made in developing laboratory tests that can short-cut long term studies, and much of the impetus behind this work can be traced to the lively interest of commercial users. Toxicity and its permanence in timber are two of the most important requirements of wood preservatives, but results of accelerated tests designed to study these factors are difficult to interpret in terms of long service usage.

It is our intention, as comparative newcomers to the problems of wood preservation, to outline some of the points associated with these studies of toxicity and permanence which strike us as needing clarification. In doing so we are more anxious to provoke argument and discussion concerning the present state of affairs rather than to point the way ahead. What we have to say should not be taken as suggesting that there is any lack of critical or studious investigation in many quarters, but that to the general observer it seems that, as yet, there does not exist any basic uniformity of opinion or approach to these matters.

2. Biological Testing

The use of animals and plants as research tools is rational. If one can isolate representative organisms from decaying wood and study their laboratory behaviour, especially towards timber, it should be possible to obtain definite conclusions as to their importance as destroyers of wood. It is of course only too easy to enumerate many points of difference between studies carried out in the laboratory and the status and economy of wood destroying organisms in nature, but this variance merely underlines the importance of correlating field and laboratory observations.

(*a*) *Mycological Testing*

In mycological work the most vital question to be answered is: Are the fungi being used for testing strictly representative of those met in service? Although many fungi seem to have a more or less worldwide distribution, *Lenzites trabea*, which is known to flourish in the U.S.A. but is absent from the United Kingdom, is one example that makes one wonder to what extent soil and climatic differences determine variations in the occurrence of wood-destroying species. Ecological studies of the economic microfloras in some parts of the world and in certain specific usages have been extensive, but it is indicative of this department of knowledge that the number of *Basidiomycete* test organisms commonly used can be counted on the fingers of both hands; and that reliance on certain strains has become almost traditional in spite of restricted comparative study of the behaviour between different strains of the same fungus species. To determine which fungi are representative is a laborious and costly proposition, but one which has not perhaps been faced up to with equal success everywhere, particularly as there seem to be some grounds for the belief that not only does the significant wood destroying population vary from region to region, but also that there is a distinctiveness of biological hazard attached to each varied major service usage.

W. P. K. Findlay in a Paper to this Convention in 1951 discussed this point and cited mines as an example. The fungal flora of South African mines is demonstrably so different from our own that what might be a highly efficient preservative in one may not necessarily prove to be so in the other. This is due to the fact that in British mines *Poria* species and *Coniophora* species abound which have some degree of resistance to specific poisons, whereas the *Polyporus* species and *Hydnum* species in mines in the Union do not exhibit this tolerance. It has become accepted that the study of resistant fungi is highly desirable in theory, but the use of resistant organisms must surely be related to their economic prevalence, and from the applied point of view there is little virtue in employing those possessing resistance to preservatives unless they are also known to be economic wood-destroyers.

A certain nearsightedness over these matters may be due to the fact that of late so called standard fungi have received exclusive attention as a means for investigating various test procedures, and because of this it is possible that enough attention is not being paid to the continued isolation and identification of "new" and economic fungi. This is a point which is commented upon from time to time, but there is little evidence from the literature to show that in fact workers are attempting to extend their knowledge in this direction *as a matter of routine*. We have recently had cause to reflect that the conventional laboratory screening of preservatives need not necessarily give anything like a true indication of their potential performance in service under all possible conditions of exposure. Without reference to soft rot no one could have anticipated the behaviour of certain types of preservatives in water cooling towers and soil burial, for example, because screening programmes have not as a rule incorporated those fungi responsible for this interesting type of decay. It is not imagined that many such unforeseen and critical groups of wood destroyers await our attention, but isolation techniques, cultural systems, and screening tests are by no means comprehensive as yet, and it does at least emphasize the need for us to review the extent of our general knowledge from time to time, and to maintain a catholic attitude towards our test organisms.

Regarding test procedures we have noted with concern that one or two recent papers have indicated that certain pure culture laboratory tests parallel complex natural states. For example it has been said that the soil-wood-block method of exposure closely simulates soil burial conditions. Of all usages of timber, soil burial is perhaps the most complex biologically, physically, and chemically, and we believe that no reproduction of its intricacies is possible at one time within one standard test. On the contrary it seems more reasonable to suppose that the soil-wood-block technique, as well as the agar-wood-block method, does to some extent reproduce conditions that may occur to timbers in a building, which by some fault in maintenance are allowed to become damp. However near this may be to the truth it is important that none of us should be lulled into too ready an acceptance of postulated simple likenesses between natural and laboratory conditions, if we are to keep our sense of proportion.

From the kind of remarks we have made we hope that it will be clear that as applied preservation develops so it needs greater emphasis to be placed upon the general breadth of available knowledge rather than upon intensive specific studies. To illustrate this point we feel that the constantly recurring debate centred around the relative virtues of certain standard test procedures may tend to obscure the more real issues. However advantageous it is to increase the rate and extent of the breakdown of laboratory wood specimens by varying the test conditions, we believe that the crux is that whatever standard procedures are adopted, they should give readily reproducible and consistent results, and allow the test fungus opportunity to destroy untreated controls vigorously.

To summarize, the basis for applied mycological research rests upon our having to hand representative test strains of fungi exhibiting some degree of tolerance to various poisons, coupled with an appreciation of those special conditions under which they will be encountered. The behaviour of the fungi to preservative treated material must be measured and compared by the use of suitable tests, to be considered in a later section.

(*b*) *Entomological and Marine Testing*

The biological status of timber destroying insects results in even greater problems of handling and interpretation than those associated with fungi. The views of the Forest Products Research Laboratory, Princes Risborough, are well known and were summed up recently by R. C. Fisher's comments in his Paper "Some Problems in Forest Entomology" published in the "Empire Forestry Review" of December 1954. However, insects are being used widely as test organisms for wood preservatives. For instance, a German research institution has a considerable staff employed in exposing wood blocks to a variety of wood destroying insects, and during the course of one assay a considerable volume of timber is exposed to any one species; and although there may be ignorance of many of the biological complexities involved, it is claimed that recognizable trends, comparisons and indications can be gained. Indeed it is difficult to be persuaded otherwise.

Alternatively we cannot subscribe to the design of insecticidal tests employing limited material such as are reported upon by certain workers in this field, in which the total volume of timber screened in any one assay is small, but from which broad conclusions and even precise commercial recommendations in the form of preservative loadings are given. Although certain techniques of exposing test material to insects have been criticized, e.g. the larvae-transfer method, the argument against much applied work is that the ability to prejudge any given test block of wood as being susceptible to insect attack, is limited. For this reason the interests of applied preservation would be considerably helped if an authoritative ruling could be given as to whether this fundamental inadequacy on our part can or cannot be overcome, by exposing in any one test a sufficiently large volume of timber.

(In their specialized medium marine organisms are responsible for extensive deterioration of timber, and we should all like to know more about their habits than we do, particularly as they may affect our test methods.)

(c) The Interpretation of Toxicity Data

However satisfied or dissatisfied we may be with the range and validity of our test organisms we are bound to use them to obtain toxicity data. It has always been a problem to decide the exact relationship of these laboratory determined toxic thresholds to practical service requirements. Authorities in the past have tended to query the value of laboratory toxicity data when considering timber which may be exposed in service to weathering conditions of varying severity. More recently experimental steps have been taken, independently in several research organizations, in the attempt to gain workable indications of the permanence of toxicity, from laboratory work coupled with field observations. Even if the object of a series of toxicity tests is to gain data for assessing the potential performance of a preservative under so-called "protected" conditions, e.g. for internal constructional use, we could not necessarily expect to interpret our data correctly, should that preservative possess a significant vapour pressure. As one moves further towards the consideration of all possible conditions to which treated timber may ultimately be exposed, the consideration of permanence becomes more demanding. Thus the assessment of "initial toxicity", i.e. the toxicity of unweathered treated material, although an integral step in any screening procedure, is only a partial and incomplete yardstick. In many ways the above argument bears a refreshing similarity to that of twenty years or so ago, when debate was centred around the relative virtues of testing preservatives in a malt-agar medium as opposed to testing them in wood. In the same way as the advocates of wood won the day, on the basis that toxicity in malt-agar gives a basic estimate of toxicity not necessarily related to toxicity in wood; so "initial toxicities" gained from study of the behaviour of poisons in wood, need not necessarily relate to practical behaviours unless the permanence of that toxicity is also considered.

Reference is made from time to time to so-called "protected" and "unprotected" timbers, implying that there are two extremes of exposure without any merging of one into the other. As we shall elaborate in another section of this Paper, this watertight segregation does not seem entirely reasonable, nor indeed desirable. By reading the literature one cannot but be impressed by the number of stake tests and graveyard tests that have been instituted in many parts of the world. We should like to suggest that these studies, and particularly those made in the United States, may have tended to impart an undue bias in the minds of some workers elsewhere, because of their emphasis upon soil burial. It would be of interest to know what proportion of all commercially treated timber is exposed to the peculiar hazards of ground contact.

Even so, however much our reasoning and experience may motivate our laboratory test methods it seems that we cannot always expect to be rewarded with sharply defined toxicity data. Responses, such as those of certain copper resistant fungi to copper based preservatives, are most difficult to assess from laboratory gained statistics alone, and require correlated tests under conditions of natural fungal infection.

Once we have gained a general appreciation of our test organisms they can be used to screen preservatives for initial toxicity, and the permanence of that toxicity must next be considered theoretically in the light of the chemical characteristics of the preservative under review. In many cases a preservative may be sponsored for a wide range of usages, although this is by no means the rule. It must therefore be decided, before testing the permanence of the preservative, to what weathering stresses the treated timber may be exposed in service, and tests designed to screen the preservative in that light should be arranged. Because we contend that any detectable weaknesses shown towards weathering exposures, as interpreted from current laboratory tests, need not necessarily reflect to the general detriment of a preservative as regards all service usages in which varying degrees of weathering occur, let us now consider how physical and chemical forces may affect the permanence of the toxicity of treated timber.

3. Factors Affecting Permanence

(*a*) *General*

One reason why one needs to know the permanence of a preservative is in order to estimate how much excess of it must be injected into the wood to compensate for subsequent losses. The losses of artificially introduced chemicals from timber depend upon their mobility, and we have loosely classified in our minds the two theoretical categories of mobile preservative ingredients and immobile. Such a division must of necessity be loose because mobile constituents can under certain sets of circumstances be rendered more or less immobile, and the reverse also holds true.

The mobility of a preservative may depend upon its solubility in water, its vapour pressure, the physical state in which it is present in the treated timber, and the way its characteristics in these respects are affected by the weathering and ageing to which it is subjected in service.

All chemicals are soluble to some extent in water but the degree of solubility varies significantly. Copper sulphate is very soluble, whereas basic copper-arsenate is comparatively insoluble. In general the permanence of mobile inorganic preservatives is related to leaching, and not to such factors as temperature and air-movement.

Likewise all chemicals exhibit a vapour pressure, that is to say a proportion of the chemical is continually being lost from its surface into the atmosphere. Orthodichlorbenzene evaporates rapidly, while the lower chlorinated naphthalenes have a lower vapour pressure that causes them to volatilize relatively slowly. The higher chlorinated phenols, by comparison, have an even lower vapour pressure and they evaporate at an even slower rate. Inorganics generally have a very low and insignificant vapour pressure, and mobility as a result of vapour movements is usually associated with the organic group of preservatives, whose lack of permanence, due to volatile fractions, is mainly affected by temperature and air-movement. As this latter group are mainly oil soluble their potential mobility will vary considerably with the type of solvent used, and of course by the presence of additives incorporated to key the preservative in the wood.

The mobility of chemicals which do not react with the wood tissues or become fixed within the cell structure, e.g. sodium fluoride and creosote, will, of course, be affected by the movement of their solvents within the timber, and one basic problem is to determine the disposition of various toxic fractions of a preservative within large dimensional service timbers after a considerable time has elapsed following their installation.

Having outlined the broad differences in the mobility between various chemicals let us consider the major natural forces to which treated timber is liable to be subjected *in situ*:

(i) The effect of rain and water can fairly readily be reproduced in the laboratory and may be considered as the prime cause of the loss of mobile inorganic salts from treated timber.

(ii) High relative atmospheric humidities may result in complicated moisture and mobile salt movements within the timber, and such effects are likely to be influenced by the periodicity of alternate wet and dry conditions.

(iii) Air movement, and particularly warm drying winds, will facilitate the rapid drying of treated timbers, and contribute toward moisture movement and subsequent redistribution of the mobile fractions of a preservative. They will also speed up any evaporation of the more volatile preservatives and their solvents.

(iv) Heat, whether climatic or artificial, is, together with wind movement, probably the most important cause for losses through volatility and the "bleeding" of oil soluble preservatives.

However, we should remember that the quantitative and accumulative effects of all these factors will vary with the dimensions, particularly the surface area/volume ratio, and the relative permeability of the timber.

A passing reference must be made to chemical contamination of treated timber which may result in a reduction of the toxicity, and thus in a sense of its permanence, without the actual movement of toxic radicals out of the wood. This effect has been particularly noted in fluoride treated timber brought into contact with wet plaster. As a result of the interaction between lime and fluoride, calcium fluoride is formed, and the fluoride radical is rendered non-toxic. To what extent such kinds of chemical contamination are important in practice generally, is not known.

From a consideration of the foregoing it will be clear that the siting of treated timber may result not only in a variation of the biological hazard, but also in a variation of the type and degree of weathering factor. Let us think for one moment of the differences in exposure between the following few service utilizations chosen at random:

(i) The soil buried portion of a telegraph pole, which will be subjected to continuous assault by a host of fungi competing for food, whose vigour may well be stimulated by adjacent nutritional matter, and to moisture movements within the soil which may keep the buried wood damp for prolonged periods.

(ii) The cross-arms of a telegraph pole, which, because of the free passage of air, will show more clear cut dry and wet periods, with a tendency to rapid drying. Infection will probably be restricted to wind-blown fungal spores and perhaps certain insects.

(iii) Mine timbers, which in many cases will be exposed to high and controlled relative humidities, and to long periods of darkness. Conditions which appear to select out certain fungal species.

(iv) Railway sleepers, which in tracks carrying heavy traffic are neither soil buried nor in ground contact, but lie with horizontal grain in ballast. As the ballast is usually quick to dry due to its porosity, and holds little or no nourishment, it clearly offers a different weathering and biological medium from that of soil.

(v) Water-cooling tower laths and louvres, which in a heavy duty tower will be saturated for most of their service life, a condition which appears to select out certain microfungi which cause soft rot.

(vi) Marine piles, which will be subjected to specifically different hazards above and below flood tide level.

The sum total of variation in exposure which obviously operates from one service use to the others and even within certain uses is impressive.

(*b*) *Methods of Studying Permanence*

In the interests of simplicity we can assume for our purposes that the effects of leaching and volatility as they result from several climatic and environmental conditions are the most significant weathering stresses, and whilst it is obvious that they frequently aid one another to lower the permanence of toxicity in service timbers, let us first consider them separately.

In many parts of the world various leaching procedures are being employed designed to study the leaching characteristics of various preservatives. In this country the soxhlet type of extraction method has been adopted; in Germany a system by which the test material is immersed in water, which is changed at specific intervals, and allowance made for alternate wet and dry periods, has been standardized; the Ottawa methods allow for three degrees of severity of weathering, and are based upon air drying, heating, and leaching; Madison have tried a wide range of systems and are at this moment engaged in refining one most suitable for their purpose; and many workers have found it convenient to leach their test material by varying exposures to running tap water. As with biological screening it is impossible to reproduce within any one test all the variables which may exist under the different conditions of exposure in actual practice. Nevertheless it seems clear from reports made so far that these various techniques may at least reveal partial truths, if not the complete story. This conclusion applies with equal force to leaching procedures designed for bioassay or chemical assay.

When considering those chemicals whose permanence may be envisaged as resting upon their resistance to leaching rather than to volatility, it is our opinion that definite usable qualitative results can be obtained. For example the copper-chrome fixation mechanism, if the chemicals are in correct balance, shows a very high degree of fixation in laboratory tests, which contrasts with the very low fixation of copper sulphate. Analysis of service timber treated with preservatives containing copper-chrome confirms that a high degree of fixation does in fact hold good in practice under conditions of "severe" leaching. What we are not so clear about are estimations regarding certain other mobile inorganic salts such as the fluorides, which show a very low resistance to washing out in the laboratory, whereas analyses taken from treated timber exposed to "moderate to severe" conditions of weathering, for periods of seven years or more, show that fluorides may remain in the wood to a considerable extent. It is possible that this discrepancy is due in some part to the difference in surface area/volume ratio between test blocks and service timbers, and to the depth of penetration by diffusion of such types of mobile salts within large dimensioned members. It is because of this kind of finding that we are not altogether convinced that present techniques permit too great a reliance being placed upon relatively slight quantitative differences in laboratory evaluations between various chemicals, under so-called standardized leaching conditions. If we recall how little is known about the complex physical and chemical changes which occur when water borne preservatives are impregnated into timber, and the distribution of the various toxic fractions of heterogeneous oil preservatives in treated timber, one must appreciate the wisdom of relating laboratory permanency tests to those observed during field trials. It also follows that when reporting on the permanency of a preservative it is essential that full details of the experimental techniques and manipulatory procedures must be given. For example, it is our experience that even with the highly fixed group of copper-chrome-arsenate preservatives variable leaching data may be obtained by merely altering the preservative loading, or by using different batches of sapwood test blocks obtained from the same species of timber.

It is a relatively simple matter to design and run through leaching experiments in the laboratory, but the interpretation of the results is by no means so easy. It is perhaps better to leave such studies in a simple form and marry them up with field work, rather than to attempt to complicate the design of tests, for instance, by the introduction of washes of controlled and variable pH.

Most of the foregoing comments on leaching have been directed at the study of inorganic non-volatile chemicals. When turning our attention to the creosotes and oil soluble organic preservatives, although work in the United States has indicated that leaching may play a role of some significance in the permanence of such preservatives, it is very closely associated with, and probably secondary to, the volatility of the preservative and its solvent.

The reasoning behind the design of tests for estimating the volatility losses of a preservative are identical to those of leaching studies, i.e. a system combining speed, simplicity, reproducibility and a capacity to reveal differential permanence. However, it is open to some doubt as to whether certain methods that have been employed to speed up the process of volatilization are acceptable. For instance, subjecting test blocks to high temperatures has been practised in Canada and New Zealand, and so-called standard weathering cycles incorporate exposure of treated material to temperatures of 100°C. There are several reasons why we must know what the differences are in vapour pressure of any given chemical between normal biological temperatures and such a grossly elevated temperature and further what effects, if any, such heat may have on certain loose bondings which may occur between wood components and preservatives. Apart from these considerations it is known that physical and chemical modifications can occur to timber exposed to 100°C. for long periods.

At Madison, laboratory methods have been evolved which expose test blocks for relatively lengthy periods of time to natural weathering, and recent efforts have been made to cut down the time consumed and to increase the reproducibility of results by the design of laboratory tests which rely upon a combination of accelerated temperatures, and alternate wet and dry cycles. At the M.P.A. Berlin-Dahlem pilot work has been under way for some time employing a wind tunnel which passes a stream of air at any given rate, humidity, and temperature over test material. From a theoretical consideration it is our opinion that volatility experiments may best be undertaken with apparatus that allows regulated air movements of controlled humidity to pass over test blocks at temperatures not exceeding the maximum likely to be encountered in service.

Our assessment from the available literature is that research progress has now reached the point in examining weathering stresses when definite qualitative distinctions may be gained, but that differential quantitative responses often require an extension of existing methods.

They also re-emphasize the necessity for cross-checking laboratory findings with those from the field.

4. The Correlation of Laboratory Tests with Field Trials Employing Full Sized or Reduced Scale Specimens

All those investigators who are primarily concerned with the speeding up of evaluation techniques are nevertheless unanimous in their insistence upon the necessity for field trials.

The accumulation of service records over extended periods of time are of extreme value as proof of the commercial practice of wood treaters. They do not necessarily give us the type of precise data which we are looking for in the context of this Paper for correlation between laboratory and actual service performances. Indeed, service records need not in themselves present us with a complete classification of any given preservative, if, for example, such a preservative has been used in a limited sphere, or if misapplication has arisen through ignorance of unsuspected factors.

Field trials on the other hand are an indispensable part of any research programme, and to some extent they have become an accepted feature of investigations. However, evidence from the literature indicates that such field trials do not generally extend far beyond graveyard stake and post tests. As we have tried to suggest in this Paper, trials should be established as a matter of course in a large number of varied service usages, e.g. mines, railway track, soil burial, marine and fresh water, etc.

Providing our research can cover satisfactorily the questions posed in this Paper some form of correlation must exist between the performances of any given preservative between its screening in the laboratory, its installation in small or large dimensional test specimens in service trials, and in full scale treated timber as the end product in service. Furthermore it follows that the comparative behaviour between two or more preservatives in the laboratory must find the same expression in the field.

As C. F. Duncan, C. A. Richard, R. H. Colley and others have pointed out, the threshold retentions necessary to preserve the end product in service, small dimensioned test specimens in field trials, and wood blocks in laboratory experiments, may not be identical no matter how carefully designed and comprehensive our studies may be. However, it can well be imagined that for each preservative there is a correlating factor between the three states, and should it transpire that eventually we are able to give these factors definition, we will then be in the strong position of knowing that our laboratory techniques are satisfactory and are open to extended use and interpretation. Nevertheless until this has been established we cannot assume that our present methods will in fact lead us to this happy conclusion.

Discussion on Paper 5

The CHAIRMAN (Mr. G. S. Pound): Mr. President, Ladies and Gentlemen, I think it is always useful to know something of the background of speakers who give papers at conferences. Whilst I have not met the two gentlemen before yesterday, I have managed to get a few details of their background.

Mr. Cook was educated at Kingswood School, Bath, and studied externally for Qualifications. He was with I.C.I. from 1936-1949, and from 1939-1949 was employed as a Chemist in the General Chemical Research Laboratories, Widnes.

Mr. Cook joined Hickson & Welch Limited in 1949 as Chief Analyst and was in charge of chemical investigations connected with wood preservation, and since 1952 has been Chief Chemist for Hicksons-Timber Impregnation Co. (G.B.) Ltd.

Mr. Price was educated at Bradfield and Oxford. After five years' war-time service in the Indian Army he was for one year in Nigeria as timber agent, felling and extracting hard woods, prior to going to Oxford where he studied botany, specialising in Mycology and Physiology. Since 1952 he has worked as Micro-Biologist with Hicksons-Timber Impregnation Co. (G.B.) Ltd. and in 1953 he made a tour of Africa for special investigations.

Mr. Price is to introduce their paper, which must be of considerable interest to both producers and users of wood preservatives since it deals with two of the main requirements—toxicity and permanence. They indicate the difficulties which arise in their evaluation.

I have noted that the word "economic" occurs quite frequently in the paper, and on page (2) reference is made to "economic wood destroyers". I would have thought that no wood destroyer was economic unless the word "economic" in this case has a different interpretation compared with what I have always understood it to mean.

Perhaps the authors can satisfy me on that point.

I will now ask Mr. Price to introduce the paper and, following his summary, questions are invited from delegates. Will those who speak please give their name prior to their contribution to the discussion.

Mr. Cook and Mr. Price will endeavour jointly to answer questions.

Mr. E. A. S. PRICE: Mr. President, Ladies and Gentlemen, thank you Mr. Chairman for that introduction. You know a little bit more about our background now and in spite of knowing the kind of education which we have received, it is clear that our grammar and our choice of words is not everything that it ought to be.

We might as well iron that point out now. What we are getting at, of course, are the fungi which have an economic importance and I think we could illustrate that in this country. For example, I believe

I am right in saying that the *Coniophora* species is responsible for a tremendous amount of decay. I have heard Dr. Findlay state that in his estimation something like 80 per cent. of the decayed material that finds its way into his hands has probably been attacked by the *Coniophora* species. If Dr. Findlay has anything to say about that later I should be very glad.

There is always a reason for writing a paper and you might be wondering exactly why Mr. Cook and I thought we would like to write this particular paper. The fact is that we are applied workers in an applied industry and from time to time we find ourselves dissatisfied with the tools of our trade and the way in which we can use them. We realise that certain limitations—some of them very strong ones—are imposed upon us in our applied work. So we have come to you with all your varied backgrounds and approaches and ideas for advice. Perhaps it would be more truthful to say that we wish to confirm our impression that the time is ripe for all of us engaged upon research in wood preservation to take stock of the position, and to consolidate upon the very real advances that have been made since the war years.

We cannot expect conclusive answers to all the questions we ask, and let us hasten to add that nearly all of them have been posed in some form or another recently by authorities in this field, but it will have been worth while airing our inquisitiveness if we can clarify certain problems which have basic importance, and come to some sort of agreement about what needs to be done.

For instance, if our beliefs and misgivings are well founded, it does seem that it would be in the real interests of wood preservation for the establishment of standard tests to study not only toxicity but the permanence of that toxicity. However, the ultimate use to which any standard procedure is put is limited strictly by the background and the experience of the body having recourse to it. In this paper of ours we have not confined ourselves to activities in this country alone, as we feel that with a general appreciation of these matters it is easier to achieve and maintain a sense of perspective by applying a general sifting and review of all the information that we can lay our hands upon from all quarters of the world. Wood preservation research covers such involved paths that by reading published work it is often difficult to appreciate the precise background and views held by the various authors. Because of these facts we feel that it would be of considerable value if meetings could be arranged, if possible on an international basis, but at least on a Commonwealth one. For it is only round a conference table that uniformity of opinion over test procedures and standards will be achieved.

We are happy to know that plans are already in hand to draw up new standards of testing in this country to include permanence, and that conferences with certain overseas bodies are hoped to be held.

You will notice the stress we place upon querying the very basis upon which mycological test work stands. That is whether we can satisfy ourselves that our test organisms are strictly representative of the economic wood destroying population. In this country we are fortunate in having many years of experience behind us, and in particular the painstaking work of the Forest Products Research Laboratory, so that it can be reasonably felt that our standard Basidiomycete test organisms perform a comprehensive and tell-tale function. If certain moulds, responsible for soft rot, are also introduced as standard test organisms, as we understand is planned, we should have few qualms in the matter of our fungal test species in this country. Although perhaps we would do well to pay more attention to differences in behaviour between various strains of the same species.

I think I can illustrate that. We have recently been using a new strain of *Coniophora* supplied to us by the Forest Products Research Laboratory and we were rather surprised at a certain aspect of its behaviour towards a specific poison. When we referred this matter to the Mycological Department of Forest Products they were also surprised and there is a feeling at this moment that this new strain is in some way more vigorous than the old one and shows different characteristics with regard to wood preservative testing.

However it must not be assumed that the standard test organisms used in the United Kingdom or America, for example, are necessarily representative of the timber destroyers in other parts of the world.

We think that a word of explanation may be necessary for our comments under the heading of Entomological Testing. When referring to the volume of timber exposed in one test, we mean of course the total number of wood specimens exposed to attack, and not to the actual size of each individual wood block.

Regarding our comments on permanence, even if some of what we have to say strikes you as being inaccurate, as for example the reference to creosote as not reacting with wood tissues or being fixed, which might strictly be rephrased to read "certain creosote fractions", we hope they will form the basis for discussion from which we can crystallise some agreement as to the most profitable ways of investigating permanence by accelerated studies. We are very much hoping that we can pick your brains today and gain some idea of how we can standardise our accelerated tests, particularly regarding permanence.

As opposed to "initial toxicities" the lasting effect of toxicity is plainly of the utmost concern to the consumer, and he must be the first to be satisfied that our methods for studying permanence meet up with his ideas and his requirements.

We have brought along some lantern slides to illustrate one or two points made in the paper.

SLIDE 1

BASIDIOMYCETE TEST FUNGI KNOWN TO HAVE RESISTANCE TO CERTAIN POISONS

Fungus	Poisons which can be tolerated
Coniophora cerebella	... Zinc and Copper Salts
Lentinus lepideus ...	... Tar Oil Toxics
Lenzites trabea ...	... Arsenicals
Poria monticola ...	... Copper Salts
Poria vaporaria ...	... Copper Salts

Now the average layman is apt to get a little bit frightened when he sees Latin words. Really the idea of this slide was to get you used to these Latin tags for fungus test species. Here are five standard test fungi. I think I am right in saying that three of them, *Coniophora cerebella*, *Lentinus lepideus* and *Poria vaporaria* are standard test fungi in this country, and the other two, *Lenzites trabea* and *Poria monticola* are standard in the United States. I thought you would be interested to see their resistance to poisons, which stresses the point we make in our paper, that it is obviously of great advantage to use fungi which are known to show resistance to poisons. We did consider filling out that list with all the standard test fungi used the world over. We have not done so, but had we done so I do believe that list would not have been more than approximately doubled in size, so that you can see that the number of fungi which, in fact, are being used as standards, is very small.

SLIDE 2

EXAMPLES OF THE KIND OF DIFFERENCES OBSERVED IN THE THRESHOLDS OF DECAY BETWEEN TREATED SPECIMENS EXPOSED TO FUNGAL ATTACK BEFORE AND AFTER ARTIFICIAL LEACHING

Type of Preservative	Test Material	Test Fungus	Threshold of decay as % treating concentration	
			Before Leaching	After Leaching
A proprietary water-borne preservative that is substantially "fixed" in timber.	Pine sapwood	*Lenzites trabea*	0.5	1.0
A proprietary water-borne preservative that is only moderately "fixed" in timber.	Pine sapwood	*Lenzites trabea*	0.1	3.0

This is just an example selected at random to show you the very real differences before and after leaching. This leaching procedure actually was one of our standard methods that we adopted and with which we are far from satisfied, but nevertheless it does give a picture which I am sure everyone here will appreciate and of which they will understand the significance. You take *these* two preservatives. I have forgotten how we classify them exactly, but you will obviously not ask me what they are. *This* one showed less toxicity before leaching than *this* one, whereas after leaching the reverse holds true.

SLIDE 3

EXAMPLE OF THE KIND OF TOXICITY RESULTS OBTAINED WHEN TESTING COPPER-BASED PRESERVATIVES AGAINST COPPER-RESISTANT FUNGI

Type of Preservative	Test Material	Test Fungus	Treating concentration used to impregnate specimens	% weight losses of duplicate test blocks
A proprietary water-borne preservative.	Pine sapwood	*Poria vaporaria*	4%	3.4 0.0
			3%	4.9 4.9
			2%	4.2 5.8
			1%	14.2 16.7

Now there is a paragraph in our paper where we make the comment that however comprehensive our test procedures might be and however well designed they might be, we cannot always expect to get the kind of precise data which we would like to get. We quote *here* and produce these figures for copper resistant fungi. This effect *here*, I think I am right in saying, is somewhat unusual. It is more usual to find that the threshold of decay occurs quite sharply between two fairly closely-spaced concentrations of treating preservative. *This* we call "nibbling", and what it means in real life we do not honestly know. For our part we believe that it has not got a great deal of significance. Perhaps there is a little bit of wishful thinking in this, therefore we are not satisfied to leave it there. We believe this is an example of a situation which does demand an extension of laboratory studies into the field, and of exposing similar sized material to your laboratory specimens in the field under conditions of natural fungal infection.

SLIDE 4

EXAMPLE OF THE TYPE OF DIFFERENCE WHICH MAY BE OBSERVED BETWEEN STUDYING THE LEACHING CHARACTERISTICS OF SODIUM FLUORIDE IMPREGNATED TIMBER IN THE LABORATORY AND IN THE FIELD

Source of Data	Amount of fluoride retained in timber
Laboratory specimens treated with sodium fluoride (in the presence of chromium salts) and leached by the Soxhlet extraction method for 100 hours.	12—20%
Railway sleeper treated with sodium fluoride (in the presence of chromium salts) and analysed after seven years in the track.	About 60%

We are showing this slide to expand our comments on the difficulty of understanding the chemical analysis in the laboratory of leaching experiments. What we would like to believe is that, if we treat material in the laboratory, subject it to a fairly vigorous leaching procedure and analyse how much chemical has come out of the timber, that will tell us what will happen in real life.

As we have said in our paper, we do believe that in many cases this can be done, but there are certain special cases where it cannot be done. I think you will agree that this type of example does illustrate that point. The railway sleeper having been in for some seven years or so, of course we have had to estimate what went in there originally, so it is very much "about 60%". But it does compare very differently with *that* type of laboratory gained figure.

SLIDE 5

A COMPARISON OF THRESHOLDS OF DECAY IN LB./CU. FT. OF CREOSOTE IN LABORATORY TESTS, FIELD STAKES AND POSTS

Source of Data	Threshold retensions in lb. creosote/cu. ft.
1. **LABORATORY TESTING**	
Lenzites trabea (weathered specimens)	3.2
Lentinus lepideus (unweathered specimens)	3.5
Lentinus lepideus (weathered specimens)	7.5—11.8
2. **FIELD TESTS**	
¾″ stakes	9.0—11.0
3. Pole diameter posts	9.0

(*Extracted from* R. H. Colley's "Correlating Evaluation Tests of Wood Preservatives".)

This final slide, I think illustrates two points which are of utmost importance to us in the consideration of this paper. The first is that there is a correlation, i.e. one can make a correlation, if one selects from laboratory material. You notice that the *Lenzites trabea* weathered specimens have a very low threshold. The unweathered *Lentinus lepideus* has a low one also, but the weathered *Lentinus lepideus* correlates pretty well with the stake tests and the larger dimension timbers also undergoing field trial.

Two points arise out of that: the first is that it shows the tremendous importance of wherever possible pin-pointing the most resistant source of decay or attack to any given preservative. The second point is that if this weathering procedure *here* gave these figures out of sheer coincidence, obviously one cannot apply that particular method to the screening of preservatives generally. If, on the other hand, it is an accelerated study which does truly measure up and condense into a matter of weeks what takes years to occur in real life, then it is of vital significance to all of us engaged upon laboratory research.

I have only one thing to say in conclusion, I have heard one or two comments made here already on other papers. There is, perhaps rightly so, a feeling that we should not in any way frighten people away from the use of wood by reference to the sources of decay and attack. In the same way, we would certainly not wish to frighten anyone here into the idea or feeling that laboratory work is so restricted in its use and application that it is not worth while. I hope you will appreciate that this type of paper is bolstering up all that we can do in the laboratory and in no way lessening its value.

The CHAIRMAN: Ladies and Gentlemen, your applause is indicative of the appreciation that we show to Mr. Price for so ably introducing his paper. There is no doubt whatever that the paper contains a lot of meat that will provoke a long discussion, probably a controversial discussion, and without delaying any further I will call for contributions to the discussion from the lecture room. Mr. Price and Mr. Cook will jointly answer the questions, they will decide between themselves which they will answer; there may be a bit of over-lapping in certain cases, but I have no doubt that we are in for a very interesting discussion indeed.

Mr. E. H. NEVARD: I have had the privilege recently of examining a report and also discussing the report with the author who is in this room today, Mr. Mateus from Portugal. I hope he will pardon me if I make some reference because I know he is diffident about airing his English which, I am sure, is far better than any of our Portuguese.

The two main points of his paper meet, in some respect, the requirements that Mr. Price has put forward. One of them is concerned with the sharp definition of the TIP. Whereas our normal technique has been in using the loss of weight to get the TIP, Mr. Mateus has worked out a scheme whereby he utilises the degree of stiffness of a small beam. You will appreciate that because of the dimensional effect, any loss of weight which results from attack, the attack will also result in some effect on the strength of the fibres, and because of dimensional effect you are virtually magnifying the loss. From what he has shown me there is no doubt that his definition of the TIP is very much sharper and clearer defined than it is with weight losses.

The other point which I think will be of interest to Mr. Price is that Mr. Price has asked for incorporation of leaching tests and weathering tests. Mr. Mateus has already done this; he not only tests timbers that have been treated and then air dried, he also tests specimens that have been treated, subjected to a rather severe leaching, and alternating that with a heating-up at 50 degrees. In other words, he is catering not only for the water soluble extractives there may be, but also for the volatile constituents which may be driven off at 50 degrees Centigrade which, as I have already mentioned to Dr. Findlay, coincides with our ideas, our suggestions, for the amending of B.S.838. We have fixed on 50 as being somewhere near the normal that you might get under tropical conditions.

I could carry on longer and I know Mr. Mateus would like me to—I am pretty sure he would—but I will leave those two points. They are not questions, but a bit of information which you have not yet had the chance of seeing.

Mr. E. A. S. Price: Thank you, Mr. Nevard. I think we ought to pass our thanks on to Dr. Mateus for supplying us with this type of information.

Speaking for myself, I have never been satisfied that the estimation of thresholds of decay by weight loss measurements was the ultimate in testing. I think any work which applies itself to considerations of the estimation of toxicities by mechanical means will prove itself to be of extreme value, particularly as that type of estimation may tell us considerably more than the limitation imposed by weight losses alone.

Dr. D. McNeil: The problem which is posed in this paper is by no means confined to wood preservation. In any field in which the durability or the efficiency of a material is affected by environmental factors, we have this lack of correlation between laboratory tests and actual performance in practice. I am afraid that just as in the case of fertilisers, drugs, paints, road-building materials and so on, at this stage the only final test for a preservative's efficiency is the "service record" test.

I would not agree completely with the authors' implied view that workers in the field of wood preservation are complacent about the test methods used at present. I rather feel the authors of this paper are preaching to the converted. All the workers in the field of wood preservation are vitally concerned with this lack of correlation between the laboratory test and the performance in service. There is no doubt that accelerated tests can be extremely valuable. I feel myself that the use to which the results of these tests is put by the research workers is a reasonable and valid use. Where they become dangerous is when used in the hands of commercial protagonists. It is quite obvious that by proper, or perhaps one should say improper, selection of results from accelerated laboratory tests, one can actually prove anything.

I do think, however, that the paper is extremely valuable in pinpointing the difficulties which occur in these accelerated laboratory tests. There is one point—I believe it is implied in the paper—that I think ought to be rather more emphasised: in the reports on most graveyard tests one is simply told that a certain post was taken out of service or had failed. As far as I can see from the literature, there is very little attempt made to conduct post-mortems on these failed posts to discover which combination of fungi or insects was responsible for that particular failure. I would be rather interested to hear from our friends at Princes Risborough whether such post-mortem tests are carried out or whether the carrying out of such tests would involve a considerable amount of work, the value of which would not be commensurate with the effort.

Mr. E. A. S. Price: Thank you very much, Dr. McNeil. Might I answer first the charge that we are implying that the trade, particularly on the technical side, is by any means complacent. We do apologise most sincerely if anyone else apart from Dr. McNeil has got this impression. It was not our intention to do so. We know of no one in the industry who can afford to be complacent at this time. We do agree thoroughly that service records are the ultimate proof, but we cannot afford to wait a lifetime, half a generation, to get our results. If we do so our progress will be strictly limited. We feel that advances in technique, knowledge, experience and personnel are now placing us in a position where we can—and I take up the other point made—technically come to reasonable deductions and inferences by good laboratory practice allied with field studies.

May I, on your behalf, take up your last question with Dr. Findlay and Mr. Savory. Just in passing I would like to make a credit note here to Dr. Becker in Berlin. There they are carrying out a very large number of studies, and amongst them there is this aspect of the colonisation of treated and untreated timber in ground contact. The work at this moment, I believe, is in its infancy, but undoubtedly from such investigation we shall gain very valuable data.

Can I, Dr. Findlay, call upon you to answer, through the Chairman?

Dr. W. P. K. Findlay: Mr. Chairman, I think some of the data which were presented in Mr. Savory's paper yesterday answer part of Dr. McNeil's question. We have during the last year or so, as you know, been particularly interested in the breakdown of treated wood by microfungi, and we are very conscious of the need for studying the reason why it eventually does break down and the organisms that cause it. We are certainly very interested and propose continuing that work of examination.

Mr. S. A. Richardson: Mr. Price in his introduction used a couple of words which I think have been too greatly used in the past in laboratory tests—"wishful thinking". I think it is most refreshing to find a commercial laboratory whose personnel at any rate is obviously not going to be satisfied with wishful thinking tests. We have all of us heard papers over the last five years and one has, on many occasions, detected wishful thinking contained in some of the results of the laboratory tests. I want to thank Mr. Price and his partner, Mr. Cook, for emphasising that wishful thinking is something we must eliminate from laboratory tests in the timber preserving world at any rate.

Mr. J. R. Aaron: Could Mr. Price tell us whether in assessing penetration, X-ray techniques have ever been contemplated using opaque fungicide such as barium chromate or barium naphthenate?

Mr. C. D. Cook: I think Mr. Aaron has raised a most interesting point. It is one of our sorrows that we have not yet been able to use physical methods of detecting both the depth of diffusion and what happens to the salts in the timber. I was personally extremely interested in Dr. Liese's electron-microscope work. I certainly feel that many of the newer physical instruments will profoundly affect our studies in the chemistry of timber preservation.

Mr. S. A. Richardson: I will not monopolise this, but have any of the laboratory workers yet investigated the possibility of the oscilloscope—it is the cathode ray tube modification of the television set—in detecting organic bodies in timber?

My son and I—it is nothing to do with our commercial interests—have been experimenting with an oscilloscope and it does offer possibilities. It is so sensitive on the graph recorder on the cathode ray tube that one feels that it could be applied to the detection of different types of fungi, because everything seems to have an emanation which records a different graph on the cathode ray tube. I am wondering if anyone here has done any work with the oscilloscope for detecting.

I hope you will forgive me for putting this.

Mr. C. D. Cook: I do not think I can add very much more to what I have just said. I think the comments which have been made should be noted by everyone here and I certainly believe there is a case for committees to discuss their application, and review the way we should study this work and if this could be done we shall go a very long way towards increasing our knowledge in this field of work.

Mr. F. F. Ross: I have only just been able to get here. You will not find my name on the list. I am from the Electricity Authority and I am chiefly interested in the cooling tower side which is a very special field. I do not want to talk about it too much, but I would like to say that my general impression of the relation of laboratory work to field work is that the laboratory work is exceedingly valuable, absolutely essential, but perhaps largely in a negative way in that it does enable one to eliminate quite cheaply and rapidly the things which will not work. It is, therefore, up to those of us who are users to co-operate closely with the people working in the laboratories to afford facilities on a reasonable scale for field testing, and to carry on with anything which the laboratory work indicates is promising. Of course we must not be too disappointed if the treatments which have passed the laboratory's examination fail when they go on to get their degree.

There is one other thing I would like to say, which perhaps only adds a bit more to the confusion: it is that we have got to be careful in realising that new uses of timber in new environments create new possibilities for the emergence and attack of micro-organisms which have not so far been considered of importance. I believe I am correct in saying that there is a large use of a particular species of timber in the United States for cooling tower work. When there were only a few cooling towers in existence there was no mass infection available of new types of fungi. Now that these cooling towers are dotted all over the countryside, I understand that a new species of *Poria*—and not being a mycologist I am very suspicious of naming these fungi anyway—is now exploiting this new field and learning to attack quite rapidly. I do think that is an aspect we have got to consider when a new timber is used in a new situation which has not previously existed. Something like poliomyelitis will come forward and be important, whereas before it was just hidden in a comparatively small field.

Mr. E. A. S. Price: Thank you, Mr. Ross. Your opening remarks are a good illustration of the point I made in the introduction when

I said that we have got to satisfy the consumer that our laboratory methods meet up with his requirements and his ideas of what an accelerated test might be. The Central Electricity Authority are consumers, we are suppliers. We do not place quite the same limitations upon laboratory work perhaps as Mr. Ross might do at this moment. We do feel that we can go a little bit further than just weeding out the poor standard material from the good.

How far we can go, I do not think any of us would like to draw a sharp line at this stage.

Mr. Ross raised the point of field trials. I hope that in our paper we have placed sufficient emphasis upon the extreme importance of carrying out many different types of field trial particularly when one is dealing with a new usage, or a usage which is receiving special attention for one reason or another.

The last point raised by Mr. Ross, I think, does tell a good moral. The position is always changing; it is always in a state of flux. We might feel today that in twenty years' time we will have overcome our problems, but I am quite sure we will be faced with new ones and we have got to be ready to meet them and be adaptable and be prepared for them.

Dr. R. C. FISHER: Mr. Chairman, I should like to thank Mr. Price for raising a matter which, I think, is of the utmost importance in relation to the investigation of insecticides and preservatives. He suggests, I believe, that the time has come when some further consideration should be given, possibly internationally, certainly within the Commonwealth, if possible even within Europe, to the establishment of tests to investigate the value of preservatives and insecticides. In that case I would distinguish between these two types of preparation —not necessarily the same—wood preservatives for preventing attack and insecticides for eradicating infestation already present. Mr. Price says that our views at Princes Risborough are well known and are certainly quite well defined. I think we have been open to some criticism in that we have not undertaken tests which have been carried out in some other countries. The reasons for that, I do not propose to repeat again. Mr. Price probably knows them and gentlemen here must also know them, but the time has come, I am sure, when we should overcome some of the points Mr. Richardson has raised, the wishful thinking problem which has undoubtedly come out of some tests carried out in some countries.

Now each country has its own experience with its own particular tests and I am convinced that the time has come when that experience should be shared and a really solid attempt should be made to draw up, to specify, some kind of standard test against insects. Hitherto that standard test has not been possible because the biological basic data have not been available. During the past ten years or so workers in various countries have made that possibility a little nearer than it was in the past. There is still much to be done, but there is a great deal that can be shared, not by publication but by direct discussion.

In this connection I understand that in Europe a meeting recently took place to investigate the possibility of setting up some kind of standard European test in relation to termite attack. That is only a suggestion put forward by Dr. Becker, and I believe it is being explored further. Why should the investigation on termite attack not be extended to look into the possibility of other insects with which we are directly concerned here? Until that can be done a standard test is still far away.

Dr. W. P. K. FINDLAY: I wonder if Mr. Price would agree with me that the phrase "field test" requires perhaps a little more definition. Would he agree that it does not imply by that a graveyard test, a stake test? I feel that a stake test may not be at all closely related to a service test. I am thinking, for instance, of timber preservation, of mining timber; an effective mine preservative might give a comparatively poor performance in a stake test. Again the surface area volume ratio of the test piece, I feel, is very important. We have heard Mr. Savory say that softening of some inches, certain fractions of an inch, can occur in treated timber. That may be completely insignificant on the stake, but the loss of one-sixteenth from both sides of one-eighth of plywood is certainly severe.

Mr. E. A. S. PRICE: Dr. Findlay, I do agree with you that perhaps in our paper we have been a little bit loose and we have not defined ourselves clearly enough. By "field tests" we have now learned to think in terms of various usages: the mines, the railways, cooling towers, they are all open to field tests and field trials in the same way as graveyard tests fulfil a specific type of field testing function.

Mr. S. H. HOLLICK: I would like to ask Mr. Price what is his opinion on the effects of chemicals which are naturally in the timber upon chemicals which are introduced? Is it not possible that here we have a fruitful line of investigation? Is it not possible that some of the incomprehensible service results obtained in tests are due to this cause?

Mr. C. D. COOK: I think Mr. Hollick has introduced a subject to the meeting which is of some considerable interest to those investigating timber preservation, particularly preservatives which are water soluble compounds. As we all know, most of the water soluble compounds depend on chromate for fixation; chromate, whether present as sodium chromate or sodium dichromate, reacts with certain reducing agents within the wood to form chromium compounds. As the reduction proceeds the pH of the timber increases or the alkalinity of the timber increases. Various mechanisms are set in motion which fix both the copper in copper chrome, the copper and the arsenate in Greensalt; the normal Wolman salt type of formulation. So the first point of Mr. Hollick's question is that the reaction between timber and the preservative is a very important factor in the fixation of the preservatives.

Mr. R. SAWYER: I wonder if the speakers can tell us if any use can be made of radio-active isotopes checking distribution of preservatives in the wood cells.

Mr. C. D. COOK: I understand that in various parts of the world—and I must admit I am very envious of them—radio-active isotope studies are being carried out. We both would be very interested to know if there is anyone here who has been associated with the universities who have carried out such studies, and we look forward to any publications that may be made from these research centres.

Dr. D. MCNEIL: On that last question, I might say that we have done a small amount of work, not in the question of wood preservation, but in the use of labelled fluorene for the analysis of tar oils. I cannot see there should be any difficulty in using this technique for determining the distribution of inorganic salts throughout wood fibre. It is extremely sensitive. You could undoubtedly get your materials labelled by Harwell. It would not cost you very much and I think you would get some very interesting results.

While I am on my feet, there are two other points I would like to make. The crux of this paper, as Dr. Findlay has pointed out, appears to be that we do want to develop a standard accelerated test for the efficiency of wood preservatives. I am no mycologist; I have never done any wood preservation testing, but on the analogy of accelerated testing in other fields, the normal thing is to attempt to isolate your conditions at the highest level for a time and then to interpret the results statistically. It is this question of the statistical evaluation of results that I am a bit concerned about. This statistical designing of experiments, and interpretation of experiments has made very great advances in the last few years. It is now possible by a comparatively small number of experiments to find out which factors are important, and perhaps even more important than that, which combination or interaction of factors is important. I have wondered whether in the attack on preserved wood by organisms there is any competition between various types of organisms. In other words is there interaction between the presence of the various types of fungi and insects? I thought the Princes Risborough people would be much more familiar with the literature on this than I am, and I wondered whether this statistical design of experiments and interpretation of results has actually made much progress.

The second point is that I have been interested for some time in the very valuable work which Professor Hinshelwood of Oxford has been carrying out in which he has treated bacterial growth and reactions involving enzymes as heterogeneous chemical reactions. He has more or less rejected the idea that the agents are living organisms and treats them exactly as one would treat a classical reaction. One has been able to define rates of reaction, energy of activation and so on. I wondered whether that approach to the action of fungi, which, I understand, act by enzymic breakdown of the wood, might throw some further light on this particular problem.

Mr. E. A. S. Price: Thank you, Sir. I will say straight away that I am out of my depth. I think perhaps Dr. Findlay might like to have a word about it. But if I could just pass an opinion, I do feel that method would not be strictly applicable to our present stage of development in testing. We are isolating fungi from nature, from a most complex economy of nutritional demand, competition, a fight for survival; it really is a most complex set up in every way. We are then putting them in pure culture in a laboratory.

It has always been a bit of a problem, I have found, to make up my mind whether a given fungus has a better opportunity for destroying test material in the laboratory than it gets in nature. I do not know.

I do not know if you can help there, Dr. Findlay?

Dr. W. P. K. Findlay: I can only agree with you thoroughly.

Mr. S. A. Richardson: Surely, Mr. Chairman, all this depends entirely on the metabolic processes of fungi and insects. When we get down to metabolism we shall then know all the secrets of these various forms of decay, but so far we are working round the perimeter without getting in the centre of the thing. Let us get down to the metabolic processes and we shall discover all the secrets.

Dr. D. McNeil: Mr. Chairman, if I may add to my previous remarks, I think the very fact that there are so many random factors in this particular work is the reason why it is essential to treat the problem statistically. One can determine which are the important factors, which interaction factors are important. As far as I have gathered, that is one of the big gaps in the question of the development of preservatives.

Mr. R. A. Bulman: First I would like to say how very helpful this paper is, and how very well the whole subject was introduced by Mr. Price. There are certainly very many aspects still to be considered in Preservation, although I must say that many of these same principles discussed in the paper have been considered for very many years. I think a number of them were thoroughly looked into when B.S.838 was introduced some years ago.

There is one point I am puzzled about: that is the question of resistant strains of fungi. I think Dr. Findlay answered this question one or two years ago, as to whether there are fungi which can become resistant to preservatives, rather on the lines that we have various insects which can become resistant to D.D.T. and so forth. At the time I think the answer was that there was no evidence to show that fungi can become resistant in that manner. I would actually like to raise that question again now.

There seem to have been many developments since that time, and I wonder if there is any further information.

Regarding information, I will take up Mr. Price's request for information, and I would like to make some comments regarding his early remarks in connection with pure cultures and mixed cultures. As Dr. McNeil mentioned, the problems which have been considered in this paper apply not only to timber, but to many other materials, and one in which it falls to my lot to be interested in is the field of textiles. A very considerable amount of work has been done in that field regarding both mixed and pure cultures and, as in so many other instances, views, even these days, are somewhat conflicting. I think the concensus of opinion is that mixed cultures are better.

I do not know whether the authors are familiar with that work. If I can help in producing a reference to the paper concerned, I shall be only too pleased to do so.

Perhaps I may now enquire about one or two items as they arose in the paper. My first query is in connection with insects, and I wonder if any work has been done on the lines of that carried out by Kelsey in New Zealand, in connection with the copper chrome arsenate which may go under such names as Ascu or Greensalt, and which I gather has been very largely developed in recent years by the Bell Telephone Company of America.

I believe Kelsey has done a lot of work on water soluble preservatives, including those with and without copper. The result of this work shows that they seem to give rather poor results, in particular against anobium which he used in his tests.

Referring to your comment on page 7 and the discussion on the mobility of preservatives, it seems that can be reduced to the fact that in general the inorganic types of preservatives tend to suffer from leaching, and the organic types may suffer from either volatility or leaching.

In that connection, I think we ought to bear in mind the fact that some so-called inorganic mixtures may contain organic components, and some of the so-called organic types may contain, for instance, a metallic element for fixation purposes which not only will reduce the leachability, but also reduce the volatility.

I would like to ask if the comments on the oil soluble preservatives, to the effect that the most important cause of loss is volatility, are perhaps rather sweeping, and if there is any special information available on the subject and upon which those comments were based.

Remarks have been made about the enzymic action of fungi and I wonder if that factor should be considered in connection with the methods of studying permanence as opposed to the leaching and volatility considerations.

I wonder also if we ought to consider the effect of ultra-violet light which is a factor that plays an important part in preservation. Possibly one weapon which may be used in that field is the weatherometer machine in which the samples can, of course, be exposed to humidity or dryness, high or low temperatures and ultra-violet light in close sequence.

Several times variations in results are mentioned and the suggestion made that the wood samples may cause this. I think this is possibly one factor to be considered in connection with Slide 3, when I think the term "nibbling values" was used. I wonder if it is considered that that sort of variation is inevitable in so far as I think it is impossible to get two identical samples of wood and since it is inevitable, surely that will have some bearing on the practical results obtained in connection with service tests, causing wide variation in the results.

On page 10 it is suggested that the use of varying pH values should not necessarily be considered. I submit that is a most important feature for any timber in service.

There is one simple illustration of the importance of atmospheric pollution: I feel sure that the general pH of leach water in practice will vary considerably and, of course, it arises especially in connection with soils. I think we ought to give due recognition to the work done already by Princes Risborough in considering soil variations.

Mr. E. A. S. Price: Mr. Chairman, we are very grateful to Mr. Bulman for making good some of the points which we could not cover in this paper. We wanted to write a paper in simple, general terms, and when you set out to do that you lay yourself open to generalisations, making remarks which are perhaps a little bit too sweeping and occasionally giving the wrong emphasis and the wrong impression.

I am afraid I cannot contribute very much just now to some of the questions which Mr. Bulman raises. If he will forgive me, I would just like to deal with the last matter, the matter of the pH values.

Our ideas on this matter are quite simple; in fact, it all rests in simplicity. You mentioned soils: the soil pH varies significantly and widely. Timber is liable to find itself in contact with a very wide range of different pH's, all caused by the different chemicals present in different soils. We feel at this time that to attempt to design standard tests—and that is the crux—involving variations in pH would be asking us to do a little bit too much. We feel that the first step is to seize upon something which is reproduceable, consistent; therefore our suggestion, initially at any rate, is to use distilled water.

I thoroughly agree with your remarks and obviously with time we shall have to learn more about the effects of washes of different controlled pH's.

I will take up any other points privately with you later, if I may.

Mr. R. A. Bulman: Thank you very much indeed.

Mr. W. R. Saunders: There is one small point, but before I say anything about that I would like to thank Mr. Price and Mr. Cook for the paper, and also for being so non-partisan in the presentation of it.

Dr. McNeil, I believe, mentioned some of the results which could be interpreted from laboratory work, etcetera, and he also called later for certain statistics and certain statisticians to work these out. My own view is that several interpretations could be applied to statistics; they could be made to prove anything.

In this respect I believe about twelve months ago certain questionnaires were sent to firms engaged in wood preserving in connection with the life of treated timbers and service records. I was just wondering if those papers were filled in, and if so, have you any news yet of anything of value emerging from those reports? I believe the B.W.P.A. were connected with those circulars.

Mr. E. A. S. Price: I am sorry, Sir, I did not catch the papers you were referring to.

Mr. W. R. Saunders: The circulars were sent out by the B.W.P.A. about twelve months ago to the firms engaged in wood preservation, asking for various details as to life of timber which had been treated. I was just wondering whether any information had yet emerged; whether the statisticians had obtained any information of value from those circulars?

Mr. E. A. S. Price: I do know the *pro formas* to which you refer and as far as I am aware myself they have been filled in, submitted, duly filed and I imagine are at the time being studied most carefully.

The Chairman: Ladies and Gentlemen, with much regret I have to draw this discussion to a close. As I indicated earlier, the paper has promoted discussion and it has raised controversial subjects. However, the paper has been of extreme value in pointing the way which all those concerned with wood preservatives and wood preservation should follow. This is a paper dealing with developments and these developments will continue to be studied; although we do not appear to have the answer at the present time, so long as people are working on the development of accelerated tests which will indicate in a short time what performance a preservative will give, then I think we are all working in the right direction.

It only remains for me to thank the joint authors, Mr. Cook and Mr. Price, and Mr. Price for having introduced this paper so ably and contributed so well to the discussion. Thank you, Ladies and Gentlemen, for the attention you have given them.

(6.) THE ARCHITECT AND TIMBER PRESERVATION
—The Problem of Historic Buildings.

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1. Introduction

It is stimulating to find amongst all sections of society a renewed realization that this country contains a priceless heritage of historic architecture which is not surpassed anywhere in the world. For example, nowhere else is there such a fine array of exquisite mediaeval buildings or such a rich collection of traditional domestic architecture. Nor is this heritage confined to the buildings themselves. Everywhere there abound beautiful fittings and furniture in wood, the craftsmanship of which could never be equalled.

The impact of the last world conflict, with its trail of destruction, has brought home very forcibly the real value of this heritage. With this has come the realization that many of these ancient and historic buildings are in an extremely bad state of repair and in several cases require urgent and drastic attention. Much of the damage caused to old buildings is due to rot and/or fungal attack in the timber work of roofs, floor and internal joinery work. In this paper, the author is attempting to consider some of the causes of failure of old timber structures and to put forward some fundamental principles and methods of conservative repair. It is inevitable that there will be some repetition of papers presented by architects to previous Conventions but this may not be too bad a state of affairs as many aspects of timber preservation require constant emphasis: No attempt has been made to enter the scientific or trade field of preservation as already many very good publications are available through the F.P.R.L., the T.D.A. and the B.W.P.A. The author is content to draw on his own experiences as a practising architect and also as Director of the York Institute of Architectural Study. This Institute, which has a close liaison with the B.W.P.A., has for the past four years specialized in post-graduate courses on a variety of subjects, especially those connected with the protection and repair of historic buildings.

2. The Case for Preservation of Historic Buildings

The paramount consideration is the aesthetic importance of this country's old buildings with their historical, educational and cultural value. They constitute a national asset whose loss would be irreplaceable. Whilst other countries can show larger and more splendid churches and palaces, none can rival in number and beauty the English parish church or the country house in their familiar setting. These buildings represent an association of beauty, of art and of nature and form possibly the greatest contribution made by England to the visual arts.

At first the Church claimed all the best craftsmen but later, when church building became less active, fine craftsmanship was concentrated on the building and decoration of the great houses. In both church and domestic building, the mason, the bricklayer, the carpenter and wood carver, the plasterer and metalworker found ample opportunity for the fullest expression of their skill. It is very important that, whenever possible, these examples of handicraft and applied decoration should be preserved in the building for which they were designed and made.

3. Causes of Failure in Traditional Timber Structures

In mediaeval times the principal structural timber was oak, with some sweet chestnut and, occasionally, a small amount of elm. From the middle of the 17th century onwards imported fir became increasingly popular as oak supplies diminished. Beech was also sometimes used as flooring. Pitch-pine and other North American timbers did not come into general use until well into the 19th century.

Traditional timber construction falls naturally, by virtue of its mechanical properties, into "post and beam" form with all its numerous derivations such as the various types of "crucks" and the "jettied" or cantilevered construction of overhanging upper storeys, so common in mediaeval towns and cities. Various types of mortice and tenon joints secured with oak pegs are the commonest form of joint, with many kinds of shoulders and notchings where necessary. Tension joints consisted of some form of dovetail. In the earliest timber buildings the carpenter copied the masons' joints and details for enriched or moulded work. The panels between the main timbers in framed structures were infilled with various materials and in various ways. There was wattle and daub, lath and plaster, brick nogging and sometimes the whole fabric was sheathed in plaster, weather-boarding or tile. In the 16th century there was a close liaison between carpenters and shipwrights with the result that many of the decorative motifs were to be found both ashore and afloat. In the late 18th century in the south-east of England the "mathematical tile" was used in vast quantities. This simulated brick but was "hung" in fact on a light softwood frame.

There can be no doubt that the principal cause of failure in timberwork of old buildings, whether structural or in fittings, is the decay of the wood itself due either to fungal attack or to the ravages of boring beetles or in many cases to both. Decay is almost always due to lack of proper and regular inspection and maintenance repairs. Leaking roofs, gutters and rainwater fittings left unattended for even short periods are responsible for enormous damage annually.

Other causes can be grouped under the heading of what we would now call "faulty design". However in all fairness to the builder of old it should be realized that they were building in the best methods known at the time. The ends of timber were left exposed to the weather or built into walls where they were liable to damp or to be without ventilation. There were of course examples of bad mechanical design. Shrinkage or "drift" have also aggravated the position.

4. Principles of Conservative Repair

There are three fundamental principles which should always be observed when dealing with historic buildings, and in particular with traditional timber structures. The first and by far the most important is to make the fabric of the building sound and watertight so as to preserve the whole and to prevent further deterioration and damage.

The second important principle is to retain and conserve as much of the original work as possible. Every old building possesses certain physical characteristics such as length, width and height, but it also possesses a "personality" very much its own. This quality is often referred to by architects as a "fourth dimension". Once it is destroyed or damaged it can never be recreated. It is impossible to restore this "personality," and therefore any attempt to do so must be condemned. The result, at best can only be "period fakes." It is therefore vital to preserve the original work.

The last principle is to repair the building in such a manner that it does not detract from the original aesthetic effect. At the same time laboured reproductions or "restorations" should not be made. New work should always be in harmony with the old, but subservient to it.

5. Methods of Preservation and Repair

The essential preliminary to any repair must of course be a thorough and comprehensive survey. Causes of failure and decay, direct or contributory, must be diagnosed. At this point it is salutary to review the various parts of a traditional timber structure where defects commonly occur. Timbers buried in walls, whether joists, wall-plates or ends of principal rafters must always be suspect even if apparently hard on the face. Decay is often due in the first instance to fungal attack followed by beetle. The cause of initial dampness must be located at once.

Timber lintels are especially vulnerable components. After a certain amount of use they tend to sag, causing the panel-infilling or masonry above to crack slightly even if only at the joints. The rain is therefore allowed to penetrate and conditions for more rapid decay are provided.

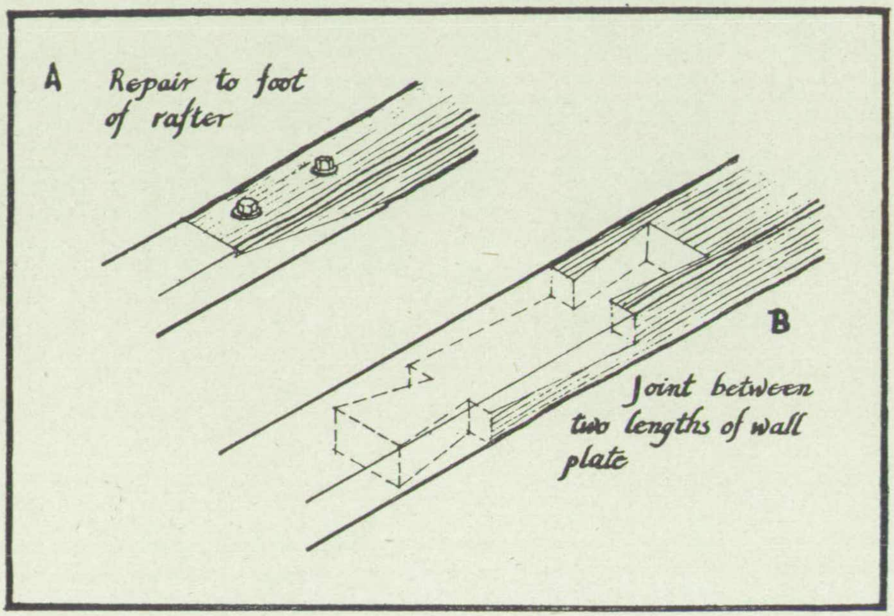
Old buildings do not possess dampcourses and for the most part are simply built on the ground. Rising damp is therefore one of their greatest enemies, particularly those which are timber-framed. Timbers in contact with the ground or with masonry plinths at ground level are specially susceptible to decay from fungal attack. The feet of posts and sills of framed structures are examples.

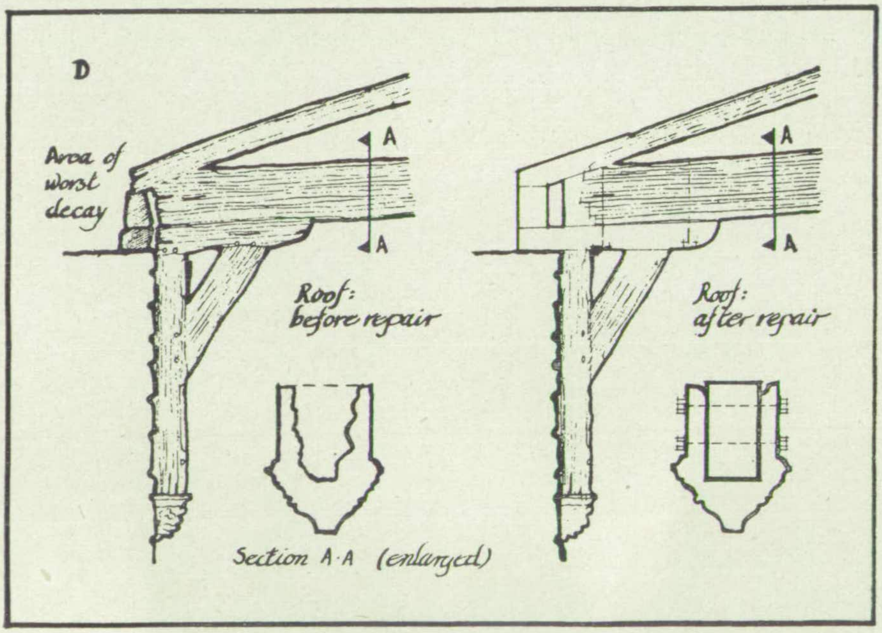
Sapwood which has not been removed from main timbers usually becomes attacked first and the appearance of large roof members so affected can be frightening. The damage is however more often than not confined to the sapwood, which when cut off with a blunt chisel or knife, reveals a sound heart. It is worth remembering that in the old buildings the timbers are generally of much bigger scantlings than would be employed to-day. Even if they are partially decayed, there is frequently plenty of sound wood left to carry the stresses to which a particular member is subjected.

Intermittent wetting of timberwork can cause great damage, especially if the water is due to leaking gutters or roofwork. Such items as sole boarding or bearers for valley gutters should always be carefully inspected and maintained. Indeed any place where water can lodge, such as the top of exposed horizontal framing members, ledges or shakes should be well investigated. Crevices in or between timbers, for example at joints or pegs, form ideal places for beetles to lay their eggs. In framed buildings the wooden parts of wattle and daub or lath and plaster infilling of the panels is often almost completely destroyed because it is commonly sapwood. In fact it is only the daub or plaster with its egg-shell like limewash protection which is holding the panel together. Once disturbed the whole disintegrates into small pieces. The problems related to the preservation and repair of historic buildings are many and complex. It is not always fully realized that work of this nature is a specialist study, which requires not only a sympathetic approach but also special knowledge and experience.

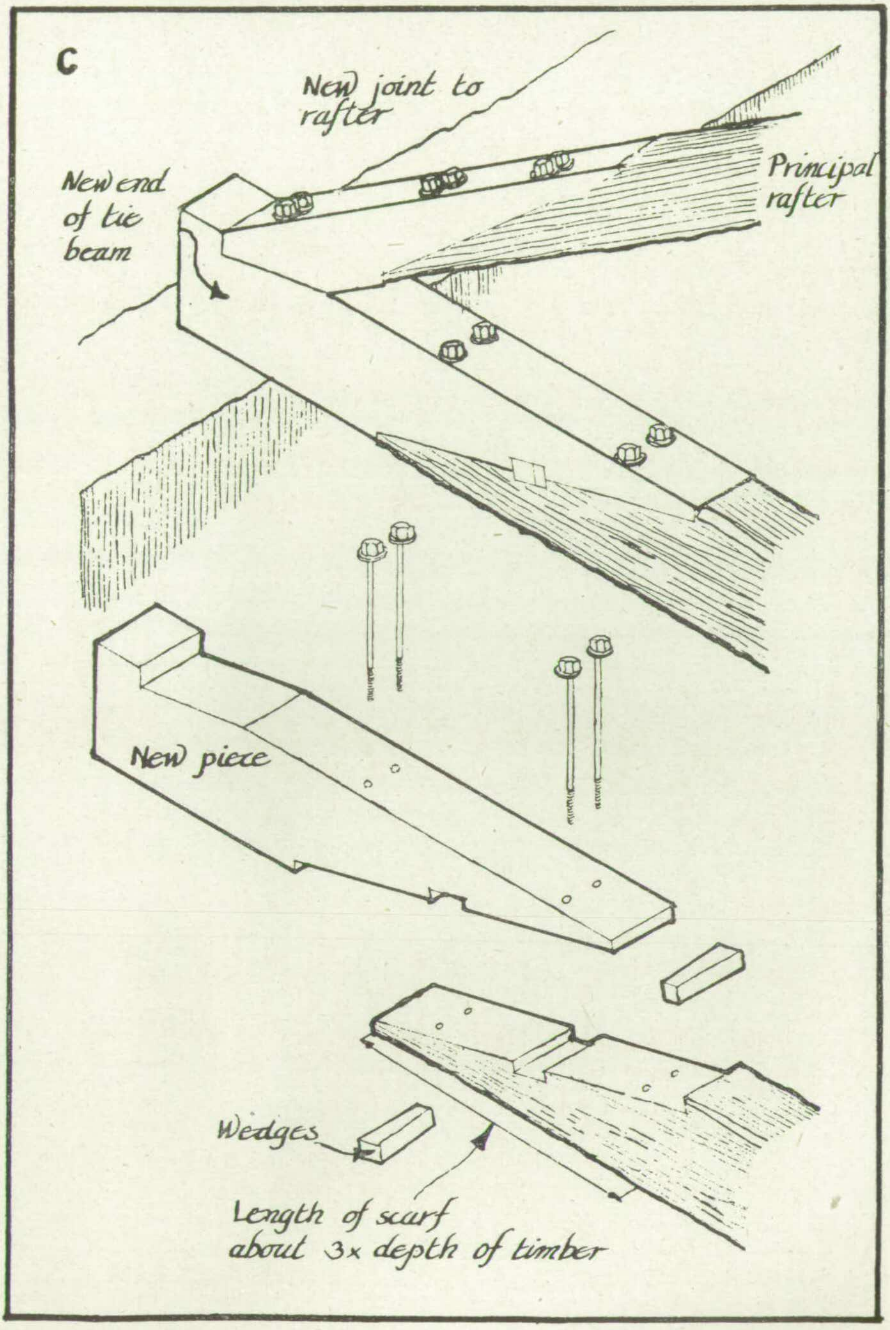
The repair of historic buildings should therefore be entrusted only to those architects, surveyors and builders who have this specialized knowledge. In its 1951 Annual Report, the Society for the Protection of Ancient Buildings, stated, "The lack of such knowledge leads to irreparable harm being done and time and again the Society finds evidence of expensive, over-drastic and frequently unnecessary reparations carried out by the ignorant and the inexperienced. The difficulties at present affecting the building trades, intensified by the lack of skilled craftsmen, contributes further to the problem." Alas, suitably qualified persons are too few, but steps have already been taken by several institutes and societies to alleviate this shortage.

It is a fallacy to imagine that carefully thought out preservation and conservative repair is more expensive than wholesale stripping followed by complete renewal. In almost every case the reverse is in fact the case. Many cases are known where the cost has been more than halved by well supervised conservation.

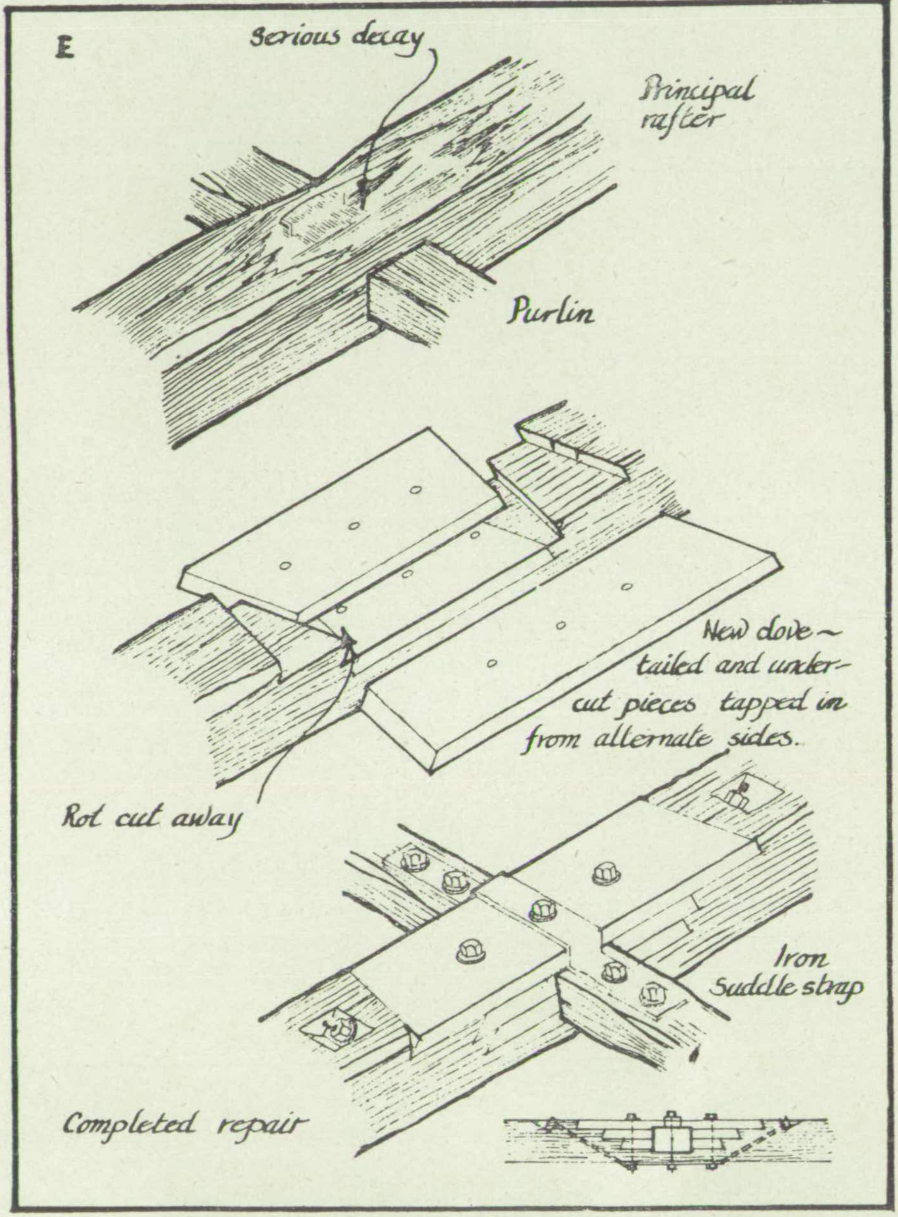




Bearing in mind the principles of preservation and repair already outlined, the diagrammatic sketches on this and following pages illustrate some typical details. Defective rafters, usually the feet can be repaired by splicing in short new lengths of timber to replace the decayed section using a scarfed joint (fig. A). The end of beams which bear on



the wallplate can be similarly repaired by splicing (fig. C) while the wall-plates themselves can be joined by a halved and dovetailed joint (fig. B). All new timber used in the repairs should of course be suitably treated with preservative before being installed.



Decayed joints often occur in timber roofs where the purlins are housed in the principals, at the ridge or at the eaves. These can be repaired in a variety of ways, but some ingenuity is required in inserting new work and at the same time preserving the old (fig. E).

Beams weakened in the core due to shakes, fungal attack or beetle can often be repaired by cutting out the defective part in such a manner that the moulded or carved profile is left intact. New timber is inserted and the whole may be stiffened with wrought-iron straps or flitch plates (fig. D). Metal work however, should always be used as a last resort and avoided wherever possible as it is foreign to the original design. If iron is used care must be taken to see that the side touching the oak is suitably protected to prevent corrosion by tannic acid.

Decayed plaster panels in framed buildings can be renewed in plaster on wood lathing or woodwool slabs. Panel infilling often becomes loose owing to differences in the thermal expansion and contraction of the framework and the panel. This can be overcome by repointing or "caulking" with mastic which will permit some movement while at the same time sealing the joint. Wide joints in framing and even shakes can be treated in the same way.

Timber as a structural material has a liability to shrink on drying and swell on wetting—this movement being considerably more across the grain than along it. This is an important fact to remember when the repair of timber structures is being considered. If the timber is securely held so that it cannot expand on absorbing moisture, internal stresses are set up. On drying out the timber starts from its new width and therefore will shrink. This effect is cumulative until an eventual limit is reached. It follows therefore that it is no good "wedging-up" open joints unless it is quite certain that no expansion will take place.

It is worth remembering that timber-framed structures which have become distorted can be pulled back into shape or jacked up. In the case of simple roofs this is comparatively easy, but it can also be undertaken even in more complicated structures.

Occasionally it is necessary to make alterations and additions to old timber buildings. Slavish copying of all kinds should be avoided and in most circumstances, new work should be of sound contemporary construction designed so as to harmonize completely with the old work. Although this is not easy it is by no means impossible.

The preservation and repair of internal fittings such as panelling, should follow the same general principles as for the structural timberwork. Apart from damage caused by rot or beetle, damage from rough usage, either wilful or accidental, must be expected. Panelling placed against external walls is susceptible to fungal attack when the back is subjected to damp penetrating the wall and lack of ventilation.

Every case of repair must be taken on its merits and it is difficult to generalize. However it is often possible to preserve carved or enriched panels, which have decayed at the back, by having the affected wood carefully scraped or planed off. The remainder can then be treated with a preservative, stiffened or mounted on a new backing before reinstatement.

6. Conclusion

In this paper an endeavour has been made to state the problems related to the preservation of historic buildings, particularly traditional timber structures, in as fair a manner as possible. There is nothing very new in what has been said, but it is vital that old buildings should be handled with great care and sympathy. Finally a plea is made for specialist and experienced advice in all matters concerning historic buildings. Careful supervision is essential and it is well to remember that it is always better to preserve than restore!

Discussion on Paper 6

The CHAIRMAN (Mr. T. G. ROBINSON): Ladies and Gentlemen, it is a real privilege this afternoon to introduce to you Dr. Singleton. He has got so many initials after his name that I am not going to attempt to repeat them, but he is the senior lecturer in architecture at Manchester University and he is also the Director of the York Institute of Architectural Study. He is going to tell you something more about the work of the Institute before we finish this afternoon.

It is very fitting indeed that in this city of ancient buildings, before we close this Convention, we learn something about the methods of preserving such buildings. We have spent a good deal of the morning engaged in perhaps the more strictly scientific and chemical side of timber preservation, but we must not forget that there is the other side, and perhaps the older side, of looking after timber itself and seeing that the proper precautions are taken in the construction of the buildings to ensure that they are preserved to the best possible extent.

That is all I have got to say except to welcome Dr. Singleton on your behalf and ask him to address us.

Dr. W. A. SINGLETON: Mr. Chairman, Ladies and Gentlemen, it is a very great pleasure and privilege for me to be addressing you this afternoon. I consider it is a very great privilege not only for myself but for the York Institute of Architectural Study which I represent on this occasion.

As your Chairman has said, I would like to tell you something more about the Institute and its work before we finish this afternoon's session because it is the first institute of its kind in the world and I think it has—and others like it—a great future in the work of preservation and repair of historic buildings.

What I wish to say to you about my paper is really to stress one or two of the important points and to show you a few slides to illustrate the points still further. In this country at this time there is more interest than ever before in the preservation of our heritage of historic buildings. This heritage consists of innumerable buildings, mainly churches and great houses, but also a large number of minor buildings, particularly domestic buildings. Although there is more interest aroused in the protection of these buildings, the buildings themselves are beset by more dangers. We know only too well the effects of the wars, or rather the after-effects of the wars. We know only too well the effect of taxation on the large country houses.

There is not time here to discuss ways and means of overcoming some of these dangers, but I do consider that this is very much a time for vigilance, a time when we should look out for the welfare of our old buildings so that we can pass them on to those who succeed us in as good, if not better, condition than we find them. What is more important, I consider that it is very much a time for action; we must do something about it. Your Association is very much concerned with doing something about it.

I do want to stress most strongly that I consider work on historic buildings of any kind is specialist work; it is not the work for people who have not had any training or have not had any experience in the work. The more I go about and look at old buildings that need repair or have been repaired, the more I realize that people employed on that sort of work, whether they be professional people, whether they be craftsmen, should have some training, and of course following that should build up a wealth of experience. In that connection and following from that need for specialist work, I think there are certain very definite principles of repair and protection. The subject of protective repair is full of pitfalls and it is extremely difficult to generalize. Every case must be taken on its merits and what is applicable in one case is seldom applicable in another. However, there are some fundamental principles which I consider should be strictly observed.

Every old building has a personality which is very much its own; it has physical characteristics of length, breadth, height and so on, but it has in addition a personality. Once that personality has been lost it can never, in my view, be re-created. So the first condition of good repair is that it should be conservative repair, it should be aimed at preserving as much as possible of the original work because once it is lost it cannot be recovered.

That leads to the other two principles, that no form of restoration or reproduction should be used, no slavish copying of carving or motifs, because it is impossible to re-create the original. The conditions under which modern work is carried out, not only the actual physical conditions in the workshop but the social and economic conditions of the craftsmen themselves are different, and therefore the original work cannot be re-created; so no slavish copying. The new work, which should be kept to a minimum, should be in harmony with the old but subservient to it. To achieve that it needs co-operation between the architect, the builder, the specialist and the trade. I think that on the whole we get that co-operation; there is a very good working basis between the various people concerned, but it is important to maintain that.

In that connection I feel it is important that an Association such as yours should provide good information to the various people concerned with the work. It is not easy to prescribe what that information should be, but quite clearly the type of information should be designed for the person who is going to use it. The information required by an architect or surveyor would be quite different from that required by the actual craftsman, and certainly different from that required by the owner. I think it is important that the right sort of information is available to all those concerned.

I do not consider it would be appropriate for me to say very much more. I have a number of slides which emphasize the points that I have made; they are divided into two groups; one deals with roofs, mainly church roofs, and the other one deals with timber-framed walls. So we will have the slides and talk a little bit about them, and then I hope we shall have a really good discussion because this question of protection repair of historic buildings is full of difficulties and no two people have the same views about it. I think it is very valuable to have an opportunity like this for people to put their views forward and discuss them.

That slide is similar to the illustrations which were reproduced in my paper. It shows how different types of roof members which have become decayed for one reason or another can be repaired without ruining the entire member. I think that should always be the aim, to use different kinds of joints and use as much ingenuity as possible to carry out conservative repair. Very often, in fact in most cases of my experience, it is cheaper to carry out a conservative repair than to condemn all the old work and put in something entirely new. From the architect's point of view it may be a little more difficult. He has to give it more supervision and it is the sort of thing that you cannot provide drawings for very easily, or even very much in the way of specification; but it is the sort of work which must have constant supervision and it is not easy to do that, but I do think that in every case it is worth while.

I have heard of cases where, shall we say, a new roof of a church has been recommended at a cost of £20,000 and in actual fact by some means of conservative repair, apart from retaining much of the original timber, the cost has been brought down to as low as £5,000. That is quoting an actual figure.

Here are some photographs showing new pieces of timber that have been inserted in the timber roofs. I think they are all fairly evident and that is a case where one, of course, would put back timber or replace timber suitably treated with preservative. It is a case where the preservative chosen should harmonize as far as possible with the original timber; it is no good putting a very light timber in here matching up with the old. It should be in harmony with it, but it should not look as though nothing has ever happened. It should be in harmony with it but not too light a colour in relation to the dark oak.

These pieces put in do show up rather brightly, but much of the old has been retained wherever possible.

Here, looking down on this roof, a piece has been put in preserving as much as possible of the underside which is probably carved and moulded.

We have a piece spliced in up here, retaining the original along the bottom wherever possible.

Here we have a piece of fine carving; it would be quite impossible to re-create that exactly as it was in the spirit in which it was made. It has been kept and new work has been put around it.

Here is a piece put on here again.

This is a roof-beam of Penistone church; this is after it had been repaired there.

This is before repair, taken out like that; and it is just as well to remember that many of these beams—in fact, most of them on the mediaeval churches—are perhaps as much as four times the section we should use today. Therefore quite a large proportion of the beam can be decayed and stripped off without the beam becoming dangerously slender.

This shows the work during the process of repair.

The last one shows it as it was finished. Much of this could normally be done in the workshop. In this case it was done actually on the church roof itself on a platform *in situ*. This method has many advantages.

This is a photograph of beams taken out of a church before the war on the grounds that they were dangerous, and they were thrown away. A new roof was put it; and actually the Society for the Protection of Ancient Buildings, to whom I am indebted for the loan of some of these slides, found these in the churchyard; they had been discarded as being useless. They were, in fact, far from useless, but when they were found it was too late. You can see by the end of this beam that they are not in too bad a state.

It is quite possible to repair this. You see the beam itself and the mouldings on it are substantially whole. That sort of thing is caused really through ignorance; anybody who had any knowledge or experience of repair of old buildings would not agree to those being taken out and discarded completely. The cost of renewing those would be much greater than the cost of repairing where necessary.

The next section of slides deals more with domestic structures, houses with timber-framed walls and infilling panels of some material. This is the priest's house in Prestbury, the village in which I live. It is a very delightful half-timbered house. I will just show one or two to show the range of buildings we are considering.

The next one is a world-famous example, Moreton Old Hall, in Cheshire, a moated Elizabethan manor house which is extremely fine and is in very good condition. The principle is exactly the same in all these timber-framed structures, they have a plinth or base of stone and a timber frame with a sill and heads, vertical members and cross members, and in-filled panels with windows, or with some sort of bricks or wattle and daub.

The next is Warburton church in Cheshire, the side of which is timber-framed. Here again the same principle applies, a plinth with a sill, a head, cross members, vertical members and panels. Some space is being filled in with windows and doors.

That shows a skeleton of a typical domestic timber-framed building; you can see the plinth and skeleton quite clearly.

Here is another one; this is one not far from where I live, at Alderley Edge, with a skeleton frame showing it made up of timber framing, the timber being 10 by 5 inches thick and how in place of wattle and daub panels you sometimes get windows.

That is rather old, but it shows very clearly the principles, the plinth and the timbers. Of course, you only have to look at timber in a position like that near the ground on a stone plinth without a damp course, at the various joints that get open, the cracks you get in the timber, to realize that repairing a timber-frame building and keeping it sound, particularly the walls, is no easy task. With a timber roof you can do something to cover the timbers up with a good sound roof covering; but in the case of the timber walls, well you cannot cover them up satisfactorily, and the timber is in many cases meant to be exposed. Here is the wattle and daub panel of one type, and it is very often in retaining the timber frame and repairing and replacing the panel that the greatest difficulty arises. In most of these wattle and daub panels the timber has completely perished, and as soon as they are knocked they break into powder. Of course, the secret in any case is the egg-shell-like coating of limewash on the inside and outside which protects the whole panel.

Here is one with another type of wattle and daub, quite different in character from the last.

Here are various ways of treating panel-infillings with damp courses and pointing up with mastic and recessing the panels for protection. Here is one using woodwool slabs. I do not think it is any good replacing the panels with wattle and daub. One has to use some modern material to give a similar aesthetic effect of the timber frame with the panels in between. Here is one actually on a lath and plaster, and this one is a brick nogging.

Here are three methods that you will find of wattle and daub. Generally the early panels were narrow and were often filled in that way. The later panels were rather more square and consisted of vertical laths which were sprung into a slot at the top and the bottom, or sometimes it was a slot at the bottom and a groove at the top so that the verticals were put in and slid upright. Then it was interlaced with hazel. Here is yet another type which is not very common; this has been fastened together with leather thongs.

I know you have had a lot of scientific lectures and you probably know all about these beetles—a lot more than I do—but I just want to show you three photographs which I think are rather interesting. They are interesting to me because they were taken by an amateur—an amateur in photography—the Clerk of Works at York Minster. I think he has taken these three photographs extremely well. There, of course, is a death-watch beetle in some form of transformation.

These are all taken from beetles at York Minster.

This shows the state of the lead roofing of a north transept at York Minster where the lead was punctured by the death-watch beetles escaping. I thought you would be interested to see those, because for an amateur photographer I think they are extremely interesting photographs.

The last one is just a reminder that sometimes under timber panelling you will find all sorts of interesting things. This is at a house in Norfolk where the panelling was removed and on the timber frame behind was found the remains of this wall painting. It sometimes happens that behind panelling you will find wall paintings, but they are not very common in this country; therefore they must be preserved. A word of warning—to be careful how panelling is removed and treated.

I think that is all I would like to say at the moment, and I hope we shall have an interesting discussion.

The CHAIRMAN: I am sure, Ladies and Gentlemen, there will be a number of questions you wish to ask Dr. Singleton.

Mr. T. L. KINTON: May I just ask something on the commercial side? Most of us are interested in the preservation of old buildings and preserving our national heritage and I think that we would all be interested to know what we could do to help, because it is not generally known, for instance, that one can become a member of the National Trust for a very small subscription which entitles one to visit any of the buildings which come under the Trust, and also the contribution goes towards the maintenance.

There may be other things which one can do, but I think it is a problem which does concern most people, as to how these places are going to be preserved and properly maintained. The Government are doing something but we would like a little expert guidance.

Dr. W. A. SINGLETON: I can give you a certain amount of information about the various societies that exist for the purpose of aiding preservation. As you have mentioned, there is the National Trust, which I think most people know about. There is a National Trust for Scotland and there is a National Trust, as far as I know, for Ireland. As has been stated, you can join the Trust for a nominal membership fee and you do, for that membership fee, get access to all their properties when the subscription is paid. They do extremely valuable work in preserving old buildings, mainly domestic buildings.

There are one or two other societies; there is the Society for the Protection of Ancient Buildings which has now been going for rather more than eighty years. Its foundation was based on a manifesto of William Morris in an effort to stop what he called the vandalism of Victorian restoration. They do extremely valuable work; their offices are in London, 55 Great Ormond Street, W.C.1. They keep a permanent secretariat there; they have a technical advisory panel and they take active steps wherever possible with the funds available to aid preservation. They will appear and give evidence at inquiries and things of that sort.

There is another society which is newer than the Society for the Protection of Ancient Buildings, and that is called the Ancient Monuments Society, which has been in operation for about twenty-five years. It was founded in Manchester but has now become a national society. Its objects are much the same as the Society for the Protection of Ancient Buildings except that it does include in its work ancient monuments whereas the Society for the Protection of Ancient Buildings only deals with buildings. They have a technical advisory committee who will give advice and will, if they think it advantageous, give evidence at inquiries and help with press campaigns and so on.

Those, I think, are the main sort of amenity societies except for the Georgian Group and the various Georgian societies in the country which, as the name implies, deal with Georgian and Regency buildings.

There are the other societies, the Council for the Preservation of Rural England and the Council for the Preservation of Rural Wales. They deal mainly with the preservation of amenities in the countryside, but of course buildings and monuments also come within their purview. I think support of the National Trust and for the other societies mentioned goes a long way towards preserving our heritage of historical architecture.

I think I can speak of either of the other two societies, S.P.A.B. and A.M.S.—I happen to be a member of both—in that they are pleased to hear of any cases of buildings of merit that are threatened with damage or destruction. After all, it is impossible for them to know about everything unless people in the areas in which the buildings are situated give the information. So either society would be glad to know of any cases where they might be able to help. They exist for that purpose. Does that answer your point?

Mr. T. L. KINTON: Yes, thank you very much.

Lt.-Col. P. L. SAWYER: As a brother architect from another cathedral city, I would first of all like to take the opportunity of congratulating Dr. Singleton on his paper.

There is one thing in the paper, a technical point, which I would like to take up with him because I think it is of particular interest to this Conference; that is his reference on page 144 to the use of woodwool slabs where he is talking about the replacement of lath and plaster with wood lathing and woodwool.

Wood lathing we know how to preserve; you gentlemen have taught us how to preserve it. But I am not so sure about woodwool slabs. As far as I know they are made by firms who have no particular interest in the timber trade from timber which is your waste product. Into a slab probably goes timber of all different kinds and sorts, held together with cement, a mixture of some sort into what in building terms is an ideal building blotting paper. I would say that woodwool slabs are just asking for trouble in years to come. I doubt very much whether they will last as long as the old wattle and daub has lasted.

I would be equally interested to hear what Mr. Singleton says about them and also to hear what the B.W.P.A. have to say about preservation of timber in woodwool slabs.

Dr. W. A. SINGLETON: I can only say that I have seen a number of cases, and I have heard of more, where woodwool slabs have been used for this purpose. Admittedly they are not very old. The ones that I have seen have struck me as being perfectly sound.

The difficulty with woodwool slabs, as you have pointed out, is the "blotting paper" effect, therefore one must keep the water out. The cases I have seen, that have been rendered, generally limewashed as well (which is a very effective damp preventer) and properly caulked around the perimeter, have shown no signs of deterioration. I did feel that it was a good solution because it was an easy one, and it did seem to be standing up quite well. I have no reason to think that they will deteriorate very rapidly. I do not know quite when these slabs were first produced, but they have not been in general use for very long, therefore the examples that I have seen have not been in existence very long. From what I have seen and from the reports I have had from other architects, they seem to be standing up quite well; I can only say that.

The CHAIRMAN: Dr. Singleton, you did not say exactly what the principal cause of the damage in these photographs which you showed us was.

Dr. W. A. SINGLETON: The principal cause of the damage in those photographs was death-watch beetle with, to some extent, rot. As you know, they tend to go together, but in most cases it was beetle.

Col. J. A. GRAHAM: Mr. Chairman, we have heard this very interesting paper about preservation of historic buildings, and I am wondering if I may mention a matter which cropped up quite recently when one of our officers came back from Malta. One of the objects of his visit was in regard to a lot of our timber stocks which are very badly deteriorated and which Dr. Findlay and Dr. Fisher know something about. In conversation I listed from this chap that in Malta it is well known, of course, that the island is ravaged with *Lyctus* and furniture beetle and we have also got *Hylotrupes* which we found in our own timber stocks. Then he said they take no notice of it at all in the local buildings—these wonderful old churches—either of the timber portions of the buildings or more importantly—and he has been out in Malta about three or four years—of these wonderful old carved wooden statues. He says they are completely riddled with furniture beetles and probably *Lyctus*.

I was wondering whether there would be an opportunity for some interested body in this country to take some interest and try to help out the Maltese in their own love of the sometimes rather gaudy but most interesting carved wooden statues. They vary from about a foot high to things about one and a half times life size. He says he has been round several of the older churches and literally when you just touch one of these old models you can feel that if you put a fingernail in, a corner would come off; they are simply riddled with beetle.

I just offer the suggestion to anybody who might perhaps take an interest, and incidentally he suggested that the only way of getting at the Maltese would be to write direct and officially to the Government Commander-in-Chief. It is no good writing to the Chief Priest or anything like that; it has got to be taken up on a fairly high level.

Dr. W. A. SINGLETON: Mr. Chairman, I have been to Malta and I can bear out what has been said; all the old timber work that I saw, non-structural and particularly the statues, was completely riddled with beetles.

I do not know what can be done about it. Most societies that would be prepared to help really have not the means to send people over there to advise. There is one possible line of approach that occurs to me, and that is that there is a school of architecture in the University of Malta in Valletta and it might be possible to do something through them. There is also—I am not sure what its correct title is but I suppose in other places it would be called the National Museum—

which deals with the antiquities of Malta, the excavations and the old buildings generally. They, too, would no doubt be a line of approach.

Mr. C. SISLEY: Mr. Chairman, there is one very interesting point I should like to hear Dr. Singleton's views upon—various views have been put forward—and that is the progressive increase in the beetle attack of wood which does seem to be culminating today in a sort of general and magnifying destruction. It cannot have been going on in the past at this rate and various views have been given about the cause of this speeding-up and I would be interested to hear what Dr. Singleton has to say.

Dr. W. A. SINGLETON: Well, Mr. Chairman, the more I go round, particularly round churches, the more I become convinced that it has been going on for a very long time; but it is only recently that anybody has bothered about it.

I have been in a number of churches recently, three in particular; one not very far from where I live which is riddled with death-watch beetle and is having, not a new roof I am glad to say, but extensive repair to the timber roof. In these three churches, talking to the members of the parochial council, I have been told, "Oh, well, as long as we can remember we have been sweeping these beetles up in the spring off the floor." "You do mean those little black beetles that we find on the floor?" and so I am really inclined to think that it has been going on for a long time.

I am not really in a position to say whether it is in fact getting worse or whether we are more conscious of it. I rather think that to a large extent the community, and the technical people particularly, are becoming more interested and more conscious of the damage that is being and has been done by the beetle, and to some extent it may be increasing as well.

The CHAIRMAN: Dr. Fisher, can you add to that?

Dr. R. C. FISHER: Only I think, Sir, to endorse what Dr. Singleton has said. I think we are quite definitely of the opinion that the death-watch beetle at least has been in the buildings to which attention is now drawn for many, many years and its presence has only recently been discovered. In that connection I think there is only little evidence of real spread of infestation by that insect in sound buildings; there must be some conditions present which invite attack before it will spread.

I should like to ask Dr. Singleton a question while I am speaking. I noted with great interest the recommendations he made for the retention of the old building, the old roof and the old characteristics. In so doing, is not one of the great difficulties to determine how much timber one can leave with safety? How certain can you be that you eradicate completely active infestation by the death-watch beetle in timbers which are difficult to examine?

Dr. W. A. SINGLETON: Of course, that is the crux of the matter. It is extremely difficult, if not impossible, to do that. In some cases it seems relatively easy; in other cases it is extremely difficult. That, of course, is certainly a weakness in the idea of conservative repair. But I rather think it is a matter where one would have to treat each case on its merits and take all reasonable precautions in individual circumstances to make sure that you have done the right thing. I rather think that even after you have done the work you have to continue with an intensive policy of preservation for a long time until you can be reasonably satisfied.

Dr. R. C. FISHER: Mr. Chairman, is that not a very strong argument in favour of this type of work being done by specialist architects with specialist knowledge of a very difficult problem?

Dr. W. A. SINGLETON: I would agree with that entirely. I know there are some members of the architectural profession who perhaps do not hold the same views that I do; that this work is a specialist job. I have heard it said on many occasions, "An architect with the ordinary training ought to be able to tackle it." I think it applies equally well to builders and surveyors. I disagree with that completely. I think as you get more experience you are capable of tackling the problem better. But I do think there is some fundamental training necessary if you are going to avoid some of the pitfalls which beset a person dealing with old buildings.

The more we run our courses in York, the more we realize how much basic information an architect, surveyor and builder should have if he is going to tackle the building with confidence.

The CHAIRMAN: That brings you on to your next stage, Dr. Singleton.

Dr. W. A. SINGLETON: I did ask your Chairman for a favour. I asked him if I could tell you something about the work of our Institute, and particularly about an interesting project which we have in hand at the moment.

I do want it to be clearly understood at the outset that this is in no was a talk for advertisement; far from that, we do not need any advertisement. Our activities are over-subscribed and we really have more to do than we can deal with. But I thought you would be interested in hearing something about the Institute because it is the first and only one of its kind in the world. It is interesting because it is an entirely private venture; it draws no funds from any official sources. It is organized by the York Civic Trust which is a body in York akin to the National Trust, a body of local citizens who got together after the war not only to try and improve the amenities of York but also to make available its treasures which consist mainly of archives and architecture, for the benefit of everyone, and particularly for serious-minded students.

Seven years ago they started by organizing a summer school for architectural students. It now runs every year in York in August for about forty or fifty students. They come to York to study, measure, sketch and photograph York buildings and in the evening they have lectures by well-known architects and architectural historians. That is now in its seventh year.

Four years ago the idea was conceived of extending the resources of the Institute and extending its work with the aim of eventually building up a full-time Institute.

As you have been told, my main appointment is at Manchester University and with their permission I am allowed to organize courses at York and they are run in the vacations, at Easter and in the summer. So it is part-time in that respect although we have a permanent secretariat. These courses were started four years ago, courses on the protection repair of historic buildings and since then over a hundred and twenty architects, builders and surveyors have been to the courses and over two hundred students have attended the summer schools. This year we have greatly increased our work. We are having four courses, two at Easter and two in September, three summer schools occupying four weeks in all in July and August. The courses are on the "Modernization of Obsolescent Dwellings"; "Timber as a Structural Material in Building"; "The Care of Churches" and "Public Park and Garden Design". There will be three summer schools, one for Americans, in co-operation with the National Trust, on "The English Country House"; the usual fourteen-day course for architectural students, and a one-week school for interested laymen on "A History of English Architecture". We have had so many applications for this year—it holds thirty-five—that we have already nearly filled it for next year, 1956.

We also publish books from time to time and a bulletin on unusual aspects of protection repair work. The interesting thing is that about a year ago we were given one of York's redundant churches (there are five redundant churches in York). This one has been empty for over twenty years! It was to be demolished, but the Civic Trust were able to stop the demolition and it was given to them because it was a liability to the city. A few months ago we launched a local appeal for £12,000 to convert the church into the headquarters of our Institute, and to show you the interest that it has created within six weeks we were only a few hundred pounds short of the £12,000.

The work has started and it will be opened officially as this country's first Institute of Architectural Study for post-graduates, using the word "post-graduate" in the widest sense to embrace specialized courses for qualified architects, builders, surveyors and so on. This building will provide us with a lecture room for sixty, a library, staff rooms and a good exhibition space. I am hoping that some members of your Association will provide me with permanent exhibits for my exhibition space. We aim to have the building open every day with a permanent Secretary, and it will be there when we eventually launch out as a full-time Institute of Architectural Study.

The York Civic Trust's next task will be to acquire an endowment, enough to provide for the running expenses of the Institute as a full-time Institute.

I have just one or two slides of the church and a sketch or two of what we are proposing to do with it. It is right down by the river in York, right next to the middle bridge, the Ouse bridge, and it consists of a central nave and two wide aisles on either side. This end was taken away some years ago to widen the road and has been rebuilt; so has part of this, but there are a number of interesting things about it. It has a turret on top which is rather rare because it was built at the time of the Commonwealth. The base of the turret is a stone tower which, when we knocked the plaster off the wall, we found to be Norman and, indeed, included a complete Norman window which has been bricked up for several hundreds of years and is now uncovered. It also has tall pinnacles which we have taken down and are going to repair and replace.

Inside it is like that. There is just sand for the floor; the floor had been lifted because in years gone by the building was liable to flooding being near the river, so the bases of the columns are down below the floor; we are putting a new wood block floor in that part.

Here is a tomb of Sir Richard Yorke, the founder of this small chapel and his armorial bearings are up in the roof above. These roofs and the aisles are actually fifteenth century, but the roof of the nave is late nineteenth century.

What we are proposing to do is almost square in plan. It has a pleasant little garden in front; we are not altering the outside at all. We are building up with partitions the arcade, making a lecture room with a platform at that end, a cine apparatus and so on, a Director's room, a Secretary's office, enquiries, an exhibition space, tutors' room and a big library. We have already collected several hundredweights of books and slides for the library.

Inside, *this* we imagine will be the library, *here* is the room that you saw before and the fine timber ceiling above, the arcade filled in and the new floor.

Here are the entrance, the enquiry desk, the exhibition space right through, and looking into the lecture room.

The last one is inside the lecture room with blackboards and so on, the arcade filled in and the new roof.

I thought you would just like to hear about that because it is something of which I am very proud and something which I think will set the pattern for a great many other post-graduate institutes in time to come.

The CHAIRMAN: Ladies and Gentlemen, time is just about up, but before we, as we say in Scotland, "skail"—very few know what that means except Dr. McNeil—I think we must show our appreciation of Dr. Singleton's talk—and thought-provoking talk—to us this afternoon. It is a matter of interest that Dr. and Mrs. Singleton left Manchester at six o'clock this morning in order to be here and I think that means we are still more grateful to them for the long journey they have undertaken. Thank you very much.

ON THE DECOMPOSITION OF THE CELL WALL BY MICRO-ORGANISMS

By Dr. W. K. F. Liese

Forstbotanisches Institut der Universität Freiburg i. Br., Germany

The work of Mr. Savory has enlarged our knowledge of the decomposition of wood by micro-organisms in quite a new domain. The very fact that under certain conditions even wood treated with preservatives may be destroyed shows us that this problem is not only of scientific interest but also of great importance in the practice of wood preservation.

Dr. Findlay's report to the Wood Preserving Conference, 1954, in Berlin, induced us to engage in study of the soft rot of the wood in Germany and I am very glad to have the opportunity to report to you briefly upon our results.

In the past we have frequently received telegraph poles which had failed with a brash fracture (Fig. 1). Outwardly the poles were quite hard and almost gave the impression that they were not decayed; usual symptoms of attack by wood-destroying fungi could not be observed. It is noteworthy that the wood was not so soft as observed by Mr. Savory on the water-cooling tower wood. This has important consequences; linesmen before climbing the poles hammer at the base to test them for decay, but a "brash-fracture" pole does not produce a hollow, decayed sound when tested so it may happen that a failure can occur when the linesman climbs the pole.

Microscopic observation of these poles showed the same symptoms on the wood as those described by Bailey and Vestal, 1937, Findlay and Savory, 1950, Findlay, 1954, Savory, 1954. Similar pictures of destruction had also been observed by Barghoorn and Linder, 1944, on wood in the sea, as well as by Varossieau, 1949, on buried wood. The attack was observed on spruce wood poles and pine wood poles up to a depth of about 10 cm. The small circular to oval holes, which first have a diameter of about 2-3μ and later flow together in larger corrosion-spots, are visible in cross-sections of the summer wood in the central layer of the secondary wall. Only the central lamina and the tertiary wall are not attacked. The springwood is destroyed at a later stage and also to a lesser degree. It is remarkable that here first the medullary rays are attacked and later also the bordered pits. The destruction of the medullary rays and of the bordered pits is seen clearly in the radial sections. Here around the bordered pits several circular cavities run together, being connected with each other (Fig. 2). On the radial section also the spiral destruction of the cell-wall, considered to be a consequence of the fibre-like arrangement (Fig. 3), can be seen.

With the aid of crossed nicols we have furthermore clearly noticed the diamond-like structures on the destroyed specimens though they are not formed by any of the well-known wood-destroying fungi.

These types of attack of the cell wall were also observed on beech wood railway sleepers. Here the difference between the springwood and the summerwood is, of course, not so clearly pronounced; on the contrary, the wood fibres are nearly equally attacked over the whole cross section.

Furthermore, we examined canal lock-gates of pine wood which had lain above water for many decades. Here a granular destruction of the secondary walls in the summerwood also has been found.

When closely observing attacked wood one can occasionally find fine hyphae as described and cultivated by Findlay and Savory. These fungal hyphae are very small and are not found in wood as often as expected. Therefore we have examined attacked wood with the electron microscope* in order to learn more about the decomposition of the wood as well as about the micro-fungi and to find out whether perhaps further micro-organisms are concerned, especially as small organisms can be seen on the cell walls, when they are examined under the light microscope at higher magnifications (Fig. 4).

In a macerated suspension of the destroyed wood two different particles are clearly recognized by use of the electron microscope. Probably these represent enzymatically decomposed cell-wall-components such as lignin and cellulose, the latter being reduced to short-chained structures. Using the "replica" method of preparation a view of the surface irregularities of the dissected cell walls can be obtained, and the action of the wood-destroying micro-organisms observed.

When examining the wood electron-optically we found hyphae with a diameter of about 0.4-0.7μ. Furthermore, we could observe numerous bacteria, sometimes appearing singly, sometimes aggregated inside and outside the cell walls; on account of the special method of preparation actual bacteria could be seen as well as replicas (Fig. 5). They are approximately 0.4μ wide; thus we are here concerned with rather small forms of bacteria.

Although it is known that sometimes bacteria can appear as secondary infections in wood destroyed by fungi, their presence in large numbers in this material is surprising.

It is worthy of note that this type of attack mostly appears on very wet wood where bacteria can grow better than fungi. As a result of our study we therefore suspect that besides the fungi perhaps also bacteria have participated in this remarkable destruction of the wood in a more or less high degree.

*The electron-microscopic investigations have been carried out by the Radiologic Institut, University Freiburg i. Br. We thank Dr. Braun heartily for kind assistance.

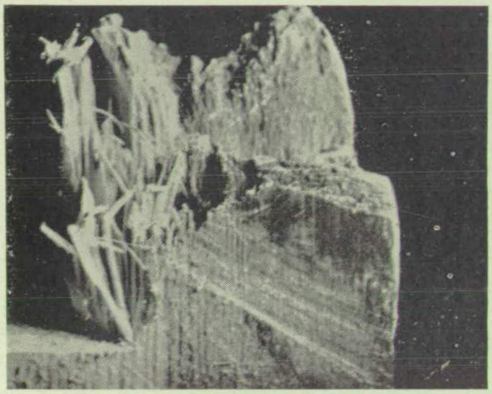


Fig.1. Telegraph-pole with brash fracture up to a depth of 5 cm.

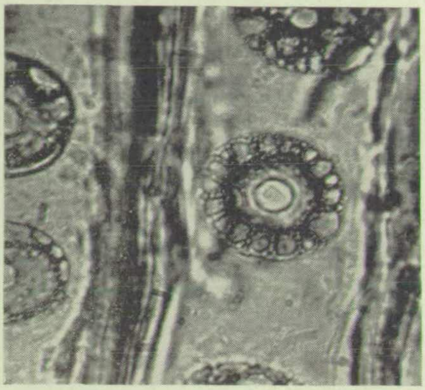


Fig. 2. Destruction of the bordered pits in the springwood. (x 1200)

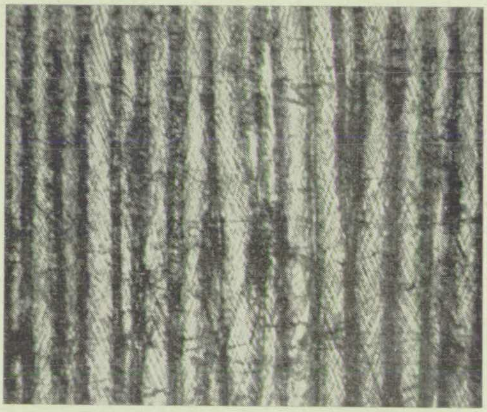


Fig. 3. Spiral destruction of the attacked cell-wall. (x 175)

Fig. 4. Micro-organisms on the cell-wall of a tracheid. (x 1350)

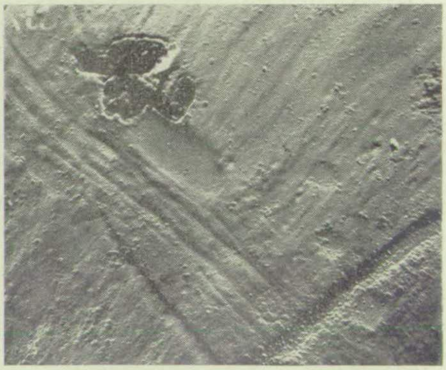


Fig. 5. Electron micrograph of a cell-wall of a tracheid with a fungalhypha and bacteria. (x 7200)

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SUMMARY OF CONVENTION PAPERS

By S. A. Richardson
(*Richardson & Starling Ltd.*)

The Chairman (the President),

Mr. J. A. Richardson, Mr. President, Ladies and Gentlemen,

This is the Twenty-fifth or Silver Jubilee Year in the history of this Association and so I hope you will forgive me for occasionally making references to the past during my summary of this year's papers.

Firstly, I must congratulate the Chairman and the members of the Convention Committee and our Secretary and his staff for the excellent arrangements made this year for the accommodation of the delegates and their guests. As a consequence of the railway strike, the outlook was very grim only a fortnight ago and I think there is cause for considerable gratification and congratulation that very, very few cancellations were received so that a total of over 200 members and guests have attended this Convention. It is particularly gratifying to learn that few of the overseas visitors were discouraged by our transport disruptions and every year the number of these visitors increases. If the popularity of the B.W.P.A. Conventions increases it looks like becoming one of the great international events of the year.

Now for the papers. Again they are well chosen and provide something of interest to every branch and twig of the timber preserving industry, including the users of the treated timber.

PAPER No. 1

The paper presented by Mr. J. G. Savory is what we all expect from an officer of the Forest Products Research Laboratory and so well follows the excellent paper presented last year by Dr. Findlay who introduced to our Convention debates the "Soft Rots". Reading through Mr. Savory's paper and the papers presented at previous Conventions by other officers of the D.S.I.R. makes it more and more apparent that all organisations engaged in the development and evolution of timber preservatives should have a mycologist and an entomologist on their staffs in addition to timber technologists, specialist chemists, engineers, service record experts and possibly an architect to advise on building structures and nomenclature. Mr. Savory's paper is of interest to those engaged in every branch of timber preservation for in it he refers to water-cooling towers, wooden piling in sea and fresh water, plywood, telegraph poles, railway sleepers, boats, fence posts, floor boards and blocks, draining boards, vehicles, etc., where, in many cases, the microfungi have attacked and decayed wood which had been pressure treated with well-tried preservatives. I know other organisations are already greatly interested and are experimenting with fresh chemicals and techniques to combat the effects of these fungi, particularly on water-cooling towers, but it is obvious that everyone engaged in timber preservation should have some knowledge of this form of decay as it seems to occur where the Basidiomycetes, with which most of us are familiar, cannot exist.

I should like to place on record how much we value the papers presented by the F.P.R.L. Looking through the pre-war journals of the Association, I find that the very first paper to be read at a meeting of this Association was presented by Mr. R. S. Pearson, the Director of the F.P.R.L., in November, 1930. In 1932 Mr. Cartwright read a paper on the Diseases of Timber; in 1933 our very esteemed friend Dr. R. C. Fisher, who is with us this afternoon, contributed a paper on "Research in Wood Preservation". In 1934, my namesake, Mr. N. A. Richardson, read a paper on Creosote, in 1935 Dr. W. P. K. Findlay contributed an article to the Journal on Laboratory Tests for Wood Preservatives. Since the War and the revival of the, more or less, dormant B.W.P.A., we find almost every publication of the B.W.P.A. owes something to the F.P.R.L.

PAPER No. 2

Mr. R. A. Bulman makes out a convincing case for Copper Naphthenate in his paper on "The Development and use of Naphthenates for Timber Preservation" but says very little about other naphthenates, in fact, makes only one or two brief references to zinc naphthenate. Are we to assume from this that the copper salt is pre-eminently the most effective as a timber preservative? I should like to have had more information regarding the results of tests carried out to determine the value of metallic naphthenates when used to inhibit or destroy our indigenous and most common fungi and insects, in particular, *Merulius lacrymans* and the death-watch beetle, as large quantities of metallic naphthenate solutions are being used in this country to control these pests. I think we will all agree that preservatives of this type have their place in the field of timber preservation in that they provide an easy and readily available material for use by carpenters, joiners and all who handle timber which is likely to be submitted to the hazards of decay and that they will greatly prolong the "life" of such timber provided the material is intelligently and conscientiously applied.

PAPER No. 3

When one sees trains and lorries loaded with untreated pit props being conveyed to the coal mines, it is not unreasonable to think—"If only they were treated with preservative, how much longer they would last and how much less would my fuel bill be as a result." But Mr. Hollingsworth has shewn us in his paper that a large proportion of pit props do not need treatment and if treatment were given it might put up the costs of coal production. It seems probable, however, that treatment of all mining timber employed permanently or even semi-permanently might be of economic value and might increase the safety factor in mine workings by reducing the danger of failure and collapse and, assuming the correct materials are used, the risk of fire.

PAPER No. 4

It is interesting to learn "how the other half lives", and to those of us who are not directly connected with the creosote section of the industry, Mr. Philip Grindell's paper was of great interest. How much more interesting it was to those engaged in pressure treatment of timber was brought out in the discussion which was so well handled by Mr. Grindell. I think we will find in another year or so that the Convention Records will form the finest encyclopaedia of timber preservation in existence and papers such as Mr. Grindell's will give to them a text-book value. The possibility of setting examinations on timber preservation and issuing diplomas of competence has been under consideration by a sub-Committee for some time and a syllabus has been discussed. One great problem to be overcome is the academic facilities available to students of timber preservation and another is relevant reading matter and text books. Papers such as that presented by Mr. Grindell greatly assist in resolving these problems.

PAPER No. 5

I am inclined to disagree with the title of Paper No. 5 by Mr. Price and Mr. Cook. I think it should have been "*Are there any* Recent Developments in the Evaluation of the Permanence and Toxicity of Wood Preservatives", for it seems to me that Messrs. Price and Cook have put into words what has been revolving in the minds of all laboratory workers for many years. In the introduction to the paper they state that, "During the last few years considerable efforts have been made in developing laboratory tests that can short-cut long term studies", but having read the paper one is left with the impression that few or any of these tests are really convincing or are likely to give a true indication of the results of practical application. However, they do suggest paths to be followed in the future by the laboratory workers.

I have dabbled in this sort of thing in the past and try to keep pace with new developments but the opinion I formed many years ago has not yet been changed and that is that no claims should be made for wood preservatives until they have been employed on the job for which they were intended for at least five years. Laboratory tests and even field tests should decide whether the expense and trouble of carrying out the full-scale test on the end product in service is justified but should not in themselves be regarded as proof of efficacy.

PAPER No. 6

When in York, some years ago, I met a gentleman very closely connected with the care and maintenance of the Minster. I asked him what was being done about the death-watch beetle in the timber and was told they were burning them! He informed me that all timber showing the slightest sign of infection was being ruthlessly removed and replaced with fresh timber. Very naively I asked if chemical control treatment had been considered and was told in a loud voice that nothing had any effect on the death-watch except fire. I murmured, almost under my breath, that they must find it rather expensive to hold such views, and withdrew.

Now we have Doctor Singleton from York presenting the case for the *in situ* preservative treatment and retention of insect and fungal attacked timber where it exists in historic buildings, and is sufficiently sound for its purpose, if only to save its "personality" or "fourth dimension". He tells us the causes of failure and emphasises that neglect is one of the greatest contributory factors. How true that is! If those responsible for the maintenance and care of churches, historic buildings and even buildings that are not historic had always kept the roofs, gutters and drains in good order, one branch of the timber preserving industry would be far less in demand than it is at this present time. Dr. Singleton's diagrams of suggested methods of repair where the ends of rafters, plates and beams have decayed brings to my mind an interesting feature often seen on mediaeval churches, and that is the shape of previous roofs which one often sees marked on the wall of the tower over the existing Chancel, Nave or Transept roofs. Often a series of inverted chevrons each of a shallower pitch occurs where the flashings or cement fillet of previous roofs have left their impressions on the wall. The reason for this is connected with timber decay for when the feet of the rafters decayed, the workers of bygone days cut them off and used what was left. They did not, as Dr. Singleton suggests, scarf fresh pieces on to restore them to their original length and so the pitch of the roof gradually dropped until even the stone tiles had to be replaced with sheets of lead. I am sure we all endorse Dr. Singleton's opinion that the repair of historic buildings should be entrusted to specialists. Those of us who spend so much of our time in the beautiful churches, colleges and other national heirlooms are so frequently shocked by the cheeseparing, makeshift and often sacrilegious methods adopted by some architects to deal with deterioration. Quite often, in dealing with the damage caused by neglect or ignorance, they try to impose their own wills, thoughts or designs so that the restoration bears little or no resemblance to the original. This is repeating what we condemn of the Victorian restoration and is a form of vandalism equal to that of the Cromwellians. The Church of England is now very much alive to its responsibility in regard to churches for which it is responsible and an order has been passed—having received Royal assent—to enforce a quinquennial examination of all church buildings by specialist architects.

Well, Mr. President, ladies and gentlemen, that concludes my summary of these six papers which, I am sure, had something in them of value to everyone engaged in timber preservation or interested in the final results.

The CHAIRMAN: Ladies and Gentlemen, I am sure that you would wish me to convey to Mr. Richardson our thanks for the very able manner in which he has presented the summary of the papers. We have now reached the end of the Convention apart from the Reception and Dinner this evening and, before closing, I would like to thank all those who have prepared and presented papers, taken the Chair at official sessions, and also all delegrates who have participated in the discussion periods.

I would also like to place on record our appreciation of the work undertaken by the Association's Staff.

Major A. G. SAUNDERS: Mr. Chairman, before the session ends I would like to express, on behalf of all delegates present, our thanks to you as President for your own part in ensuring the success of this year's Convention.

I would also like to place on record a vote of thanks to the Chairman and members of the Convention Committee for this year's arrangements.

B.W.P.A. CONVENTION, 1955

(Alphabetical list of Delegates and Visitors)

A

AARON, J. R.	Forestry Commission
ADAMS, H. C.	Ministry of Transport & Civil Aviation
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ALLEN, T. C.	Admiralty
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ASHLEY, S. D. E.	Calders Ltd.
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AYLWIN, W. E.	Midland Tar Distillers Ltd.

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C

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Cox, H. A.	British Wood Preserving Association
Cross, A. C.	*Gas Journal*
Cunnington, W. G.	Midlands Electricity Board
Cutbush, P.	British Standards Institution

D

D'Ambrumenil, C. H.	Pyman, Bell & Co. Ltd.
Davis, E. N.	*Chemical Trade Journal*
Dodd, A. H.	Cobra (Wood Treatment) Ltd.
Donnelly, G. V.	Wm. Brandts (Timber) Ltd.
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