RECORD

of the

1957 ANNUAL CONVENTION

of the

BRITISH WOOD PRESERVING ASSOCIATION

Cambridge,
July 3rd—6th, 1957

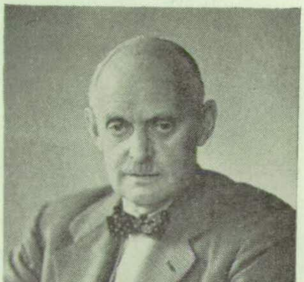
BRITISH WOOD PRESERVING ASSOCIATION
6, SOUTHAMPTON PLACE, LONDON, W.C.1

W. K. Hutchison

C. S. White

T. G. Robinson, O.B.E., T.D.
President of the British Wood Preserving Association

W. E. Vesey



B. Hickson

The British Wood Preserving Association

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

It is a great pleasure this morning to welcome you all to the seventh Annual Convention of the British Wood Preserving Association. Many of you have come for some years past and for others again it is a new experience to attend this gathering but each one of us, I am certain, will find the two days both stimulating and interesting. I hope also that all who are strangers will make many friends before we disperse.

I particularly wish to convey greetings to those who have come from overseas—from Canada, Eire, France, Holland, India, East Africa, Norway, Portugal, the United States of America and Sweden and to express the hope that on Saturday they will think their long journey to Cambridge to have been fully worth while.

Representatives are present from the Admiralty, British Transport Commission, the Building Centre, British Standards Institution, Coal Tar Research Association, Central Electricity Authority, various Area Electricity Boards, Edinburgh University, the Fire Research Station, Forest Products Research Laboratory, various Gas Boards, London County Council, the Ministries of Supply, Civil Aviation, Fuel and Power and works, the National Coal Board, the National Federation of Box and Packing Case Manufacturers, the Post Office and, very closely allied to us, the Timber Development Association and the Timber Trade Federation of the United Kingdom and to each and all I would like to say how much their presence here is appreciated by every member of the British Wood Preserving Association.

This Convention is only one section of the work carried out by the Association but it does present, in striking form, and perhaps especially so this year, the wide and growing interest which has been so noticeable in recent times in the problems connected with the protection of timber. The presence of our friends from overseas lays emphasis on this and even more so the fact that so many representatives of timber consuming industries have thought it of value to be present. I cannot stress enough how much their help is appreciated and valued, because it is only from the experience of the users that much of the knowledge about the problems of adequate prevention can properly come.

This year in the papers which are to be presented for our thought and discussion there is introduced a broad variety of the factors affecting preservation and the consideration of these various aspects will, I feel certain, keep us all on realistic lines, because not only are we to be faced with certain of the enemies of timber, but we are also to consider the means of preservative application both before and after the timber is in its final structural position. It is extremely important and, although I said it last year, I stress it again that we should all appreciate that a reliable preservative is only one half of the answer and that effective methods of application require equally close and sustained study.

We as an Association are concerned primarily with the assembling and production of knowledge and, therefore, at these Conventions publicity and publicising have hardly been mentioned in our discussions. I wonder, however, if perhaps almost in shying away from such considerations we have not gone somewhat wrong. All of us know that on matters of timber preservation superficial confidence can be extremely dangerous, and to-day many people who handle timber in one form or another may not ensure adequate protection simply because of lack of knowledge. The fact that this is so does not make it any better for timber, and only too often we have evidence of perfectly reliable preservatives failing in proper protection because they have been applied in some entirely superficial and unknowledgeable manner. To say that the average user of timber is conservative in outlook is an overstatement and, therefore, I suggest that in addition to the scientific problems of our industry it is necessary also to give much thought as to the means of adequate presentation of knowledge to those who will ultimately be responsible for placing timber in structures of all varieties and kinds. So, although at these Conventions matters of publicity and the dissemination of knowledge have not perhaps been given their full place it is, I am sure, for very careful consideration as to the best means of spreading sound understanding abroad.

I also plead, Ladies and Gentlemen, for realism in our discussions. At a gathering of this nature sometimes enthusiasm for the treatment may outweigh practical considerations and it is to be remembered that many of us are confronted with such considerations each business day. In other words, good preserving cannot really be separated from reasonable remuneration. I make no apology for referring to this to-day because if one thing is clear from the combined experience of the past 50 years it is that it is the greatest possible mistake to sacrifice treatment to a too rigid regard for cost. It may be difficult sometimes to see how the buyers' and the treaters' points of view on such a matter can be properly resolved, but does the answer not lie in the adoption of recognised standards of treatment. Our own Association, the British Standards Institution and certain public bodies are all concerned and, for myself, I am convinced that the stricter the standards the better in the long run it will be for the timber merchant, the treater and most important of all, the ultimate user.

Unfortunately the Timber Trade is an extremely competitive one and all the time the seller of timber is striving to make his commodity as inexpensive as possible and I think that in the past if not in the present that timber preservation has suffered from this state of affairs. It is in no one's interest if quality, and I mean quality of reasonable standard, is to suffer because of price and if in the present we adopt safeguards against this then the task of our successors whether they be concerned with the selling of timber or in the management of treating plants or as users in many varieties or forms will be lightened in great degree.

Ladies and Gentlemen a great deal of thought and work has gone into the preparation of the papers which are to be presented to you, and your interest and I know sincere appreciation will be verbally displayed if you take part in the various discussions. In past years the constructive criticism arising from such discussions has been striking and I am sure that it will not be less so this year. My part is nearly at an end, and, therefore, I have the greatest possible pleasure in declaring open yet another Convention of the B.W.P.A.

(1) AN ACCOUNT OF MARINE BORERS WITH SPECIAL REFERENCE TO BREEDING

by Professor J. E. G. Raymont

(*Zoology Department, The University of Southampton*)

Introduction

Among the most destructive agents of timber in sea water are several species of animals which bore into the wood and so rapidly reduce its strength. Perhaps the oldest known of these marine borers are the ship-worms. They are believed to have destroyed the triremes of the Greeks and the galleys of the Romans; down through the centuries they have continued to be a menace to wooden ships. Ship-worms, however, will attack all kinds of wooden structures and an early investigation of this borer followed its ravages on the wooden dykes of Holland in 1733 when a large part of the country was threatened with inundation.

The speed and extent of ship-worm attack is remarkable. The well known infestation by one species in San Francisco Harbour during the First World War caused damage estimated at ten million dollars; in the 1930's the spread of borers to Plymouth, Massachusetts, caused destruction of every wharf in three years and at Lynn Harbour, Massachusetts, the damage in one year was assessed at a million dollars.

In British waters there are several species of ship-worm but some of these occur mostly in floating timber and only two (*Teredo navalis* and *Teredo norvegica*) are of real economic importance. *Teredo norvegica* is relatively a northern species; it is found for example as far north as the Arctic waters of the U.S.S.R. *Teredo navalis* is a more southern species; it is now widely distributed, having been carried by wooden ships to most commercial ports the world over.

I. Teredo.

General Account of Teredo

Ship-worms of various species are generally similar in appearance, being worm-like in shape. British species may be 12 in. or so in length. They lie in the galleries which they have excavated in the wood, each worm lining its gallery with a calcareous secretion. *Teredo* belongs to the group Lamellibranchiata (bivalve molluscs), and thus, despite its greatly modified body form, retains the pair of calcareous shell valves.

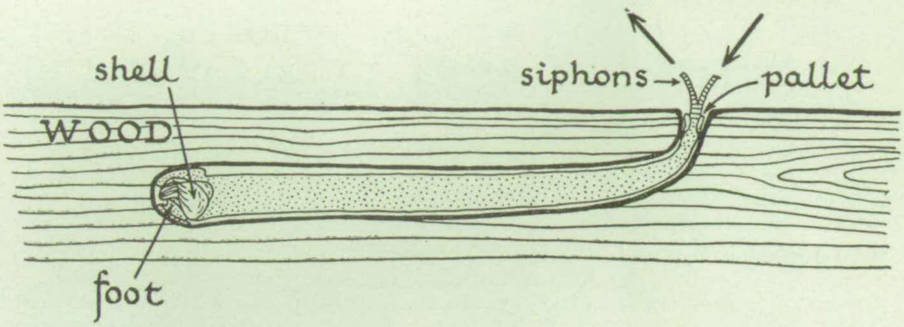


FIG. 1.

These are small and lie at the front of the animal. (Fig. 1). They are marked with lines of tooth-like projections externally; internally the two shell valves are hinged on each other, both at the top and below, by a kind of ball-and-socket joint. Strong muscles cause the shell valves to rock on each other, and the movement causes in turn the toothed ridges on the shells to rasp against the wood of the gallery. A small muscular protuberance (the foot) at the front of the worm presses against the end of the burrow so giving sufficient purchase for the boring process to be effective. There is no chemical aid to this boring; it is done mechanically by the shell valves.

The only external opening of the gallery on to the surface of the wood is very small ($<0{\cdot}5$ mm.) and at the hind end of the animal. It can be closed by two small plates (pallets). From this opening there can extend from the animal two fine tubes—the siphons. When these siphons are extruded to the sea water, one of them acts as an inhalant tube drawing sea water in, while the other (the exhalant siphon) passes water out again. The function of this current of sea water is to carry oxygen in the water to the *Teredo*, but it also brings in minute microscopic floating life (plankton) on which the ship-worm partly feeds. After a long controversy it is now known that the ship-worm can also partly digest the wood which it rasps away.

On the whole, unless there are numerous worms in the same piece of timber, *Teredo* will make its burrow along the grain of the wood, taking the line of least resistance. But if several worms occur in the same piece, boring will go on in all directions, though a *Teredo* will not invade another's burrow. A wood pile, however, with a heavy infestation can become completely riddled by the galleries, and then only a slight shock is necessary for the timber to collapse. The especial danger of *Teredo* attack is that piles can get into a very weakened condition without any obvious diseased appearance from outside; the external openings to the burrows of the ship-worms are so small that they are very easily overlooked.

Salinity and Temperature Effects

Teredo of course cannot live in freshwater; hence the old practice of taking a sailing ship into freshwater to kill the worms in the hull. However, they can stand considerable dilution of sea water and, according to Kofoid (1921) and Blum (1922), remain active at salinities even below 10‰, as compared with normal sea water (35‰). Blum records that at lower salinities the animals close the galleries with their pallets and thus survive for a long time; the average lethal salinity is about 4-5‰. Kofoid, however, believes that the larvae need higher salinities of 10-15‰.

In general ship-worms appear to be more sensitive to temperature than to salinity. In Europe *Teredo navalis* becomes inactive below 5°C., though it can withstand even freezing for some time. It is most active over the temperature range 15-25°C. and can tolerate even 30°C. In Canadian waters also the optimum temperature is high (more than 20°C.) and low temperatures are unfavourable, though limited survival occurs even near freezing point. *Teredo norvegica* on the other hand is a more northern species and might be expected to be adapted to lower temperatures. Nevertheless, in Norway it has been shown that the most severe years of attack of *T. norvegica* on the whole correspond to the warmer years.

Breeding

It is, however, the susceptibility of the young of *Teredo* to low temperature rather than the effect on the adult animals which limits their distribution. This raises the important problem of the breeding of ship-worms. It is surprising that as late as 1855 the young of *Teredo* were not generally known; Jarvis for example, attributed the rapid growth of *Teredo* attack to spontaneous generation! Some 5 or 10 years later, however, the young larvae of *Teredo* had been well described.

The young larvae are of very small size and they drift with the floating population of minute animals and plants—the plankton—which occurs in the sea. The larvae, therefore, can infect new timber only in random, haphazard fashion, relying on the currents and tides to bring them into touch with fresh wood. Experiments have shown nevertheless that the larvae are attracted to wooden surfaces and settle on those, whereas larvae of the same age touching concrete, iron or other surfaces will continue to swim and so drift away again. They will also choose untreated timber to settle on rather than timber which has been creosoted.

Teredo norvegica appears to be able to breed over most of the year in Britain (Lebour, 1938). This is presumably because it is a fairly northerly species, so that winter sea temperatures are not too low in normal years. In colder Norwegian waters, June/July is the most intense period for attack, though spawning can occur from May to September.

Teredo norvegica releases its eggs into the water where they are fertilized. The ship-worm is rather unusual among animals (though not so exceptional for Mollusca) in that it produces sperm first (i.e. as a male animal) and then later changes to a female condition and produces eggs. The young larva which develops rapidly from the fertilized egg in the plankton measures only some 0·05 mm. at first. It has a small shell of 2 valves, thin and without teeth. A little fleshy lobe can be pushed out of the shell covered with fine hair-like projections (cilia) which beat to and fro. By this means the larva can swim. It, however, can do no more by this limited movement than change its level slightly in the water and take in food; it is swept along entirely at the mercy of the tides and currents. The larva grows for probably about 3 weeks until it is approaching half a mm. in length, when metamorphosis to the ship-worm condition must take place. But metamorphosis, if it is to be successful, must occur on a wooden surface. The shell valves by this time have developed four sharp tooth-like projections; siphons are beginning to grow from one side of the animal and a minute foot has also developed. As soon as this late larval stage touches a wooden surface, the shell valves begin to rasp away with their teeth at the wood, and the small larva rapidly pushes itself into a very shallow burrow. Further boring takes it deeper into the wooden structure and the animal now elongates rapidly. The shell valves remain near the front end of the animal while the body with the siphons grows extensively in length to give ultimately the elongate body form of the typical ship-worm.

In several weeks of larval life it is clear that many of the larvae will die or never reach a wooden surface. Nevertheless it is believed that a single *Teredo norvegica* can produce several million eggs, so that the possibility of heavy infestations is still apparent.

In the case of *T. navalis* the ship-worm is viviparous (i.e. it retains the eggs inside the body and these are fertilized and develop there). The larvae are released into the plankton only when they are about a tenth of a mm. in length, and they remain in the plankton only for a short time. They may remain clustering near the wooden surfaces close to where they have been released so that somet'mes they hardly enter the plankton. When in the plankton it appears that they have a somewhat shorter time than *T. norvegica* larvae before metamorphosis. If settlement occurs on a wooden surface the shell valves commence to bore in; the larva has developed meantime its siphons and foot, and rapidly assumes the ship-worm shape.

In British waters *Teredo navalis* probably breeds mostly in spring and summer (Lebour, 1938). In North America its breeding season is given as from May to October but a single female may spawn several times, producing altogether several million larvae. (Grave, 1928). Nelson suggests they breed actively only in temperatures above 15°C., with an optimum at about 20°. Probably again the breeding season varies with the water temperature. The larvae appear to be more sensitive than the adults to low temperatures; temperatures much below 10°C. are unfavourable for larvae and certainly temperatures near freezing will destroy them although the adults may still survive. Nevertheless, there is some suggestion that the larvae might have acclimatized to some degree so that probably they can stand lower temperatures in more northern countries than they can in the south. In our own waters it appears probable that slightly warmer conditions favour attack by this ship-worm. Some of our sudden outbreaks have been attributed to wooden ships from foreign waters carrying adult ship-worms in their hulls, lying for a time in harbours with slightly warmer conditions, so that the larvae liberated can survive in large numbers.

Many other conditions will affect the intensity of larval attack. Apart from the differential susceptibilities of various woods, some experiments have suggested, for example, that larvae of some species prefer timber which is in fairly deep shade. Lowered salinity certainly seems to be less favourable to the larvae than to the adult, but it appears that low temperature is the chief limiting factor.

Having bored into the timber, the young ship-worms can become sexually mature fairly rapidly—in North America in as little as two months—and they are full grown in a year (Grave, 1928). The liberation of some millions of larvae can, therefore, go on so rapidly that a high rate of infection can be set up in a short time. Test blocks which have been put out in a heavy infection (e.g. at Swansea Docks during the last war) have shown the surface of the timber to be dotted with minute holes where young ship-worms had entered. It is true that many of these will die, and that relatively few will grow into full-sized worms excavating large galleries. Nevertheless, it is clear that with a sudden attack, timbers can be rendered useless over a comparatively short period.

II. Limnoria.

While ship-worm attack is perhaps the most devastating of marine borers, damage due to crustaceans is also enormous. The chief crustacean attack is by *Limnoria*, commonly known as the gribble. *Limnoria* measures only some 4-5 mm. in length when full grown. As a typical crustacean the body is divided into distinct segments and it is covered with a chitinous exoskeleton. The whole body is flattened; the head is provided with paired antennae and bears also a pair of very small eyes. On the under side of the head are the mouth parts of which the most important are the paired mandibles. These are the organs used for excavating the burrows. The two mandibles are not identical: the one on the right hand side has a small protuberance projecting from its basal joint ending in a sharp point. The surface of the protuberance is roughened and works in a coarse groove on the left mandible. The two act like a rasp and file and together form an efficient mechanism for boring into the wood.

The head is very inconspicuous and the main length of the body is made up of 7 segments of the thorax region. Each of these segments bears a pair of jointed legs ending in a claw. The legs brace the gribble tightly against its burrow and this gives the necessary purchase during tunnelling. In the female the lower half of the thorax forms the brood pouch for the young. There is a much shorter 6-segmented abdomen, of which the last segment is by far the largest and is rounded behind. The abdomen bears below small plate-like limbs which can be used for swimming: the limbs are also important in respiration.

There are several closely allied species of *Limnoria* which are difficult to separate. *Limnoria lignorum* was first described but it appears to have been confused often with *L. quadripunctata*. Both are widespread in distribution; *L. lignorum* is boreal and can stand the low temperatures obtaining in the Barents and White Seas and off Iceland, as well as occurring in the temperate regions of Europe and off both the Atlantic and Pacific coasts of America. According to Menzies (1954) these two species are succeeded in the warmer waters of North America by the temperate/tropical species, *L. tripunctata*. He suggests that this species can occur in creosoted wood but at present there are no obvious grounds for regarding it as more dangerous. In Southampton all three species occur side by side in one timber, but a piece of wood from another British port (with possibly higher temperature conditions) showed, on recent examination, *L. tripunctata* only.

With *Limnoria* there very frequently occurs another small crustacean, *Chelura*. There is still considerable argument as to how far *Chelura* is destructive to wooden structures; according to some authorities it does little more than enlarge gribble burrows. It appears under laboratory conditions not to survive without *Limnoria*. In any event *Limnoria* damage is overwhelmingly dominant, and discussion will be limited to this animal.

In the British Isles *Limnoria* is so widespread that hardly a wooden pile which has been exposed for any length of time in a harbour is free from attack, and although *Limnoria* is small in size (3-4 mm. in length) it can occur in enormous numbers. Apart from the much smaller diameter of gribble burrows as compared with ship-worm galleries, the gribble differs in that the tunnels are excavated close to the surface of the wood with small bore holes sent up vertically at intervals to the surface. (Fig. 2). Boring begins in a soft part of the wood and runs in at an angle, but once the tunnel has been begun, the excavation is continued parallel to the surface of the wood. The tunnel is comparatively short (about one inch) but the young push out new burrows on each side (Fig. 3) so that in a comparatively short time the whole of the wooden surface becomes weak and rotten and is rapidly worn away. The damage due to *Limnoria* can be quite as severe as that caused by ship-worms and can be rapid. Indeed in many ports around our coasts *Teredo* is fortunately almost unknown, but there is hardly an area which is not heavily infested by *Limnoria.* However, it is true that the wearing away of timber owing to gribble attack occurs from the surface inwards. In so far as this goes, the dangers of a serious *Limnoria* attack are somewhat less than those due to ship-worm since the damage can be readily assessed.

Temperature and Salinity

Although *Limnoria* would appear to be less sensitive to low temperature than ship-worms, the effect of temperature on rate of boring is quite marked. Tests which have been carried out in our laboratory by Hockley and Eltringham (unpublished) have shown that boring activity increases fairly steadily from 5° to 27°C. In point of fact, temperatures in the British Isles will, of course, not reach this upper level, and about 17°C. may be regarded as approximating to the usual summer maximum. If we regard the boring activity at this temperature as maximal, the activity at 10°C. is only 20 per cent., and at 5°C. boring activity appears almost to cease altogether. Since, over winter, temperatures as low as 5°C. may occur for some weeks in inshore waters, it appears that the destructive activity of *Limnoria* will be greatly reduced from, say, January to March. Although, however, activity at lowered temperatures is reduced, burrowing does not cease; new burrows are started but their average length is much less than at higher temperatures. Moreover, even at much lower temperatures the gribbles, though inactive, are not killed.

Lowered salinity has a much more marked effect than has lowered temperature on viability and activity of gribbles, and here *Limnoria* appears to be more sensitive than ship-worms. Experiments by Hockley and Eltringham (unpublished) have shown that there is a fall in burrowing activity with a reduction in salinity, but the fall is not very marked until a salinity of about 15‰ (i.e. ca. half seawater) is reached. Below this level, even a small further drop in salinity greatly reduces the activity. Experiments, for example, have shown that at salinities less than 10°/oo activity is virtually zero. Most authorities agree that lowered salinity rather than lowered temperature is the main factor limiting *Limnoria*, although the precise limits vary somewhat. Thus some investigators place the limit at ca. 10°/oo, stating that *Limnoria* die if exposed for any length of time to salinities below this value; Sømme (1940) quotes 15°/oo for Norwegian waters while others suggest the limit for full activity is as high as 20°/oo.

Breeding

In any one burrow there is usually a pair of *Limnoria*, one female and one male, the female lying at the blind end of the gallery and apparently carrying out the active boring. (Fig. 2.) This pairing appears to last for several months and the male probably fertilizes the female several times. Only small, relatively new, burrows contain a solitary individual which has not yet paired. (Fig. 3.) The female after fertilization does not liberate eggs into the sea but they are passed into a brood pouch under her body. The number of eggs produced is infinitely smaller than in the case of ship-worms. The number usually quoted is 20-30 per female; Sømme (1940) gives a range of 10-35 for Norwegian waters.

Menzies (1954) shows that the number of eggs tends to fall from the boreal species *L. lignorum* with a mean of 22 per female (range 10-35) to *L. andrewsi*—a tropical species with a mean of 4-5 (range 2-6). *L. tripunctata* is perhaps intermediate with a range of 1-22 eggs per female (mean 4-10), as also is *L. quadripunctata* (mean 9·5; range 1-17). Eltringham (unpublished) also suggests, however, that for any one species the number of eggs is directly correlated with the size of individual.

Although the number of eggs therefore is so much reduced as compared with *Teredo*, young gribbles do not face the tremendous mortality of planktonic life as do *Teredo* larvae. The young develop, protected by the female, until they are liberated as complete small replicas of the adult. On liberation from the brood pouch these young

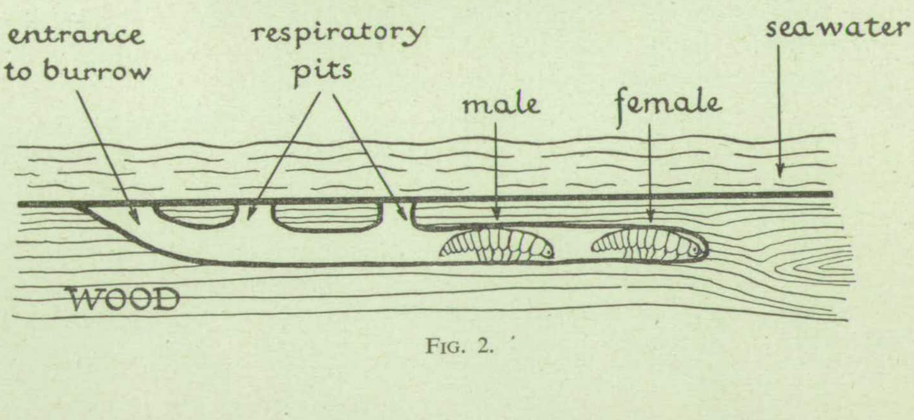


FIG. 2.

FIG. 3.

immediately begin to burrow on their own account pushing out galleries from the side of the parent burrow. (Fig. 3.) In this way they remain protected almost throughout their lives, and a very large population of gribbles may be built up comparatively rapidly in a small piece of timber. It has been estimated for example, that a really heavily infested piece may have up to 400 *Limnoria* in a square inch of wood. Menzies (1954) gives even up to 600 per square inch.

It appears that a single female may produce several broods (4 to 5) during a season and that breeding is possible all the year round in a temperate climate like the British Isles. The young develop in a few weeks: Sømme (1940) quotes 5 to 6 weeks for Norwegian waters so that probably about a month is sufficient in our waters. Eltringham suggests a lower limit of ca. 7°C. for development; he finds about a month for development at 15°C., but less than 3 weeks at a temperature of 19°C. On the other hand, even in Britain, reproduction is more intense over the spring and summer: the effective breeding season runs from about May to October with the maximum from May to July (Hockley and Eltringham—unpublished). On the west coast of U.S.A., Johnson (1935) states that gravid females occurred in all months, but with a maximum in April/May; Sømme finds that in Norway hatching of young goes on throughout the summer but is reduced over winter. Eltringham suggests, however, that there is a difference between the species so that while almost no breeding occurs over winter in *L. tripunctata*, an appreciable degree of breeding goes on in other species.

In North Carolina Coker also did not find breeding in *Limnoria* (probably *L. tripunctata*) in winter.

Migration

Since *Limnoria* does not release its young into the plankton, the spread and infection of new timber would appear to present a problem. During a limited part of the year there is a migration of young gribbles from old to new timber. Johnson (1935) found that this migration was confined to the period January to July with a marked maximum in March, April and May. It is not clear why this migration to new wood occurs; but overcrowding may operate. *Limnoria* can swim effectively and fast, but in the laboratory they appear to cease swimming after a comparatively short time. It would appear that they migrate actively only over relatively short distances. Longer migrations must be effected passively in floating wood. Once arrived at a new wood surface the animals bore in, and subsequent reproduction for the rest of the year is confined to the same timber.

Summary

As for *Teredo*, there are factors other than temperature and salinity, which affect the intensity of *Limnoria* attack. Apart from different degrees of susceptibility in various timbers, it is suggested that shaded areas are sought out and that low tide level may be a particularly marked region for colonization. Silt would appear to deter gribble attack as also does a heavy settlement of barnacles. But the main conclusion is that *Limnoria*, while withstanding low temperatures, is susceptible to lowered salinity, while *Teredo* can flourish in fairly low salinities but is greatly affected and limited by low temperature.

It has been sometimes suggested that heavy pollution, more particularly chemical pollution in harbours, greatly depresses the incidence of both types of borer; this would bring us to the ironical conclusion that as a harbour is made cleaner it may become more liable to heavy attack by both ship-worm and gribble. Heavy infections do occur, however, under markedly polluted conditions, and the need for precise observations both in the field and in the laboratory on this problem also is once again obvious.

BIBLIOGRAPHY

BLUM, H. F., 1922. On the effect of low salinity on *Teredo navalis*. Univ. California. Publ. Zool., Vol. 22, pp. 349-368.

GRAVE, B. H., 1928. Natural history of the shipworm, *Teredo navalis*, at Woods Hole, Massachusetts. Biol. Bull., Vol. 55, pp. 260-282.

JOHNSON, M. W., 1935. Seasonal migration of the wood-borer *Limnoria lignorum* (Rathke) at Friday Harbour, Washington. Biol. Bull., Vol. 69 (3), pp. 427-438.

KOFOID, C. A., 1921. Factors controlling the distribution and ravages of the marine borers. Proc. Amer. Wood-Preserv. Assoc., Vol. 17, pp. 327-339.

LEBOUR, M. V., 1938. Notes on the breeding of some lamellibranchs from Plymouth and their larvae. Journ. Mar. Biol. Assoc., Vol. 23, pp. 119-144.

MENZIES, R. J., 1954. The comparative biology of reproduction in the wood-boring Isopod Crustacean *Limnoria*. Bull. Mus. Comp. Zool., Harvard College, Vol. 112, No. 5, pp. 364-388.

SØMME, O. M., 1940. A study of the life history of the gribble, *Limnoria lignorum* (Rathke) in Norway. Nytt. Mag. for Naturvid., Vol. 81, pp. 145-205.

Figures 1 and 2 are reproduced from the book "The Sea-Shore" and the New Naturalist series, by kind permission of the publishers Messrs. Collins and the author Mr. C. N. Yonge.

Discussion on Paper 1

The PRESIDENT (Mr. T. G. Robinson): Ladies and Gentlemen, it is a great pleasure to introduce Professor Raymont who is to lead the discussion on his own paper dealing with marine borers.

Professor Raymont has been associated with so many universities that I am not clear as to which one he owes the most. After I tell you that he has been connected with Exeter, London, Harvard, Edinburgh and now Southampton, you perhaps will wonder. Being a Scotsman, I have not the least doubt, and I see most of you agree with me on that! Professor Raymont has a most distinguished career behind him and we are very fortunate in having him with us this morning.

After making his introductory remarks, he is going to show some slides and then the time will come for questions. Professor Raymont wishes to answer each question as it arises and not hold them back until he has a store, so perhaps you will remember that.

I again repeat it is with the greatest of pleasure that I ask Professor Raymont to introduce his Paper.

Professor J. E. G. RAYMONT: Mr. President and Chairman, Ladies and Gentlemen, perhaps I cannot quite answer your question as to which university I owe most allegiance; but can I say one thing for Edinburgh! At least I took my wife from that university!

I am truly honoured, Sir, that you should have asked me to addre s your Association. I am not quite sure I am honoured, at least I am n o quite sure that I am pleased to be first man in, as it were, in the morning. I feel here you are all fresh from breakfast and all ready with a great series of questions. I am perhaps particularly fearful because normally I have to address my own students and they seem to run away with the idea that there is a great fount of knowledge among the academic staff and so one can get away with a lot! I am in a further difficulty, Sir, because, of all things, I have no knowledge of timber and certainly know nothing about preservative measures, so that I feel rather at a loss coming here to speak to you.

The particular subject I would like to introduce concerns first of all a general survey of one or two of the most important marine borers, and then I would like to turn your attention to certain experimental work done on *Limnoria*, the crustacean borer, which, as you know, has been conducted from my laboratory in Southampton. I have chosen that because, although there is a most voluminous literature on marine boring animals, I would go as far as to say that there is very little detailed strict experimental quantitative work. Much more must be done in the laboratory before one goes on to use methods in the field. I am quite ready to be shot down for that, I put it out as a challenge but that is my contention. I therefore believe that there is a lot to be done in the laboratory on an experimental scale. Normally that is the way it develops in pure and applied science: one starts from the laboratory and then one goes to practical measures. I just wonder, Sir, if we have not jumped the gun when it comes to marine borers.

First of all, I would like to talk a little about *Teredo*, though I should emphasise that we have very little ship-worm, very fortunately, in Southampton, and so this is not experimental work which we are conducting ourselves. It is just a quick review of the current literature. Perhaps I could have the slides as we go, I think that might be easier. Could I have the first one please?

Slide. This is a direct print from my Paper and I have put it in only to call attention to the opening you see there, where the siphons are coming out from this minute hole in the wood. I would like to stress that this external opening, the only opening which the *Teredo* has to the outside sea-water, is extremely small. That makes a difficulty when you come to doing experimental work on *Teredo*. Two of the factors which have been quoted so much as affecting ship-worm are, of course, temperature and salinity. If you try to do experimental work on the survival of *Teredo* at lowered salinity—that is to say, working down from full sea-water, 35 parts per thousand downwards—you will find that the lower limit for survival is something which is difficult to determine. If you look in the literature, I think you will find there is a good deal of discrepancy as to what the lower limit is. The real difficulty is that the ship-worm can, by means of these pallets, shut the hole off for quite a considerable period of time, and, therefore, can survive with the little sea-water in the burrow, although the external sea-water, if it were truly exposed to it, is at a concentration which would kill it. This then just illustrates one of the difficulties when you come to detailed investigation. It is not without some practical significance because, of course, it does mean that your ship-worms can go fairly far up an estuary, and provided they get an occasional high tide to give them a higher salinity, they can survive quite well and even burrow quite effectively in the wood although they are in a reach of the estuary which is really beyond their natural limit.

There is no doubt that temperature is a much more potent factor in limiting *Teredo* than is salinity, but here I would like to go on straightaway to considering the effect of temperature on the young of *Teredo*. This introduces, in fact, the subject of breeding which is really what I shall be talking about mainly.

Slide. These are outline diagrams to try to indicate the life history of *Teredo*. One of the reasons that *Teredo* can go ahead and produce such mass infestation so rapidly is that it produces a very large number of young; they run into millions. Further, the young are released from the adult animal into the sea-water, into the plankton. I would like to pause here for a minute because I have been told that I have not made it entirely clear as to what I mean by 'released into the plankton.' The slide that you have just seen showed you that *Teredo* has a minute hole through which it can put itself in communication with the sea-water. Through that hole eggs are liberated and pass into the water; they then mix with a vast multitude of minute plants and animals which is collectively termed the plankton. They live there, and they do have as they develop a limited power of movement, but that movement is such that it is completely ineffective against the set of tides and currents. I hope I have made that clear and that is what I mean by 'released into the plankton.'

The development of the eggs goes on in the plankton as the eggs drift about and, of course, by means of this drift they are taken considerable distances and can infect new wood; hence the very great infestations. This is a brief diagrammatic representation of the way the young develop. From the egg stage, after a matter of two or three days, this larval stage is reached which in size is only of the order of about a twentieth of a millimetre across. It has a little lobe here covered with cilia—fine hairs—by which it has a very limited power of movement. This is a somewhat later stage and shows that the larva has developed a little bi-valve shell. After about a fortnight from the production of the egg, you reach this stage where the larva is really in the process of metamorphosis. Now, at this stage it must be on a wood surface in order to complete its metamorphosis properly. It has now reached a new wood surface and it changes rapidly. The shell begins elongating; the shell also develops these spines shown here which help it to bore into the wood and a little later on we have this stage. Here is the beginning of the elongation which is the foot and forms the effective purchase for the adult *Teredo* when it is burrowing in its gallery.

Slide. This shows you a later stage. I should, perhaps, have said that the total development takes about three weeks to completed metamorphosis. This stage is a further five weeks after metamorphosis, in other words, eight weeks from the egg stage. This is the shell which has developed its familiar ridges of the *Teredo.* These ridges on the shell with the teeth, form the burrowing agents. The larva is now elongating considerably—getting in more ship-worm shape—and here are the siphons by which the animal remains in communication with the outside water. The development then is very rapid and this in turn, of course, affects the heavy rate of infestation. Moreover, it is only a matter of a few months before this animal here can become sexually mature itself and start producing its own crops of eggs.

Slide. I would now very briefly like to turn to *Limnoria* which is the important crustacean burrower. I want to indicate here the results of an experiment we did on the rate of burrowing by *Limnoria* in selected pieces of wood in the laboratory at different temperatures. I should say, by the way, that I have only put in a few points here. We have checked this carefully and the graph which is shown here is a calculated regression line. It may look a little curious that we are going up to 200 per cent. here. The reason for that is that this temperature which will normally occur in British waters—that is to say at the height of the summer—is something approaching 20°C. and we have made the amount of burrowing equivalent to 100 per cent. You see that below that the amount of burrowing falls off very greatly. Below 10°C. the burrowing is negligible and it actually, according to our results, ceases entirely at something like 5°C. or 6°C. You will see, however, that if water is warmer than one normally gets on British coasts, there will be a very rapid increase in burrowing rate.

Slide. We made a few experiments on the other most important environmental factor of salinity. There is little doubt that salinity acts as a very powerful brake indeed on *Limnoria*, and this shows again some laboratory experiments in which we have plotted burrowing activities against salinity. In this case, of course, we have made 100 per cent. equal to full salinity water which comes about there, that is about 35 parts per thousand. You see a sharp drop as salinity declines and we believe that certainly below 10 parts per thousand salinity—I know that is considerable dilution—the burrowing activity is virtually zero. Although then, in my opinion, salinity is the most powerful brake on

Limnoria, I do want to stress that temperature has a very marked effect, particularly on breeding. We have also done a few experiments here and our results were complicated fairly early on by finding out that we have three closely allied species of *Limnoria* in the Southampton area. This is nothing new, it has been reported before, but I believe it is the first time in this country that it has been shown so clearly that there are three such closely allied species all in one region. In fact, we have a piece of wood in the laboratory where we have all three species in one and the same block. The results are complicated by these three species because they do show differences in their breeding times and in their breeding intensities in relation to temperature. If you take what was always called the recognised *Limnoria*, *Limnoria lignorum*, the northern species, this will breed fairly happily to a small extent throughout the winter, certainly round Southampton, and I believe generally round the British Isles. It does not seem to breed in winter further north; for example, off Norway I believe the breeding intensity drops almost to zero during the winter months. However, in Southampton there is a reduction of breeding during the winter but still some does occur.

The species known as *Limnoria tripunctata*, however, is really a warmer water type. It is a semi-tropical form common in America, but the breeding of this species is cut off completely during a normal winter and a real burst of breeding activity occurs round about June, July and August. We have a few results on the numbers of young per adult, and we have been able to show—as others have—quite conclusively that the numbers of young vary between the three species again. However, in my opinion, all this emphasises the need for exact work on *Limnoria*: laboratory work, for instance, on salinity and on temperature; measurements in relation to burrowing activity, but working on each of the three species in turn. This is a line of research which is only starting; there is little in the literature showing detailed work on species. This Paper shows you such work starting. I do plead here, in conclusion, that these are not just pure academic studies of no value practically. I believe that there is a need for detailed laboratory work and that one must determine the species precisely and work on each species in turn before one can really list results which will stand up to the test of time and which will ultimately be of value in advising on practical results.

The PRESIDENT: It is now time for questions.

I would just like to set the ball rolling by asking Professor Raymont a question of my own. The Clyde for hundreds of years has serviced the Western Isles of Scotland with a series of small craft, mostly sloop or ketch rigged wooden smacks. I have been told that at times the crews of these smacks had to haul them ashore fairly frequently and scrub them down to avoid serious attack by *Teredo*, but that at other periods there seemed to be complete disappearance of attack, or it was very slight, and they did not need to haul them up for that purpose so often. My information about this is also backed up by what is found in the Clyde today in that 20 years ago *Teredo* was very evident, 10 years ago it was not so much so, and I think today it is starting to come back again. My question, after that rather long-winded introduction, is, simply, does the incidence of *Teredo* move in waves? Are there periods in which we may get very little attack, or is it just luck that the circumstances about which I have spoken occur?

Professor J. E. G. RAYMONT: Mr. President, you say your question is simple; I think you have asked rather a lot. My answer must be in the nature of a guess. I do not think it can be much more unless one could really follow the progress of these ships exactly. However, my belief is that you do not get waves of development. I think it is probably much more likely that the time the boats stay in any one area may have varied to some degree. They may have been laid up for a time. Have they, for example, been to any fresh-water canals? There is the Crinan canal somewhere in that region which they could come through. Of course, it was the old practice to go through a fresh-water strip to clear your boat of *Teredo* and that might have been a factor.

The other thing which, I think, may be a factor is how many wooden ships coming from the tropical waters, where they are much more likely to be heavily infested, are really lying in Clyde ports now, forming a centre of infestation? Until one is sure of that, it is much more likely that the infection of your boats is a chance phenomenon rather than an actual wave, that the boats happen to have been lying in a place where there is a concentration of *Teredo* larvae which could infect them.

Perhaps I could add one thing to this. The temperature limits of *Teredo* larvae are certainly very small. It is only a matter of a small degree of warming up which is necessary to get the larvae surviving in such numbers that you get a whole burst of infestation. If I could use the example round Southampton, I would say that in about a 50 mile radius of Southampton I can think of three places where there is quite a lot of *Teredo*, and several places, fortunately including Southampton itself, where we hardly know it. I think it is just a pocketing there of a chance ship that comes in and lies there, where the temperature of the water is that little degree higher, which gives you that survival which allows you to have a whole burst in that one area.

The PRESIDENT: Thank you, Professor Raymont.

Mr. S. A. RICHARDSON: Have you yet investigated the effect of the Marchwood Power Station? You and I perhaps have this very much at heart, but other people perhaps do not realise that there has been a local scare about Marchwood. What would you say was the effect of Marchwood Power Station on *Teredo* and *Limnoria* in Southampton?

Professor J. E. G. RAYMONT: I feel rather like a Parliamentary Secretary who says, "I must have notice of that question." May I say our interest in marine boring animals really started when I was approached by both the Southampton Harbour Board and the Central Electricity Authority to ask whether we would investigate the sort of changes if any, which were going on. I truly have no evidence whatsoever that there is any increase in *Teredo* or in *Limnoria* over the past three years, and this, of course, is the time during which Marchwood has operated.

We are, however, interested in these laboratory studies which show what the effect of boring activity in the case of *Limnoria* will be if there should be a marked change in temperature, and this is our approach to the problem. It is true that we have test blocks out in the water, as I think you know, Sir, and we are inspecting these at intervals to try to assess the amount of destruction. However, it is far too early to say that there has been any marked change over the past three years. In the first year there was no station operating, and therefore we started, as it were, from a base line, but there has been no obvious change, yet.

Mr. J. SCHOFIELD: It is common practice for timber importers to keep stocks of large dimension timbers in rivers, creeks, pond and docks. These are sometimes subject to attack by *Limnoria*. I believe the concentration of attack can be reduced by landing these timbers for a time, but I wonder whether you could tell us, in your opinion, how long these borers can live out of water under such conditions?

Secondly, you do refer in your Paper to degrees of susceptibility of timber. Does this susceptibility relate to density of timber for ease of tunnelling, is it irritants in the timber, or is it possible that *Limnoria* can digest the wood and therefore have a preference for certain species?

Professor J. E. G. RAYMONT: I was not clear on the first question. How long should the timber be out of water?

Mr. J. SCHOFIELD: Yes.

Professor J. E. G. RAYMONT: I think in the case of *Limnoria* a matter of about 48 hours would probably be sufficient if it dries out reasonably well. That is rather a guess.

With regard to your second question, I really feel that most of the gentlemen here could give far better answers than I can about susceptibility of timber. I really mean that. However, I can say there is a double factor here. I think there is no question about it, *Limnoria* do digest, probably through micro-organisms inside the gut, something of what they absorb, contrary to what you sometimes read. If there are alkaloids or similar substances in your timber, they will act to some degree as a deterrent. However, the second side of the picture shows that there is no doubt that the hardness of the wood is important. We have found in putting out test blocks of different types that harder wood does show without any treatment less intensive attack. We also find that if you put out a standard wood—if you have such a thing—that the first attack by the *Limnoria* does seem to go in the softer places. I know that several people here, of course, are interested in whether that can to some extent go with this soft rot.

I have tried to answer as best I can, but I hope that perhaps someone else will come in on the susceptibilities.

Dr. D. McNeil: There is a suggestion, Mr. Chairman, in Professor Raymont's Paper that preserved timber tends to repel the young larvae of *Teredo*, and that those which overcome their reluctance to it develop normally. I wonder if that is actual fact, or whether one finds in preserved timber incipient attack which has been stopped because of poisoning of the young rather than simple repulsion. If it is the former, if the preservative acts as a repellent rather than a poison, is there any suggestion that particularly resistant species are being evolved?

Professor J. E. G. Raymont: On the question of repellents the evidence is taken largely from results on other organisms. What we do find is that when you have molluscs, which are living in the plankton as larvae and are coming to a state of metamorphosis, if they strike what I can only term an unfavourable surface, they can delay their metamorphosis. I will not say voluntarily but they certainly can delay it for quite a considerable period of time, for a matter of several days, which, if you think of the length of larval life, is a very considerable time. This is known from quite a number of larvae, and there is a suggestion—and I think it is no more—that *Teredo*, if they land on a surface which is not the most promising sort of wood—in other words, treated wood or, of course, stone surfaces, iron surfaces, or what have you—will then delay their metamorphosis and allow themselves to be swept along by the tide again until they alight on a more favourable medium. That is the only evidence that I have on *Teredo* and, as I say, it is not very direct.

I think you are perfectly correct in that the way I put this was probably misleading. Normally once they reach the wood and really start, many young ship-worms are killed off because of the actual poisonous effect of preservative in the wood.

Dr. R. C. FISHER: Mr. Chairman, might I say on my own behalf at least, how much I welcome listening to a biological paper on a subject which has great practical applications? I wonder whether Professor Raymont recalls a statement made by the late Dr. W. T. Calman of the Natural History Museum many years ago when the work of the Institution of Civil Engineers on marine boring organisms affecting timber and other materials in sea-water was first started? Dr. Calman then drew attention to the need for the type of work in this country which Professor Raymont has started. I think I am right in recalling that hitherto there has been no other work of this kind in this country, but we have read in the last few years of Dr. Becker in Germany undertaking this very type of work. We are, perhaps, slow in starting, but now we have started, and Professor Raymont is accumulating fundamental data which will undoubtedly help to explain many of the problems in the use of preservatives and in the apparent differences in resistance of timbers to attack in different localities.

One question in particular I should like to ask Professor Raymont, in relation also to Mr. Robinson's questions. It does appear that *Teredo* attack around the British coats varies in intensity. Why is that? Until we can find out, whether, for instance it is merely a question of temperature or salinity, we cannot truly assess the value of different treatments or the resistance of different timbers. There have been empirical tests started in various places over a long period. The Forest Products Research Laboratory collaborated in some started about 1929 or 1930 in Dover Harbour; *Limnoria*, the gribble, came along at once, but at first there was no sign of damage by *Teredo*. Subsequently, some tests were carried out at Blyth Harbour. I do not know whether there was any *Teredo* there, I doubt it; but *Limnoria* was again abundant.

Am I correct in the assumption that around British coasts, *Limnoria* is widespread and important, while *Teredo* is sporadic and not always very important unless it occurs in quantity?

Professor J. E. G. RAYMONT: I think you have summed up the position perfectly. *Limnoria* occurs right round the coast. You will not find a spot anywhere where you will not get an intense attack. It is not, however, so much in the news. *Teredo* is much more sporadic in distribution.

I am reminded of the President's question now in that connection. I wondered if in relation to the ships going to the west coast they happened to come on a pocket. I know there was one in Loch Ryan, for example, which suddenly flared up. I do not know how bad it is now, I have not been up there. There was a sudden flare up of *Teredo* in Loch Ryan where it had not been known for years. It is sporadic, but the difficulty is that usually there have been no tests on salinity, temperature and the multitude of other factors, which probably really are also responsible in that particular area, before the outbreak starts. We are always a lap behind in this sort of research and that is why, when we started in Southampton, although we had not got *Teredo* we said: "For goodness sake, let's look for *Teredo* so that we can assess the salinity, temperature and other conditions, as far as we can, so that we do not get *Teredo*." If we now get an outburst in some years time and one particular factor, whatever it is, has changed very markedly, of course it does not prove the case, but one might assume then, as a beginning, that this factor is responsible for the outbreak.

However, you are quite right, Sir, that, as far as I can see, this country does lag behind in realising that detailed laboratory work is really essential. It has been going on in other countries; I am not sure whether we really think it is worth while. I would much rather that delegates said so if they really feel that way; but we certainly are not getting enough of it here.

Mr. L. LOWSLEY: With regard to your statement about the density and resistance of timbers, as far as East Africa is concerned, we are now carrying out quite an extensive research programme into the uses of all our timbers, to determine the life of any given species, in the harbours of Mombasa, Tanga and Dar es Salaam. The outcome of this may be interesting to this Association in the future. It is being carried out by the three utilisation officers of those territories. So far we are working on traditional timbers known to be resistant—timbers used for the construction of dhows, compared with traditional marine timbers such as greenheart, and timbers from the Caribbean, known to be resistant to marine borers.

If I may, I would like to raise a point about effect of flow on the attack, which you mentioned. We have found so far that there is a decided attack of the species on that side immersed in the water, facing the entrance to the harbour in this particular case; that is in the flow and the outflow of the tide. It has been most interesting. We have also found from timbers treated with pentachorophenol that treatment has been effective in retarding attack, but then, again, we have to consider the mechanical property of the timber in its uses. Although we know greenheart will withstand shock, treatment, of course, is difficult. We can treat softer timbers which will withstand the attack of *Teredo* but will be useless mechanically. I thought I would like to mention that in passing because the outcome of these tests in Africa will, I think, throw some light on the problem and our practical work may be of use to you in conjunction with your laboratory work.

Professor J. E. G. RAYMONT: We certainly would be most grateful, Sir, to know what results you are getting there. I think it would be a fascinating picture to tie in with the sort of study that we are doing.

On your point about the side facing the incoming tide showing better survival, can I just point out that is this a good illustration of how careful one has to be in deciding which factor is responsible. In my own opinion, I think it probably is the salinity; but an early paper from America suggested that since *Teredo* had a much stronger growth on the seaward side because you had your flow in of richer plankton there, *Teredo* could take in richer food. In those days when that paper was written *Teredo* was said not to feed on wood. You know the old story that it did not digest wood at all. That has proved definitely to be wrong. Nevertheless, it does rely for a large part of its food on the plankton, as described in the American paper which was written in the 1920's. This is not something you can throw away and say: "We do not believe in it"; I do not believe in it myself, but it is something we have to test.

Mr. L. LOWSLEY: It is certainly true that the salinity does not vary in each direction.

Mr. T. GABRIEL: To follow Dr. Fisher's remarks, have investigations shown an intensity of attack on the parts of our coast directly affected by the Gulf Stream, where, presumably, the temperature of the water will be slightly higher? I have no knowledge of these things at all and I was wondering whether I could be told if there are any differences in salinity of the water in the slightly higher temperatures on certain parts of our coast, or if the difference in temperature is so small as not to affect the salinity.

Professor J. E. G. RAYMONT: I think I can answer the second one first. The difference in salinity would be negligible, especially when you realise the change in salinity which you have over a twelve-hour cycle with the tide. That is a far more potent factor so I think you can wipe that one out.

It is difficult to answer your point about the Gulf Stream, I am afraid, as I would have to have a map beside me and try to pick out all the points where I know there is *Teredo* attack in any great intensity. The only thing I would say is that I have one particular area in mind along the south coast where the Gulf Stream influence is certainly slowed right down, and yet there are three or four places I can think of with tremendously different intensities of attack there. So I doubt it, but I could not really prove that it might not be a point.

Mr. P. G. WILLIAMS: In this most interesting Paper, Gentlemen, Professor Raymont says that infestation from *Limnoria* is equally dangerous to infestation from *Teredo*. There is a popular belief that *Limnoria* is less dangerous because it only penetrates about a quarter of an inch. I wonder if that is a wholly mistaken belief.

Professor J. E. G. RAYMONT: No, Sir, it is not a mistaken belief; it does burrow in from the outside. It burrows close to the surface in a parallel burrow. I do not know whether you could find a slide that would illustrate that point? I could show you them on the screen if I could find it. It does burrow in veiy close to the surface but the point is you get young, which I hope you will see here, burrowing out to the sides. They are close together and parallel to the surface, but they do burrow out to the sides giving you a very rapid infestation.

Slide. This is a diagram, of course, showing you a section of the wood with the outer surface here. Here is the point of penetration of your young *Limnoria*. It then turns in parallel to the surface, cuts out its burrow, which is about an inch long when fully formed, and you have a pair a male and female, living in the fully formed burrow. You see these little pits here by which the burrow communicates with the outside sea-water.

Slide. This is intended to be a slice of wood cut out about an eighth of an inch, if I remember rightly, parallel to the surface, and it shows here a cut burrow, more or less complete, running along parallel to the surface. Here are some of these pits which put the burrow in communication with the outside sea-water. In the case of this main burrow, here you see a fairly large *Limnoria* which is an adult. However, you see here, outside the main burrow, these little offshoots which are the side burrows populated usually only by a single animal, and these are the youngsters who make these small side channels.

You will see that the effect is wholly on the surface. In time the timber becomes so friable that you get that bit breaking off altogether. The *Limnoria* goes a stage further down. They gradually go deeper and deeper until the pile is worn away. I have seen beautiful illustrations in museums of piles broken off, huge baulks of timber eaten right through. *Teredo* is much more dangerous in a sense because it goes in through such minute holes and penetrates the baulk in a more or less vertical direction if it can, and you only see these minute pores if you are clever (usually you do not see them at all). So the whole timber can be bored through and then a sudden shock can knock it down. It is that side which makes it more dangerous.

Professor J. BAYLEY BUTLER: The question I intended to raise has been partially answered by Professor Raymont. Whilst he mentions the number of *Limnoria* per square inch, I would be interested in the number per cubic inch, and what is the average depth of penetration? I know it is a very superficial organism, but it is a question of what can be taken as the average and of the maximum depth of penetration from the surface.

Professor J. E. G. RAYMONT: Thank you for pointing out that error. I had spotted it in the proof and it is an error; that should read "per cubic inch." I am thinking of a square inch surface going down an inch depth, which is further down than they normally penetrate. If you think of your cubic inch block, then you get the sort of numbers, 400 or 600, which I think I quoted, but it is more than the normal penetration would be.

Mr. C. SISLEY: Mr. Chairman, I should like to ask Professor Raymont this question. Surely some very extraordinary change in habits of these creatures must have occurred since man arrived on the earth. It is rather a pity he did so, I think, in many ways, but there it is; he put up all these jetties with squared timbers. The original marine borers in their natural state must have lived on trees that came drifting down rivers. These were in the round with the bark on, and although there must have been plenty of them in the tropics, I should not have thought that there was very much timber coming down rivers in England before man appeared. Man may have been there, but before he put up jetties, piles and that sort of thing, it has always puzzled me how the borer managed to live before we obliged him by putting up these structures?

Professor J. E. G. RAYMONT: All I can say, Mr. President, is that this is further back than I can look, I am afraid!

Mr. F. F. ROSS: I would like to say something on this question of sporadic outbreak. This is a question of ecology, and perhaps people will think back to the effects of myxomatosis on rabbits and the effect we thought this was going to have on foxes, mice and so forth. Some people predicted that there were far too few mice for the foxes to feed on constantly, and this is the same sort of thing. It is obvious that although *Teredo* produces a million or so eggs, on an average only one of these survives, in some cases none at all, in other cases it may be a thousand, and so the conditions for a very rapid spread of infection, or mere survival, on a slight turn of conditions, are present when an animal produces such a very large number of eggs and releases them into the plankton. I should have thought that if one knew sufficient about it, which one probably never will, this spread of *Teredo* might very well be tied up, for example, with the herring catching or other animals which feed on the plankton. It is quite obvious that most of the efforts of *Teredo* go into feeding something like herring.

Mr. H. A. COX: I would like to ask Professor Raymont if he has any evidence of the effect of pollution on sea-water of the occurrence and numbers of *Teredo*? I asked that question because I know some years ago the water at Belize was very badly polluted, and the *Teredo* attack there was as bad as ever it has been reported, I think, anywhere.

Professor J. E. G. RAYMONT: I have not evidence myself, Sir. I have looked into literature on this a lot and talked with people. Yours is just another case of what I have heard said so often, namely, that far from pollution keeping down these organisms, it very often seems to go with quite a burst. I think the real point here depends—it sounds a bit like Joad, I know—on what you mean by pollution. In other words, if it is what I call chemical pollution, and the chemicals are of a certain type, then they may be truly toxic and you would wipe out a lot of your plankton population, and, of course, with that you wipe out, or at least reduce, *Teredo* and *Limnoria*. If, however, you have an organic pollution—for example, sewage pollution—to a small extent, in effect, though probably it sounds a shocking thing to say, usually all that happens is you get higher nitrate and higher phosphate in your water and you get a beautiful condition then for getting your plankton growing thoroughly. I, for many years, was doing an experiment in which I was putting nitrate and phosphate in a small body of sea-water to try to raise the productivity, and you can do that to a phenomenal degree. I was told in the end that my pond stank to high heaven, but it was still producing very fine plankton!

Mr. A. C. OLIVER: Have you any records of *Limnoria* attacking bark? Also have you any records of *Limnoria* affecting bark as opposed to wood?

Professor J. E. G. RAYMONT: There are records in literature of *Limnoria* affecting bark. We have no blocks with bark on as all ours are dressed wood. However, there are records in the literature, I think it was an American paper, where, after an investigation on attack of wood with the bark on and dressed wood, it was strongly suggested that all piles being driven in should be natural with the bark still on. I believe you will find though that modern investigation shows that bark has very little significance in keeping out attack.

Mr. E. H. B. BOULTON: Could you enlarge on *Teredo* and tell us the longest burrow that they can make and the length of time that they take to make the burrows? One hears stories of burrows being 1 to 4 feet long and an inch in diameter in the tropics.

Professor J. E. G. RAYMONT: I am sorry I cannot tell you. I believe in the tropics you can certainly have them several feet long as a standard thing, but I am afraid I just cannot give you the longest dimension. I can give you a little evidence on how long they take to make a full burrow. Grave in America showed that you could get a full burrow with a fully sexually mature animal in something like two to three months from metamorphosis. That, I think, is a reasonable estimate. However, it is difficult; I have had no experience of tropical work, but if you work in the tropics I am sure that you will get very, very high rates.

Mr. E. C. HARRIS: I am wondering how the susceptibilities of timber to *Limnoria* are to be assessed. On the one hand there is the number of burrows per surface area and on the other the rate of erosion with time.

Are these two linked together? The rate of erosion, presumably, depends upon the movement of tides. Could you expand that?

Professor J. E. G. RAYMONT: We have tried to do a little on this; the sort of results that I showed on the slides were obtained on small pieces of timber where we put a number of test animals with them. We then used a finely graduated wire, after taking the animals out of the burrows, and inserted it in each burrow in turn and added up the total length of the burrows. That is one way of doing it.

We also have test blocks which are out for varying periods of time in the water at different levels. We cut them in small pieces, take cross sections in fact, and estimate the loss of section. We did try weighing, but there are so many variables with all the stuff that settles on them, and if you try scraping it off, you take off the friable wood with it, and so we decided that weighing really gives you quite hopeless results.

We did find that loss of section is not too bad and all I can say is that the results tie in reasonably well except that your time factor is so different here. If you let the little test block in the laboratory, with 50 or 100 animals going for it, lie for too long, you have so many burrows that you have the poor research assistant spending a week trying to get her little piece of wire into all the burrows in turn; so we have to limit our experiments to a comparatively short time, a week or a fortnight.

When we have loss of section we have blocks out 6 months, 12 months, 18 months, 24 months and even a little longer and therefore it is rather difficult to tie up those two because of the time factor.

The PRESIDENT: Ladies and Gentlemen, I am sorry that the time has come to draw this discussion to a close. Professor Raymont has certainly stimulated our interest, and has also shown, I think, that the subject is not nearly at an end and there is much still to be discovered.

I should like to say to him, as far as the Clyde is concerned, that I think he put his finger on something when he referred to the Crinan canal. I am quite certain that the smacks serving the Western Highlands, certainly in the winter, and I expect in summer as well, were accustomed to use that canal. As I know very well it may take a boat six or seven hours to go through, and that might just be one of the answers to the question I asked. Secondly, again on the Clyde, the upper stretches of the river which are tidal have practically no evidence at all of attack by either *Teredo* or *Limnoria*. It is not a problem for the Clyde Navigation Trust to give protection against these things. I do not know the answer but it may be a lesser degree of salinity or it may be pollution.

Finally, Ladies and Gentlemen, we are most grateful to Professor Raymont. We hope that in the future he will be able to come back again and tell us more about his work and the further discoveries that he has made. I would just like you to give him a very hearty vote of thanks indeed.

(2) TIMBER PRESERVATION FROM THE POINT OF VIEW OF THE ARCHITECT

by Eric L. Bird, M.B.E., M.C., A.R.I.B.A.
(*Building Centre, London*)

In the year 1929 when I was the most junior member of the Science Committee of the Royal Institute of British Architects, I was asked to attend a meeting on behalf of the Committee at which a proposal to establish a British Wood Preserving Association was to be discussed. I attended the meeting, at which Sir Harold Boulton was in the chair and I met for the first time Mr. R. G. B. Gardner who later became Secretary of the Association.

I duly presented my report to the Science Committee who showed no enthusiasm at all for my recommendation that they should concern themselves with timber preservation. Members argued that there was a well understood tradition of building construction in which timber was isolated from damp and was adequately ventilated and that, in any case, timber was so cheap a commodity that its replacement where necessary was not a costly affair. Members said that pressure impregnation with creosote was all very well for railway sleepers and telegraph poles, but had certain disadvantages in buildings because of the odour which in certain conditions might be picked up by foodstuffs and the liability to creep in plaster. The Committee decided that my report should lie on the table.

In extenuation of the attitude of the Committee it can be said that at that time creosote dominated the wood preserving field, other methods being not then advanced nor well known. Also there was much to be said then for the argument that, timber being cheap and abundant, the extra cost of preservative treatment of timber for building was hard to justify.

The Committee were, however, by no means unaware of the ravages of dry rot and beetle attack in timber generally. They had taken a great interest in, and I believe suggested, the erection of the "Dry Rot Houses" at Princes Risborough. This house was deliberately constructed wrongly in order to encourage the growth of dry rot.

Also, for about two years, the Committee conducted a desultory correspondence with the Port of London Authority relative to the state of the timber ponds at the Surrey Commercial Docks. The Committee said, possibly with justification, that the timber waste and dunnage in the yards at the docks were infested with disease and beetle and they wanted the Authority to undertake a clearance and spraying campaign. The Authority coldly denied that they harboured disease and beetle, and firmly refused even to consider spraying. This correspondence eventually died of inanition.

I relate these incidents partly to show that I have had a long, if slight, connection with timber preservation, a connection which has been continued by three years service on the Forest Products Research Board as official representative of the R.I.B.A., by the courtesy of the B.W.P.A. in inviting me as a guest to their Conventions since the first and by the fact that I have many personal friends connected with the B.W.P.A. who firmly talk shop at me whenever we meet. I also relate these incidents to show that architects, or at least their official representatives, are not so unaware of or so disinterested in timber preservation as some members of the wood preserving industry seem to think.

The Attitude of Architects

Architects have four main fields of interest in wood preservation. The first is what may be loosely described as rot, both dry rot and wet rot (I use their terms rather than the scientific names), outbreaks of which they are trained to prevent by correct methods of design which isolate timber from damp and ill-ventilated conditions. Most of them are occasionally concerned with eradication of these diseases in existing buildings which they have to restore. The second is eradication of one or more of the species of wood-boring beetle from existing buildings. The third is the use, both in new buildings and as replacements, of pre-treated timber, for example by pressure-impregnation, aimed at preventing rot and beetle attack. The fourth is the use of timber treated to render it fire-resisting. I discuss these later in this paper.

Before doing so I wish to make an effort to capture mentally the attitude of the average working architect towards the various aspects of timber preservation, the industry and the consultants concerned with it. To be able to give opinions which would be more authoritative than my own, I sent a brief confidential questionnaire (see P. 5) to 20 architects whom I know personally to be good all-round technicians and having general practices covering all types of building, both new and old. I avoided sending it to architects who specialize in the restoration of old buildings because they would be likely to know most, among architects, about the subject; nor did I send it to those who are mainly concerned with the erection of those modern buildings which a French architect has, rather unkindly, termed "tin-clads" and in which timber is little used.

Twenty out of 15,000 is not a statistical sample of the whole profession. But I have not tried to conduct a survey but merely to find out the extent of knowledge of and the customary practice in wood preservation of a group of competent practitioners. I think the results of the questionnaire may be of interest.

Before discussing the results, I want to state the position of the architect in regard to all specialist techniques of which wood preservation is but one. The chief task of any architect is to spend his client's money to the client's best advantage. In doing this he has to assess a mass of imponderables on all sorts of subjects and, having done so, to select materials he deems to be appropriate and have them assembled in a building. In making his assessments and selections he has to balance the first cost of building against the cost of maintenance, both of which his client will have to pay. For example, he may have to decide whether the extra cost of preserved timber will be justified by what he thinks may be the risk of rot attack and beetle infestation. He has to make many similar decisions on all items of the construction and equipment.

In the great majority of buildings the architect's chief difficulty is building down to a price. Sometimes the price limit is not unduly tight, but usually it is. There is always a good case for specifying the best of everything, but often the client can afford no more than a second best or, in some instances, even a third best. Machine-made tiles instead of hand-made, common bricks instead of facing bricks, paint instead of wall tiling, untreated timber instead of preserved timber are typical of the alternatives with which an architect is faced in building down to a price.

The same kind of consideration of cost must go to many jobs where dry rot or beetle has to be eradicated. Perfection means stripping down and examining *all* woodwork, with the subsequent cost of reinstatement and full redecoration. Such a cost may be a serious financial blow to the client and even beyond his means. It must be the architect's responsibility to assess the risk inherent in partial stripping in just the same way as he assesses the risk of machine-made tiles laminating under frost.

On the question of the architect's technical knowledge it is customary for specialists in one or another technique connected with building to expect the architect to be knowledgeable in their peculiar subjects, and to be somewhat contemptuous of him when he is not. He (the specialist) does not realise that half a hundred specialists in other techniques expect the same of the architect in their subjects. The architect, human capacity being what it is, can have no more than a smattering of knowledge in the great majority of techniques, though some individuals are occasionally fairly expert in two or three of those which especially interest them or which they have met repeatedly in their work. Having said that, I must admit to being a little surprised at the extent of knowledge on wood preservation which my questionnaire revealed.

Specialist firms have different ways of dealing with this half-knowledge of the architect. I would suggest, with great respect, that it is equally wrong to pretend he is an expert as it is to behave as if he were an ignoramus. I have had both methods tried on myself; the former one feels to be bogus and the latter slightly insulting. Admittedly different men react in different ways and to feel for and take the right approach with each architect is the essence of good salesmanship.

If an architect has been led to specify a material or a treatment which he suspects to be not worth the money which he has got his client to pay for it, either because he thinks it has cost too much, or the performance does not come up to the promise, or because of some ancillary nuisance like a delay, a smell or a mess on his building job, he is likely merely to avoid specifying the material, treatment or firm again. He may not tell his client about it because it is his job, as an architect, not to be misled or overcharged. He may not even tell the firm concerned but merely refrain from specifying them again.

Therefore my advice to any specialist or firm dealing with any technique or material used in building is to avoid so far as possible either misleading or overcharging an architect. The secret of obtaining and keeping a connection with an architect I am firmly convinced lies in providing him with a service, especially a service which he feels to be reasonable in cost and which frees him from trouble. He likes to specify a firm or product, together with a sum of money based on a firm estimate and not be bothered with the matter again, except to give supervision and approval. I am aware that it may often be very difficult, if not impossible, to give a firm estimate for the eradication of dry rot or beetle. But I think everything possible should be done to avoid confronting the architect with a final bill that is far larger than he was at first led to expect, largely because he will have the task of justifying the extra to his client.

With dry rot and beetle eradication the architect may ask for a guarantee against a recurrence of the trouble. I do not know whether such a guarantee is a practicable proposition. If no real guarantee is possible, the architect should be told so without equivocation. It is unwise to give one of those guarantees which promises boldly on the face and then renders itself largely worthless by wording in tiny type printed on the back. That kind of behaviour is bad service. Refusal to give a guarantee may lose an order to a rival, but guarantees that turn out to be more or less worthless eventually recoil on the heads of the givers. If a guarantee is given and something goes wrong, it pays in the long run to put it right without wriggling, even if it hurts financially at the time. The building industry has many hundreds of firms who have prospered, some even for longer than a century, simply by providing the best service they could at a reasonable cost. The history of the industry is also littered with the bankruptcies of many which have not.

It is as well to realise that of the 15,000 architects in Great Britain, only about 5,000 at any one time are responsible for the selection of materials and firms to an aggregate value of at least £1,000,000,000 per annum (the remainder are assistants). A general good name among those 5,000 means steady good business. The building industry and its ancillary manufacturing interests differ from many other industries in that products are sold repeatedly through specification by architects. Few of the 5,000 architects will consent to be sold an inferior article or service more than once.

I do not wish to infer that architects are all alike. That is not to be expected in any profession, especially an artistic one. One has to take the rough with the smooth, the overbearing with the gullible, the technically competent with the ignoramus, the vague with the over-meticulous, the casual with the business-like.

After those pious words of gratuitous advice, I now come to my questionnaire and what it reveals about the architect's attitude to the technique of wood preservation. The questions are not arranged in any order of importance.

Questions to Architects

1. Do you specify pressure-preserved timber for:
   (*a*) General structural carcassing work?
   (*b*) For replacement of timber attacked by dry rot or woodworm?

2. If you specify pressure-preserved timber do you:
   (*a*) Specify a process or manufacturer?
   (*b*) Leave it to the builder?

3. In dealing with a case of severe dry rot attack do you:
   (*a*) Obtain the services of a consultant or specialist firm?
   (*b*) Instruct the builder on the necessary measures and yourself supervise the work?

4. In dealing with a case of severe attack in structural timber by wood-boring beetle do you:
   (*a*) Obtain the services of a consultant or specialist firm?
   (*b*) Instruct the builder on the necessary measures and yourself supervise the work?

5. If, in an old building, you found a beam infested with woodworm which appeared still to have an adequate margin of strength and you decided to have it treated *in situ*, would you consider more than one treatment necessary?

6. If you employed a specialist firm to eradicate dry rot or woodworm would you expect them to give you a guarantee against a recurrence:

(*a*) With dry rot?

(*b*) With woodworm (say Death Watch Beetle)?

7. Have you heard of the House Longhorn Beetle (*Hylotrupes bajulus*)?

8. Do you consider you have been supplied with enough technical information on:

(*a*) Measures to cure dry rot?

(*b*) Measures to cure infestation by wood-boring beetle?

(*c*) The different methods of preserving timber?

9. Where some timbers are attacked by wood-boring beetle do you give specific instructions for all timbers to be examined thoroughly?

10. In buildings showing signs of dry rot attack do you:

(*a*) Instruct the builder how far to strip out the woodwork (e.g. remove architraves, panelling, skirtings, floorboards, etc.)

(*b*) Supervise the work of stripping out?

(*c*) Examine (so far as possible) bonding timbers, lintels and other built-in timbers?

11. Remarks:

Pressure-Preserved Timber

The first two questions are about the use of pressure-preserved timber. Why did I select pressure-preserved? The answer is that I did not wish to become entangled in what might be termed a "pressure-dipping-brushing" argument with my 20 architects nor do I wish to do so in the discussion on this paper. I feel that the merits of the different methods are a matter for the industry to evaluate.

Four of the 20 architects say they always specify preserved timber in new building and four do so occasionally. In replacement work, 12 specify it always, and four occasionally. But several remark that it depends on the money available for the job and the extent to which they think infestation to be likely. Two point out that some local authorities require it. One appears not to know of preservatives other than creosote and adds the information that it is equally effective when applied under pressure or merely brushed on!

All but five architects say they specify a process or a manufacturer, which argues some knowledge of processes or at least that an effective one has been found. The remaining two say they leave it to the builder. One architect volunteers the opinion that the time has come when all softwood for building should be preserved before it is sold.

Some of the 20 architects appear not to know that stocks of treated timber are available. I infer this from references to the delay on the building site which results from having timber treated for the job.

Finally on this question I quote the following remarks by one architect: "To hear some wood preserving specialists talk one would imagine that it is now unsafe to use any wood in untreated form, whereas the answer is that untreated wood has been a material in use for many years and all that is necessary is to know where and how to use it and *when* it is desirable to take the *additional* insurance of special treatment. I am referring here primarily to new work, but the same principle should be applied for economic reasons to restoration work after outbreaks. The majority of outbreaks are due to bad maintenance of the structure as a whole." (the italics are his).

Three conclusions may be drawn from the foregoing; (1) There is still room for education and propaganda among architects on the uses of preserved timber both in new building and in replacement work. (2) There is nothing approaching uniformity of practice in its use. (3) It is unlikely that preserved timber will be used universally, provided untreated timber at less cost is available.

I have already referred to the traditional timber design methods whereby it is carefully isolated from moisture and stagnant air conditions. These methods amount to a kind of "defensive tactics" which the architect employs almost subconsciously and which reveal themselves in a variety of design details, the typical ground floor construction being one. These tactics or design methods limit the uses of the material and may add to cost in some cases. In recent years the insurance against dry rot given by preservative treatments has permitted boarded floors to be laid on concrete, the boarding being fixed to battens embedded in the screed. Other uses may be possible. I do not know whether anyone has studied common design methods in the terms of what amounts to another material—preserved timber. An architect uses a material according to its qualities and I suggest we need to know more about design possibilities with preserved timber, which may differ considerably from those with untreated timber.

Dry Rot and Beetle Attack

The remaining questions, with the exception of No. 8, were aimed at discovering how much the 20 architects know about these related subjects, what methods they adopt in dealing with cases, whether and when they employ specialist firms or leave the work to a builder and how much they supervise operations.

The answers show conclusively that all the architects know quite a lot about dry rot. This is to be expected because they learn about it in the architectural schools and meet it all too frequently in practice. They seem to know rather less about beetle. It will be obvious that question No. 7, "Have you heard of the House Longhorn Beetle (*Hylotrupes bajulus*)?" is intended to discover how far their knowledge is up to date, *Hylotrupes* being a comparative newcomer to this country. Only four of the 20 have not heard of *Hylotrupes* while three have experienced cases, one of whom reported his case to F.P.R.L.

There seems to be considerable variation in methods of dealing with both dry rot and beetle. Cost is a factor which affects selection of method, but the more important factor is the size of the job. Consultants and specialist firms are employed chiefly in cases where the infection appears to be extensive and its cure something of a major operation.

The remarks section of the questionnaire contains four grumbles about the high costs of specialist firms. The word "luxury" is used by one architect. It is obvious that a firm which sends men to a job and boards them while they are there, must have higher overhead charges than the builder who uses local men to ply a blow lamp and paint on a solution. Moreover a dry rot and beetle eradication service is somewhat of a thankless selling line because, when the work is done, there is nothing to show for it and no one relishes spending money on that sort of thing. Nevertheless I feel bound to report the grumbles.

One architect raises the problems of site organization when specialist firms are working with builders, especially in "determining the limits within which authority and responsibility are delegated." These problems are common to all forms of specialist work.

Builders appear to be employed for small and localized infestations but several architects indicate that they are careful to choose "a reliable and conscientious builder"—to quote from one reply—and that they give more supervision than they would with a specialist firm doing the work. This indicates that they are aware that eradication work must be done thoroughly and that success depends ultimately on the conscientiousness of the workmen.

All the architects reply "Yes" to question No. 10 which covers the extent to which they have woodwork stripped out. It appears that they are well aware of the fact that *Merulius* can send its filaments long distances and through the interstices of walls and that beetle damage is not necessarily confined to the positions of visible flight holes.

Question No. 5 is intended to discover whether anyone thinks beetle can be eradicated with one treatment. I am glad to report that all agree more than one treatment to be necessary.

The question (No. 6) which deals with guarantees, produced diverse answers. About half expect a guarantee with dry rot and slightly more with beetle, but many qualify their "Yes" and "No." One says "I should go only to a firm with a reputation. This is as good as a guarantee." Another says "I would never employ a firm which offered me a guarantee." A third says "I consider myself fairly experienced and I would not give my client a guarantee. I am therefore suspicious of those firms who do."

Finally as a summary of this part of my subject I quote the following lengthy comment: "No two jobs of eradication of dry rot (and beetle) are ever the same and each has to be treated on its merits. Origin of infestation—method of and care in removal of origin—probable or possible extent of infestation—ease of access to parts affected and to parts possibly contaminated—likelihood of contaminated parts erupting again after the source of infection has been removed—financial position of the client—extent of his future interest in the property—are all factors to be considered. Commercial firms often do not appear to consider many of these. Those who give a guarantee cannot do so and often therefore insist on far more work (and incidental expenses on redecorations and the like) than an intelligent appraisal of the situation demands." These remarks are a good example of the assessment of imponderables which the architect has to make on behalf of his client than I mentioned earlier in this paper. They also indicate that the writer is knowledgeable about the subject.

Information

Almost all the 20 architects say they have enough technical information provided for them on all three major aspects of the subject (question 8). This confirms my own view. However, one says he has insufficient information regarding dry rot and three say the same regarding beetle infestation and methods of preservation. I suspect that these architects have not really made an effort to discover what is available or read what is supplied to them. Against this it can be said that all architects have far too much technical literature to read; indeed four of them remark on this in the answers to my questionnaire and ask me to press for condensation and simplification as much as possible.

To discover what is available I asked my colleague in charge of the information counter at the Building Centre to show me what literature he could produce, either for an architect or lay person, who asked him the common question. "I have dry rot (or woodworm) in my house, can you let me have any advice or literature on the subject." He told me that this was a more than usually easy question to answer because the literature which he had available covered both subjects very well. He at once produced for me, F.P.R.L. leaflet No. 6 on dry rot and, on the various species of beetle, leaflets Nos. 3, 4, 8 and 12. He followed this up with copies of 12 leaflets of proprietary treatments and services.

He told me that comments on the F.P.R.L. leaflets were invariably commendatory. I studied them again myself and found them to be concise, simply worded, readable, thorough and free from scientific abstractions. These are features which are too often absent from those publications by scientific bodies which are intended to be read by non-scientific persons. Technical leaflets issued by firms not infrequently suffer from imprecision with the addition of being cluttered up with "sales talk."

As an example of writing that is clear and comprehensible by the non-scientific person, I quote from F.P.R.L. Leaflet No. 6 the following description of the fruit bodies of *Merulius*: "The fruit bodies of *Merulius* are shaped like plates or pancakes, and have a tough, fleshy consistence. The margin is light grey or whitish, but the centre portion, which is covered with a series of shallow pores or folds (See Fig. 2) soon becomes a bright rusty red owing to the production of the spores (fungus seeds)". I feel that the dullest reader could not fail to identify a fruit body of *Merulius* from that description and its accompanying picture. I quote it as an example of good technical explanation for the non-specialized—a craft the difficulty of which is not sufficiently appreciated.

The literature supplied by the industry strikes me as good on the whole. Some leaflets seem to fall between two stools in trying to inform the layman (who buys a can or two) and the architect who specifies a firm or process and occasionally a material. The former needs extremely simple explanations, the latter technical facts on such matters as coverage capacity, penetration and costs as well, perhaps, as some information on species of fungus and beetle. Generally I think it is a mistake to aim the same literature at the layman and the architect, though it is probably more possible in the field of wood preservation than with some other techniques.

As regards timber preserved against all forms of attack, including fire, my colleague at the information counter of the Building Centre had no leaflets to give to callers, though he had three in the catalogue files. One is a fairly elaborate booklet and two are simple leaflets.

I regret that when I first drafted this paper I had not seen all the publications of the B.W.P.A. This was probably my fault, but the Secretary quickly remedied it. As I should have expected, they are clearly written and well presented. They are thorough statements—perhaps too thorough for the architect and some certainly so for the layman. But I realise that the authors in representing so many interests had to do justice to all. Certainly I learned of some processes and treatments for the first time.

Recently I have been making a special study of aspects of what has come to be termed "Technical Information for the Architect" in which the literature provided by manufacturers is an important item. There have been numerous complaints by architects about trade literature. They say that technical information is often incomplete and confused with sales-talk and that leaflets are received by them in such a variety of sizes that filing is almost impossible. A movement is on foot to get trade literature improved. One item in it is a competition for "Manufacturers' Trade and Technical Literature" which, at the suggestion of and in collaboration with the Royal Institute of British Architects, the Building Centre is holding this year. The entries are to be in by mid-day July 31st, 1957, and will be judged by a jury of architects appointed by the President, R.I.B.A.

Here are some conclusions from my own study of trade and technical literature. To take the contents first. A leaflet that an architect is likely to keep and file is one that provides all or nearly all the information that will be of use to the draughtsman and specification writer. He will not keep leaflets that are purely sales-promotion, though he may look at them. If in an individual leaflet, sales-promotion pictures, slogans and "blurb" outweigh the technical information so that the latter is hard to find, almost certainly the architect will discard it immediately. Therefore it seems best to confine sales-promotion and technical information to separate leaflets, the former to be looked at and discarded and the second retained and filed for future use. It is this second category of leaflet that the joint competition is intended to promote.

As regards size, there is an equally strong movement to obtain standardization. The competition specifies that all entries must accord with one of the two sizes specified in B.S. 1311:1955. These sizes are 11 in. $\times$ $8\frac{1}{2}$ in. and $8\frac{1}{2}$ in. $\times$ $5\frac{1}{2}$ in. Of the 12 samples of trade literature which I obtained from the Building Centre information counter, five are to the larger standard and two to the smaller. I was glad to note that all the B.W.P.A. leaflets are to B.S. sizes.

This question of bringing some sort of order into the mass of technical information with which the architect is assailed is a result of a pronounced change in building procedure during recent years. Building is becoming less a matter of putting together common materials such as bricks, stone, timber and slates and more one of assembling components which are in varying degrees prefabricated. This movement has resulted in a great expansion of the amount of trade and technical literature received by the architect. Filing this literature for easy reference has become a problem—a problem which has already been solved in the U.S. by the production of Sweet's Catalogue which is a highly standardized series of volumes of information sheets supplied by manufacturers. No building industry manufacturer in the U.S. would even consider producing technical leaflets which did not conform to the Sweet system. We are beginning to move towards a similar objective in this country. Meanwhile it can be said that the manufacturer who makes his technical literature conform with B.S. 1311, as regards both contents and size, is more likely to find it retained by the architect than one who does not.

One complaint about trade and technical literature which architects frequently make is that many examples omit all mention of costs. I am aware that the nature of the work done by the wood preserving industry makes it difficult to quote prices, but I suggest this point should be borne in mind and, where possible, some idea of costs given. Of my 12 examples of trade literature on eradication of dry rot and beetle, four give particulars of costs, while on preserved timber, two out of the three, but those two are products of the same firm.

To sum up this question of the information service to architects on wood preservation I feel I can say that the official publications are good and that the trade publications could be better.

Timber Treated with Fire-retardants

I now turn to a field for the use of preserved timber which I think has been insufficiently explored. This is the use in building of timber which has been treated with a fire-retardant either by pressure-impregnation or a surface coating. There are several possible uses but I wish to concentrate attention on two only.

In recent years the technique of structural fire protection has made great progress. The essential foundation of this progress has been research, in particular that carried out at the Fire Research Station. A recent significant step has been the introduction of fire grading into the Model Building Bye-laws, a step which is ensuring that architects must pay attention to a technique which hitherto has been much neglected.

Under British Standard 476 a great number of elements of structure have been tested and graded as regards their fire-resistance, i.e. their ability to perform their functions of support or enclosure, or both, in terms of time. There are dozens of published tests of columns and beams of reinforced concrete and steel, but virtually none on those of timber. Only among the floor tests are some of timber constructions to be found.

I have myself seen in building fires, cases where substantial timber members, such as columns, have continued to perform their function of support after comparable steel columns have failed. But there is no test data by which such survival can be accurately assessed, and in these days when science-based building is on the increase there is little credence given to claims which are not supported by authoritative test reports.

In a B.S. 476 fire test an unprotected steel column failed by buckling in 11 minutes. We have no idea what would be the failure time of a comparable timber column carrying the same load. I suggest that tests for such a column, both untreated and treated with various fire-retardants, are desirable if the present erroneous belief, that because a structural element is combustible it is therefore not fire-resisting, is to be eradicated from the minds of architects, building owners and the framers of building bye-laws.

The fire-resistance of the steel column is, of course, commonly increased by encasing it in a fire-resisting material. Encasing the steel column mentioned above in plaster on metal lathing increases its fire-resistance to Grade D (1 hour). Encasing it in 2 inches of reinforced concrete increases it to Grade C (2 hours)—a fire-resistance grading commonly demanded by urban authorities, notably the London County Council. We do not know what Grade would be achieved by encasing that column in boarding treated with a fire-retardant because, so the Joint Fire Research Organization inform me, no tests have been conducted. From what I know of the subject I hazard a guess that Grade D could be attained easily and inexpensively with a casing of treated timber. If Grade C could be attained, the construction would almost certainly cost far less than the customary 2 inches of reinforced concrete and have other advantages such as reduced structural loads.

In the field of single-storey shed-type buildings such as are commonly provided for industry I suggest there is a further potential use for timber treated with various fire-retardants. The recent fire at the Jaguar factory has drawn special attention to the structural fire hazards of the industrial shed type building, and to the adverse effect of these hazards on the nation's export trade.

I have observed with interest the work of the Timber Development Association on the design of shed-type buildings of timber framing and its advocacy of them on economic grounds. I have also studied reports of fires in some American examples of such buildings.

There is little to choose in respect of fire-resistance between the timber-framed and the steel-framed shed building. Both are quickly ruined by a fire in the contents of the building. Although timber members of large section may outlast steel members of comparable strength, the fire in the timber building is likely to be the more fierce and therefore the harder to combat.

But these matters are relatively unimportant compared with the time period between the outbreak of fire and the collapse of the roof, because it is within this time that the fire can be effectively attacked. Incipient collapse of the roof drives firemen out of the building, after which they can attack the fire only at long range; in a large shed type building this range frequently exceeds the throw of the hoses.

A fire in the contents quickly builds up high temperatures beneath the roof, softening structural steel or igniting frame members of timber. It is not uncommon for a steel-framed shed building to start collapsing within 15 to 20 minutes after an outbreak of fire. I do not know what the pre-collapse time of a comparable timber-framed shed type building is likely to be, but the modern lattice truss has members of small section with a high ratio of surface to volume so that they can ignite readily and burn through quickly. A peculiar disadvantage of such a timber-framed roof is that it presents the firemen with two fires at once, one in the contents on the floor and the other overhead.

It seems to me that a timber framework the members of which are treated with a fire-retardant, is likely to have a pre-collapse time far greater than that of a steel framework. This means that fire damage in the contents is the more likely to be kept small, because the firemen can attack the fire closely without fear of the roof collapsing on them or of having to fight at the same time a second fire over their heads.

I think it likely that, in the fire-retardant timber shed building, the timber industry has something of great value to offer architects and industrialists. It would be inherently fire-resisting whereas a steel or aluminium framework must have protection added, which means additional cost and longer building time.

But in getting the fire-resisting shed building of timber accepted by architects and industrialists, verbal assurances will not be enough. There must be the backing of official test reports to carry conviction. Moreover, as was pointed out by Mr. W. E. Bruce in a recent paper on *Timber Preservation and Industrial Uses*, treated timber is resistant to fungal attack, requires negligible maintenance and is not liable to condensation, the last being a matter of great importance in many industries.

In discussing the relative fire behaviour of different forms of framing, I am assuming that the roof decking and its insulation are incombustible or have a Class 1 rate of flame spread (under the Spread of Flame Test, B.S. 476). The hazard of an insulating underdrawing of an untreated fibreboard (Class 4) is likely to outweigh the advantages of a fire-resistant framework so far as damage to the building's contents are concerned.

Discussion on Paper 2

The CHAIRMAN (Mr. H. E. Rowdon): Mr. President, Ladies and Gentlemen, I consider it a great privilege to be given the opportunity of introducing Mr. Eric Bird, M.B.E., M.C., A.R.I.B.A. He has prepared for us a very excellent Paper which, I think, is likely to provoke considerable discussion. Mr. Bird is very well qualified to speak on this particular subject as from 1946 to 1956 he was editor of the Journal of the Royal Institute of British Architects, and since 1956 he has been Technical Education Officer at the Building Centre.

Mr. Bird is a past member of the Forest Products Research Board, and of the Fire Research Board of the Department of Scientific and Industrial Research. With Mr. Stanley Docking he wrote a book on "Fire in Buildings," and he is also the author of the publication, "House Maintenance for the Intelligent Owner," which has recently been published.

Without taking up any more time, I will now ask Mr. Bird to open the discussion.

Mr. E. BIRD: Mr. Chairman Ladies and Gentlemen, the Conventions of the British Wood Preserving Association, all of which I have attended, are accustomed to objective papers based on research. Mine is almost entirely subjective. It is a collection of opinions, mainly my own, and I am prepared to have my opinions challenged. You may well say that this highly unscientific Paper of mine reveals a lack of precise knowledge of the industry. I would like first of all to drive that ball firmly back into your court by saying, if so, my ignorance is a reflection on the industry which has not given me—an architect who reads more technical literature than most—a more accurate picture of its doings. In other words, I am here to be told rather than to tell.

My Paper begins with a statement of the attitude of architects to all specialist techniques, the British wood preserving industry in particular. I thought it was desirable to state this attitude, although many of you may say: "We know all that," in order to avoid misunderstandings in the discussion. Some of you, of course, may feel slightly insulted by my pious words of gratuitous advice on how to deal with architects.

I have five main points which I would like to emphasise.

All building industry services and manufacturers live by being specified by about 5,000 architects. These people specify goods and services to the tune of somewhere about £1,000 million a year in this country. It is important, I feel, to obtain and maintain a reputation among those 5,000. Admittedly they are changing all the time as old men die off and new ones come in, but a reputation with them is not too easily gained and is easily lost; it is gained, of course, by repeated good service. I do not say in my Paper, what I think will be obvious to anyone who thinks, that there is a considerable amount of off-the-record discussion among architects on materials and firms. It is certainly so in the provincial societies of architects who meet fairly regularly and who all know one another. I have heard many discussions, usually around a bar, about some firm or some product when someone says, for instance, "I see you are using So-and-so" and the other man may say: "I shall never use it again" or "A very good material."

Secondly, the architect's responsibility to his client: he is the man who "takes back the can." If anything goes wrong in a building, he is ultimately responsible for it. He may pass the kick on to someone else but it is his responsibility, and he has to exercise great care in selection, especially when building down to a price.

The third point is how to deal with the half-knowledge of the architect, and bear in mind that he is expected to be knowledgeable in half a hundred different services and special techniques, and he is liable to be sneered at sometimes by specialists who think he is rather ignorant.

The fourth point is the reaction of the architect when he feels he has been "led up the garden path" in a matter of cost, or has not been given what he considers to be service for money. The kind of service which you do in eradication of beetles or dry rot is a thing that nobody likes paying for. If a man spends £1,000 on a car he has got something to look at. If he spends £1,000 on eradication of dry rot, all he has is a building as it was before and nothing new to look at. I do appreciate it can be quite a thankless service to sell. However, if an architect feels that he has paid too much, he may not necessarily say so to anybody, but decide not to specify that firm again and try another.

The fifth point covers the question of guarantees on which I have an open mind and about which I would like comments.

I have reinforced my views by consultation with 20 architects, who are all good general practitioners. I made up the questions which you, of course, yourselves can question as to whether they achieve the purpose. I have made the questions generally for yes and no answers because one cannot expect busy men to write little essays, though one or two of them were remarkably forthcoming in their comments.

My general conclusions with regard to preserved timber, are three. There is still the need for quite a lot of education and propaganda among architects on the uses of pre-preserved timber. I do not know whether that is a proper technical term, but by it I mean before the timber goes into the building. Secondly, there is as yet nothing like uniform practice among architects in the use of preserved timber. Thirdly, I think universal use is not likely while unpreserved timber, raw timber, costs less; although, of course, the use of preserved timber can be quite considerably extended by judicious propaganda.

I also make the point that preserved timber is virtually a new material and that the architect has been taught to use timber in certain ways, some of which are almost subconscious, to avoid its weaknesses such as vulnerability to moisture. There might be quite a different approach to building construction with what is virtually a new material, and I wonder whether anybody has made it or is thinking of making it?

With regard to dry rot, I think architects know a lot about it and usually deal with it on the right lines. But they know less about beetles, and I was rather surprised at the variety of replies about beetle which I got from my 20 architects, some of whom obviously knew quite a lot while others very little.

I then turn to the whole question of providing information, the problem of providing the architect with technical information which he will file and use, and will not immediately dump into the waste-paper basket. I have done a lot of talking to societies of architects on this particular subject and I have heard their opinions. The general conclusion seems to be that somewhere about 90 per cent. of trade literature received in the post goes into the waste-paper basket immediately, or almost immediately. I know that a publicity man might say: "That's all right, I am quite happy about that, it has cost us 3d. to get the name of the firm and the product under his eyes for 10 seconds and that's worth while." That very well may be so. However I think one should consider trade literature under two heads; that which is mere sales appeal literature, the object of which is no more than to bring the product and the name of the firm to the notice of the man for 10 seconds, and the second a document which he will file and use, or rather which his assistants, who write the specifications or make the detailed drawings, can find in the reference files and use.

I also go on to discuss in my Paper the question of sizes and mention the drive which the Royal Institute of British Architects is making towards getting standardised trade literature and standardised sizes of trade literature, and the fact that they have asked the Building Centre to run jointly with them a competition for trade and technical literature.

I emphasise the importance of quoting costs in trade literature and I think that architects have stressed this point with me more than any other. It is mainly a question of being able to get *some idea* of costs. Of course, this industry is not so amenable to stating costs in a trade pamphlet as a firm, for example, selling some kind of fitting, but I think it is important to do it wherever possible.

I then turn to a quite different subject which is the treatment of timber with fire retardants, and on this I am giving my own opinions as someone who knows a little about it, rather than acting as a mere reporter. There is an absence of research data on treated and untreated elements of structure in timber, though there are hundreds of fire tests of columns, beams and walls in all sorts of other materials. So far as I know there are none on wooden columns and yet everybody, who knows anything about fire, knows that a wooden column will, in many cases, continue to perform its function of support long after a steel column has wilted and brought down the building. Research data, I feel, are badly needed on this question. We might even get treated timber accepted as a fire resisting material for the protection of steel work. I can see—I do not know, I am wanting to be told—that it might be quite an economical method of protecting steel work as compared with the two inches of reinforced concrete which is commonly used to give fire protection.

I turn finally to the industrial shed type building and this has been very much in my mind, and in a lot of other people's minds, because the Jaguar fire has triggered off tremendous interest among industrialists on this question. I attended recently a fire test of an experimental shed building which was lined with asbestos insulating board. There were 600 people there and they came from all over the country, from big firms, great combines, fire officers, technical directors and people of that sort, which revealed the enormous interest in this matter at the moment.

I think the most difficult thing which has to be done in this matter of fire is to make the manufacturer, the building owner and the architect, realise the difference between fire resistance and incombustibility. I would undertake to build a shed type building which consists of 80 or 90 per cent. combustible material and another shed building of wholly incombustible material. Yet the fire resistance—the time before collapse—of the combustible building, could be considerably the greater, and I will tell you, if I may, how I would achieve that. The first shed building would have a timber framework treated with a fire retardant, either by coating or impregnation, and clad with Robertson's protected metal, which has bitumen on it, and with an underdrawing, for insulation, of fibre-board faced with asbestos paper. The complete structure would be about 10 per cent. metal and the rest combustible material. If the second building were steel-framed and clad with asbestos cement, insulated with glass fibre, you have a wholly incombustible building. Yet the fire resistance of the first building, I am quite convinced, would be much greater than that of the second. It is very difficult to get people to understand the difference between fire resistance and incombustibility. They say that timber burns and therefore it must be bad. Once we can get that across—when I say we, I mean you—I think that industrialists will begin to take an enormous interest in the protected timber frame shed building and it might very well compete with steel. Remember that steelwork begins to soften at a temperature of 450°C., and aluminium at 225°C.

The CHAIRMAN: I am sure we have all learned a great deal from Mr. Bird's amplification of his Paper. Before inviting questions I should like to be permitted to make just one point. You remember that in his Paper he said that he did not wish to become entangled in what could be termed a pressure-dipping-brushing argument. He also went on to say that he hoped that this would not arise in his Paper. I feel, however, that certain queries may arise which do in fact touch on this question, and I should, therefore, like to recall remarks our President-elect, Mr. Bernard Hickson, made when in 1954 he introduced the paper by Mr. Hatfield on solvent preservatives. He said: "There are fields of perservation for the different classes, and it is a question of architects, surveyors and engineers understanding just what each product will do." If, therefore, we accept Mr. Bird's reference to pressure treatment, purely as an example of one of the treatments available, then, I think, the implied limitation on the type of treatment is perhaps more justified than it would first appear.

I now declare the subject open for discussion.

Mr. R. FENNER: Will the speaker agree that one of the difficulties encountered to-day is that the different Ministries, particularly in this country, such as the Ministry of Works, Ministry of Education and the Services, all have their own ideas about fire protection and methods of treatment, despite the fact that we have a Fire Research Organisation, partly sponsored by the Government, and an authority, from which these architects should seek advice, and would he agree that their advice should be more readily accepted by the Government architects? We have had many conflicting ideas put before manufacturers of retardants and treatments which are used for timber.

My other point is that I quite agree with Mr. Bird that it is about time some organisation sponsored the test between the value of timber properly treated and preserved and steel structures.

Mr. E. BIRD: I agree with Mr. Fenner that Government Departments are no less ignorant than individuals. The subject of fire research is very young, you must remember. It is considerably younger than timber research and there is still a very long way to go. The British Standard 476 tests have done a certain amount but there is room for other tests.

Much information on the subject is at present entirely empirical, much of it being based on the observations of firemen, and I am not going to tell a scientific audience that a fireman is an accurate observer, his job being to put out the fire and not to observe it. Therefore, much of the knowledge is largely hearsay, and therefore as inaccurate as such information is likely to be. There must be research, I think, before we can hope to advance finally to a general knowledge of this subject, which among Government Departments and individual architects, engineers and industrialists, is still pretty primitive.

Mr. E. H. NEVARD: Mr. Chairman, Mr. Bird deplored the lack of data on wooden columns subject to fire. I think he will agree that the results of this fire test would only apply to the column tested and the design of the column tested.

Secondly, is there an outlet for wooden columns, even if they are treated and even if they stand up? The reason I ask is that, whilst we would very much like to have such tests carried out, it seems an awful waste of money to pay out something like £200 for such a test at the present time, particularly if the results of that test are so limited.

The other point mentioned was the casing of steel beams. That has been done quite often, with treated timber and particularly in the last few months in a very big building.

Mr. E. BIRD: On Mr. Nevard's last point, I would like to ask him if there is any accurate research data on that?

Mr. E. H. NEVARD: There are no data such as you personally would expect to have. However, I think the people concerned have weighed up the pros and cons and decided it is well worth doing.

Mr. E. BIRD: On the question of would anybody use wooden columns, I would ask, why not? The Americans are doing it. They are making laminated trussed members and laminated portal trusses, and eventually it will come down to a matter of cost; which is the cheaper job, wooden columns or steel columns provided they have the same performance?

A lot of architects would like to use wood but they think it burns, which it does, unless it is treated by a fire retardant.

Mr. F. A. RUHEMANN: I want to thank Mr. Bird very much for his Paper. As an architect who has specialised for many years in timber rot, I would like to endorse everything Mr. Bird has said.

I would now like to reiterate what I have been doing since 1946. It is a plea that somebody—our Association and the Government—should do something about the great lack of architects who know much of timber rot, and who could act both as timber rot specialists and architects because I feel there is a great need for persons who are a blend of architect or surveyor, on the one hand, and who know as much as possible about timber rot, on the other. I do not think that the existing scheme of training timber technologists meets this need. I feel there should be courses for young people who could be trained just to be able to detect rot, to diagnose it, to know how to prevent timber rot and woodworm and how to eradicate it and prevent recurrence. They should not be burdened with timber technology in the general sense, or with other scientific subjects which may be very important for many members of our Association and for many young students.

Secondly, I feel that courses should be arranged for architects, surveyors, public health inspectors and district surveyors. These courses I suggest should be politely called refresher courses.

Thirdly, I feel there should be, particularly in London, more opportunity for architects interested in our field to talk shop. There should be many meetings where they could exchange practical experience, and I wonder if our Association could not do something about that.

Mr. J. L. Spooner: Speaking on behalf of the unfortunate section of the Community that gets the kicks from the Architects, when they pass it on, I have been a designer and manufacturer of timber structures since the war. The Government Departments have given me plenty of support—the private architects are over sceptical! I would not be in business now had it not been for the Government Departments. I think that you, as an Association, have a wonderful opportunity to-day of "putting it over," but you must do it collectively. I do not mean that you should have refresher courses for architects. The only way is to get a first-class set of technicians to produce papers which could be handed out personally by the representatives of each Company—not for that specific company alone but collectively for the industry. It would not just be sales talk—it would be sheer common-sense—and I think that you would be doing the Timber Manufacturers a good service—yourselves a good service—and the architect would not be confused, or confused in such a way that he would specify either steel, aluminium or anything other than timber.

Mr. O. Downing: I think we can endorse Mr. Bird's comments in his lecture about literature and the need for brevity as well as, of course, the difficulty in keeping up to date. He has in his Paper highlighted various aspects of treatment of timbers as far as the building construction industry is concerned: namely, the battle against fungi, insects and fire. If I may be naive in this, I would suggest that in future in these Conventions, or the papers, or in other literature, whenever we see the word timber preservative, we also think of timber resistance and we see whether it makes sense or not. It would not add to the amount of literature that we read and it would kill three birds with one stone.

In Mr. Bird's Paper on fire resistance, I would like to correct an impression that might perhaps get across in that the British Standard 476 Specification is the 1932 issue. There have been two issues, one in 1932, and I think that Mr. Bird has quoted grades (C) and (D) from it. The British Standards Institution revised their specification in 1953, after 21 years, which, I think, will take into account some of the points raised by Mr. Bird in his recent comments.

Mr. E. BIRD: Yes, Sir, I did make an error in quoting from the grades, (A), (B), (C), (D) and (E), but having been brought up on them, I still think of them and entirely overlooked the fact, of course, that it is now the practice to refer only to time and not to the letter of the grade.

On this question of propaganda about timber usage, I think that the people who most need it are those young architects who have been timber starved since 1939 up to the end of rationing. They were taught for years and years to use as little timber as possible, or to use none at all, because they were told it was a rationed, expensive commodity. They do not customarily think in terms of timber as older architects, like Mr. White and myself, do. I was brought up on Moulmein teak and best Austrian wainscot oak and all that sort of thing. They do not now think of timber in those terms at all, they think in terms of steel, plastics and metals. I think that they are only now beginning to realise that timber is a material they can use—I am referring to these young architects—but they do not know how to use it and they do not understand it. They have not the feeling for timber in their bones, as older architects have. I think that the timber trade generally, in addition to the British Wood Preserving Association, could do a lot of very useful propaganda aimed at those young men.

Mr. C. S. WHITE: Mr. Bird has contributed a Paper, one of the four or five we have had from architects. I personally valued his Paper more than those given previously. He is an extremely practical person with long experience of technical affairs and has approached the subject in an interesting way.

Although I no longer teach I still have a good deal to do with schools of architecture up and down the country and I find there is a growing interest in timber. The time is ripe for more guidance in these schools—guidance from the industry and from this Association—so that students who are now in a receptive mood could continue on the right lines. I do not know how this is to be implemented but I put it forward as a point for consideration.

Another point concerns information and leaflets. Those which I invariably file are the Building Research Station Digests, and, of course, the B.W.P.A. bulletins. These are easily filed in their stiff folders which stand upright on a shelf. Anything that can be done by manufacturers to make their literature compact and concise would be helpful. It is not only the private practitioner at whom one should aim, it is also the young assistants, who are often more methodical than the boss. They regard this information as part of their private libraries of information.

I would like to ask Mr. Bird one question which is to do with fire. I entirely endorse what he has been saying about the vulnerability of uncased steelwork as compared with treated timber. In this connection not only have you to convince architects, but also to convince local authorities. I do not know what steps could be taken to overcome this prejudice against timber which, for many purposes, is a perfectly satisfactory structural material capable of resisting the effects of fire for a considerable period if properly treated. Every few years bye-laws are revised and I think some representation should be made in this respect, in the appropriate quarter, to see if some of these misconceptions can be dispelled.

Mr. E. Bird: On the question of local authorities and bye-law-making authorities, I think all the technical committees of the British Standards Institution, the Ministry of Works and the Ministry of Housing and Local Government have officers of the Building Research Station, or F.P.R.L. or Fire Research Station on them as is appropriate. However, these officers can do no more than advance knowledge which they have themselves obtained in their laboratories, and if the knowledge is not there—and I say it still is not there in the case of fire research—it cannot be implemented, and in consequence the bye-law-making authorities naturally say that they must go on their own feeling or hunch or ideas, unless someone can prove them wrong. I am quite certain that if the standard 8 by 6 steel column, which fails in 11 minutes under a B.S. 476 column test, were tested along with a timber post taking the same load—in other words, doing the same job and undergoing exactly the same test—you would then have a comparison between the timber post and steel column. You could have two timber posts, one treated and one not treated. That is the kind of accurate research data I want to see, and a great deal more of it, but there is nothing being done like that at the moment.

Mr. P. Grindell: I find Mr. Bird's statement with regard to timber building of particular interest and I propose at the next meeting of the Timber Structures Advisory Committee of the Timber Development Association to bring his statement to the attention of the Chairman and members because it is of primary importance to us.

Mr. R. A. Bulman: Mr. Bird prefaces his remarks by saying his Paper was not based on research, but I think he was merely underestimating the great efforts which he has put into his Paper. I feel that it does contain some invaluable information which is based on statistical research, if not on laboratory work.

There are several points of special interest in the Paper, one of which is the question of guarantees. Mr. Bird stresses that in many cases the client cannot afford to pay the full price of an exhaustive treatment. I certainly agree that is merely a matter of economics for the individual concerned and no doubt in many cases only partial treatment can be acquired; but I think it will be generally agreed that in those circumstance no-one could reasonably give a guarantee for the whole structure.

With regard to the questions that Mr. Bird asked his fellow architects, they sometimes remind me of a famous question, "How often do you beat your wife?" In answer to the first question, Mr. Bird says four architects always specify pressure treatment and I wondered if he got any information on what the other twelve architects do, as they are definitely a majority, amounting to some 60 per cent. of the whole?

In question five Mr. Bird asked if more than one treatment was considered necessary for woodworm; but he does not specify, or even exemplify, the woodworm as he does in question six, where he specifies Death Watch Beetle as an example. I suggest that the treatments would vary according to the insect concerned.

Going back a little earlier in the Paper to the question of cost of treatments in general. I wonder if Mr. Bird will agree with me that there is quite a big difference in the relative costs of pre-treating the timber of a house as compared with the different costs of handmade tiles and machine-made tiles?

Mr. E. Bird: I did not go very much into questions of cost in this Paper; the machine-made tile versus the handmade tile was just a general illustration. Frankly speaking, I do not really know much about that and I expect more practical people than myself to tell me.

On my question of the number of treatments, I did not go into that because I had always been given to understand that you required a different number of treatments according to the beetle and that the House Longhorn was a particularly troublesome one in that respect. I may be wrong.

On the question of pressure treatment, I thought it best, as I said in my Paper, to stick to one treatment otherwise we should get entangled in a lot of arguments. My general feeling was that some of the architects took my pressure treatment question to mean any treatment, and that some of them actually inferred brushed or a dipping treatment and not necessarily a pressure one. You may perhaps think that my question fell down. I should perhaps have put a secondary question on another method. However, generally I think that the majority of architects do not use treated timber at all.

Mr. J. Schofield: I notice Mr. Bird makes a plea for standardisation of forms and literature for ease of filing and reference. Could I in turn make a plea to Mr. Bird for more standardisation in the size and components of building members? I do not mean, of course, that all houses should look alike. He also refers to the fact that he would like architects to know where they can get treated timber, but the multiplicity of sizes and lengths of treated timber required by the architect and delivered is nobody's business. The amount of capital that one would have to tie up in treated stock is quite considerable and I would like your comments on that.

Secondly, on page 3, I am rather intrigued to see that you have to estimate the risk of rot attack and beetle infestation. Could you inform me how you can estimate the risk of attack by furniture beetle in premises, say, in 10 or 15 years' time?

Mr. E. Bird: You cannot do so, of course, you can only say, "Well, we will risk it." You say, "There is beetle in this half of the roof, or this portion of the building, we will treat it. As far as we know the rest of the building does not contain beetle, so we will take the risk" and that is all really. Nothing may happen, it is just taking a risk.

On the question of my telling the building industry and the architectural profession to reduce the number and size of timbers; Good Heavens! what a shocking job to do. I am not the man to do that. You want to start at the top with the Royal Institute of British Architects and the National Federation of Building Trades Employers, various firms and manufacturers and the British Standards Institution. Of course there is a movement towards simplification which is known as "modular co-ordination", and it is a lovely bee which is buzzing round the bonnets of quite a lot of architects. There is probably something in it, as some of the Americans have taken to it. The difficulty is, however, that nobody can agree as to what the unit module should be.

Professor J. Bayley Butler: I would like to congratulate Mr. Bird on his Paper. I must say I think it is one of the most valuable papers we have had, certainly at the Conventions I have had the pleasure of attending. He has put the case forward very fairly and it is of great interest to everybody concerned. I personally have a dual interest in timber preservation. I started some nine years before Mr.

Bird, and that was 1920, when I left the Army, as a consultant. I drifted into this, having been a botanist first and then a zoologist, and was brought in by architect colleagues to send them a report on buildings. Strangely enough in Ireland we ran into severe dry rot problems very much earlier than you did in England, because during the "troubled times" a great many country mansions were burnt down by the I.R.A. and under the Treaty the Irish Government had to compensate the owners. It meant that the buildings had to be reconstructed, and it was then, on reconstructing an old building that the incidence, or the danger, of recurrence of dry rot came in. For about 15 years I was acting in an advisory capacity and I was dissatisfied with the results. I found that if contractors were allowed to handle the treatment we did not get good results. Therefore, on the suggestion of the then Professor of Architecture, I formed a little company which actually trained the operators. So in that way I have a dual capacity, partially as an advisor and partially as having a commercial interest. I am always very careful to explain to my clients that I have a commercial interest in the company with which I am connected. However, I would like to thank Mr. Bird for his Paper.

Mr. B. HICKSON: I only want to emphasise to our members here today two or three points in Mr. Bird's Paper and thank him for putting them so strongly.

With regard to the guarantee question, in my opinion any architect who accepts a guarantee concerning timber preservation is doing so with his eyes closed. An efficient firm will not give a guarantee and no man honestly can do so. That is my opinion; I do not know what anybody else thinks about it, but I would welcome that being recorded because I have been asked that so many times in different parts of the world.

On the question of specifications, I would say that certain matters have been raised on various committees of the Association and of the B.S.I., and being on those committees I can give a little comfort to those of you who do not see so much of the working. We are moving, though slowly, towards a better system of dealing with specifications for timber preservation and the Association is in very close and happy co operation with the British Standards Institution. How soon the final ones will be finished it is impossible to say, but year by year definite, if gradual, progress is taking place.

The matter of specification for flame-proofing is important and I fully endorse Mr. Fenner's question as to whether all this could be put to the Joint Research Fire Organisation instead of every Government Department having its own ideas. If that could be rammed home to architects and the Joint Fire Research Organisation, who have a lot of information about flame-proofing, I think it would be very valuable and the Government Departments in due course would use it more.

In conclusion, Sir, I would like to throw out an idea that fire resistance, fire retardancy and fire-proofing are very difficult words, and I believe our friends in America use the term flame-proofing which, in my opinion, is a better term because it proofs the wood against the flame for a period, whereas if you put wood in a strong fire, even if it is properly fire-preserved with a retardant, after a considerable period it will end up as charcoal and it has not any substance though it does not contribute to the fire. I would put to those of you here the thoughts of our committee that flame-proofing is a better term than fire-proofing or fire retarding.

Mr. W. E. Bruce: Mr. Chairman, I realise the time is getting short but I would like to make one point. Some time ago the Council of the British Wood Preserving Association set up a special panel to prepare a leaflet, in response to popular demand from architects, surveyors and local authorities, on the subject of flame-proofing, fire resistance or fire retardant treatment. This committee has done a tremendous amount of work and will be producing—I cannot speak for the Chairman of the committee, Sir—but within the next 12 months, I hope—a practical leaflet on fire retardants or flame-proofing treatments.

The Chairman: Mr. President, Ladies and Gentlemen, I think we have had a most interesting discussion. In a way it is rather unfortunate that it has come to an end because I am sure there are quite a lot of other interesting questions which could have been asked. However, I am quite certain that you do not want me to encroach upon your half-hour before lunch, and, therefore, on your behalf, I should like to thank Mr. Bird most sincerely for the presentation of his Paper and also all the individuals who have participated in the discussion.

(3) SOME OBSERVATIONS ON BRITISH STANDARD 913 (1954)—PRESSURE CREOSOTING OF TIMBER

by N. A. Richardson, B.Sc., A.R.I.C.
Technical Adviser, Association of Tar Distillers.

Nowadays the value and need for wood preserving specifications is fully recognized and it is perhaps somewhat strange that official standard wood preservation specifications have only been in use for a relatively short time in this country. This is all the more remarkable when one bears in mind that since about the middle of the last century pressure-creosoting has been recognized all over the world as the most effective method for preserving wood and that it played such an important part in contributing to the rapid development of railway transport and communications. It is true that the Post Office has had creosoting specifications of its own since the 1890's but these were in the nature of private specifications. Up to 1913 poles were treated by the Full Cell method with a retention of 12 lb./cu. ft.; from 1913 to 1954 the Rueping treatment was specified with 12 lb./cu. ft. gross (about 5 lb. net retention) and from 1954 the figures were increased to 15 lb. gross and 7/8 lb. net. The railways too had specifications of a kind but sleeper treatments were until recent years largely governed by rule of thumb methods.

One possible explanation of this informal approach to the standardisation of wood preservation treatments is that sleepers and poles in this country were from the start provided by Northern European pine or native Scots Pine—*Pinus sylvestris* which, with its readily penetrated sapwood, presented no difficulties in treatment. Other species, including those more resistant to impregnation such as Douglas fir and spruce, came into use much later. Attention was given, however, quite early on to the quality of the preservative, and as far as creosote is concerned specifications have existed for over ninety years as will be seen from Table 1 which gives, in summary form, some of the more important creosote specifications.

As far as pressure creosoting is concerned the first British Standard was issued in 1940 as B.S.913 "Pressure Creosoting of Timber," following a request from the Institution of Municipal Engineers, and it was thoroughly revised in 1954. It is still the only British Standard for a wood preserving treatment.

The test of a good specification is that it should be possible to check whether all its provisions have been fulfilled. As far as wood preservation specifications are concerned, however, it is rarely practicable to ascertain that this has been done unless the treatment has been witnessed by a competent inspector. This fact has always been recognized by the

TABLE 1

SOME CREOSOTE OIL SPECIFICATIONS FOR PRESSURE TREATMENT.

(N.M. = Not more than)
(N.L. = Not less than)

Year	Name	Specific Gravity	Tar Acids	Distillation	Liquefying Point	Water	Naphthalene	Free Carbon	Remarks
1865	Dr. Letheby	1·045 to 1·055 at 15° C. (as near to 1·050 as possible).	N.L. 5%	N.L. 90% at 315° C.			None at 40° F.		
1869	Belgian Govt.			None below 200° C. Two-thirds above 250° C.			N.M. 30%		Based on recommendations of M. Coisne.
1883	Dr. Tidy	1·035 to 1·065	8%	At least 25% above 315° C.	38° C.				
1884	Sir Fredk. Abel	1·035 to 1·065	N.L. 9%	At least 25% / N.M. than 30% } above 315° C.	38° C.				
1899	G.W. Railway	1·04 to 1·08 at 15° C.	N.L. 8%	At least 25% above 315° C.	29·5° C. To remain liquid at 24° C.	N.M. 3%			
1903	G.P.O.	1·050	N.L. 8%	N.L. 60% at 315° C.		N.M. 2%	N.M. 30%		If residue at 315° C. was high, this was to be compensated for by a high percentage of naphthalenic solids (40%).
1904	G.P.O.	1·050	4–8%	At least 25% above 315° C.		N.M. 2%			
1905	English Bros.	1·035 to 1·065	10–15%	N.M. 4% below 170° C.	45° C.				
1905	L.N.W. Railway		N.L. 8%	At least 25% above 315° C.					
1905	L.S.W. Railway		N.L. 8%	At least 25% above 315° C.					
1905	L.B. & S.C. Railway.	1·04 to 1·06 at 32° C.	6%	At least 25% above 315° C.	48·5° C.	Free from			
1905	G.N. Railway	1·025 to 1·045 at 35° C.	N.L. 5%	N.M. 4% up to 170° C. N.M. 12% 170–210° C. N.L. 50% / N.M. 60% } 210–270° C. N.L. 25% / N.M. 30% } above 270° C.	35° C.		N.L. 30% at or below 15° C.		

Year	Name	Specific Gravity	Tar Acids	Distillation	Liquefying Point	Water	Naphthalene	Free Carbon	Remarks
1917	A.W.P.A. and A.R.E.A.	N.L. 1·03 (at 38° C. compared with water at 15·5° C.).	Grade 1 *2 *3	N.M. 5% up to 210° C. N.M. 25% up to 235° C. N.M. 8% up to 210° C. N.M. 25% up to 235° C. N.M. 10% up to 210° C. N.M. 40% up to 235° C.		N.M. 3%		N.M. 0·5% insol. in benzene.	Grade 1, 2, 3: Coke residue N.M. 2% float test N.M. 50 secs. at 70° C. if residue at 355° C. exceeds 55%. A.R.E.A. Spec. the same except that S.G. of certain fractions is specified.
1921	B.E.S.A. (now B.S.I.) Type A	1·015 to 1·07 (38° C. compared with water at 38°C.).	N.L. 5% N.M. 16%	N.M. 7% up to 205° C. By vol. 40% up to 230°C. 78% up to 315°C.	38° C.	N.M. 3%		N.M. 0·4% insol. in benzene.	Residue at 315° C. from distillation of 100 ml. (at 38° C.) N.L. 22 grams.
	Type B	N.L. 1·00 (38°/38°) N.L. 0·94 for Blast Furnace Oil.	No upper limit	N.M. 85% at 315° C.	38° C.	N.M. 3%		N.M. 0·4% insol. in benzene.	Residue at 315° C. from distillation of 100 ml. N.L. 15 grams.
1936 (Amended 1941)	B.S.I. Type A	1·010–1·110 38° C./20° C.	N.L. 3% N.M. 16%	N.M. 6% up to 205° C. By wt. 40% up to 230° C. 78% up to 315° C.	38° C.	N.M. 3%	—	N.M. 0·4%	Insoluble in benzole.
	A.2	0·995–1·065 38° C./20° C.	N.L. 5%	N.M. 6% up to 205° C. By wt. 40% up to 230° C. 85% up to 315° C.	38° C.	N.M. 3%	—	N.M. 0·4%	
	B	0·995–1·065 38° C./20° C.	N.L. 5%	N.M. 6% up to 205° C. By wt. 40% up to 230° C. 85% up to 315° C.	38° C.	N.M. 3%	—	N.M. 0·4%	
1951	A.W.P.A. P.I.	N.L. 1·03 38°/15·5° C.	—	N.M. 5% up to 210° C. N.M. 25%, N.L. 5% up to 235° C. N.L. 20% up to 270° C. N.L. 60%, N.M. 85% up to 355° C.		N.M. 3%	—	N.M. 0·5%	Coke residue N.M. 2%. S.G. of fractions 235° C.–315° C. N.L. 1·025 315° C.–355° C. N.L. 1·085 (38°/15·5° C.).
1954	B.S.I.	1·005–1·110 38° C./20° C.	N.L. 3% N.M. 18%	N.M. 6% up to 205° C. By wt. 40% up to 230° C. 78% up to 315° C. N.L. 60% up to 355° C.	38° C.	N.M. 3%	—	N.M. 0·4%	Insoluble in toluole.
1955	U.S. Federal T.T.W. 556·3 Type 1	N.L. 1·03 38° C./15·5° C.	—	N.M. 5% up to 210° C. N.M. 25%, N.L. 5% up to 235° C. N.L. 20% up to 270° C. N.L. 75%, N.M. 85% up to 355° C.		N.M. 3%	—	N.M. 0·5%	Coke residue N.M. 2%. S.G. of fractions (38/15·5° C.) 235° C.–315° C. N.L. 1·025 315° C.–355° C. N.L. 1·085.
	Type 2	N.L. 1·03 38° C./15·5° C.	—	As for Type 1 except N.L. 65%, N.M. 85% up to 355° C.		N.M. 3%	—	N.M. 0·5%	

* (Grades 2 and 3)—omitted after 1934.

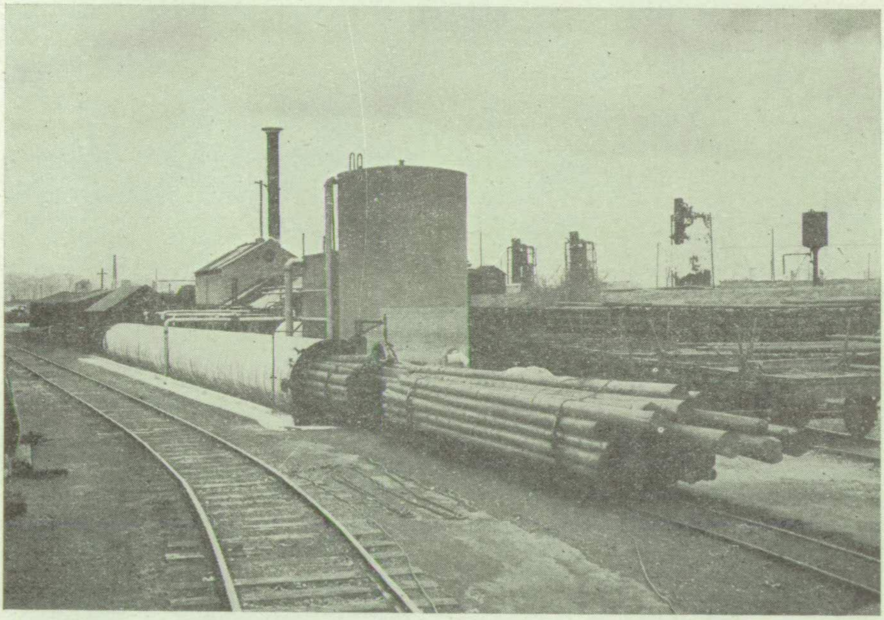
Post Office engineers, and they have as a result obtained a handsome dividend in the form of long and reliable service from their poles. Other large users of preserved timber are now beginning to realize the need for supervision or inspection of the treatments. In the U.S.A. where treated timber is used on a large scale as a constructional material there are firms specializing in inspection services but there are no similar undertakings in this country.

Any specification for wood preservation should take into consideration such items as species and dimensions of the timber, proportion of sap and heartwood, degree of seasoning at time of treatment, method of seasoning, purpose for which the timber is to be used, kind of preservative, retention and penetration of preservative, and should possibly contain some guidance on the method of treatment. It should not, however, rigidly fix details of the treating operations which will be subject to much variation, but it should specify temperatures, pressures and treating times that will ensure that the timber will not be damaged by treatment. Methods for judging the treatment should be included wherever possible.

There is no need to emphasize here the value of coal tar creosote as a wood preservative; this has been established by service records and experience extending over a century, and creosote has long been the standard by which other preservatives have been judged. In recent

Pressure Creosoting Plant used for Poles and Timbers up to 120 feet in length.

Reproduced by permission of Burt, Bolton & Haywood, Ltd.



years it has become usual to carry out research and laboratory and field tests on preservatives including creosote, but as far as creosote is concerned these are certainly not needed to confirm its value as a good preservative and they are, in fact, done in the main in an attempt to find out why and how it functions so satisfactorily.

As with all other preservatives, however, it is essential that the timber be properly impregnated if the best results are to be obtained. This point has rightly been stressed at every B.W.P.A. Convention and will no doubt continue to be so. There is rarely any excuse for bad or inadequate treatment and in an excellent paper at last year's Convention Mr. K. L. May gave examples of unnecessary failures of treated timber. The only failures of creosoted timber that occur in practice are invariably the result of inadequate treatment. This need for proper treatment as a prerequisite for preserving wood is the main reason why specifications have become necessary, and since creosote is still the most widely used preservative it is natural that creosoting specifications should predominate.

Although B.S.913—"Pressure Creosoting of Timber"—meets all the requirements that have been considered as being desirable in a specification of this kind it is thought that some comments on the various clauses of the specification would serve a useful purpose.

Foreword & Clause 1. These explain the scope of the specification and draw attention to the fact that successful preservation is largely dependent on the penetration and the amounts of creosote left in the timber. A brief explanation is given as to how these are affected by species of timber, size and condition and on the processes used to impregnate the timber. There is no need to describe these processes as they are all well known.

Clause 2 stipulates that all pressure creosoting is to be carried out with creosote to B.S.144 (1954). This is important as it ensures that a satisfactory preservative is used in that it will contain sufficient high boiling compounds to be permanent and at the same time be fluid enough to penetrate the wood readily. Fortunately, coal tar creosote is an indigenous material, and its cost is low and cannot be reduced in this country by adulteration with other oils such as petroleum. Analyses of creosote in the storage tanks of treating plants should be made from time to time to ensure that the creosote conforms to the specification.

Clause 3 states that the timber prior to creosoting must be seasoned to a moisture content of from 25 to 30 per cent. It should be obvious to everyone that it is not possible to impregnate timber satisfactorily if it has too high a moisture content. There are some, however, who have tried to do so and they have found to their cost that it just cannot be done. Proper seasoning is an essential first step for all pressure treatments. This too has been repeatedly emphasized at B.W.P.A. conventions and there are, gratifyingly, signs that the lesson is being learnt. Quite apart from the aspect of poor and irregular penetration there is also the fact that unseasoned timber may well subsequently split in use and thereby expose untreated timber to infection. There is no question about this clause being an important one. It also calls for complete removal of all bark including inner bark prior to treatment. This is included because the inner bark is very resistant to impregnation and not to improve the appearance of the timber as is sometimes supposed.

Clause 4 says that whenever possible all preparation and machining of the timber is to be done before creosoting. The need for this is generally appreciated nowadays. If post-treatment cutting or boring exposes untreated wood it will allow fungal attack to start, and decay of treated timber above ground level can generally be attributed to subsequent cutting or drilling. Sleepers and poles are now invariably sawn and drilled before being creosoted, although it is not so many years ago since it was the practice to cut the cross arm slots on telephone poles after creosoting. Where holes have, inescapably, to be bored after treatment use should be made of a special pressure bolt hole treater which forces creosote into the holes under pressure. Refractory timbers such as Douglas fir, when over 3 inches thick, are usually incised before creosoting, and there is much to be said for having this done before stacking the timber for seasoning, since the development of large splits during the seasoning is thereby avoided. Incising also has a beneficial effect in reducing the tendency to split in service and wooden sleepers of all species are now being incised and this has the effect both of improving the distribution of the creosote and of reducing the tendency to form large splits in the track, which is one of the main causes of failure.

Clause 5 defines the penetration that is to be obtained when any sapwood is present and this is so important that it is repeated in a later clause (clause 12) and in the Schedule given in Appendix B on page 14. It simply states that all sapwood present must be completely penetrated. Creosote has the advantage that the penetration is readily visible and this requirement can therefore be easily checked. Complete penetration of sapwood will ensure that internal decay of round timber will be prevented. If all the pieces of timber in a charge show complete penetration of sapwood it follows that the treatment has been carried out ideally.

In practice the main causes of failure to obtain complete penetration of the sapwood are (*a*) working to a too low or restricted absorption; (*b*) too short a pressure period; and (*c*) insufficient seasoning of the timber.

The question of treating wet timber has already been discussed. Factors (*a*) and (*b*) are closely related and can be illustrated conveniently by referring to some practical examples. Pressure treatment of timber should not consist merely of putting timber into a pressure cylinder, and applying pressure for some arbitrary period. A plant operator should at all times know what is happening in the cylinder and a good operator will control the treatment in the light of this knowledge. It is important for him to know, for example, the rate at which the timber is absorbing the preservative, and this can quite easily be ascertained by taking regular readings of the volume of preservative in the working tank. If these figures are used to plot a time/absorption curve this will provide a most useful means of following the treatment. Figure 1 shows some typical curves obtained in this way during the treatment of poles. Curves B and C are typical of those for the pressure creosoting of poles of a permeable species such as Baltic redwood and curve D shows the behaviour of a more resistant timber such as spruce. A and A2 represent charges of Corsican pine which has a very high proportion of sapwood, A being a Full Cell and A2 a Rueping treatment. It will be noted that the rate of absorption is at first high and that it gradually slows down until the amount of preservative absorbed in unit time becomes very small. In the case of curve B, which

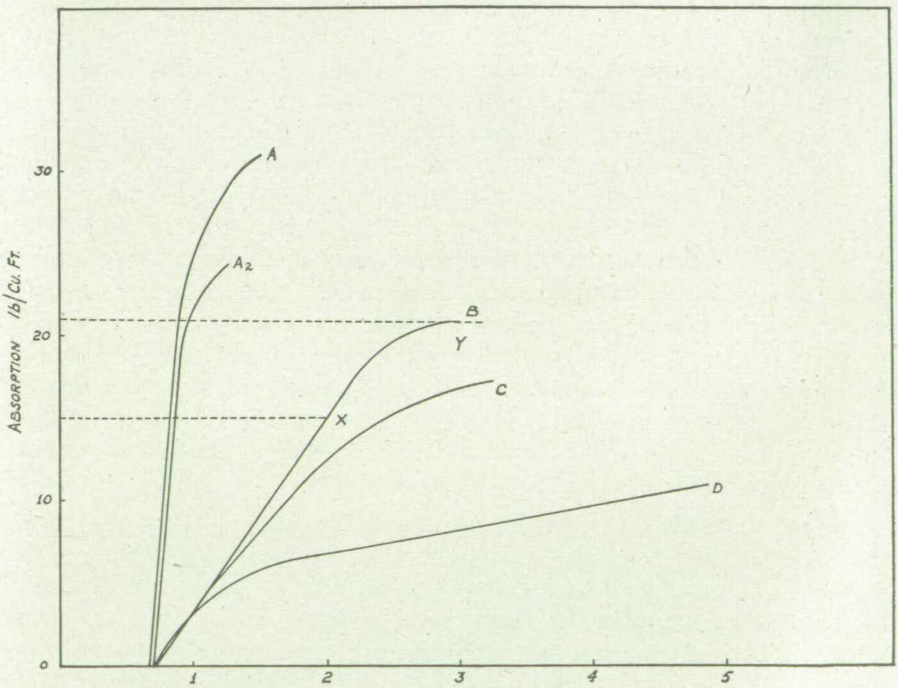


FIG.1 ABSORPTION OF CREOSOTE DURING PRESSURE PERIOD OF POLES OF VARIOUS SPECIES.

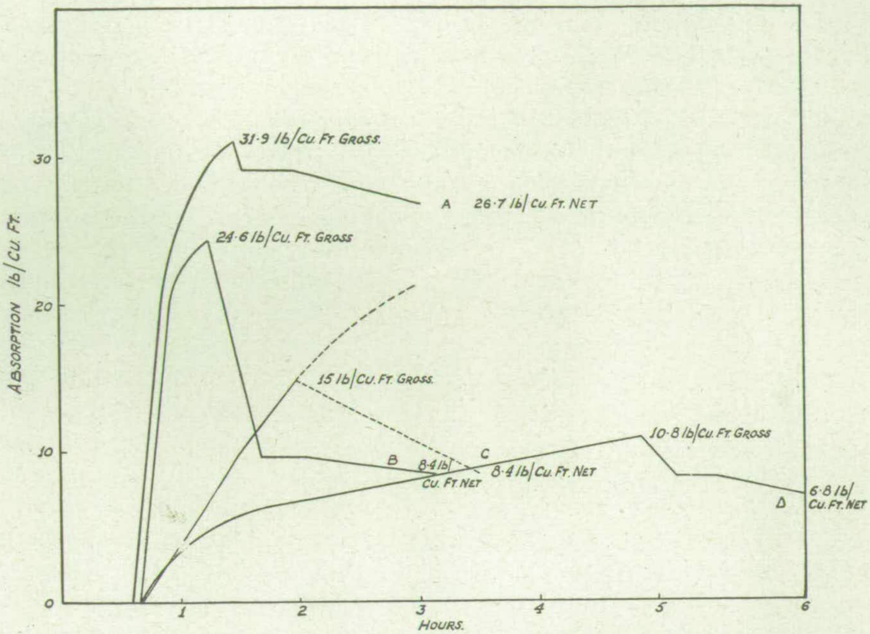


FIG. 2 . ABSORPTION CURVES OBTAINED IN PRESSURE CREOSOTING OF POLES.

represents a typical charge of Baltic redwood poles, it will be seen from the slope of the curve that if the pressure is stopped at point x when the timber has absorbed about 15 lb./cu. ft., the timber will not have absorbed sufficient preservative to have penetrated all the sapwood. At the point x the timber is still absorbing liquid at an appreciable rate and sapwood is clearly being penetrated up to the point y where the rate of absorption makes a radical change. In this instance the pressure period should obviously be continued beyond the point x. This would of course mean that the gross absorption would be much higher than 15 lb./cu. ft.—possibly 20-24 lb./cu. ft.; and if similar charges were being regularly treated the net retentions would have to be controlled, when using the Rueping process, by adjusting the initial air pressure to suit. Figure 2 shows some treatment curves obtained with some home-grown species of poles and is based on results of some treatments made at the Forest Products Research Laboratory. These are similar to those in Figure 1. but have been extended to show the gross and net retentions obtained.

Some years ago the F.P.R.L. creosoted a large number of Baltic redwood sleepers for service trials both by the Full and Empty Cell methods. The Full Cell treatments were carried out to the specification then in use by the railways, i.e. to leave about 9 lb./cu. ft. of creosote in the timber. The net retentions aimed at in the Empty Cell treatments were $7\frac{1}{2}$ lb./cu. ft. with both unincised and incised material. The absorptions of individual sleepers were measured by weighing and the results were used to obtain curves similar to those shown in Figure 3, which are based on one given in an as yet unpublished report of the F.P.R.L. They clearly show the undesirability of treating to a restricted retention.

The individual absorptions of sleepers treated by the Full Cell method varied from about 1 to 20 lb./cu. ft. with an average of 9 lb./cu. ft. as demanded by the specification. Obviously those with the lower absorptions were inadequately treated, but this is just what may happen in practice unless care is taken to avoid it. The corresponding spread for the Empty Cell treated sleepers was from 4 to 12 lb./cu. ft. and it will be seen from the curve that a much greater proportion of the sleepers have absorptions approximating to the average.

These examples are given just to show how operating to a restricted absorption leads to a wide variation in the absorption of individual pieces in a charge. In pressure treatments of timber containing sapwood the pressure period should, of course, be continued until the rate of absorption is clearly such that it indicates that all the sapwood is penetrated. Unless the timber is required for marine work the Empty Cell method should be employed to avoid using excessive amounts of preservative.

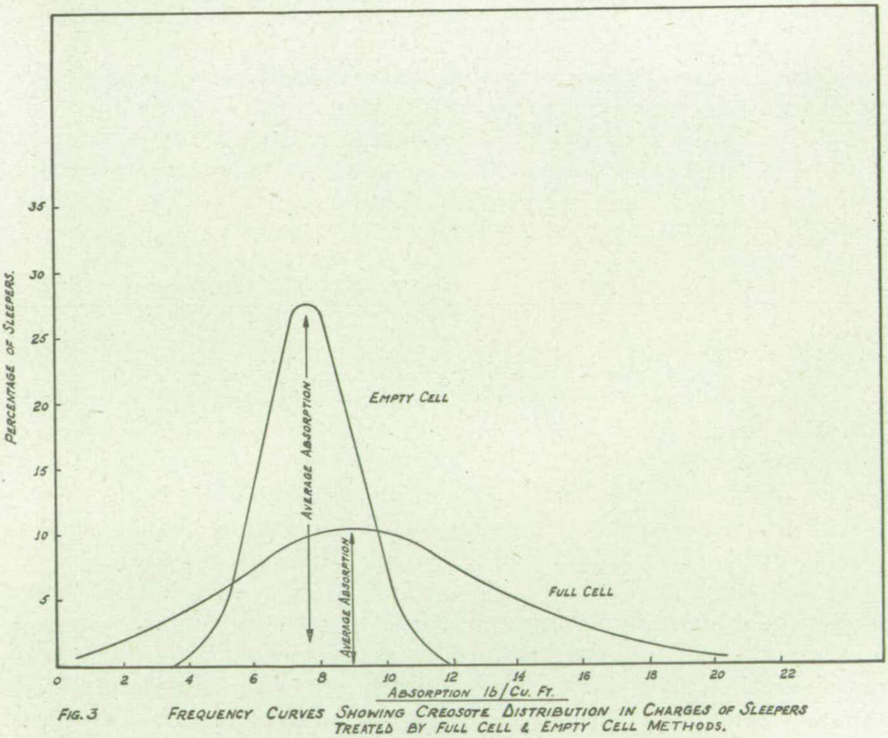


FIG. 3 FREQUENCY CURVES SHOWING CREOSOTE DISTRIBUTION IN CHARGES OF SLEEPERS TREATED BY FULL CELL & EMPTY CELL METHODS.

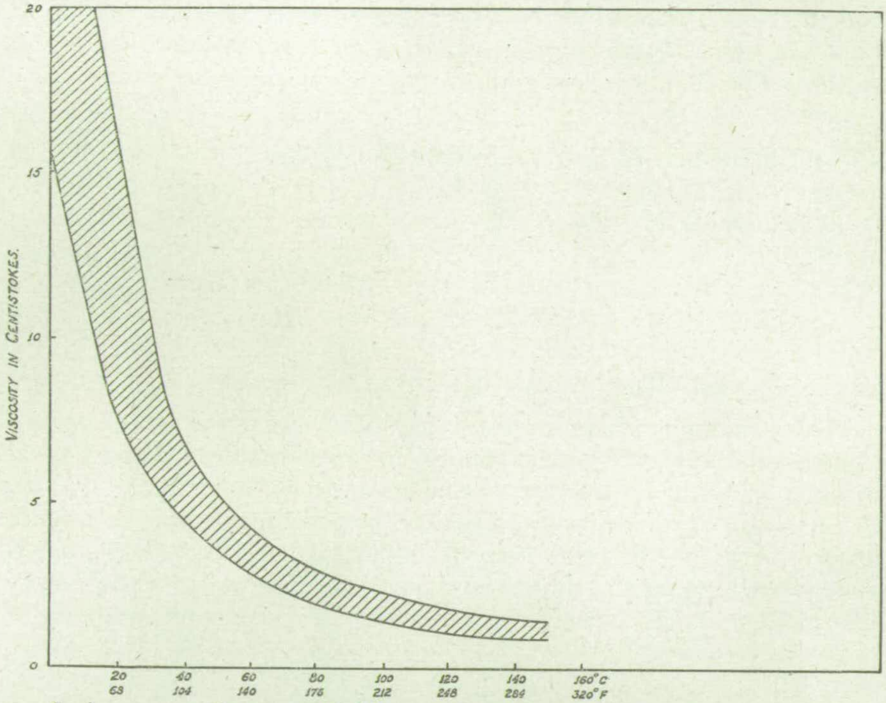


FIG. 4 CHANGE OF VISCOSITY OF CREOSOTES WITH TEMPERATURE.

Clause 6. Attention is drawn to the desirability of treating timber of the same species and similar cross-section in the same charge. This should be obvious but it is so often ignored in practice. As is the case with mixed heart and sapwood the more permeable pieces or species will absorb more than their share of preservative and leave others hardly penetrated unless the treatment is carried on long enough.

A less important part of the clause refers to the stacking of the timber in the cylinder to allow of free access of the preservative to all surfaces of the timber.

Clause 7 defines the temperatures and pressures that are to be used. Creosote temperatures are to be between 150°F. and 200°F. and the pressures used are not to exceed 200 lb./sq. in. It is pointed out that lower pressures may be necessary with some timbers if damage to the timber is to be avoided. The main reason for heating the creosote is to ensure that its viscosity will be low enough to enable good penetration to be obtained. Many factors of course affect the penetration of liquids into wood but the most important one is viscosity. Figure 4 shows how the viscosity of some common types of creosote varies with temperature. The curves represent six different creosotes now being tested by the Western European Institute for Wood Preservation, and have been plotted from data given in the Institute's Bulletin No. 4 (1956). The curves clearly show the big fall in viscosity when creosote is heated from 20°C.-100°C. and the advantage gained thereby.

In the U.S.A. it is common to heat the wood as well as the creosote. This has the advantage that the creosote is not chilled as it enters the wood and penetration is thereby improved. Heating is also employed to sterilise the timber and this is a well worth-while precaution with timber such as Douglas fir and Western hemlock which often have internal pockets of incipient decay. Pressure creosoting has a big advantage in that such sterilising treatments can be carried out easily as prolonged heating is without adverse effect on creosote.

As the heating of creosote has such an important effect on the penetration, designers of treating plant could well give some attention to this. With the normal method of heating by means of steam coils lying near the bottom of the cylinder there is much variation in temperature within the cylinder, particularly during long runs. This can be avoided by the use of an external heater and circulating the oil throughout the treatment, and this method of heating the creosote has much to commend it.

It has been mentioned that combinations of high oil temperatures and high pressures can cause collapse of timber and are to be avoided. The use of high oil temperatures with moderate pressures is generally considered the best method for obtaining good penetration without damaging refractory timbers such as Douglas fir.

Clause 8 merely states that air and creosote pressures and vacuum are to be applied and released gradually.

Clause 9 refers to the use of the Bethell or Full Cell process which is employed for marine timbers and some sleepers. It is also necessary to employ this form of treatment where it is not possible by other processes to obtain the retentions specified in the Schedule.

Clause 10 deals with the Empty Cell processes—the Rueping and Lowry processes—which are used for the treatment of permeable species and where it is desirable to obtain as good a penetration as possible with a given retention.

Clause 11 defines net retention as the amount of creosote remaining in the timber on removal for the treating cylinder, and in practice it is checked by the use of representative samples in the charge which are weighed before and after treatment. Volumetric measurements of the creosote in the working tank are also used to determine the net retention, the necessary corrections being made for any differences in the temperature of the creosote that may occur. The minimum net retention of creosote in pounds per cubic foot is to be as specified in the Schedule.

It is emphasised that these are minimum figures and that higher retentions will often be necessary where high proportions of sapwood are present or where the maximum possible life is required.

When Empty Cell processes are used the gross absorption may have to be two or three times the net retention if the penetration requirements of the specification are to be met. With European redwood and Scots pine poles the gross absorption must not be less than double the net retention specified. In order to obtain the required penetration of timbers containing a large proportion of sapwood, and at the same time to keep the net retentions from being too high, it is necessary to use an Empty Cell treatment.

Clauses 12 *and* 13 deal with penetration and extended pressure periods. As was mentioned when discussing Clause 5, Clause 12 is probably the most important one in the Specification. It states simply that as an over-riding requirement *all sapwood shall be completely penetrated.* This has been underlined to emphasise it and it should really have been printed in bold type in the Specification. The clause then goes on to state that in certain cases, where there is exposed heartwood the minimum penetration of the heartwood given in the Schedule must be obtained.

Fortunately these important requirements can be easily checked; the normal method for doing so is to take borings (not near the ends) from a number of pieces in a charge. When such borings are taken creosoted dowelling of the correct diameter should be driven into all the holes made. While the retentions and penetrations laid down in the Schedule can be obtained with most of the timbers specified, there are some refractory ones which vary greatly in their penetrability. Douglas fir is an example of such a timber. The Pacific coast variety can be treated much more readily than that grown farther inland and it is possible to treat this material with the specified retentions. On the other hand mountain-grown fir is extremely resistant to impregnation and it is usually impossible to obtain the required retentions. Where the retentions specified cannot be obtained it is laid down that the timber shall be kept under pressure at temperatures and pressures specified to avoid damaging the timber, for the following times:—

marine piling . . . . . 6 hours.
sleepers . . . . 5 hours.
other timbers . . . . . 4 hours.

Clause 14. The final clause of the specification refers to the handling of timber after treatment. This too is important and every care should be taken in practice to avoid damaging creosoted timber. Cutting or the boring of holes in treated timber cannot always be avoided and when these are done all exposed surfaces should be given a liberal application of hot creosote and any holes filled with hot creosote or better still treated with the special pressure treating tool, to which reference has already been made.

The tops of piles are sometimes damaged in driving or are afterwards cut, and when this is done the softwood surfaces should be given at least two surface treatments with hot creosote followed by a heavy application of molten coal tar pitch.

There are two appendices to the specification, one describing the methods of determining the moisture content of timber and the other setting out the minimum retentions and penetrations for the timbers normally creosoted. As it does in fact summarize the requirements of the specification it is reproduced in full, and I am indebted to the Director of the British Standards Institution for giving me permission to do so. This Schedule is the real heart of the Specification and should therefore be incorporated in the body. The figures given for the retentions for various classes of timber are minima and it should be emphasized that where the longest life is required higher absorptions should be obtained. The extra cost of leaving additional creosote in the timber is very small indeed when compared with the total cost of the timber and structure, and will prove well worth while. In fact, over the life of the structure there will invariably be a considerable saving in cost.

The value of high absorptions in timber used for structures with a high hazard is recognized in many countries. For example in the American Federal and A.W.P.A. Specifications absorptions of the order of 14 lb./cu. ft. for Douglas fir and 20 lb./cu. ft. for Southern Yellow pine are specified for creosoting timber for marine work and for structures exposed to the most severe conditions, and creosoting is the only preservative treatment recognized for such purposes.

SCHEDULE.

(Appendix B—B.S.913: 1954)

Group	Use	Species	Minimum net retention*	Minimum penetration*		Incising	Treating process
				Sapwood	Exposed heartwood		
			lb./cu. ft.		in.		
I	Poles	ALL	7	Complete	—	Optional	Optional
II	Sleepers	Corsican pine					
		Maritime pine					
		European redwood	8	Complete	1/4	Optional	Optional
		Scots pine					
		W. Hemlock			3/8	Essential	
		Douglas fir			3/8	Essential	
III	Crossing timbers	Corsican pine					
		Maritime pine			1/4	Optional	
		European redwood	8	Complete			Optional
		Scots pine					
		W. Hemlock			3/8	Essential	
		Douglas fir			3/8	Essential	
IV	Piling, marine longitudinal railway bridge timbers.	Beech	25	—	—	—	
		Elm	15		3/4	—	
		Larch	6				
		Douglas fir	6	Complete	3/8		Full Cell
		Pitch pine	6			Essential	
		European redwood	15		1/2		
		Scots pine	15		1/2		
V	Fencing and sawn timbers: (a) In contact with the ground.	ALL	6	Complete	1/4	Essential if of resistant timber, including Douglas fir, over 3 in. thick.	Optional
	(b) Not in contact with the ground.		5	Complete			

* When these requirements cannot be fulfilled, the charge shall be treated for an extended period, as defined in Clause 13.

Discussion on Paper 3

THE CHAIRMAN (Mr. E. H. B. Boulton): Mr. President, Ladies and Gentlemen, I would like to say that I have just stepped into the breach because Mr. G. W. Robertson has had an accident and he is therefore unable to attend the Convention. He very much regrets that he is unable to be with us to take the Chair this morning. I would like you all to join with me in asking Mr. Bruce to send him a message from this Convention telling him how much we miss him, as he has been such a staunch supporter in the past, and that we wish him a very speedy recovery.

It is my duty to introduce the third Paper. Although I have known Mr. N. A. Richardson a long time, I did not know that he had travelled the world so widely, both in connection with timber preservation and research work on fire prevention. Mr. Richardson was for over a quarter of a century, in fact 26 years, at the Forest Products Research Laboratories. That is a very long time to be connected with research work. Therefore, I am sure that we are going to have a very excellent Paper and discussion.

He was the officer in charge of the wood preservation section, and he has done a considerable amount of work on the fireproofing of timber. He has read and published scientific papers and journals, and he has also, of course, read Papers at B.W.P.A. Conventions. He visited Canada and the United States in 1950, and in 1955 he joined the Association of Tar Distillers as technical adviser on wood preservation. He has recently visited firms in Germany interested in this field of preservation.

I now ask you to give Mr. Richardson a very hearty welcome and ask him to present his Paper to you.

Mr. N. A. RICHARDSON: Mr. President, Mr. Chairman and Gentlemen. Thank you, Mr. Chairman, for those kind introductory remarks.

In introducing my Paper I will assume that you have at least glanced through it even if you have not read it fully. It may seem somewhat strange to some of you that I should be presenting a Paper on such a well-known document as British Standard 913—"Pressure Creosoting of Timber." When I was asked to present a Paper on what is one of the oldest and unquestionably the most important and widely used wood preservative process, I hesitated in accepting as I felt that there was little of interest that I could add to what was generally known on the subject. On reflection, however, I remembered that over the past few years there has been a good deal of ill-informed comment and information issued on wood preserving processes, particularly on creosoting. Some of this has been the result of ignorance but some has, I am sorry to say, undoubtedly been made for other reasons. I also realised that although B.S. 913 is very well known as a title, it is perhaps not so well known in detail as it should be. I had come to this conclusion by the fact that so many instances have come to my notice where experienced architects and engineers have glibly specified timber to be pressure-creosoted to B.S. 913 without bothering to acquaint themselves with the provisions of the specification. I should mention this with some trepidation, in view of Mr. Bird's remarks this morning, but I do so as it is my actual experience and that of others too.

It is also evident that many users are themselves not sufficiently aware of the requirements of the specification, nor do they always appreciate their full significance, and it is with these facts in mind that I have prepared this Paper.

The use of timber as a structural material requires careful thought and consideration, and any work with timber should be properly planned from the start. We have had this aspect brought up at several of our Conventions and when it becomes more widely known most of the difficulties will disappear. Consideration must also be given to the conditions of use and the choice of timber, that is to say, whether it is strong enough for the job, and whether a durable timber or one that can be satisfactorily preserved is to be used. Although this may seem obvious to most of you here, how often does one come across the situation where the question of durability and preservation of timber is the last one to be considered, often being left until the work is about to be started on site? Then it is usually too late to provide the most durable structure.

As to the Paper itself, B.S. 913 has been drawn up on the basis of the highly satisfactory experience with pressure-creosoted timber extending well over 100 years. Only last week I read of piles having been recovered from San Francisco Bay, where marine borers are acknowledged to be extremely active, as was mentioned in Professor Raymont's Paper this morning. These creosoted piles were in such excellent condition after 30 years that they are being re-used. Other creosoted piles in the same waters are still in a usuable condition after 59 years.

Recently some American engineers came over here to collect for exhibition and research purposes some old Post Office poles which had been in service for 63 and 64 years and which were still in an excellent state of preservation; in fact they had been classified by the Post Office engineers as "fit for re-use." Reports of records such as these, of pressure-creosoted timber used under severe conditions of exposure, are of common occurence in the wood preservation literature of the world.

However, with all preservative processes it is necessary to ensure that the job is done properly, and pressure-creosoting is no exception.

Many of the requirements of B.S. 913 are naturally applicable to all forms of preservation treatment, and I only propose to comment on some of those which have special significance in regard to creosoting.

As to the specification itself, the Foreword and Clause 1 deal mainly with its scope. In this connection the only comment I would make is that B.S. 913 is at present the only British Standard for a wood preserving process, but this is not surprising when it is realised that pressure-creosoting is the only method recommended or specified for timber in use in contact with the ground or sea-water in most parts of the world and where the maximum life of timber is required.

Clause 2 refers to the material used as the preservative, that is to say the creosote itself, and it demands that the creosote should be to another British Standard, B.S. 144. This is an important clause in so far as adherence to this specification ensures that a satisfactory preservative of uniform quality is employed, bearing in mind both its preservative qualities and its suitability for impregnating timber. I have appended a list of creosote specifications as being of historical interest. Perhaps the most interesting feature of this list is that one will notice that from about the beginning of the century the emphasis in the specifications has been to provide a high boiling oil and one that is at the same time sufficiently fluid under conditions of treatment for satisfactory penetration of the timber.

Clause 3 of the specification refers to the moisture content of the timber at the time of treatment. The timber is to be dried to a specified moisture content, and this, of course, is another case of a requisite for all preservative treatments. With regard to moisture content it is important to bear in mind that creosoting does not increase the moisture content of the timber, and therefore does not affect its dimensions. There is no need to re-dry the timber after treatment, nor is there any added risk of timber splitting through re-drying. Another advantage which is sometimes put to good use is the low electrical conductivity of pressure-creosoted timber.

Clause 4 refers to the desirability and the need for carrying out all machining, drilling and so on before treatment, which again is not peculiar to creosoting, as it is equally applicable to all preservative treatments.

Clause 5 refers to the desirability or rather the need for complete penetration of any sapwood in a charge. This is very important if good results are to be obtained; in point of fact, failure to do this accounts for practically all the failures of treated timber in service. In the Paper I have indicated the more important causes of failure to penetrate all the sapwood in a charge. Briefly, these are too short a pressure period and treating to a restricted absorption or retention. No appreciable heartwood penetration can occur until all the permeable sapwood has been penetrated.

Clause 6 refers to the desirability of treating the same species, or species of equivalent penetrability, and sizes of timber in one charge. This is again, of course, a desirable feature for all pressure treatments.

Clause 7 refers to the temperatures and pressures that are to be used for treatment. In the case of creosoting, high temperature of the oil is advantageous in that it lowers its viscosity and thereby improves the penetration. It also helps in obtaining clean treatments. In spite of what has often been said, there is no need for pressure-creosoted timber to be dirty. There are many examples of pressure-creosoted timbers which are perfectly clean and there are some buildings at Risborough constructed of pressure-creosoted timber and weather boarding which have never been anything but clean in appearance. Some years ago we creosoted the timbers for a milking shed at the County Farm at Stoke Mandeville, and before preparing this Paper I took the precaution of confirming that there has never been any complaint of dirtiness or contamination of the milk from the use of creosoted timber in the structure. Cleanliness is achieved in the main by treating with the oil at a high temperature and the use of a suitable treating schedule. In connection with the desirability of using high temperatures, the use of external heaters and circulating pumps is something that could well be borne in mind.

Clauses 8, 9 and 10 refer to the various processes that are used, the Bethell, Lowry and Rueping processes, and they are so well known to you that there is no need for me now to go into them in more detail.

Clause 11 refers to the net retentions that are required for different classes of timber. These are easily checked with creosote and the same applies to clauses 12 and 13 in which penetration, which is closely linked with the retention, is specified, the extent of penetration being clearly visible from examination of a boring or by other means of sampling.

Clause 14 which refers to the handling of treated timber and the care that should be taken in handling treated timber is again applicable to all forms of preservative treatment.

Finally we come to the Appendix which is in the form of a schedule and sets out the retentions and penetrations for five different classes of timber. This really is the meat of the specification and it seems a little odd that it should have been relegated to an Appendix. The important point to which I want to draw your attention in connection with the Schedule is that the figures given in this Schedule are to be regarded as minima. Earlier in the Paper I have discussed and shown how unwise it is to attempt to restrict retentions or to use low retentions. The aim should be to use even higher retentions than those specified in the Schedule where the maximum life is required. The extra cost is very small in relation to the cost of the structure. The advantages of using round timbers for such purposes as piling have previously been discussed and emphasised at these Conventions.

This briefly summarises some of the points I have made in the Paper; I have been purposely brief in these introductory remarks in the hope that sufficient time will be left for a useful discussion which I now await with a good deal of interest.

The CHAIRMAN: The Paper is now open for discussion.

Mr. G. S. WADE: I am uncertain, Mr. Chairman, what results the Service Records Committee have produced. I probably ought to be aware of some, but I do not think I am. However, the stress of this British Standards specification appears to be on the quantities of oil far more than on the question of the condition of the timber. I think Mr. Richardson will agree that timber which only has a moisture content of 20 to 25 per cent. may not be seasoned. We frequently find timbers with a moisture content of 22 per cent. or thereabouts, which appears to us to be completely unseasoned, is full of resin saps and sticky to the touch. I do not think anybody will argue that a great deal of the satisfactory experience of the Post Office and other users proves that timber creosoted by the Rueping process during the period about 1915 to 1925 has to a great extent given very good service. We suggest that this is mainly due to the fact that practically no timber was creosoted within 12 months of arrival, practically none of it was treated until a year after it reached this country. That timber was treated with five pounds or less of oil per cubic foot. I suggest that a great deal of that timber has given satisfactory results.

We now aim at a far greater consumption of oil, but I suggest we pay too little attention to the condition of the timber. I would be very glad to have Mr. Richardson's views on that.

Mr. N. A. RICHARDSON: Mr. Chairman, I am a little confused as to Mr. Wade's definition of seasoning. The degree of seasoning, as defined in this specification, applies only to the moisture content, and if the moisture content of the timber, as estimated by the method prescribed in the specification, is within the limits specified there can be no question of it being dry enough and suitable for treatment. I do not know if there is anything to be gained by leaving poles much longer than the time necessary for them to attain the specified moisture content, but I very much doubt it.

As regards your other remarks about poles, there were no retentions specified between 1915 and 1925. It may be your own impression that these poles were properly treated of course, but I would respectfully point out that it was mainly a result of an analysis of records of their poles by the Post Office authorities themselves that brought about the demands for the increased retentions. Oddly enough there was no pressure at all from the creosote suppliers, much as it was to their benefit. The request for increased retentions came entirely from the user interests and they were embodied in the revised specifications as a result of practical experience although, as you rightly say, there were a large number of poles which had given satisfactory service. There were, on the other hand, others which failed rather sooner than they should have done, and it was to reduce this possibility and to improve the standard of preservation that the retentions were increased when the specification was revised in 1954.

Mr. B. T. Boswell: I was very interested, Mr. Chairman, to read the remarks in the Paper about temperature effect and the author points out that Clause 7 calls for a temperature between 150° and 200° F. I take it that the intention of the specification is—I would like confirmation of this—that this temperature should be maintained throughout the treating period. If so, does he not think it would be a very good thing to state that categorically, because it certainly does not happen in practice? Speaking from one of the service departments, one of our difficulties is that we are very tightly bound by the lowest tender requirements, and people who neglect this temperature factor nearly always put in the lowest tender. It is very difficult from our point of view.

Mr. N. A. Richardson: There is no question of the virtue of using higher oil temperatures, particularly when dealing with timbers of a refractory nature. Experiments in this country and America have clearly shown that better penetrations are obtained using high temperatures of oil with moderate pressures than by employing higher pressures at lower temperatures. With certain species of timber there is another advantage in using high oil temperatures and it is that during long treatments any incipient decay, which may be present in the timber, has a chance of being sterilised, and in fact the good creosoters are aware of this and allow the temperatures and times of treatment to be such that the centre of the timber reaches a temperature at which it will be thoroughly sterilised. That is just one of the advantages of high temperature. It is unfortunate that there are odd cases where the specified temperatures are not attained in practice, but the ideal should be that the specification requirements should be demanded and met. It is not an unimportant clause; it is a very useful and necessary one, and I hope the tendency will be for all plants to be made capable of meeting these requirements. The reason I have mentioned the value of external heaters is because they provide a very good way of getting a uniform and high temperature oil in the cylinder by keeping it circulating throughout the treatment. The other important thing, of course, from the treaters' point of view, is that fuel costs can be reduced considerably by adequate and good lagging of the cylinder. All cylinders should be insulated to prevent heat losses, as otherwise it is a costly business to attempt to maintain high temperatures.

MR. D. M. SPRANKLIN: Mr. Richardson has pointed out the big temperature variation that may be found in the treatment cylinder with steam heating. The Standard lays down temperatures which should be achieved in the treatment, but there is no evidence of the points at which temperatures should be measured. Can Mr. Richardson give us some indication as to where the best point would be, and can he also give us some indication whether the temperature should be measured at a point where it is usually expected to be at its lowest or highest?

Mr. N. A. RICHARDSON: That is a leading and a difficult question. It is another advantage, of course, of having the oil circulating because you then have uniformity of temperature, and it would not matter where the temperature is taken. It is a weakness of the specification that it does not state where the temperature is to be taken—I accept that—and I think that is something which should be brought forward when it comes up for revision. In practice it means that as high an oil temperature as is practical for a particular plant is generally used. The actual temperature recorded, I am afraid, is not of great value in many cases, because, from the measurements I have taken, I know there are stagnant parts in the cylinder where you get no circulation and where the oil can differ by as much as 50° F. in temperature from the remainder, which makes the specification on temperature unrealistic. I think this is a real, valid and proper criticism of the clause of the specification with which I agree entirely—the position of the thermometer used to obtain the temperature of the oil should be stated.

Mr. F. F. ROSS: Mr. Chairman, as discussion is a little slow, it may not be irrelevant to this subject of the creosote specification to tell the Conference that a firm in America is proposing to manufacture a low temperature tar from over two million tons of coal a year and expect to have something like 20 million gallons of low temperature creosote which they are hoping to sell for wood preservation. Dr. McNeil has some information on the analysis of this, perhaps Mr. Richardson also, and I would like to know because, from the point of view of electricity production, this technique they are using for stripping the tar from coal is going to—or they are hoping that it will—reduce the price of coal for electricity production by about 20 per cent.

Therefore, it is a very interesting development from the Electricity Authority's point of view.

I would like to have the opinions of Mr. Richardson and Dr. McNeil upon this low temperature tar for wood preservation.

Mr. N. A. RICHARDSON: Mr. Ross, I am not quite sure of the actual process to which you refer. If it is comparable with the low temperature carbonisation which is carried out in this country, I can say that tests and experience have shown that the creosotes prepared from that type of tar are satisfactory wood preservatives. In fact they are used in very large quantities. However, I am just a little puzzled, I cannot quite see how it is related to the saving of coal in the production of electricity. Nor can I quite see where the carbonisation comes in.

MR. F. F. ROSS: The carbonisation process consists of mixing, not of pulverising, the coal, and crushing the coal to fragments of about a sixteenth of an inch and passing it into a chamber in which partial combustion takes place. The suspended mixture is heated up to about 900° F. and the char is then centrifuged off, and the tar and gases are led away and condensed. The tar is then separated into fractions, and about half of the fraction will be of creosote grade. The process is one of partial oxidation in restricted supply of air.

Mr. N. A. RICHARDSON: I am not sufficiently well acquainted with that particular process, so Mr. Chairman, may I refer it to Dr. McNeil for comment?

Dr. D. MCNEIL: I think that the process which Mr. Ross has been telling us about is the process being developed by the Pittsburg Consolidation Coal Company for the fluidised carbonisation of fairly low grade coal which is first pre-oxidised. We have through the courtesy of that Company had a sample of their tar and it will really be made in colossal quantities. We have done an analysis on it and our conclusion is that from the point of view of paraffin content, tar acid content, aromatic hydrocarbon content and so on, it is somewhat midway between our normal continuous vertical retort tar, which, of course, we know gives extremely good creosote for wood preservation, and the more familiar low temperature tar in this country, which is actually produced at a rather lower carbonisation temperature. It approaches, I think, more closely to the low temperature tars than to the vertical retort tars. Whether it will be a good wood preservative, I do not know, but I take your word for it.

Mr. Chairman, there was one point which I meant to ask Mr. Richardson on his Paper. One gets the impression on reading it that B.S. 913 is a good specification in that it does specify the things that are important. However, it is not a good specification in that it is very difficult from the final product to determine whether the clauses in the specification have been carried out. It seems to me that if you have a piece of wood—a telegraph pole or a sleeper—allegedly treated to this specification, how can you tell from that piece of timber that the correct quality of creosote has been used, that the correct schedule of impregnation has been carried out? In other words, unless you have inspectors there while the process is being undertaken to see that the specifications are carried out, there is no way of really telling that B.S. 913 has in actual fact been followed.

The other point refers to figure 3: I was very surprised to see the extremely wide spread in the retentions of sleepers treated by the full cell process. These tests, I think, were carried out under conditions which have been even more closely controlled than those in actual commercial practice, and you have this tremendous spread; you said that you get the usual Gaussian distribution which you would expect; nevertheless, the other, shall we say, outliers are very numerous. I know that this refers to the treatment of restricted retention, but there are two points that I would like to ask Mr. Richardson about it.

First of all, if this process is carried out to a fuller retention, does this curve in actual fact become much sharper or is it simply pushed along to the right? Secondly, can a variation in retention of this order actually be obtained in commercial practice?

Mr. N. A. Richardson: As regards your first point, Dr. McNeil on the question of inspection, in the case of certain classes of timber—large bulk timbers like poles, sleepers and so forth—one must remember that the overriding requirement of the specification is that all the sapwood must be impregnated, and the amount of heartwood to be penetrated is also specified, and it is quite easy by boring or other means to check up on this. The actual retention in pounds per cubic foot, of course, can only conveniently be taken by inspectors at the plant, and in point of fact large users do in fact employ this method as being the simplest. The other method, which can be applied to all other preservative pressure treatments, involves analysis of the treated timber. This is, however, a very complicated and tedious way of doing it and it is much easier to have someone inspecting the actual treatment. As I said just now, the overriding factor is that all sapwood should be penetrated, and that is in any case the most important aspect from the preservative point of view. With poles, for example, if you have any untreated sapwood that in itself is enough to reject a particular charge.

Your other point was regarding retentions and the curves in Fig. 3. These were drawn from actual data obtained from treatments we carried out at Risborough some years ago, and they show the undesirability of treating to an absorption restricted to less than that the particular charge is capable of taking up. It is under those particular conditions of treatment, when they have been restricted to give lower absorptions of this kind, that you get this very wide distribution of individual retentions. If, on the other hand, you continue the treatment until all the sapwood is penetrated, the curve does not shift as you have suggested, but becomes narrower and approaches the one shown for the empty cell treatments. If you carry out a full cell treatment which ensures that you get all the sapwood impregnated, you need about the same gross absorption as with an empty cell treatment but less recovery of creosote is obtained. The carrying out of the treatment in this manner closes up the very wide range of 1 to 20 pounds per cubic foot obtained in the example given for a full cell treatment. I am afraid that a large range does sometimes occur in practice for the reasons I have given and that is why you sometimes get odd pieces in a charge showing practically no penetration while others are well impregnated. The drier or more absorbent pieces absorb more than the average while others get very little.

Mr. D. W. Robinson: I see that the Americans work with Douglas fir to retentions of 14 pounds per cubic foot, which is high by our standards and high by the B.S. 913. I was wondering whether Mr. Richardson would tell us what the main technical differences between the American treatment and the treatment in this country are.

Mr. N. A. Richardson: Yes, Mr. Robinson, they are briefly these. They have the advantage of having freshly sawn balks of timber which are nearly always treated by the boiling under vacuum process (Boulton). During the seasoning part of the process the timber is thoroughly heated and is in a more absorbent condition than the drier and sometimes over dried material we get in this country. You are quite right in the inference behind this question, "Why can't you get a high absorption here?" The fact is that you cannot always do this.

The Chairman: I would just like to say something. About 1932 I read a Paper to the British Wood Preserving Association on the penetration of creosote into various species of timber. My audience was fifteen; the Association was very small. I had a series of photographs that I had taken of various types of timber as seen under the microscope and I traced through the penetration of creosote according to the anatomy of the different cellular structures of the timbers. I found quite clearly that we could get a lot more creosote through the cellular structure than was actually visible on the surface. The interesting thing when you come to green and dry timber, especially with Douglas fir, is that in the cells, the tracheids as they are called, nearly all the movement of the liquids from one cell to another is in the radial section. The medulary rays—or the rays, as we call them—running through will carry the creosote forward and they move in a radial direction. The greatest stoppage is on the tangential side, which is the outside of the tree. The interesting thing is that in green timber these holes through which the liquid passes from one cell to another have membranes down the middle and a pad which is called the torus pad. As the timber dries that torus pad moves to one side and stops up the hole, whereas in green timber it is flexible moving either way until the liquid can pass from one cell to another through the membrane over the torus pad into the next cell.

The other interesting point that you would not expect—you can correct me if I am wrong because this dates back to 1931—is that when you come to the summer wood, the dense portion of the timber, especially in Douglas fir, usually absorbs more creosote than in the open spring wood. The reason for that is that these little portholes—the bordered pits, as they are called—are on all four sides of the summer wood tracheid so that you get tangential and radial penetration going through the summer wood of the timber, whereas you have only got radial penetration in the spring wood.

Mr. N. A. RICHARDSON: That is still pretty true now.

Mr. E. CARR: Mr. Richardson's Paper is particularly interesting to users in that he does emphasise all the prerequisites for satisfactory preservation, and really the only way in which the user can satisfy himself that all those conditions have been carried out is by having inspectors all along the line, as we have in the Post Office. We are big users and something like a million gallons of creosote are used in preserving our poles every year, and we can do this. But as Mr. Richardson pointed out in his Paper, it has paid very handsome dividends to the Post Office in good and satisfactory service, and I think it has also been of very great advantage to the timber industry and the wood preserving industry because if you have decay of treated timber it is not a very good advertisement, either for the timber or the preservative. However, on the other hand, I think the Post Office and the industry can look with some satisfaction to the fact that there are something like two thousand poles still in service which were creosoted some 60 years ago. As a matter of interest, the poles which Mr. Richardson mentioned, which have been bought by the American firm, are being taken over to America and sent on a tour of the United States to show what has been done with creosote in this country.

Mr. G. S. WADE: May I just make one remark? May I remind Mr. Carr that those poles were treated with cold oil and oil which was very far from fluid. Admittedly the full cell process was used, but it was stone cold oil, it was not heated at all in those days, and they have given very, very good service. They were also kept at least a year before they were treated.

Mr. N. A. Richardson: Perhaps they would have given even better service had they been treated with hot oil.

Mr. J. Schofield: In connection with Clause 3 of British Standards, Mr. Richardson states that timber should be seasoned to 25 to 30 per cent. moisture content prior to treatment. I think, however, that he would agree that in certain cases where pre-conditioning is effected first, such as steaming in vacuum or boiling in vacuum, one can obtain fairly satisfactory treatment with higher initial moisture content.

One sometimes wonders whether in the specification laying down the minimum retention you are not excluding the best possible treatment because contracts for treatment are competitive. They are based on price by the contractor for the amount of oil that he is expected to inject—minimum retention under B.S. There are occasions, using the Rueping method to the best advantage when the timber can and does take more preservative. Oil is very costly and somehow or other this cost cannot always be recovered. I know one or two Government and local authorities do pay for the extra oil involved, but I feel myself—and I would like Mr. Richardson's views on this—that until some scheme can be devised, whereby the consumer or user will pay for the amount of oil which is injected by the best possible treatment, only then will we be able to raise the standard for pressure preservation.

Mr. N. A. Richardson: I am in full accord and sympathy with your views, Mr. Schofield. I would respectfully remind you that it is not my specification. The moisture content figure was carried forward from the original specification and was in line with common usage at that time. Practically all timber used for creosoting purposes was air-dried timber, and that range of moisture content represents a reasonably dry condition. I agree with you that it is not the only condition which is satisfactory for creosoting. One must bear in mind, however, that by allowing any laxity on this clause, one does open a field which is fraught with danger. I think that Mr. Schofield will appreciate this fact. Some treaters, fully aware of the situation, can deal with it in a satisfactory manner, but to haphazardly allow a wider range of moisture content in the specification would, I think, be distinctly dangerous.

As regards the question of the relations between the treater and the user concerning the amount of oil left in the timber it has been my earnest wish in this Paper to give the user the facts and to emphasise the advantages to be obtained by good and proper treatment. I think it will be only a matter of time before users appreciate the advantages to be gained by having good penetration and plenty of oil left in the timber, and before it is realised that the extra cost of the oil will show a very good investment. This is not something which can be done immediately, I think, however, that it can result from activities of an Association such as this which should encourage everyone to do the job to the best advantage of all.

Colonel F. M. Potter: Mr. Chairman, I have no authority to speak for the British Standards Institution as such, but, in connection with British Standards 144 and 913, I would like to say that I was delighted when I saw the title of Mr. Richardson's Paper and the fact that they were to be discussed at this Conference. I think it is a great advantage to have a B.S. specification discussed at an open meeting of this kind and I am certain that, when it comes to a revision, those who have contributed to the discussion may be sure that the remarks which have been made will be brought up before what, after all, is a relatively small jury. It is true that the draft specifications are submitted to the trade, but I think you get a freer expression of opinion; and it is the first time in my memory that a B.S. specification has been thrown open in this way for discussion. I have listened and sat back hoping for even more healthy criticism or questions than we have had.

Having listened to this morning's very interesting Paper by Professor Raymont, I would like to ask Mr. Richardson one question and that is with regard to marine piling. It is perfectly true, particularly in the United States where all the work has been done, that creosote is used almost wholly for marine piling work, but the tendency now is to use a mixture of creosote with 30 to 50 per cent. of tar added to it. That means, of course, not only an addition of more creosote but also of pitch, that pitch giving you a hard coating on the surface of the timber. It does seem to me that there is some explanation as to the value of that process in Professor Raymont's Paper this morning, where he shows that if the surface is unsuitable to the Teredo larvae they will just pass it by and leave it alone. It may be that this is a method which we ought to consider in this country in due course.

Mr. N. A. Richardson: Thank you, Colonel Potter, for introducing that very useful aspect to the discussion, may I say I entirely concur with your remarks regarding the open discussion of a standard specification.

As regards your remarks on the question of marine timbers they are equally true. Research work in the United States has shown that mixtures of creosote with pitch or tars are giving better results against marine borers than even creosote alone, particularly against the gribble, *Limnoria*, about which we heard a lot this morning. As you know this Association is carrying out trials on preservation against marine borers. We have sets of samples at two sites where tests are being carried out. Samples treated with creosote, creosote plus tar and a creosote treatment followed by a tar paint coating are included so we shall have some comparative results from these particular tests which should be very interesting. I expect them to confirm experience elsewhere, but we shall have to wait and see.

Mr. D. M. SPRANKLIN: I think Mr. Richardson has mentioned that too short a pressure period can prevent the complete penetration of sapwood. I should like to mention a very limited series of tests which we have carried out under controlled conditions, in which we have shown that a short pressure period can particularly affect complete penetration of sapwood in cases where you are near the borderline in moisture content of the timber. The oil to obtain the necessary retention is pumped in as quickly as possible and this gives rise to pockets which are not penetrated by the creosote, whereas when the timber is dry, these pockets are usually not present.

Mr. N. A. RICHARDSON: Yes. The point which I really made in my Paper was that it was not the time for which the pressure is applied—the correct time can be obtained from curves similar to those which I give—but it was that all the treatments should be intelligently carried out. In other words, the operator should know what is happening in the cylinder. When you have a charge of mixed timber or of mixed heart and sapwood where there is a big difference in the penetrability, time/absorption curves of the type shown in my Paper should be prepared by the operator, and he can then see at a glance when the more permeable portion of the charge, which in the majority of cases is sapwood, is completely penetrated. The curves I have given in the Paper are taken from actual treatments. The fact that these curves do not turn over in a short period shows that under those particular conditions, and with those particular timbers, it was necessary to carry on the treatment for one, two, three hours or even longer. However, the main point I had in mind was that it is not a question of just loading the timber in a cylinder, putting on the pump and stopping it at some odd moment at the whim of the operator. A good treatment should be intelligently carried out with the operator knowing and following what is happening in the cylinder. As he cannot see inside it his only course is to take measurements of the absorption during the treatment, which is a simple and convenient way of doing this, and that is my main reason for including some typical curves of absorptions with time in my Paper.

Professor J. E. G. RAYMONT: Mr. Chairman, this point which has been raised interests me very much. As a layman on preservatives, may I ask what is probably a very simple question? Is it known whether the addition of pitch to the creosote actually affects the physical surface of the wood? Does it in some way alter the hardness and therefore make the pile more resistant to the initial boring, or is it known whether it increases the toxicity? I think these are the two possibilities and there are probably others which are going to be very important if one puts this matter to a real test, which is what I would like to see done.

Mr. N. A. RICHARDSON: I am not absolutely certain about the history of that particular development, Professor Raymont, but I think I am right in this; anyway I will take a chance on it. When I visited Professor Clapp's laboratories in Duxbury, a few years back, he told me that by chance some frames in which he had his specimens had been treated with a mixture of creosote and tar and these had shown up rather better than those treated with creosote alone. I think I am right in saying also that the further developments followed from practical trials of this sort. As far as I know, the only explanations that have been offered for the superiority of creosote mixtures have been purely speculative and I do not think there is any experimental evidence to confirm these views. I believe the explanations that have been put forward, such as that by filling the pores of the surface it is more difficult for the gribble to get started, are purely matters of opinion. No work has been done as far as I know to establish whether it acts in this way. There was a man working on the West Coast in Los Angeles, either a Mr. Wakeman or a Mr. Shackell, who did some toxicity tests on creosotes towards marine boring animals, but I do not remember any comparative tests being done on mixtures of creosote with other substances such as tar. I know that some toxicity tests have been done with neat creosote, but I cannot add anything further to that.

Colonel F. M. POTTER: I would add that it is the hardness of the surface rather than the toxicity, because in so far as you put tar in, you are putting in probably 50 per cent. of the same creosote; but it is the actual hardness which acts as a deterrent. My own feeling is that one way to do the job is to creosote the timber—it is so cheap now to spray tar by mechanical methods—and then to surface coat the timber, bearing in mind that this is for marine work and not for any other purpose. It is my own guess after reading the literature, that the borer does not like the hard surface.

The CHAIRMAN: Mr. President, Ladies and Gentlemen, time draws near for tea and a break. I think we have examined this British Standard most carefully. Perhaps one day we will have British Standards for all methods of preservation and all preservatives. That would no doubt be a real step forward. I think the whole thing boils down to light and heavy oils of creosote, the species of timber, a knowledge of timber, moisture contents, good and proper cyclinders for impregnation, and above all, properly trained operators to carry out the job. If one bears all this in mind one will be able to fulfil the British Standards' requirements.

I do thank Mr. Richardson most sincerely for his handling of the very difficult task of putting over a Paper on this subject, especially as it is the first Paper on such a British Standard that has been submitted. It has been a difficult job and I think he has done it extremely well.

(4) *IN SITU* TREATMENT OF BUILDING TIMBER FOR THE CONTROL OF WOOD-DESTROYING INSECTS AND FUNGI

by S. A. Richardson

Governing Director, Richardson and Starling Ltd., Winchester

IN SITU treatment of building timber is usually demanded after deterioration has commenced through the activity of wood-boring insects or fungal rots. Very few property owners appreciate the value of timber preservation until the property they own is threatened with destruction by timber decay and it is apparent that something must be done or very expensive structural repair works will be necessary.

No branch of timber preservation covers such a wide field as that of *in situ* treatment. Whether for small pieces of infected joinery or the structural timbers of great buildings and the few remaining wooden ships, methods and materials have been evolved to control insect and fungal activity and provide protection against further deterioration. Methods may vary from simple application with a brush, to the very skilled and involved technical processes for dealing with the complicated structural timbers, joinery and ornamental woodwork of great cathedrals and churches, universities and colleges, etc., where often the most difficult problem is gaining access to the affected timber and (in the case of dry rot) the adjacent masonry, walls, sub-floor spaces, etc.

Unfortunately, a great deal of *in situ* treatment of timber is carried out by individuals and firms with no knowledge or experience of the complex problems involved, and with little or no sense of their great responsibility when dealing with ancient and historic monuments and heirlooms. They enter the industry, if it can be called an industry, armed with a little knowledge picked up from leaflets and advertising literature generally aimed at selling a panacea for all timber troubles and, therefore, over-simplifying the problems involved. In no branch of the timber preserving industry has so much wishful thinking been used to compound and produce astounding products always claimed to be "the latest of their kind backed by years of intense study," or "research," or "experiment," according to the whim of the advertiser, but very rarely based on experience.

The production of a material for *in situ* treatment of timber is by no means simple. So many factors are involved and the evolution of a suitable material so often begins by thinking of a powerfully toxic material, subsequently to find that it does not retain its toxicity sufficiently long to cover the life-cycle of the insects, or that it cannot be conveyed into the wood by suitable vehicles, or it is irritating or dangerous to the operatives in confined spaces, or it corrodes metals, softens veneers, or stains delicate woods, ceilings, decorations, fabrics, etc. A material that could quite safely and successfully be used to preserve a fence, bridge, shed or garage, may be quite unsuitable, for many reasons, for treating the interior timbers of a dwelling house or church.

Materials for the *in situ* treatment of building timbers must fill a number of requirements and possess many properties. As they must both kill and inhibit fungal and insect infestation, they should be powerfully *fungicidal* and *insecticidal* not only on application, but for a prolonged period afterwards. It is on this score that most, or probably all, gas fumigants fall short. It is doubtful if even the smoke fumigants have an active "life" sufficiently prolonged to embrace the life-cycle of most wood-boring insects. Gas and smoke fumigation is a satisfactory form of treatment where it is required only to destroy existing insects and where re-infestation is unlikely to occur—for example, the destruction of tropical insects in timber brought to this country—but for dealing with timber affected by indigenous insects, it is unlikely to prove effective for more than a very short time in relation to the "life" of the building or ship in which treatment is being applied.

It is generally agreed that the organic solvent type of preservative is the most suitable for *in situ* treatment of timber. Such a preservative must, of course, be insecticidal or fungicidal, or both—preferably both. As an insecticide it should contain chemicals which act as stomach, respiratory and contact poisons and leave a deposit which will remain in and on the wood and retain its toxicity for many years, thus removing the necessity for repetitive application, the cost of which would nullify the justification for treatment as opposed to replacement.

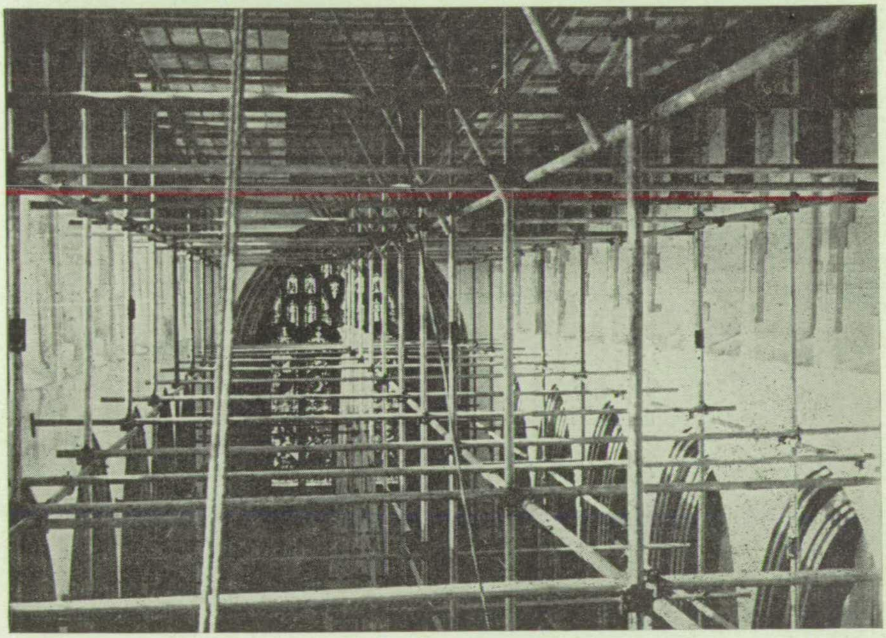
There are products on the market today which, according to instructions on the label, must be used two, three or four times before the makers consider they will be successful in ridding infested timber of borers. This is absurd, for if the product has any lasting powers, then one application, efficiently applied, should be sufficient. It is unlikely, of course, to kill all the larvae in the wood at once, but in the course of time these larvae will become adult beetles and will eventually emerge. If the wood is coated with a toxic chemical, then beetles which succeed in emerging or any other beetles which subsequently alight on the wood are unlikely to lay eggs on the toxic surface or, if they do, the larvae will be destroyed as they consume the poisonous deposit.

If, on the other hand, the toxic chemicals are so volatile or unstable that they can only be applied successfully against insects on or near the surface of the wood, several applications must be given in consecutive years in order to exterminate each batch of insects which emerge over the longest possible period of the life-cycle. Even so, it is obvious that if success is achieved and all the insects destroyed, no permanent deposit remains to prevent re-infestation, a possibility which might occur the year following the last of the repeated applications.

Stomach poisons can be expected to kill larvae only, for with most wood-boring insects it is the larvae which eat and digest the wood and not the adults. Respiratory and contact poisons must be employed to kill adult beetles, and the contact poisons must be able to act through the soft stomach integument, as other parts of a beetle, unlike flies, mosquitoes and other such insects, are not vulnerable to the effects of contact poisons. To stimulate the penetration or to synergize the contact killers, such as D.D.T. or Gamma B.H.C., other additions are necessary or the effect will be that mating and egg-laying can occur before the chemicals start to have any effect.

The solvent, also, is exceedingly important. It must form a true solution with the toxic chemicals so that they are conveyed into the wood to the full depth of penetration of the solvent. Very often the solvent will penetrate but leave the toxic chemicals on the surface, and considerable experimentation is necessary before a suitable solvent to act as a vehicle for the toxic chemicals can be chosen. It should be volatile, but not too quickly volatile. If too quickly volatile, the penetration is rarely satisfactory and, during application, such a vapour is produced that working conditions become impossible without respirators or oxygen apparatus, more particularly in confined roof spaces during the summer months. Light and volatile petroleum solvents are generally favoured by manufacturers of organic solvent preservatives, but the lighter and more volatile they are, the greater the danger from fire by spontaneous ignition, electric spark, or some foolish act on the part of the workmen.

PLATE I. *Tubular scaffolding erected by specialists for use by* in situ *treatment operations.*



In recent months several fires have occurred in buildings where preservative treatment was being applied. One because the electricity failed and the workmen decided to carry on with a candle, another where the electric cable insulation had been worn through by the passage of the workmen along a cat-walk in a church roof, another where an ignited electric light bulb was dropped, just as the atmosphere had reached saturation point, and the vapours exploded. Where there is a danger from fire caused by vapour ignition, a chlorinated hydrocarbon may be added to the compound to blanket the ignited vapours immediately. Careful calculation and experiment will enable the correct proportions to be chosen in order to neutralize the effect of vapour flash.

The heavy solvent naphthas and the light creosote oils can be used, but the smell of these solvents generally makes them unpopular. The inexpensive petroleum oils all have some odour, but usually the vapour and smell disperse quite quickly and rarely give rise to complaint.

There are occasions, however, when infested timber has to be treated in cheese factories, wheat silos, oasthouses, tobacco warehouses, breweries and other such places where contamination of the contents is likely to occur. This calls for a choice of a completely odourless and non-poisonous solvent, still able to act as a penetrant and vehicle.

In most instances where *in situ* treatment is being applied, it is essential that the preservative shall cause no staining of the timber, plaster, plasterboard or other linings. It should not soften, blister or change the colours of paints, varnishes, distempers or emulsion finishes; nor must it corrode metals or cause irritation to the skin of the operators, harm their clothes or stain fabrics and upholstery. It must be reasonably inexpensive, so that treatment costs are infinitely less than those for replacement.

Once having prepared the material, it is necessary to evolve a method of application which will be effective against whatever species of insect or fungus is attacking, or is liable to attack, the timber. It is obvious to those who know something of the life history and habits of the various species of wood-boring insects in this country, that the methods used for dealing with *Lyctus* beetle, with its life-cycle of only one or two years and its habit of attacking only semi-seasoned sapwood of hardwoods, are unlikely to be so successful when employed against the Death Watch Beetle with its life-cycle of up to ten years and its predilection for fungal infected wood, whether it be sapwood or heartwood, hardwood or softwood. The House Longhorn Beetle, also, is in a category apart, for although it confines itself mostly to the sapwood of softwood timbers, it packs its galleries so tightly with bore-dust that the injection methods which might be successfully employed against the Death Watch are quite useless against the House Longhorn. The Common Furniture Beetle is, of course, the most versatile of all the insect borers. It attacks softwood and hardwood, sapwood and, occasionally, heartwood, indigenous and tropical timbers, pieces of wood of any size from the finest veneers up to the largest structural timbers found in buildings. It seems to need no particular conditions of humidity, although it waits for the wood to season, and requires no help from fungi. Very often the greatest concentrations of Furniture Beetle flight holes occur on the polished, varnished or painted surfaces of the affected timber, and yet we know that the eggs are never laid on such surfaces, but only on bare wood and, generally, in fine cracks, joints and crevices.

This knowledge and, in fact, all the peculiar characteristics of the borers and fungal rots, should be known to the personnel who apply the *in situ* treatment. Each man should be educated to the point where he can identify the common wood-boring insects by their flight holes, bore dust, larvae, pupae and imagos, and be able to tell the difference between *Merulius lacrymans* and other types of fungal decay. Until he has this knowledge, no man will apply *in situ* treatment satisfactorily, for he will not appreciate the necessity for modifying his method of application to suit the different forms of insect infestation and/or fungal decay.

Brush application with the light, mobile liquids generally used for *in situ* treatment is quite out of the question. Those who advocate such a method have never attempted to treat overhead beams and rafters by dipping a brush into a very thin liquid and then trying to get it on to the wood. When the brush is lifted towards the timber, more than 50 per cent. of the liquid runs down the handle, down the operator's arm and, very often, down his body into his boots. Various devices have been designed to put on brush handles and prevent this, but nothing less than a large umbrella will protect the worker for more than a few minutes.

Brush application with even the thicker and more oily forms of preservative cannot be successful, for it can only be applied to the exposed and easily accessible faces of the timber, leaving the backs of rafters, purlins, wall plates, the hidden sides of built-in bonds and studding timbers untreated. Contrary to the opinion expressed in one book on the subject, brushing does not *force* organic liquids into wood, nor does spraying deposit organic liquids in tiny droplets which will not disperse or penetrate. All organic solvents will penetrate just as well if properly sprayed on to wood as they will when brushed, but the spraying must be controlled so that the surface of the wood does not become over-saturated too quickly and so cause drip. A trained operative will move his spray lance backwards and forwards along a beam with such skill that he will gradually build up to saturation point without wasting preservative. This, of course, is very important when applying treatment to the waggon rafters of valuable plaster ceilings. Even if the fluid is completely colourless, some staining always occurs if the preservative is permitted to penetrate.

Left : PLATE II.
Trimming with the draw-knife.

Below : PLATE III.
Vacuum cleaning to remove dirt, trimmings and bore-dust

Top Right : PLATE IV.
Controlled spraying.

Below:

PLATE V. *Dry-rot control—drilling masonry to assist drying and the penetration of fungicide.*

PLATE VI. *Dry-rot control—heating masonry with high temperature flame-throwers.*

Although Dry Rot (*Merulius lacrymans*) is essentially a disease of timber, the treatment required to eradicate and control its growth is more far-reaching than the mere application of chemical preservatives to the timber. Timber preservatives intended to destroy Dry Rot infestation must be suitable for applying to brickwork and masonry, concrete and other building materials. It has been found that certain chemicals which are powerful fungicides on timber lose their toxic powers through chemical reaction with lime, and there were many instances of Dry Rot recurrence before this fact was generally appreciated. Only a chemist could have foreseen the possibility of such a reaction, and so it becomes an imperative necessity for any responsible firm engaged in *in situ* treatment to employ a well qualified chemist or to submit their formulae to chemists with a full knowledge of their intended use, the materials on which they will be used, and the conditions under which they will be applied. Oil-borne preservatives are obviously at a disadvantage when applied to walls or site soils saturated with water. Either the affected areas must be thoroughly dried out before the material is applied or a water-soluble fungicide should be used. The water-soluble preservative must then be of a sufficient concentration to mix with the moisture of the walls or soil so that the consequent dilution will not fall below the effective toxic strength. It should also remain fixed in the treated material, and this can only be achieved by precipitation in an insoluble form in the material itself, or by the application of a second treatment with another precipitating chemical.

The old concept that brickwork, masonry, concrete and soil can be effectively sterilized by heating with a painter's or plumber's blowlamp is, of course, quite absurd. All are such effective insulators that it is quite impossible to heat them to a depth to destroy fungal hyphae and rhizomorphs which often penetrate for inches, and sometimes feet, into the fabric. Heating with flame throwers which cover a fairly large area does assist in evaporating the moisture and raising the temperature to an appreciable extent, but such heating only has value in encouraging penetration of the fungicide and cannot be relied upon to destroy the fungal infection.

All this should be known to the operatives who apply the treatment but it is on the technical surveyor that the heavy burden of responsibility rests for the original diagnosis and assessment of the extent of the infection. Judging the extent of an outbreak of Dry Rot is probably the most difficult of all problems connected with *in situ* treatment, and the ability to do so with reasonable accuracy can only be acquired from long experience of observing outbreaks being opened up and fully revealed or, better still, by actual experience of opening up. Hence the training of technical surveyors should always include a period of at least six months' work in a labouring capacity under an experienced foreman.

Teaching workmen to appreciate the significance of the forms of infestation, and to apply the materials in the best manner to achieve success, is best done by means of cinematography and other visual aids. It usually takes the average man many months to memorize the names of the various species of insects and fungi he is likely to see in the course of his work but, with the aid of suitable films, he quickly learns to differentiate one from another, and to realise whether trimming, drilling, vacuum cleaning, injection, spray, heating, percolation, diffusion, or complete removal will be necessary to cope with the situation.

A foreman in charge of a job should be able to answer any reasonable questions which even the most knowledgeable architect might ask, whether of an entomological, mycological, or structural character. He should be able to supervise the erection of scaffolding sufficient for the job, be able to stand heights, organize and direct the men, have a knowledge of building mechanics, judge the strength and stability of the timber and structures on which he is working, and also be able to prepare time sheets and a detailed report with a daily log of progress.

All men when engaged for work as sprayers or appliers of *in situ* treatment should be medically examined, and their reactions to height tested. No man with a weak heart or subject to fainting fits should ever be employed for this class of work, for it is exceedingly strenuous and hazardous, involving great heights quite often on precarious ladders, odd planks across tie beams or collars, and many other situations which call for good health and cool nerves. Men must also be prepared to stay away from home for weeks on end, living in all kinds of lodgings, the quality of which very often depends upon the location of the job.

Another, very essential, quality demanded of *in situ* treatment workers, is honesty. So often the work is carried out in palaces, houses, museums and ecclesiastical buildings where articles of great value are displayed, or just left about in a manner which could be very tempting to any light-fingered workers. In fact, the qualities of skill, intelligence, honesty, adaptability, cleanliness, courage and all the other requirements demanded of *in situ* treatment workers makes one wonder how they are ever found and what wages they demand. Actually, the work seems to attract men and, in our own organization, we always have a waiting list of men anxious to join the firm. Wages are, generally, comparable with those in the building trade, and are by no means high.

When a firm specializing in *in situ* treatment is asked to deal with a building, the first move is to send a technical surveyor to examine the problem, diagnose the trouble, prepare a detailed report on the condition of the timber and any defects in the structure, inherent or otherwise, which might have given rise to the deterioration; suggest any structural modifications to the structure, drains, etc., which might help to correct the existing situation or prevent further trouble of a similar character and then draw up a detailed specification of the methods and materials, together with costs, which must include labour, materials, hire of special plant (e.g. generators, where there is no mains current), scaffolding, transport, lodgings, insurances, overheads and profit. Such work requires a very wide knowledge of building structures and nomenclature, particularly when dealing with churches and ecclesiastical buildings, a head for heights even steadier than that of the workmen for, quite often, only a precarious and worm-eaten ladder is provided for examining roofing timbers or steeples which would be treated from a scaffolding.

One of the greatest difficulties of a technical surveyor is to estimate the depth and extent of the frass which will have to be removed during the course of the work and how long it will take the men to trim it off, clean it up, convey it from the roof space down a series of ladders or several flights of stairs, and possibly to the far end of a large estate where it can be burned. Quite frequently, the cost of this part of the work constitutes a larger proportion of the labour charges than the actual application of chemicals. He must satisfy himself that access and egress to confined spaces present no serious dangers to the men engaged in the treatment process, for it is not unusual for men to be overcome by heat or vapour concentration in poorly ventilated roofs, sub-floor spaces and cellars. He should always try to envisage what would happen if a man became unconscious, and had to be quickly taken out into the open air. If not satisfied that the conditions are reasonably safe, he should design and suggest ways and means for making them safe, such as the removal of tiles, slates or lead, provision of fans to circulate the air, provision of additional trapdoors or manholes, etc.

He must, also, make certain that all the affected timber, or that which it is intended to treat, is accessible, and that there is no timber hidden away in which beetle and fungi can continue to flourish. This often creates the most difficult problems, the resolution of which calls for great moral courage on the part of the surveyor. It calls for considerable courage and a great deal of self-confidence to tell a client that all his sloping ceilings must be taken down because they hide the rafters and wall plates, or that his beautiful Adams cornice must be sacrificed to get at the dry rot growing in the fixing blocks or built-in bonding timbers. In so doing, he accepts a very great responsibility on behalf of his firm because all this kind of opening up and restoration is exceedingly expensive, often far more than the total value of the preservative treatment, and so, if he makes a mistake or the treatment is not successful, his firm may be held responsible.

For this and numerous other reasons, the framing of a report demands ability and experience for clear expression and with full regard to legal pitfalls and professional responsibilities and ethics.

It is becoming an increasing practice of architects and surveyors to instruct timber decay specialists to examine the timber in houses which are about to change hands. They thus relieve themselves of the danger of being accused of negligence or ignorance if insect infestation or fungal rot is subsequently discovered by the purchaser, but, in so doing, saddle the specialist with the responsibility. There is a very great risk to this side of the specialist's business for, with all the knowledge in the world and using every device known to science, he could very well miss an incipient outbreak of Merulius which was completely hidden at the time of his inspection but which could develop into an extensive growth by the time all negotiations and legal formalities had been completed and the client in possession of the property.

Claims by purchasers of properties against architects and surveyors because of alleged negligence have run into many thousands of pounds during the last few years and, although most of such cases are settled out of court and "hushed up," the two professions are becoming more and more aware of the risks they run and are seeking the services of specialists to relieve them of some of the responsibility.

Although considerably less capital is required than would be needed to set up an impregnation plant, the capital needs of the *in situ* treatment business are often grossly underestimated. To establish a business capable of manufacturing or mixing its own chemicals, carrying out a certain amount of research and experimentation, to send technical surveyors and trained personnel to any part of the country with all the necessary equipment to efficiently carry out the work, to say nothing of packing machinery, containers, advertising, administrative and office staff, etc., etc., costs more than many optimistic adventurers into the realm of timber preservation imagine.

The men usually work in teams of two, four, six or eight, and are conveyed to the site in specially equipped service vans and lorries. Every team must have its own van and equipment as most jobs are situated many miles apart and so each must act as an independent unit. The equipment consists of a kit of tools for opening up floorboards, panelling, etc., trimming tools, electric leads and lamps, an industrial vacuum machine, pneumatic spraying and injecting apparatus, dust sheets and tarpaulins, various brushes, block and tackle, fire extinguishers, ladders and, where necessary, scaffolding, gantries, trestles, ladder cripples, electric generators etc. When it is necessary to increase the outside working staff, a capital expenditure of approximately £1,000 is necessary to provide a van and equip each pair of men. To ensure a high standard of workmanship, it is necessary to have inspectors travelling from job to job checking the time sheets and seeing there is no waste of time or materials, inspecting the trimming, cleaning and the treated wood to see that it has been dealt with as specified in the technical surveyor's report.

Insurance rates covering accidents to personnel, other parties and property are high because of the very considerable risks involved. Rates for fire risks usually vary according to the flash point of the material being used, the higher the flash point the lower the rate of premium.

From the business point of view, one of the greatest hazards is the periodic slump. In the Spring, Summer and early Autumn people are very cognizant of insect activity and are inclined to panic and demand immediate service from the specialist but, as the flight season passes so does business, and unless the firm is fortunate enough to be engaged on a very large job which keeps a large proportion of the labour occupied during the Winter months, it is not at all unusual to have 50 per cent. of the labour staff idle from Christmas to Easter. Fortunately, the fungal rots usually manifest themselves in the Autumn and early Winter, so that the situation is rarely so grave with firms who deal with both forms of decay as with those who only deal with insects. Even so, it is an extremely fortunate firm that can go through a Winter without some redundancy, with the result that profits made in the Spring and Summer are often lost during the Winter in paying the wages of trained personnel whom the firm dare not stand off, as it is so expensive to replace them and to teach the newcomers all they should know before they can be permitted to carry the firm's reputation in their hands.

Firms which specialize in church work find Christmas, Lent and Easter difficult periods and an odd factor which the surveyors of such firms have to consider is whether the church is Roman Catholic or, if Church of England, whether it is High or Low. Roman Catholic and Anglo-Catholic churches hold many more services than the Low churches and, more often than not, insist on holding them even when the church timbers are being treated. This, of course, interrupts the work every morning whilst Masses and Matins are held, and occasionally at other times during the day if the incumbent is exceptionally devout or over-enthusiastic. Therefore, the charge for treating Roman Catholic and Anglo-Catholic churches is appreciably higher than that for dealing with the Low churches and Non-conformist churches and chapels.

There are many architects with a wide knowledge of timber defects and the technicalities of *in situ* treatment, but they are relatively few when compared with those with only a little, or no knowledge at all, of the biology of timber decay and the methods of control. Many of the less knowledgeable are inclined to regard the timber decay specialist as being in a similar category to that of the heating specialist, the electrical contractors, roofing and flooring specialists, etc., and demand fixed estimates of the cost for dealing with decay problems based on accurate measurements, squares or cube units of timber involved. This applies more particularly to architects employed by corporate bodies, councils or organizations, where the expenditure of all money has first to be approved and passed by a committee, the members of which have little or no knowledge of the problems involved.

Quite often, competitive tenders are demanded and several specialist firms are invited to submit estimates for dealing with outbreaks of dry rot or beetle damage in buildings of great historic value. This, to my mind, is rather like obtaining competitive tenders from a number of surgeons to remove a cancer from a human body. It is only on rare occasions that the full extent of the infestation and the damage can be seen or even envisaged by the specialist surveyor.

When examining a building it is practically impossible to judge with any degree of accuracy the depth of penetration of fungal growths or beetle borings and yet, without an absolutely accurate knowledge of these factors it is quite impossible to assess the amount of labour and materials required to thoroughly and adequately apply control treatment. The result is, that should competition become a decisive factor in obtaining work of this nature, a tendency to "skimp the job" will creep in in order to keep within the figure of the fixed estimate, and it is highly probable that traces of the "cancer" will be missed, particularly in places difficult to examine. Usually, such places are of very great structural importance, such as wall plates, the ends of trusses, studding timbers, etc. Such workmanship would, of course, be criminal, particularly in buildings of historic and aesthetic importance, but if economic consideration alone is allowed to influence those in whose hands the welfare of such buildings is placed, then it is obvious that such criminal practices will be encouraged.

Discussion on Paper 4

The CHAIRMAN (Mr. C. S. White): Mr. President, Ladies and Gentlemen, I have been asked to introduce Mr. S. A. Richardson. It will not take very long. There may be one or two who do not know very much about Mr. Richardson. I think there are very few indeed who have never heard of him. However, for those who are new to this Convention, Mr. Richardson is by training a chemist, and everyone in the South of England at any rate knows of his long experience of *in* *situ* treatment of buildings, including Winchester Cathedral, with which he was first associated about 25 years ago, and of his experience in West Africa. Therefore, with the variety of experience he has had, we shall listen with the utmost interest and respect to his views.

Mr. Richardson proposes to show some slides, and there are quite a number of them. I have persuaded him to show them all and not omit any, as he at first suggested. He will open with the slides and talk as they are being shown. The discussion will be all the more fruitful if he shows the slides now and not during the discussion, or even after it.

As time is fairly short, I am going to ask Mr. Richardson to commence his talk.

Mr. S. A. RICHARDSON: Thank you, Mr. White, for those few kind words. I am going through the slides as quickly as I can because there is a great deal of acrimonious content in my Paper, of the enjoyment of which I should hate to deprive you!

Slide. The dead trees shown on these slides are the natural home of the beetles and some of the fungi that we find in buildings with which we have to deal; that is, we in the business which we are now calling the *in situ* treatment business. The beetles do not always confine themselves to the dead trees in the forest, they often—as those of you who saw my film will remember—go into dead trees which are treasured and kept as memorials or ornaments and here you see that a plaque or a notice has been put up on an old stump which gives details of the life and history of the tree. *Slide.* When you look at it closely, you find that it is full of various kinds of insects, including the Death Watch Beetle; and is obviously acting as a breeding ground for the beetles. *Slide.* On this slide you can see the beetles exploring a piece of wood. If they are females, the chances are they are seeking a convenient place in which to lay their eggs. *Slide.* You can now see some of the effects of egg-laying. This slide shows oak timber built into brickwork. At the time of our inspection it was covered with plaster. By examining the other side of the wall, it was found that the timber was there exposed as a feature of the building, a bishop's palace; removing the plaster on the other side, this is what we found: Death Watch Beetle holes which had obviously been there for a long time and evidence of damage had been caused in the past. When it had to be replastered, the plasterers stuck odd pieces of oak in to level the surface of the wall, so adding to the foodstuff, because one can see that the Death Watch Beetles have attacked the new pieces of wood.

Slide. Here is another interesting situation. These old buildings with which we deal are not always structurally sound, and not all the structural instability is caused by beetles. It can be caused by various things. We have one known as the "plumbers' rot," in which plumbers cut great chunks out of the joists to insert their heating pipes and when the floor springs up and down, dry rot is suspected; but it is not, it is "plumbers' rot!" "electricians' rot" is somewhat similar! It can be quite easily diagnosed.

Slide. Some of the methods of control are now considered. The first is the removal of the sapwood edges which are generally riddled by the common furniture beetle, or perhaps by *Lyctus* attack. This riddled frass, as it is called, is taken away because obviously there is no point in preserving it, and as it is such porous, spongy material it will take up large quantities of preservative to no effect. So the first business in dealing with affected timber is to trim it and although various methods are used, only one is shown here.

Slide. Here you see a peculiar little tool. It is one which I evolved about 20 years ago. It is an adze which has a vertical head on one side and a horizontal head on the other. If men are trimming away sides of rafters, they use the head with the vertical blade. If they are doing the flat face of a rafter, they use the horizontal blade, and this tool makes it so much easier for the men to do the job. Do not give your men big, heavy adzes to use because chipping away at timber all day long, as these poor men have to do, is no light task. The weight of the tool shown is approximately a pound and a half maximum, usually about a pound and a quarter. They can chip away for quite a long time with that without undue fatigue.

Slide. On this slide you see one of the other necessary processes, the removal of the bore-dust and the chipped off frass with vacuum machines. Vacuuming is a very essential part of the business for, apart from removing the dust and debris, it has a psychological effect. If one treats a roof which has heaps of bore-dust about, as one sees when the beetles are active, and preservative is sprayed on to the heaps, instead of disturbing them you *fix* them because the chemical itself will cake the bore-dust. The following year someone may go and look at the roof and may assume the beetles are still active because heaps of bore-dust are still present. It is very difficult to persuade the people who see the mounds that they are actually full of the chemical which had been sprayed on them. Therefore, psychologically it is a very good plan to remove all traces of bore-dust before the treatment is applied, then, if any activity does occur, it can be very easily detected by fresh bore-dust.

Slide. This slide shows another necessary phase in the treatment of Death Watch Beetle. Here it is obvious that the insects have laid their eggs along the shakes and cracks in the timber. You see the Death Watch flight-holes which indicate a fairly recent infestation with perhaps one life-cycle period, one can assume that the insects are now in the phase of the second life-cycle period. In order to deal with this the timber is drilled at various points and then liquid is introduced under high pressure with an instrument which is provided with a special type of injecting nozzle and plunger injector. *Slide*. This forces the liquid into the insect galleries and it is simply amazing where the liquid oozes out. That is an untouched photograph, and you can see that there is liquid oozing out in all sorts of places. In some of the big beams we have dealt with, it has oozed out many feet away; if I told you 20 feet you would probably think I was exaggerating, but in actual fact we did on one occasion have liquid oozing out of a beam 20 feet away from the point of injection. The reason being, of course, the beetles had worked in the depths of the shake and had more or less hollowed out the beam. Therefore, the injection at that point was going literally through a tube, which was the beam converted into a hollow container.

Slide. We now go on to the surveying side of the business. When one goes to look for dry rot or any other form of decay, one should always go first of all round the outside of the building and look for faults in the structure which might create conditions favourable to the various decay organisms.

Slide. In this slide you see a defective rain water trap. The defects were not apparent until the grid was removed and the trap was found to be full of water. No one would believe me when I told them that the rot was due to soakage of rain water through the wall, but removal of the grid and water revealed two cracks in the wall of the trap and even the rendering which had been put on the wall to try to stop the water coming through was cracked. The result was that the inside of the house was very much wetter than the outside could ever be even in a most fearful storm!

Slide. Here is another instance of trouble. This is a house, probably occupied by the military during the war—a lot of these photographs were taken not long after the war when we were having all the problems with dry rot which resulted from occupation and war damage. Here you can see water running down the wall due to a fault in the joint of the rain water fall-pipe and another patch of dampness due to a blocked pipe. The other damp patch is due to water overflowing from the hopper head at the top of the pipe.

Slide. Those are the sorts of things we look for. There is a church and around the church a brick-lined gulley was built to take the water away from the walls because of rising damp. It was a very good idea and the architect who suggested it was very, very sensible, but he did at least expect someone to look after the gulley and not let stinging nettles and shrubs grow out of the bricks so that they were all dislodged thus completely defeating the object of the gulley. In fact it rather aggravated the situation because it formed a trough which gathered the water which soaked through all the brick joints, went underneath the foundations and caused the interior of the church to become damper than it had been before they put in the gulley. Therefore, the name of the architect was mud and so was the interior of the church!

Slide. Here we are on a flat roof with a parapet gutter. The vent in the corner running out to the gargoyle is choked and has a beautiful little garden growing in it. When it rains the parapet gutters are filled with water, which gets over the flashings, underneath the lead and into the church; so trouble is caused on the wall plates which are probably the most vulnerable points of the roof.

Slide. Here we have a typical case of a church neglecting its gutters. One of the prime causes of dry rot is the neglect of gutters. I maintain, and I have reason to know, that 90 per cent. of the outbreaks of dry rot we investigate are caused by neglect of gutters and the hopper heads at the top of the fall pipes. If those were only looked after and cleaned out regularly, some of the firms dealing with timber decay would be out of business.

Fortunately, we now have the quinquennial inspection of churches which the church authorities hope will overcome this sort of thing by making it compulsory to have the church inspected once in five years by an architect or surveyor. Unfortunately many churches are now so neglected that it will take years and years to recover and catch up on this problem.

Slide. This slide shows the sporophore of dry rot which, perhaps, explains the *lacrymans* of *Merulius lacrymans* as there are the tears exuding from the surface or hymenial layer. It has cried so much that some of the tears are running down the wall. The presence of such a sporophore indicates that, at least, 100 square feet of fabric is infested with the mycelium of the fungi.

Slide. This slide shows a sporophore hanging along a piece of picture-moulding. You can see that it is beginning to peel off, suggesting that it has possibly released most of its spores, those billions and billions of spores which in mass, produce the reddish-brown coloration which you will see in the colour slides in a few minutes.

Slide. The dark patches on the ceiling and walls in this photograph are not caused by dry rot. They do not necessarily indicate that there is dry rot there, but they do suggest that a very thorough investigation of the situation is necessary because the dampness which produced them might well cause the germination of *Merulius* spores.

Slide. This is a photograph of a rather lovely room with a beautiful Adam's cornice, and here is the original clue, the original indication of trouble. It was reported by the owners that a mushroom was growing between the cornice and the ceiling. On removal of the shutter casing and the window linings, it was revealed that the growth had spread all down each side of the window, along the back of the cornice and into the roofing timbers above. The cause of that outbreak was a built-in fall-pipe inside the wall which was blocked and had been leaking through the brickwork.

Slide. This slide shows you how the mycelium will grow into and through the brickwork, and these are the rhizomorphs. The rhizomorphs are the thick penetrating fibres which go through the brickwork and are quite easily seen when you split open a brick or open the joints of brickwork. Sometimes you find rhizomorphs penetrating through brickwork, concrete and stone-work of a thickness of several feet.

Slide. This shows the final effect of dry rot and probably the reason why it is called dry rot. It has that horrible dry look about it. If you break it up in your fingers it feels rather like the cuttlefish that you can pick up on the shore; all the substance appears to have left the wood. *Slide* (Colour). This is the colouring of the fungus. It has reddish and greenish strakes described in Leviticus, Chapter XIV. This is a coloured picture of a *Merulius* sporophore liberating spores in great numbers.

I expect some of you have wondered why I wrote this Paper. I will tell you. At last year's Convention I was in a little group of the pressure treatment people and they were talking about their problems. One of them turned to me and said: "Of course, you have no problems, you only need a bucket and a brush." Because of that I thought I had better write something about the problems of the *in situ* people. In this Paper you have really a list of the problems and the organisation which goes on behind this *in situ* business. It is quite a new thing really, although perhaps one might argue that it is the oldest of all the forms of preservative treatment. However, it is only within the last 25 years that it has started to become organised and some plan has been worked out for methods of treatment. In this paper I have drawn up what I suggest might be a Code of Practice for *in situ* workers; time does not permit me at the moment to go into this Code of Practice because you want to ask me several questions. If, however, anyone likes to ask me the question: "Would you let us know what the Code of Practice is?" I will read it out to you, because it will be clear you wish to hear it. I will leave it at that so that you can ask questions.

The CHAIRMAN: Thank you, Mr. Richardson. We really have been entertained as well as agreeably informed on a number of technical matters. A number of profound truths have been brought to our notice which I am sure we will remember. I should like to open the discussion right away.

Professor J. BAYLEY BUTLER: I would like to congratulate Mr. Richardson on his Paper. I think it is of extreme value. It really does explain what the *in situ* operator has to undertake, and it would be of great value to any firm that carries out treatment of this type if they were in a position to send, say, a copy of Mr. Richardson's Paper to an architect who perhaps proposes employing an ordinary contractor to carry out the work.

Mr. Richardson has stressed very much the importance of having skilled operators and really the chemical treatment is possibly—would you say one-fifth of the work, Mr. Richardson?

Mr. S. A. RICHARDSON: Probably, Professor, yes!

Professor J. BAYLEY BUTLER: Or is that an exaggeration?

Mr. S. A. RICHARDSON: In some cases not an exaggeration at all.

Professor J. BAYLEY BUTLER: The *in situ* contractor has not only to do his own work but my experience is that he has to advise the architect on what the contractor has to do. It is, therefore, left to him to carry the onus, to say that this has to be cut away and that has to be cut away; he has to carry the whole responsibility although perhaps his part of the contract is only one-tenth of the whole job. Am I not right?

Mr. S. A. RICHARDSON: You are perfectly right.

Professor J. BAYLEY BUTLER: I do feel too that the question of guarantees which has been raised is extremely important. I would like to hear Mr. Richardson explain how he deals with that problem.

Mr. S. A. RICHARDSON: Thank you, Professor. The word "guarantee" has been much abused during the last 50 years, ever since pressure salesmanship was introduced. When one issues a guarantee, what does it mean? It means only that a certain responsibility is to be accepted by the producers of a product or those who carry out certain works. I am not sure that the word "guarantee" is the right word, but in our class of business—this *in situ* treatment business—I feel that we must accept responsibility for what we do. When a firm claims to be specialist consultants, timber technologists, timber disease destroyers and so on and they set up to be experts then they must accept the responsibility of experts. This question of a guarantee, what does it amount to? Every one of us here knows—we are not children—that guarantees, more often than not, are not worth the paper they are written on. There is always just that little clause, at the bottom, on the back or round the corner, which immediately makes the whole thing useless.

What it amounts to is that when a firm such as ours, or Boultons or any firm dealing with *in situ* treatment, goes into a building, they have got to accept a measure of responsibility for what they do. It is not fair to expect church councils to go to all the trouble of raising the money—and they do have trouble raising money—to have a church treated by experts and then two or more years later find the beetles are still there. Who pays for it? Why should the church? They have in good faith employed a firm claiming to be experts to do the job, and then the firm says, "Oh, but we didn't guarantee it." Is that right? Is that morally right? Of course it is not right, and I am one who says that if you claim to be an expert, then you have a moral obligation to look after those who, in good faith employ your services.

Dr. R. C. FISHER: I think Mr. Richardson has done us all an invaluable service in showing what a reputable firm, setting out to do a specific job thoroughly, requires in the way of equipment, training and knowledge gained from practical experience. Unfortunately, it is my experience, from being asked to give opinions on types of treatment for beetle attack, that firms who sometimes come to us at Princes Risborough say: "We wish to set up a servicing firm, can you give us some literature and some information in order to start off our business?" That happens quite frequently. That such a firm can set up with impunity in any part of the country, that any authority, such as church authorities, local authorities and so on, can approach such a firm which may be entrusted with the work, when they are so inexperienced poses a grave problem. We often hear of the cost of treatments by specialised firms, and very few people realise what is involved and that it is really justifiable. If this Association could make known what really is involved in carrying out such treatments it would be to the advantage, not only of the firms but of the whole industry concerned.

I was looking back the other day to Volume One of the proceedings of this Association in which Professor Munro gave a short account of the principles and problems of wood boring insect control. In his Paper he quoted, in connection with Death Watch Beetle damage, Professor Lefroy, and I should like to read very briefly this relevant extract. The emphasis which Mr. Richardson stresses now is exactly the same as was laid by the early workers. It is a very short extract: "The essential qualities of an efficient treatment should be, first, the penetrating powers of the material used; secondly, the killing power; thirdly, its permanency. With regard to the qualities of the insecticide against the beetle, "it should be unchanging chemically; non-inflammable; non-poisonous in application; non-poisonous after application; not a varnish solvent; simple and cheap; not smelly; not produce toxic vapour; not corrosive to metal; applicable as liquid; it should not form dust and it should not affect colour." Such a preparation, was, of course, an ideal and was not being achieved. However, I think considerable advances have already been made which meet some of these requirements. I think, therefore, Mr. Richardson has done us a great service in drawing attention to the specific problems and the need for accurate knowledge gained from experience. If something could be done to stop the development of up-start firms with no experience, which are, however, employed on the treatment of important buildings throughout the country, the nation would benefit.

Mr. S. A. RICHARDSON: Thank you, Sir. I must give an instance before we wind up about which I have already told Dr. Fisher. I was asked to look at a very large church and give an estimate for dealing with the roofing timbers. We have a special method of estimating, one that has been developed over a number of years, and we can, I think, with reasonable accuracy tell how much a roof will cost for the treatment of beetles. In this case we estimated more accurately than usual because only furniture beetles were involved, but they too have to be treated. It was going to cost by our methods and by my pricing £1,100. The architect said to me: "We've had another estimate sent in for £187." I asked: "Who gave you that?" He replied: "The local window cleaner." This window cleaner saw in the paper that the church needed treatment and because the weather was unfavourable he thought it would be a good chance to use his ladders and his men to deal with it. He was quite prepared to buy some product—I do not suppose he really worried what the product was—for treating timber. He had not the faintest notion how much material would be required and he did not even go up into the roof space. It was a plaster ceiling and to get into it he had to go up a 60 foot ladder, through a tiny trapdoor through which I could only just pass. He did not go up, he walked round the church and having done that he said to the architect: "Yes, we'll treat it," and for £187!

Mr. F. A. RUHEMANN: I would like to ask the following question. Do you think, Mr. Richardson, that the various timber pests have abated since the war, since treatment has been more wide-spread? I should like you to answer this question with regard to the various types of timber rot, *Merulius* and the various beetles.

Mr. S. A. RICHARDSON: I think that is an impossible question to answer, Mr. Ruhemann. I have not the facilities for ascertaining what the degree of infestation is and, of course, I am if anything a little biased because I only have to look at places where there is trouble. I very rarely look at those places where there is no trouble. The result is, if I relied entirely on what I could see, I would conclude that every house in Britain was full of Dry Rot, Death Watch Beetle, Furniture Beetle, Lyctus, Longhorn and everything else. It is very difficult to judge, but looking at the whole thing broadly, I would say the the situation is worsening so as far as insects are concerned and back to the pre-war level as far as dry rot is concerned. The reason is, of course, that we are now maintaining our buildings more or less at pre-war standards and, therefore, dry rot is to a great extent controlled by the efficient maintenance. As far as beetles are concerned, however—I am now thinking more of the furniture beetle than the Death Watch—we have had millions of houses built since Queen Victoria was on the throne, and those houses are now all reaching the stage where defects are creeping in and the timber is becoming receptive to beetles. The result is that every week more and more buildings are becoming affected by furniture beetle; whether they are becoming affected by Death Watch I would not like to say because, as the life-cycle of the Death Watch is so long, it would take another ten years for us to decide whether the Death Watch was on the increase today or not. You have got to wait such a long time to find out with Death Watch Beetles.

As regards the House Longhorn Beetle, we just do not know. Dr. Fisher may know but I do not. That problem was suddenly thrust upon the timber preserving world, as the result of the discovery of House Longhorn infection in houses in Camberley and other places in North West Surrey. It was thought that one house, then two houses and then 1,200 houses were affected, but how long they have been affected we really do not know. Whether it is spreading, we still do not know. We found Longhorn in Southampton only a week or two ago and it was a very vicious outbreak. We do not know again how many houses in Southampton are affected because only one person asked us to look at his house. The next-door houses might well be affected but we have not been asked to look at them so how can we judge what the extent of infection is unless, of course, an organised system of inspection of houses is introduced? That would be the only way that we could form a judgment on these various problems.

Mr. P. R. SAWYER: I am one of the school of young architects who it was suggested this morning had been brought up to take little interest in timber and I just say, coming from Mr. Bird and reading from his Paper, I was extremely worried by one sentence in which he says, "I am glad to report that all agree more than one treatment to be necessary." That is a report based on the opinions of 20 architects more experienced than myself. Mr. Richardson in his paper rather indicates that is not necessary. I wonder if you could elaborate on this point.

Mr. S. A. RICHARDSON: Certainly. If these 20 architects all said the same thing, they would all be perfectly right, and the reason they are right is because they are basing their knowledge and opinions on official leaflets which have been sent out from time to time, and all of which state that timber should have two, three or four treatments. All that goes back 20 years, and perhaps to Lefroy's time, when the main chemical of those days was para or orthodichlorobenzene, volatile chemicals which could only be effective if applied when the beetles were on or near the surface of the wood. Of course, as time goes on new chemicals are evolved and, as their properties are discovered, are applied to timber preservation. Fairly recently, chemicals have been evolved and adapted to timber preservation which retain their toxic properties for a long time. If a chemical is persistent, then repetitive treatment is not needed, provided the initial treatment is applied thoroughly. That, however, is the secret: it *must* be applied thoroughly.

You saw on the slides the necessity for carefully trimming away the frass in order to get down to the sound wood so that the chemical can actually get on to the sound wood and preserve it; not the rotted wood because we do not want to preserve that.

Another essential requirement is the uncovering of the wood which is hidden away behind plaster, in the spandril spaces over the eaves, the wall plates, the ends of beams which are buried away in the walls and the studding and bonding timbers. Unless they are fully exposed and accessible they will not be properly treated. If they are not properly treated the first time, they are still not going to be treated properly the second time, the third time or the fourth time, and so what advantage is there in continuing to treat the wood unless it is done thoroughly? The answer to the whole problem is to use a persistent chemical that will repel the beetles and stop them laying their eggs. If it is efficiently applied you have no need to carry on giving repetitive treatments.

Dr. R. C. FISHER: Mr. Chairman, one thing we have not heard is Mr. Richardson's Code of Practice; whilst there may not be time at the moment to hear it, could it not be made available at some other time?

The CHAIRMAN: I should like to feel that there was an opportunity for this Code of Practice to be examined by those who are interested. I have personally read it. Would it take very long?

Mr. S. A. RICHARDSON: Five minutes, probably.

The CHAIRMAN: If you could elaborate, personally I think it would be well worth our hearing it.

Mr. S. A. RICHARDSON: In my Paper you will find that I have skimmed over the organisation, the training and the various hazards of the *in situ* treatment business, but I have not mentioned anything about qualifications. Qualifications generally suggest to one's mind a string of letters after one's name. In this business, we have no letters that we could append after our names that would be relevant to the particular job in hand. The only way we are likely to develop qualifications, or at least indications of one's ability to do a good job, will be through the Institute of Timber Technology, or some similar body capable of judging the ability of people and issuing diplomas. If you bear that in mind first of all, and also the ability of that same body to judge the ability of firms and products, then I can read this suggested Code of Practice with some sense. I have called it the 10 Commandments of *In Situ* Treatment:

"It shall be incumbent on Firms claiming to be Timber Decay Specialists, Timber Consultants or others who carry out the treatment of *in situ* timber for the control of decay, whether by insects or fungi, to fulfil the following requirements:"

"1. To submit the names and qualifications of all personnel responsible for surveys and technical reports to the recognised authority."

The recognised authority does not yet exist but that is something we have got to create.

"2. To ensure that all such personnel have received a recognised training and passed a suitable examination in the subjects necessary for the satisfactory fulfilment of their task.

3. To submit all chemical formulae to the recognised authority.

4. To describe all methods of application, preparation and any subsequent forms of treatment which are part of the preservation process.

5. To describe all apparatus and equipment used in the course of the preservation treatment.

6. Prepare a written report covering every inspection of a property, part of a property, or of anything to which treatment for preserving timber is to be applied, to be submitted to the client or anyone appointed to act on his or her behalf, and a copy kept for a period of at least ten years."

That is for the purpose of subsequent inspection if anyone has a query.

"7. Submit all reports in the following form:

(a) Filing number and date of inspection.

(b) Address of property, with names and addresses of owner, tenant, agent, architect, surveyor, prospective purchaser (if involved) or anyone to whom the report is to be submitted.

(c) Name of firm's technical surveyor who made the inspection and prepared the report, and name of director of firm who checked, edited or in any way modified or added to the report."

It is not an uncommon thing for an assistant to go out and make a report, and when he gets back the director says, "This won't do, you'll have to put it this way". If it happens, then the director's name should appear on the report.

"(d) Description of property, if possible with plan, giving details of roof cladding, method of construction (e.g., hipped gables, parapet or overhanging eaves, mansard roof, kingpost, queenpost or simple truss, etc.), age of property, type of timber, type of walls and materials used, methods of flooring, rainwater drainage, etc."

Anyone who does these reports normally covers himself by putting all that in.

"(e) Description of damage caused by insects or fungi, names of species, any structural weaknesses or instability caused by such damage.

(f) Details of structural or other faults which are the cause of or have contributed to the development of insect or fungal infestation."

That is for the benefit of the architect so that he can put it all right.

"(g) Degree of activity and give reasons for assuming current activity (imago insects, extraction of larvae, bore dust, fresh mycelium, sporophores, etc.)

(h) Whether any treatment has previously been applied and, if possible, the type of preservative used, and whether successful or partially successful."

I would like to add a clause to that. I think that if the representative of a firm inspects a property and finds that property has previously been treated by another firm, and has reason to believe that the treatment was not successful he should report the matter to his directors who should write to the firm concerned and say, "On such a date we looked at a property which we believe was treated with your product or by your personnel, and we found indications of a breakdown in your treatment. We should like to have your comments." They can then send their people along to explain the situation, and not be condemned out of hand, as so often they are because the other firm is so anxious to get in and have the business. That is all wrong, it is not ethical and it is not moral.

"(i) Describe the methods and materials which will be used to deal with the problem or problems created by decay, and how access to hidden timbers is to be obtained.

(j) Describe any safeguards to be taken to protect the property, the firm's operatives or third parties during the course of the work, including shoring props or supports.

X

(k) Describe any scaffolding, platforms, ladders, or other equipment necessary to provide access to the areas to be treated.

(l) Notify client or anyone authorised to act on his or her behalf of any fire hazards that may occur during the course of treatment, and make arrangements for insurance coverage if necessary.

(m) Estimate cost of applying treatment, with or without assistance of building contractors, electricians or other specialist contractors, giving details of how the estimate was computed and indicating any possible additional charges or costs which may be incurred."

That has dealt with reports. We go on to number eight of the Ten Commandments.

"8. To employ trained and experienced workers under the direction of a foreman or foremen with knowledge of timber-destroying insects and fungi and the peculiarities of each species; a knowledge of the chemicals used in the preservatives and any precautions necessary during the use of such chemicals; complete competency in handling all apparatus and equipment; a knowledge of building mechanics sufficient to judge weaknesses in the structure and how to insert reinforcing props, shores, etc.; a knowledge of general building practices, joinery, masonry, roofing, plumbing, etc.; ability to prepare time and report sheets and describe the progress of the work in a competent manner.

"9. To employ experienced and knowledgeable inspectors to examine the work on completion and form a judgment on the manner in which it was carried out, how it compared with the details provided in the Report, whether all areas of infection had been located and effectively dealt with, and whether the time taken and quantity of materials used were reasonable, and to prepare an inspection report covering all relevant details, which should be attached to the original report.

"10. Implement any guarantee given or implied by document, letter, advertisements, whether in print, over radio, television, or by word of mouth."

That, Gentlemen, is a suggestion for a Code of Practice. It sounds utterly impossible, but in South Africa there is a document which practically embraces all that and is already in use, and this is it:

"Directive to firms approved by the Division of Entomology for carrying out inspections of properties suspected of being infested with wood-destroying insects and for the treatment of such infestations.

"Issued in Terms of Paragraph 4 (1) of Government Notice No. 917 of 29 April 1953."

In that you have almost precisely what I have already read out to you, but the last paragraph is particularly interesting:

"It has come to the notice of the Division that estate agents and others have been demanding commission from approved firms as high as 10 per cent. of their inspection and treatment charges. Quite apart from any other aspect of this matter the Division cannot be a party to any system whereby charges that are necessarily incurred through compulsory regulation issued by the Government are increased by 10 per cent. to the public. If the Division should take no action in this matter a very unpleasant reflection would be passed on the Department of Agriculture and the Public Service. For these reasons approved firms are asked to send the local officer administering the regulations a written undertaking that under no circumstances will they pay commission to estate agents, companies, legal firms or any other for the introduction of business."

I think that is a most interesting point because believe it or not we have had numbers of people who are prepared to give us work if we are prepared to pay a commission and that, surely, is not right. Naturally, I have always refused to do so.

There is another interesting point on guarantees:

"The whole guarantee system has evolved between firms and their clients and has never had any official approval from the Division. What the Division requires is a clear accurate report. Should a firm give a guarantee the Division will insist on its implementation. Some firms are in the habit of issuing guarantees the wording of which is to the effect that timber which has been spray-treated by them and later shows signs of infestation will be re-treated free of charge. This is of course not allowed under the regulations. Such timber must be removed at once. Such a guarantee is valueless."

I advise you, Gentlemen, if you are interested, to get this document. It makes very interesting reading and it is in a way a basis for a Code of Practice for our class of business.

The Chairman: I, for one, do not regret this slight extra time that we have allocated to Mr. Richardson's slides and the discussion on his Paper. I will not dwell on the subject, except to compliment him, having had a good deal of experience since 1940, particularly in London, of dry rot cases, more than I wish to remember, certainly more than I wanted. I have learned a lot this afternoon about rots and beetles, and I personally want to thank him for the additional interest and knowledge gained through his Paper and perhaps more so through this discussion and his admirable slides.

Mr. President, Ladies and Gentlemen, I am sure you would wish me to convey to Mr. Richardson on your behalf a very warm vote of thanks for his admirable contribution to this Convention.

(5) THE COMPATIBILITY OF WOOD PRESERVATIVES AND GLUES

By A. J. Bune, B.Sc., *Aero Research Limited, Duxford, Cambridge*

An essential part of the art of using wood is to be able to join it. One method of doing this is by means of metal devices such as nails, screws and clamps, and for structural work these devices are time-honoured. One thinks of the hammer and screwdriver as fundamental in any sort of building work incorporating wood, and it is only in recent years that there has been any serious challenge to these methods. This challenge has come from glues.

As a science, gluing made little or no progress from ancient times up to the present century, but over the past 40 years there have been a number of advances, some of the most recent of which can be regarded as revolutionary. These advances have been welcomed by far-seeing technicians who have realized that nails, screws and rivets result in the localization of stresses and strains, while in a glued joint these forces are much more evenly distributed. This means that in a glued structure there can be economy of material without loss of strength, and there can often be simplification of design.

The possibilities of glued timber structures were explored in the United States after the First World War, following the first big commercial production of casein glue. Up to that time the only glues used in significant quantities for structural purposes had been animal glues, and, in view of their complete inability to stand up to moist conditions there had been little question of using them for anything other than furniture and other internal fittings. The use of casein glues, with their moderate resistance to moisture, widened the field. In America many buildings were put up, including factories, churches, halls, shops and hangars, in which softwood arches were glued with casein. These arches were satisfactory when protected from the weather, and many of the buildings so constructed are still standing.

During the next decade, blood-albumen and soya-bean glues were introduced as alternatives to casein for various kinds of wood bonding, but it will be noticed that all these glues are of a proteinous nature, and therefore, unless special precautions are taken, they are apt to be attacked by micro-organisms and insects.

Efforts were soon made, therefore, to protect the glue from attack. It was shown in 1932 (1) that the durability of plywood bonded with casein and blood glues could be improved either by adding preservatives to the glues or by treating the plywood with a preservative. Some 12 years later a report (2) was published showing similar results with soya-bean glue. With few exceptions, the addition of 5 per cent. of preservative improved durability and mould resistance of glue joints. Generally speaking, chlorophenols were most effective, and phenyl mercury oleate at 0·5 per cent. gave good results.

With plywoods, preservatives of a volatile nature incorporated in the glue can be expected to be absorbed into the thin veneers, thereby preserving the wood as well as the glue.

Another new era of glued-wood construction began in the 1930's when it became known that some of the new synthetic resin adhesives were highly resistant to moisture. For the first time the possibility presented itself that timber, a material available only in relatively short lengths, could be bonded to make members of almost any required size, and, at the same time, able to stand up to adverse climatic conditions.

Hitherto glued structures had been feasible if they were kept dry, and under these conditions wood preservatives were not always necessary. But the possibility of exposing structures to more rigorous conditions posed with a new emphasis the question of the compatibility of glues and wood preservatives.

In this matter, wood technologists may regard themselves as fortunate. If one is asked to say in the broadest terms whether modern glues are compatible with wood preservatives, the answer is that they very often are, but cases can only be decided by empirical tests on a laboratory scale, followed, if possible, by the testing of a full-scale structure. Such tests, involving not less than three variants, the wood, the glue and the preservative, must necessarily be numerous. It may also be necessary to study the methods by which the preservative and glue are applied. Such tests have shown without doubt that impregnation after gluing is often very successful, but unfortunately it is not always feasible. The glued-up structure may be too big to be handled in the preserving plant, glue-lines may act as barriers to the penetration of the preservative, or the wood available may be already treated. The question therefore arises of gluing wood which already contains preservative.

It may be well at this stage to mention two generalizations which apply to the gluing of preserved and unpreserved wood alike. The first of these is that lightweight woods tend to glue better than denser ones. The second is that for good gluing the surfaces of the adherends must be as clean as possible. The use of any kind of preservative, of course, transgresses this second rule to some extent, and since modern glues are mostly of an aqueous nature, oily preservatives can be regarded as less "clean" than aqueous ones. They do sometimes interfere more seriously with gluing than do watery solutions, though a word in favour of oily preservatives will be said later in this paper.

Since preservatives tend to become more concentrated near the surface and to leave surface deposits, it is frequently beneficial to resurface the timber after treating and before gluing, and this is common practice in the United States. In tests at the Forest Products Laboratory, at Princes Risborough, it is customary to take this same factor into account; salts are brushed or machined from the surface, and care is taken that oily solvents shall have evaporated. It is stated that neglect of these precautions may lead to a decrease in the strength of the joint. Tests have been in progress at Princes Risborough for a number of years and a résumé (3) of the results to date has been published. The Laboratory is widening its studies on preservative-gluing problems.

Tests in U.S.A.

A report of the United States Forest Products Laboratory (4) published in 1946 gave the results of a long series of tests into the effect of treatments with wood preservatives and fire-retarding chemicals on the glue joints of birch plywoods. The findings are numerous and complex, but the report shows that with fortified urea resin, intermediate-temperature phenolic resin and resorcinol resin, joint strengths were generally well maintained.

Tests in Germany

A report on a programme of trials (5) carried out in Germany has recently been published. In these trials eight well tried preservatives were used, including six salt solutions of alkali fluorides, bichromates and silicofluorine compounds (with and without additions of dinitrophenol), chlorinated naphthalene and an oily agent (creosote). The glues were those commonly used in the German building industry—based on urea-formaldehyde, melamine-formaldehyde, polyvinyl acetate, casein, phenol-formaldehyde and resorcinol-formaldehyde. All gluing was done cold. Polyvinyl acetate and casein were used in the tests because, although they have comparatively low resistance to moisture, they are commonly used in Germany.

In the first tests beech veneers were treated with the preservatives (a) by brushing, and (b) by soaking, and were then bonded using the different glues. They were afterwards stored at room temperature and at a relative humidity of 65 per cent.

In the case of the aqueous salt solutions there was generally a considerable weakening of joints bonded with the urea-formaldehyde and melamine-formaldehyde resins. This was particularly so in the soaked specimens. This is attributed to the fact that the preservative in the wood caused a premature setting of the glue, before the wood pieces were properly pressed together. In order to check that such a chemical reaction actually took place, the pH values of the preservatives were measured, as well as changes in viscosity for batches of glue to which preservatives had been added. In this way it was confirmed that the setting reaction of the glue was actually started by the preservative. With one of the preservatives, the urea-formaldehyde glue made an excellent bond. This effect was ascribed to an additive in the preservative, but the paper says the exact mechanism of this would require precise chemical investigation. The polyvinyl acetate and casein glues generally had somewhat reduced bond strengths, and where oily preservatives had been used strengths were much reduced. This was also the case with the urea-formaldehyde and melamine-formaldehyde glues.

From an examination of the figures for the specimens which were soaked, it is clear that the greater the absorption of preservative, the greater is the difficulty of gluing.

Similar tests were then conducted to judge the effect of the preservative treatments after gluing. Here the synthetic resins showed up much better than the polyvinyl acetate and casein. Two series of tests were made under this heading—one with the test specimens still wet after soaking, and one with them dry after soaking. Here the urea-formaldehyde resin was astonishingly successful. In the wet condition the strengths often exceeded that of the dry controls and also that of controls soaked in plain water. On drying, too, there were consistently good results. The paper refers to previous tests (6) in which it was shown that urea-formaldehyde glued joints made by the preliminary-coating method in the cold showed relatively low resistance to moisture, because the curing agents applied previously to the wood were not sufficient to permit complete curing of the glue. It says it would appear that subsequent preservative treatment with salty agents counteracts this disadvantage. The polyvinyl acetate and casein glues, as might be expected, showed great reductions in bond strength with aqueous preservatives, and recovered strength to no great extent on drying.

The next tests to be carried out complied more closely with conditions in practice. Longitudinal glued joints of pine were made and tested after 48 hours soaking in the different preservatives, and joints redried after 48 hours soaking were also pulled. With salty preservatives it was shown that these treatments resulted in a reduction of bond strengths, although this was not generally greater than when plain water was used for soaking. The paper refers to these results as fairly successful, but it says it is impossible, in the light of previous experiments, to come to any firm decision concerning the advisability of employing timber preservative treatments for glued components, in the case of salty preservatives at least.

It was appreciated by the experimenters that short-term tests were not necessarily representative of conditions in practice, where consecutive moistening and drying of the wood are inevitable. It is pointed out that such moistening and drying causes a continuous fluctuation in the concentration of any free acids which may be present in the wood, and that such conditions will have a harmful effect on the wood fibre. Faults in roof structure glued with acid-cured resin adhesives had possibly been caused in this way. A programme of tests was, therefore, devised again employing the eight wood preservatives and three resin glues—a phenol-formaldehyde, a urea-formaldehyde and a resorcinol-formaldehyde. Longitudinal glued joints of pine were again used and subjected to a cycle of 48 hours at 95 per cent. relative humidity and 24 hours at 30 per cent. relative humidity. The number of cycles, 20, was based on some earlier experiments. It was found on control specimens, untreated with preservatives, that the bond strength of the joints was not reduced by the cycle of treatment. The preservative treatment, however, produced a dispersion of the bond strength values. The reproducibility of the tests was much better for the resorcinol-formaldehyde resin than for the urea-formaldehyde, and the general behaviour of the resorcinol-formaldehyde was better. The tests were done in two groups, some specimens being only sprayed with preservative and the others soaked. The consistent behaviour of the resorcinol-formaldehyde resin was especially marked in the soaked specimens.

A series of comparative tests submitting spruce and pine to the same cycle of treatment showed that with pine glued with urea-formaldehyde resin, the strength of the glue was endangered to a greater extent by the preservative treatment than with spruce, but the resorcinol-formaldehyde resin was clearly able to counteract the differences in the two woods.

The paper in its summary confirms the general conclusion that the protective treatment of wood after gluing is much safer than the gluing of pre-treated timber, and it points especially to the probability that certain preservatives may complete the setting of a glue which up till then has not been fully cured. The corollary of this is that pre-treatment of the wood may pre-cure the glue and so adversely affect the bond. The moisture content of wood is a critical factor in gluing, and therefore, as might be expected, water employed as a solvent for a preservative may reduce the adhesive forces between the wood fibres and the glue. Obviously the conditions in this respect are much more favourable in the case of the oil-like and oily preservatives, which lead to less swelling of the timber, and—due to a kind of plasticization of the wood—facilitate the relief of stress concentrations in the neighbourhood of the glued surfaces, thus causing a strengthening of the glued joint. There appear to be no great objections to subsequent preserving treatment with oil-like and oily preservatives, independent of the type of glue or wood, provided that the gluing is properly done and that the condensation reaction of the glued joint has proceeded to an extent where it has proper chemical resistance.

With regard to salt preservatives, the position is thought to be less simple. The reduction in strength in laboratory tests was not high, but it is pointed out that in full-sized structures there may be less chance of swelling stresses being relieved.

Norwegian Tests

Recent work in Norway (7) has confirmed the satisfactory nature of resorcinol glue for use with Scotch pine already treated with preservatives. Phenol-resorcinol type glues were also found satisfactory. The topic has become one of considerable interest in Norway in connection with building and also in connection with the making of boats with laminated frames and keels, a form of construction which enables vessels to be both lighter and stronger.

The preservatives most commonly used in Norway are Zn/Cu/Cr/As and Cu/As and creosote, and all of these were included in the study. The treating was done at commercial treating plants and the average retention was 0·37 lb./cu. ft. for the Zn/Cu/Cr/As salts, 0·72 lb./cu. ft. for the Cu/As and 5·69 lb./ cu. ft. for the creosote. After the treatment, the salt-treated materials were kiln dried to about 10 per cent. moisture content and they were surface-smoothed to a uniform thickness shortly before gluing. The creosoted material was kept under cover for several weeks before it was surfaced and glued. Of the four glues used, one was an acid-cured phenol, two were straight resorcinols, and the fourth was a phenol-resorcinol made in the United States. Three different curing temperatures were used—59, 77 and 95°F. (15, 25 and 35°C.).

It was found that the pine treated with the water-borne preservatives tested could be cured satisfactorily with the resorcinol and phenol-resorcinol glues when the curing temperature was 77°F. (25°C.) or more. Creosote caused greater interference with gluing, but there were indications that even this could be satisfactory if a curing temperature of 95°F. was used. To give consistently adequate results it is suggested that an even higher curing temperature may be needed. First results with the acid-catalyzed phenol glue were satisfactory, but because of the varied experiences reported on the durability of acid-catalyzed phenols, this type of glue is not recommended where long durability is required.

Great Britain

Specific problems of gluing treated timber have been investigated by Aero Research Limited over a number of years. The findings have, in general, been in accordance with the results given above. They have also shown that preservatives in which the active agent is carried into the wood by highly volatile solvents cause relatively little impairment in the strength of subsequent gluing. It is, of course, a condition that the solvent must be allowed to dry out thoroughly before gluing is attempted.

Where an oily preservative is concerned, there seems to be considerable advantage in the use of a glue containing an organic solvent. Such a solvent acts as a wetting agent and thereby helps to fulfil one of the main requisites of satisfactory adhesion—that the glue must wet the adherend.

We have found considerable variation in the gluability of wood treated with different water-borne preservatives. Acid cupric chromates, for example, have given some disappointing results. This can perhaps be attributed to fibre destruction due to acid conditions. Copper/chrome/arsenate has given satisfactory results in tests over 12 months as shown in the following table:—

Close-contact joints to B.S.1204, specimens treated with a water-borne preservative of the Copper/chrome/arsenate type and glued with 'Aerolite' 300 and hardener GBP (separate application). Joints stored at 25°C.

Test requirements B.S.1204	Dry	INT/CC	MR/CC
Minimum mean failing load (lb.)	600	450	325
After 1 week	376	494	390
1 month	814	450	412
1 year	680	520	452

Australian and New Zealand Tests

No mention has been made so far of borax and boric acid as preservatives. These are widely used in Australia and New Zealand for preserving timber, including plywood, from attack by insects, including powder post borer and common house borer. A core-loading of 0·2 per cent. boric acid (or 0·31 per cent. borax) is employed. This concentration allows a safe margin over the determined toxicity figure against powder post borer, which is about 0·11 per cent. boric acid. Unpublished information made available to me by Borax Consolidated Limited says that plywood and veneers so treated and subsequently bonded with urea-formaldehyde resin are quite satisfactory in every way. When a waterproof plywood is required, however, and a phenol-formaldehyde film glue is used, certain difficulties of delamination appear. The reason for this effect is uncertain but it seems to occur only in the presence of moisture; the dry strength is satisfactory. These difficulties are much reduced if a liquid phenol glue is used. It is thought, on the one hand, that the inhibition of adhesion may be due to a pH effect and that, therefore, the investigation of sodium pentaborate might yield useful results. On the other hand, the adhesion problem may be associated specifically with the boron ion, possibly reacting with the phenol resin to give a water-soluble or water-unstable product. The company is pursuing the question of waterproof boron-preserved plywoods.

The incorporation of preservatives in glues used in making plywood was mentioned earlier in this paper. A suitable preservative in the glue can be expected to pervade the thin veneers, thus protecting the whole board from deterioration. The method has the advantage of saving an operation in manufacture. Shell Chemical Co. Ltd., advise that customers of the Shell Company in New Zealand, who have been collaborating with the D.S.I.R. in trials in New Zealand have reported success with dieldrin in plywood glues. A local timber largely used in plywood manufacture is Kahi Katea, and this is very susceptible to attack by *Anobium*.

Panels were made up with casein, urea-formaldehyde and phenol-formaldehyde glues with concentrations of dieldrin varying from 4·0 to 0·025 per cent., and untreated controls were also made up. The panels were exposed to *Anobium* attack and it is stated that after two seasons of egg-laying only those with no dieldrin or very low concentrations were attacked. It appears that the amount of dieldrin required is 80 to 100 milligrams per square foot of glue. In order to obtain this deposit it is thought necessary to add 0·3 to 0·4 per cent. dieldrin weight for weight to the glue.

The gluing of fire-retardant-treated timbers has not received as much attention as other branches of this subject, but some tentative recommendations are given by the United States Forest Products Laboratory (8). The report says that phenol-resin film glue is probably most suitable for gluing veneers treated with monoammonium phosphate, diammonium phosphate or mixtures of the two. Fair results have been obtained using phenol-resin film glue on veneers treated with ammonium sulphate. For gluing veneer treated with borax-boric acid (60:40), melamine-fortified urea and urea glues may be used; resorcinol and phenol-resorcinol are probably also adequate, but more expensive. Resorcinol glue is also tentatively recommended with chromated zinc chloride, zinc chloride and an ammonium sulphate-diammonium phosphate-borax-boric acid mixture.

Summary

The development of glues capable of withstanding adverse conditions at least as well as the timber which they bond has led to the possibility of building timber structures of almost any required size. In many instances, however, the need arises of preserving the timber against attack by micro-organisms, insects and fire, and the question of the compatibility of glues and wood preservatives has, therefore, become one of fundamental importance.

The multiplicity of different timbers, glues and wood preservatives makes the subject a complex one, and empirical tests have been performed in great numbers with a view to establishing satisfactory practices.

Because of their resistance to moisture, synthetic resin adhesives—urea-formaldehyde (UF), phenol-formaldehyde (PF), melamine-formaldehyde (MF) and resorcinol-formaldehyde (RF), and blends of some of these, have been singled out for attention. Among these, resorcinol-formaldehyde resins show excellent resistance to adverse conditions and are very tolerant of variations in moisture in the timber being glued. Urea-formaldehyde resins, though less tolerant of moisture, are considerably cheaper for use where some protection can be given from the weather. Both these adhesives are, under correct conditions of use, compatible with certain preservatives.

Preservation treatment after gluing is often very satisfactory. If the preservation treatment is done before gluing it is often customary to resurface the timber before bonding.

Preservatives made up with highly volatile solvents tend to interfere relatively little with subsequent gluing operations.

It has been observed that with modern synthetic glues bond strengths may be weak when salty preservatives have been applied before gluing. This may be attributable to the undesirable pre-curing of the glue before the application of bonding pressure. On the other hand, the use of such a preservative after gluing may contribute to the proper curing of the glue line.

It has been observed that with oily and oil-like preservatives bond strengths may exceed those of untreated controls. This interesting effect may be due to the absence of undesirable swelling of the wood near the glue line, and to a kind of plasticization of the wood by the oily preservative in such a way that stress concentrations are relieved. With oily preservatives, a glue containing an organic solvent may wet the wood better and so improve adhesion.

Another matter which has received consideration is that under varying climatic conditions, the moistening and drying of the wood will cause a continuous fluctuation in the concentration of free acids in the wood. These fluctuations may result in fibre destruction. This is one reason for the performance of "climatic" tests.

In comparison with metal, wood is an inexpensive material and it has great strength in relation to its weight. Modern techniques, such as lamination, have extended its possible uses in ways which have so far been little exploited. It will be of great benefit to makers of wood preservatives and adhesives alike to investigate and promote these methods to the full.

REFERENCES

(1) BROUSE, D. Methods of increasing durability of plywood. *Wood Working Industries* (U.S.), February 1932.

(2) KAUFERT, F. H., and BLEW, J. O. Experiments with preservatives for soybean glue and soybean plywood. U.S. Forest Products Laboratory mimeograph R 1447, March 1944.

(3) KNIGHT, R. A. G. The efficiency of adhesives for wood. D.S.I.R., Forest Products Research Laboratory, Summary Two, December 1956, pp. 21-22.

(4) BLEW, J. O. The effects of treatment with wood preservatives and fire-retarding chemicals on the glue joints in birch plywood. Proc. A.W.P.A. 1946, pp. 364-385.

(5) KÜCH, W. Über die wechselwirkung zwischen holzschutzbehandlung und verleimung. Forschungsberichte Nr. 231 des Wirtschaftsund Verkehrsministeriums Nordrhein-Westfalen. Westdeutscher Verlag, Köln und Opladen.

(6) KÜCH, W. Forschungsbericht Nr. 106 des Wirtschafts- und Verkehrsministeriums Nordrhein-Westfalen. Untersuchungen über die Einwirkung von feuchtigkeitsgesättigter Luft auf die Festigkeit von Leimverbindung. Westdeutscher Verlag, Köln und Opladen.

(7) SELBO, M. M., and GRONVOLD, O. Laminating of preservative-treated Scotch pine. Norwegian Institute of Woodworking and Wood Technology, October 1956.

(8) SELBO, M. L. Summary of information on gluing of treated wood, 1950. Reviewed and reaffirmed August 1955. United States Forest Products Laboratory, Madison 5, Wisconsin. In co-operation with the University of Wisconsin. Report No. R.1789.

Discussion on Paper 5

The CHAIRMAN (Mr. C. W. King): Mr. President, Ladies and Gentlemen, I am very pleased this morning to have the pleasant duty of introducing to the Convention Mr. A. J. Bune who is the author of Paper 5 on "The Compatibility of Wood Preservatives and Glues." I am sure Mr. Bune is known to many members of the B.W.P.A., but for those who are meeting him for the first time I would just like to give you a little information about his interesting career.

He is now associated with Aero Research at Duxford. He took his B.Sc. degree at London in zoology with entomology as an extra subject. Prior to the war he was very busily engaged in technical journalism, and during the war he was with the Ministry of Supply where he specialised in the study of chemical gases. After the war he was associated with the Tothill Press as the assistant editor on a number of trade journals, and you will see, therefore, that he has had many and diverse interests in a relatively short career. However, not content with all those different interests, he is also famed in another direction. As a matter of fact, he asked me not to mention this but I feel I ought to. He used to prepare and read the news bulletins on the B.B.C. I think, of course, that suggests that I really ought to introduce him with the chimes of Big Ben or to a fanfare of trumpets. However, I will not take up any more of your time, and I will now ask Mr. Bune to introduce his Paper on "The Compatibility of Wood Preservatives and Glues."

Mr. A. J. BUNE: I think I ought to say first of all that I have never read a bulletin in my life, although I wrote many.

First of all, I am going to say something about gluing practice with cold-setting synthetic adhesives. Those of you who are well-acquainted with gluing methods will perhaps bear with me for a few moments.

Synthetic resin adhesives consist of two components, the adhesive and the hardener. I will describe first the mixed application method.

In this, the adhesive and the hardener are mixed together before use; the ingredients are such that the pot life of the mixture is long enough for spreading and assembling the structure. Resorcinol-formaldehyde glues belong to this class. The adhesive is a liquid, and the hardener a powder. The powder is stirred into the liquid until a smooth mixture is obtained. Gluing is best done at or above 60° F. The components are normally finished so that good contact is made between them when they are put together, though with gap-filling glues this is less important. The glue is spread uniformly on both surfaces. A short time—up to about 5 minutes—is allowed to elapse, and the parts are then brought together. If the glue is gap-filling, pressure is required only to bring the surfaces into contact with the adhesive. The appropriate British Specification defines gap-filling glues as those suitable for glue-lines up to one-twentieth of an inch. That is really quite a lot; it is more than a millimetre.

Another technique which I am now going to describe is the separate application method. The glue is applied to one of the surfaces to be joined, and the hardener, a liquid, is applied to the other surface. The glue and the hardener meet when the two parts of the joint are brought into contact. Setting times can be very much shorter than with mixed application glues. Workshop temperatures should be above 55° F.

I would now like to show you on the screen some of the things which are glued, and which may in certain circumstances require to be preserved. I should make it clear that not all the structures which I am going to show are preserved, but no doubt similar structures when erected in the tropics or in other adverse conditions would require preservation.

Slide. This is a footbridge at Dagenham. It runs out into the Thames. Barges are moored between two dolphins for unloading, and the bridge provides access. The total length in two spans is 230 feet, and each span consists of three parts bolted together on the site.

Slide. This is another view of it.

Slide. The main chords of the bridge consist of from five to seven laminations of European redwood bonded with resorcinol resin glue. All parts of the bridge were preserved after gluing. You see here the main chords of the bridge consisting of practically nothing but wood and glue; metal fastenings were used only for positioning the parts during setting.

Slide. This shows the struts being put into place between the chords.

Slide. This shows how a plywood gusset is used. This is plywood and this is the laminated timber running between the plywood. You can see the glue exuding somewhat between the different laminations.

Slide. Here are sections of the bridge before preservation.

Slide. When I was preparing these notes the company concerned very kindly sent me some coloured pictures of the bridge during erection which are shown in the next few slides.

Slide. I expect some of you remember the place at Dagenham where the pylons go across.

Slide. A final look at the finished job. Each span of the bridge took 330 cubic feet of timber, half of this is laminated and half solid timber. The decking of the bridge and its bearers are, of course, solid.

Slide. Plywood gussets were used in a similar manner in these roof trusses. It is a little dark up at the roof but I think you can see the trusses. The problem here was to provide support for a roof of fairly wide span, 45 feet, at a new finishing plant for a textile company. A high degree of resistance to steam and chemicals was needed, and the consulting engineers therefore chose wood in preference to steel.

Slide. As in the bridge, the trusses are first made by building up top and bottom chords; the bottom chord is straight and the top chord is cranked in the middle.

Slide. This is a similar sort of process to the one you saw for the bridge. Here are the various sections. The struts have been put in and the whole structure has been clamped up.

Slide. This is a close-up. It is a little misleading in that the gentleman seems to be putting a great deal of energy into the matter. Actually, when gap-filling glues are used great pressure is not required in clamping. Here again, you can see plywood gussets, three ply, I think, and a total of $\frac{5}{8}$ inch thickness probably.

Slide. That is one of the trusses finished in the workshop.

Slide. That is a collection of the trusses before preservation.

Slide. Here is a rather better picture of the trusses in place in the factory. The roof was completed with purlins carrying plywood panels, which were also preserved and on which was laid half-inch insulation board covered by a three-layer bituminous felt. The building as you see is lit with windows in patent glazing frames at the eaves.

Slide. This is another structure built rather on the same lines; that is to say, it is a laminated structure. It is a tower for the collection of wood chips. It supports a 13-foot diameter cyclone. Chips from the works are separated from the cyclone for feeding into mobile containers. The chips go away for conversion into chipboard. The laminations of the tower are bonded with resorcinol glue. I may mention that the bulk containers are built of plywood and ash, laminated and jointed with the same glue.

Slide. To return to roof structures, here are pictures of St. David's Cathedral, Cardiff, during rebuilding. The main roof structure consists of seven big trusses each with a span of 50 feet and a rise of 32 feet, giving a pitch of 50 degrees. The rafters and curved ribs are laminated components made with urea-formaldehyde resin. The rafters which are 42 feet long each consist of three 8-inch by $1\frac{1}{4}$-inch boards. The next two pictures show the making of laminated ribs on a template. Here is the template. On the floor there is greasy paper to prevent them sticking to the floor.

Slide. That man is just holding up one of the curved ribs when it is finished. It has then to be trimmed and put into place.

Slide. Here is an example of a glued wooden lattice-type girder for the main assembly hall of a school in Yorkshire. The span is 42 feet. It is shown under a loading of five tons, when the maximum deflection at the centre was 0.9 inch.

Slide. Here are the girders in place in the school. For the same school, box-beams made with softwood flanges and plywood webs were used over classrooms and as lintel trusses.

Slide. Here is a box beam being made, consisting of softwood flanges and plywood. In order to obtain a slight camber it is made to a template which is the object lying over here.

Slide. This is the same box-beam under loading.

Slide. This is a slide of the beams in position. The method of construction using softwood flanges and plywood webs offers great possibilities for the building of portal frames.

Slide. Portal frames, I am sure most of you know, are what are called three-hinged frames. That is to say there is a hinge at the base of each leg and a hinge at the peak. Very few of these are needed to support quite a heavy roof. These particular portal frames are in position for a new library at Beaconsfield. The County Architect of Buckinghamshire, Mr. Pooley, has recently specified such arches for a number of buildings.

Slide. This is the same library with a side-on view of the four portal frames.

Slide. This is the building completed but before occupation. You can see, that the portal arches make rather a nice architectural feature inside.

Slide. In a new school at Aylesbury the portal frames are exposed on the outside. There are projects afoot to produce Dutch barns made with such portal frames as these and in these the legs would be almost completely open to the wind and weather.

Slide. This is the fleche of a church at Sunderland. It is made only of glued timber. Its total height is 35 feet and it is made in three sections, hexagonal in cross section. A stainless steel rod runs down the centre of the spire and draws the three sections together.

Slide. This is the spire in the workshop. The wood is teak. This is not the easiest timber to glue but very satisfactory techniques have been evolved.

Slide. This is a type of structure used for floors, roofs and walls. Most of the things I have shown you up to the present have been only for roofs. I expect quite a lot of you know this form in which you have battens with plywood webs glued to them, and you get virtually a corrugated stiff structure which in this case has a roof board applied to its upper surface and a ceiling board to its lower surface.

Slide. This shows this form of construction being assembled in the workshop.

Slide. This shows some of it in position on a pitched roof. Specifications for this type of work often call for a preservative; sometimes this is applied before gluing and sometimes afterwards. Some architects call for the application of fire retardants and these are generally applied after gluing.

Slide. In heavy engineering, it is often necessary to provide a very hard-wearing floor supported on girders so that machinery can be installed below floor level. In the factory shown here a wooden floor is provided consisting of wooden strips about four inches wide and two foot six inches long bonded into square blocks with resorcinol synthetic resin. Actually, the blocks have two thin bolts passing right through them to hold them together while the glue sets. The glue is necessary to turn the block into a really solid structure.

Slide. This shows one of the blocks before preservation.

Slide. This is the last of the slides I have, and it shows a lamp-post. You will know that concrete lamp-posts are rather unpopular in certain quarters. The opposition to them is on aesthetic grounds. It does seem that a glued lamp-post can offer the beauty of the wood which can be combined with really elegant design.

In conclusion, I would like to say—what I am sure will already be appreciated—that my Company can only answer in my printed Paper for the work done in their own laboratories. Our only regret is that we have not been able to explore this field more fully, but this matter is only in its infancy, and I am sure it is one which can be pursued with great advantage to the makers of both preservatives and glues.

The CHAIRMAN: Gentlemen, the discussion on Mr. Bune's Paper is now open.

Dr. W. P. K. FINDLAY: I would like to ask the speaker how that bridge section was preserved. He said it was preserved after assembly. How was it preserved?

Mr. A. J. BUNE: It was creosoted.

The CHAIRMAN: As there seems to be a little hesitancy in getting started with this discussion, Gentlemen, I am going to do something which I had not intended to do, and that is to put a question or two to Mr. Bune myself. My hesitation in doing so is that I have a complete absence of knowledge of the chemical compositions of glues and what may or may not happen on the grounds of compatibility when associated with preservatives. However, as an engineer I am, of course, extremely interested in the possibilities of good design in timber, and I can fully appreciate the points that Mr. Bune has brought out with regard to the distribution of load and the simplicity of design. I think he might have added to that the advantages from a maintenance point of view in not having corrosion of fastenings. I can quite clearly see the problem that started, when glues were discovered which would stand up to weather, and the field for the use of glued timber extended from internal to external purposes including engineering.

As I read the Paper, however, I get lost in the complexities of this compatibility question as between glues and preservatives. Therefore, I hope that following the question that was last raised, we shall get more information with regard to the pictures which have been shown to us and other examples of work which have been done, and on the actual results of using preservatives for outside work on timber associated with glued joints. In other words, I was not too clear in my mind that this is a practical form of construction for use in engineering generally. The picture that was shown of the bridge was extremely interesting. It is the kind of job that in railway work we should often have to do, not necessarily over a river, but over the railway, perhaps to provide a temporary passage for passengers across the lines during the reconstruction of a station.

In other directions there are immense possibilities for the use of this type of design, but I feel that I have to know more about it in order to feel satisfied that if it was not a purely temporary structure, but a permanent one—it would give satisfactory service for many years to come. In other words, is the life aspect preserved compatible with the life of steel or pre-pressed concrete? I would like to ask Mr. Bune, is he quite satisfied that fire retardants, added to preservatives or associated with preservatives, are compatible with glued joints? As I see it, timber has always been amenable to preservative treatment, using one or other of the many preservatives that are available. However, it seems that it may be a case of two being company and three something else when we have to add fire retardants in association with preservatives in glued joints.

If we could have a little more information, Mr. Bune, on these aspects, I at least, and I think many other members, would be very much obliged.

Mr. A. J. BUNE: I am very much afraid I cannot say very much on either of those points. The answer to the first is that only time will tell whether glued structures will stand up as well as steel or reinforced concrete.

On the second point, as far as I know, no work has been done on the question of the three things together, fire retardants, preservatives and glues. If anybody else has any knowledge of that I would be glad if he would say so, but I have not found anything at all in the literature.

Mr. E. H. B. BOULTON: Can you tell us if it is possible to mix any preservative with casein glue, because in alder and birch plywood within 18 months or two years the common furniture beetle will attack this plywood, and the larvae bore very considerably in the actual casein glue. This is quite serious from the furniture manufacturer's point of view, and I wondered if some preservative could be put into the glue as the plies are assembled and put in the press.

Mr. A. J. BUNE: I think some preservative could be put in the casein glue. In fact there is mention of that in my printed Paper, but I cannot see why one should use casein and not a more modern glue.

Mr. E. H. B. BOULTON: That is what we would like to know, Sir. The reason casein glue is so largely used is, of course, its cheapness. If there is any other glue which is resistant to beetle attack and which is no dearer, then we would like to know about it.

Mr. A. J. BUNE: You are going to put the price up by putting preservatives in the casein.

Mr. E. H. B. BOULTON: Would it compete with the phenolic resins?

Mr. A. J. BUNE: I could not say.

Mr. E. H. B. BOULTON: Furniture beetle damage in plywood is quite serious and casein glue is normally attacked.

Mr. B. T. BOSWELL: I get the impression from the paper, Mr.

Chairman, that Mr. Bune is putting the emphasis on gluing first and preservatives afterwards. I would submit that this is the wrong way round.

As regards the knowledge on resorcinol glues, there is plenty of evidence from tropical establishments and other places that glue is more permanent than the timber. I think the emphasis must be on making the timber as long-lived as the glue, and I do not think one can do that by preserving after it has been fabricated, except in the cases of the very simplest structures. There will be all sorts of cases of distortion if efficient preservation is attempted after it has been glued, and there is also the difficulty that the preservative will not penetrate the glue-line. There is a certain amount of evidence that if you glue a preserved timber, you probably face an initial loss of strength of about 10 to 15 per cent. However, one can then rely on the retention of that initially reduced strength virtually throughout the life of the material.

The research should be on glues to enable full strength to be maintained or the maximum strength from properly preserved timber, rather than emphasising the value of getting very high strength out of your glue initially, and then having an inferior standard of preservation.

Mr. A. J. Bune: Yes, I would agree. I think that this should be the aim.

Mr. J. C. S. Davies : Is it possible to pressure-impregnate glued timber without damaging the glued joints? If a pressure of 200 pounds per square inch is employed to treat a laminated beam would penetration be stopped at the glue-line?

Mr. A. J. Bune: I do not know the answer to that definitely, but I would agree with you that pressure impregnation may damage glue lines.

Mr. B. Hickson: Mr. Chairman, can I make a comment on that particular point? There is a great deal of plywood pre-glued which is pressure impregnated after the gluing and there is no difficulty whatsoever in getting complete impregnation in the centre plies all the way through without damaging the glue.

On the question of pre-treating the sections before gluing, I would completely agree with that. If you are dealing with timbers—I do not know quite how thick your pieces are—and have ideal conditions for complete penetration by impregnation before gluing, it should be quite satisfactory. The work that has been done in the last few years on the compatibility of glues with the chemicals which are now used in preservatives has made very great strides. I believe that it has not yet reached completion but I do not think I am speaking off the record when I say that the perfection of the combination between preservatives and glues is within sight. I think that also applies to the fire retardants because when all is said and done fire retardants are generally based on boron compounds and ammonium phosphates, and they are inorganic chemicals not very dissimilar to organic chemicals used in water soluble products. The fire retardant question is a delicate one and the treatment with fire retardants before gluing would have to be very carefully looked after.

Mr. G. Gobert: I would like to know how to impregnate plywood structures with water soluble salts under pressure. I am not convinced Sir, that the inner layer which may contain heartwood is completely impregnated. I think, if it is impregnated circumferentially to a depth of three or four inches on the inner plies, we should be adequately preserving the timber. I think it is a clear case for inorganic solvent type preservatives. In this case the delicate kilning operating will be saved subsequent to treatment.

I would like to ask Mr. Bune whether he has further knowledge on experiments carried out by Dr. Hildebrandt of Bayers, where he incorporated pentachlorophenol in phenolic resin glues and found this was completely encased by the glue, in fact imparting no fungicidal or insecticidal effect to the adjacent surface. However, he did add an accelerator, and with his special additive he found that there was evidence of the insecticidal properties on the outer surfaces of the plywood panels. I would like to know if you have any further information of tests in this country.

Mr. A. J. Bune: No, I have no information on that.

Mr. R. A. Bulman: Mr. Chairman, may I make some comments on incorporating preservatives in glue? Some years ago we were doing some tests on that point and used "Gammexane" rather than pentachlorophenol; the two behaved rather similarly, and dieldrin will behave in a similar manner, the idea being that during hot pressing the preservative or the insecticide will disperse itself into the wood on either side of the glue-line.

The tests were fairly exhaustive and one thing we discovered was that it was very difficult to get anything like uniform penetration of the preservative although it did spread to some limited extent. I gather that this system has not been really perfected and uneven distribution results is a major difficulty. It may possibly be associated with the varying amounts of glue over the course, glue-spreading being such a difficult operation, and one cannot get completely uniform quantities of glue for every square foot of the board. I do not know whether you can comment on that point of the distribution and what would then happen.

Mr. A. J. Bune: I do not think we have any comment that we can make on that.

Mr. A. H. NEWTON: I would like to come back to Mr. Boulton's query about the use of preservatives in the glue-line in relation to casein glues. Information is amplified in a Paper on work done in New Zealand. It was only started two years ago and so it is a little premature to give full results and to be too specific about it. However, from the Paper one can see that very low concentrations of dieldrin were used—I think B.H.C. was used in a very similar manner—and very adequate protection was afforded for the period under test. In the case of deildrin we can tell Mr. Boulton that the additional cost of adding deildrin to the glue would be something like a penny per pound of glue; that is, using about 0.3 per cent. of deildrin on the weight of glue in the glue-line. Deildrin, of course, does not have any fungicidal action, but no infection of insects takes place in this case.

Mr. A. J. BUNE: There is an awful lot of glue these days being used in boats. I do not know whether anybody could say something about preservation of boats.

Dr. W. P. K. FINDLAY: I think that has been fully explored in the United States, and there are quite a number of large-sized wooden vessels which have been made of pressure-treated laminations put together. I think we can say that the United States Navy is perfectly satisfied with the results.

Mr. R. A. BULMAN: I think Mr. Bune is perhaps asking for a second Paper when he raises this particular topic of treatment in boats. However, it can be said that in boat building, more particularly the small boats in the big shipyards, one of the major difficulties of course, is that so much timber has to be fabricated on site and treatment by pressure or any other method is very difficult. Therefore, the general rule is that timbers are treated actually at the job and probably glued as well, and then treated with organic solvent type preservatives. I think that goes for many of the shipyards in this country, and I believe it is very satisfactory. It might be of some interest to people who may not be aware of that fact that some preservative was applied on the "Mayflower"; which I hope contributed to getting it safely across the Atlantic.

Mr. A. J. BUNE: I do not think the "Mayflower" was glued though!

Mr. G. GOBERT: This is nothing to do with wood preservation, but could you enlarge upon the use of high frequency heating. It is something which has fascinated me in connection with laminated structures. I saw this method being effectively used in a joinery plant engaged in the mass production of laminated structures with automatic clamping and the subsequent application of high frequency heating. Would you enlarge on this a little, please?

Mr. A. J. BUNE: Of course you could use high frequency heating but I would rather confine myself in this instance to large structures and, therefore, to cold setting adhesives. I think perhaps another Paper is needed. In engineering structures, such as I was showing, radio frequency would not be generally applicable.

Mr. G. GOBERT: Having seen the slides which were beautifully prepared, I was horrified to see all this manual work. I was thinking of the poor man who would have to foot the bill at the end of the erection of the building. How did it compare with the cost of the erection of steel structures?

Mr. A. J. BUNE: It is cheaper and the supply position is much better.

Mr. G. GOBERT: Despite manual clamping?

Mr. A. J. BUNE: Yes, undoubtedly.

Mr. G. GOBERT: That is very interesting. Thank you.

Mr. A. J. BUNE: I have some figures for portal frames. A builder who put up a furniture showroom employing ten timber portal frames stated that the cost was almost half what it would have been using welded steel.

Mr. J. R. SUTHERLAND: I think on high frequency you would be faced with Tyric deep charge if you used high frequency on it with large members plus the output of setting required. I am not sure of this but I think the largest set available in this country now is 25 kilowatt. However, something beyond that is really wanted to make it pay on the production line.

Mr. P. N. HERON: I would just like to refer for a moment, if I may, to the subject of incorporation of preservatives in the glue-line, with particular reference to a small paragraph in the Paper and the subsequent reference to dieldrin made by other speakers. The particular paragraph in the Paper reads: "With plywoods, preservatives of a volatile nature incorporated in the glue can be expected to be absorbed into the thin veneers, thereby preserving the wood as well as the glue." I was just wondering whether this phrase "volatile nature" merely referred to the fact that, when the veneers were being pressed at an elevated temperature, the preservative was then sufficiently volatile at that temperature to diffuse in the plies and thereafter at normal temperature it would remain stable, or whether you were thinking of a compound which was relatively volatile at ordinary temperatures and would continue to diffuse from the glue into the wood on that account. If the latter were the case, I was wondering whether the volatile nature —I am considering the two outside external plies—would carry the preservative through the plies and would eventually be lost due to volatilisation leaving no preservative in the outside layers at all, which is where, in the nature of the preservative, one would expect attack by insects or fungi to occur.

I wondered whether Mr. Bune or any other member would care to make any comments on this.

Mr. A. J. Bune: That was rather a generalisation but what I intended there was, volatile under the conditions under which the plywood was made, and therefore there might be the stabilising effect on gluing, in which case the preservative would be retained to some extent in the outer skins.

Mr. G. Gobert: Your second paragraph is not borne out by the test carried out by Bayers in Germany. They tried all sorts of volatile materials and found most of them were actually trapped by the glue. However, with the accelerated tests they did not make compounds volatile. They therefore suggested that the inner ply—five or eight ply—would just be protected and that the subsequent coating should be applied to the outer plies, which are subject to deterioration in the atmosphere. In the case of heartwood present there would be no penetration.

Mr. E. H. Nevard: I believe I am right in saying, Mr. Bune, that the accent on the tests in Australia and New Zealand has been rather on protection against insects. They are very conscious of insect attack out there. I would suggest that that treatment would not meet the requirements we have in this country. I think Mr. Boswell's comments just now rather tend the same way. I think for conditions in this country we must guard against not only insect attack but also decay, not only by Basidiomycetes but also Ascomycetes, soft rot and so on. For that, I think, there is no doubt whatsoever there must be the maximum penetration with a preservative which is stable and, at the same time, maintains full adhesive strength in all the glue-lines. That would apply equally well both to plywood and laminated structures.

I think too that Mr. Hickson was right when he said that the advances in the past two years have been greater than ever before. I do not think there is any doubt about that. I would suggest that the limitation of this advancement has been due as much to the lack of demand as anything else. I think that in this country, only in the last few years have people become conscious of the possibilities of laminated construction, and this, Mr. Chairman, is the reason why there is not anywhere near a full solution to the problem. However, the results, so far as we know at least, are very promising, whether they apply to ordinary preservatives against insect or decay, or preservatives against the spread of flame and fire.

Mr. D. M. SPRANKLIN: In order to understand better this question of compatibility, can Mr. Bune tell me if the glue, in order to get an effective bond, is purely on the surface or whether it needs to penetrate any appreciable depth into the wood? In particular, in the case of timber pre-preserved with oily preservatives, is it the surface tension effect with aqueous glues which prevents the bond being effected? Lastly, in this case have any trials incorporating surface-active agents in the glue improved the bond?

Mr. A. J. BUNE: On the matter of penetration, proper adhesion does not depend upon penetration at all. That is to say, we readily glue metals to metals these days. It was at one time thought that a lot of gluing did in fact consist of dovetailing the glue into the wood, but that is not the case.

With regard to the question of oily constituents and watery ones, oil is a non-polar body and the water is a polar body, and therefore one cannot expect adhesion. That is one of the fundamentals of adhesion: one must glue a polar body with a polar adhesive and a non-polar with a non-polar adhesive.

Mr. R. A. BULMAN: Mr. Chairman, can I ask Mr. Bune with regard to his last remarks whether, in the case of gluing metals, the metal surfaces are roughened in any way, or can we apply the glue to absolutely plain metal surfaces.

Mr. A. J. BUNE: The surfaces are cleaned not roughened.

Mr. R. A. BULMAN: Would that be with an acid which might penetrate?

Mr. A. J. BUNE: Yes, they are etched but it is not an increase in surface which results in better adhesion.

Mr. G. GOBERT: Has Mr. Bune any figures? I believe that in the case of organic solvent preservatives, these are sometimes referred to as oily preservatives, where in actual fact they are as oily as their carriers. In other words, if they are spirit borne, we find that paint surfaces are not in any way affected. If they are oil borne—diesel oil or creosote tar oil—then they will indeed upset any subsequent paint, and also, I believe, a gluing film. Is that so?

Mr. A. J. BUNE: Yes.

The CHAIRMAN: Gentlemen, we have come to the end of our time. I think this has been a very interesting and helpful discussion, and, at any rate so far as I am concerned, some of the complexities which worried me when I first read the Paper have been cleared up. What I think is most reassuring are the comments of Mr. Hickson and Mr.

Nevard that some people in the Association know where they are going and that there is a real answer to this problem. I feel, therefore, that, as far as engineers are concerned, we can adopt this construction, where suitable with every confidence, and if we seek the help and guidance of the B.W.P.A., neither we nor the structures we put up will come unstuck!

I think, therefore, that we are very much indebted to Mr. Bune for writing this Paper, showing us the interesting slides and dealing so well with the questions which have been asked.

I would, on your behalf, like to express to him a very hearty vote of thanks for what he has done for us at this Convention.

(6) A MECHANICAL TEST FOR STUDYING WOOD PRESERVATIVES

by TOMÁS J. E. MATEUS, *Head, Timber Section, Laboratório Nacional de Engenharia Civil, Lisbon*

Introduction

IN a recent report issued in 1954 under the title "A new test for wood preservatives based on measurements of deflection*" we have presented the first results obtained in the study of the effectiveness of antiseptics employed in the preservation of wood using a new method of testing quite different from that followed for the same purpose in the majority of European laboratories. Such method consists fundamentally in measuring the variation of stiffness that may occur in little beams, treated with the preservative under test, and subjected to the attack of pure cultures of fungi, and it has been used ever since in Laboratorio Nacional de Engenharia Civil of Lisbon for studying the *toxicity* and *permanence* of wood preservatives.

Successive simplifications and improvements have been introduced in this method and the results already obtained with it look so interesting that we suppose that this new test will be a very practical and useful tool in laboratories that study the action of fungi on the wood, treated with preservatives or not.

The purpose of the present report is to give a brief description of this test, to present some of the latest results we have obtained with it in the study of the effectiveness of wood preservatives and the natural durability of wood against fungi and to compare it with the loss of weight method.

Principle of the Method

It was the knowledge of the results of the tests carried out by von Schrenk, Abbot, Colley, Baxter, Longyear, Cartwright, Scheffer and other investigators in the study of the influence of fungal attack on the mechanical properties of wood, to which reference will be made later, and at the same time, the difficulties which arose when interpreting certain results obtained by the loss of weight method, that led us to make a critical analysis of the present standards and to try to find a new test method for determining the inhibition point of wood preservatives. A method was sought which might be more sensitive and more significant than the above method, and by which it would be possible

* "Caracterização dos produtos preservativos para madeiras por um novo método baseado na medição de flechas"—Publ. n.° 48 do Laboratório Nacional de Engenharia Civil, Lisboa.

to follow the development of the fungal attack from the beginning, without having to remove the test piece from the vessel in which this attack takes place.

For these conditions to be satisfied it was necessary that the criterion to be adopted for verification of the degree of attack, should be based on an easily obtainable mechanical characteristic and at the same time should not entail the destruction of the test piece. Hence the idea arose of measuring the variation in deflection of a small beam treated with the preservative under test and placed in conditions in which it would be attacked by the fungus. It was to be expected that such a variation, caused by the reduction of the effective moment of inertia of the beam resulting from the decomposition of the wood, would give a significant measure of the degree of attack observed during the test.

Moreover as the deflection, for a given applied force, is a function which has the form $f = K \frac{1}{I}$, where K is a constant and I is the moment of inertia of the beam equal to $\frac{bh^3}{12}$, it was also to be expected that the method would be very sensitive, as small variations in h (the height of the piece) caused by the destruction of successive layers of wood during the test, would, due to h being raised to the third power, correspond to large variations of I. The width too, also being affected, would make the variations of I even greater.

Another advantage of this technique would also be, as discussed later, that of eliminating some of the variables which affect the results of the tests when the loss of weight criterion is used to check the degree of attack.

Brief Description of the Method

The wooden pieces used in the test have the shape of small beams (fig. 1) with the longitudinal axis parallel to the grain and are protected at the surface with small aluminium plates that are fixed in the sections where the forces act during the bending test for measuring the deflections.

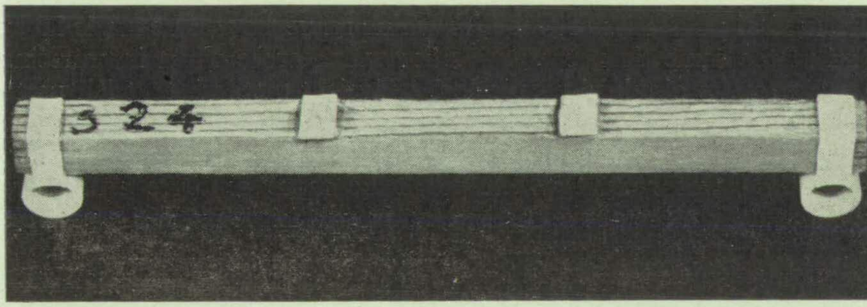


Fig. 1

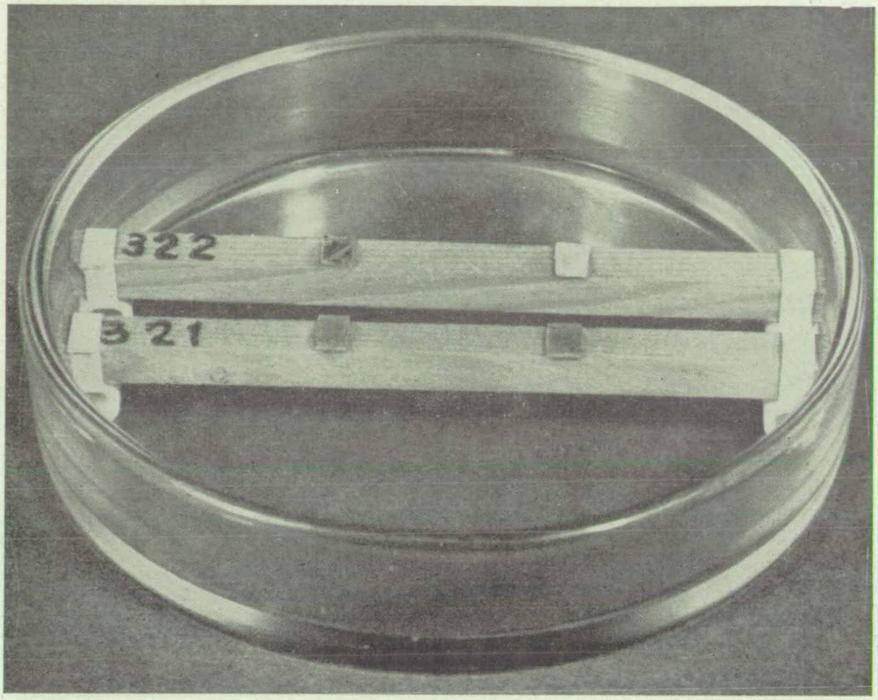


Fig. 2

The beams are supported above the culture medium, in which the fungus is growing, by means of small rigid supports, as can be seen in the same figure. We have employed for this purpose small porcelain hollow cylinders six mm. in diameter that are normally available for insulation of electrical wires.

The wooden specimens are impregnated with different concentrations of the preservative to be studied and afterwards are left in the air for some weeks to allow the product to be fixed in the wood. After being saturated with distilled water they are put in pairs in Petri dishes 10 cm. in diameter, as is shown at fig. 2.

The culture medium is then poured in those vessels and its solidification by cooling will fix the supports at the bottom of the dishes.

The volume of medium employed is such that its surface does not touch the lower face of the test pieces. An interval of about 1 mm. is enough for allowing the deformation of the beams during the bending test.

The fungus is inoculated at the centre of the exposed surface of the culture medium between the two pieces and, after some days, a transparent plastic disc about 12 cm. in diameter is placed on the lower part of the box (fig. 3) and after placing the lid on this, the plastic is glued at three or four points to the external wall of the box, in such a manner

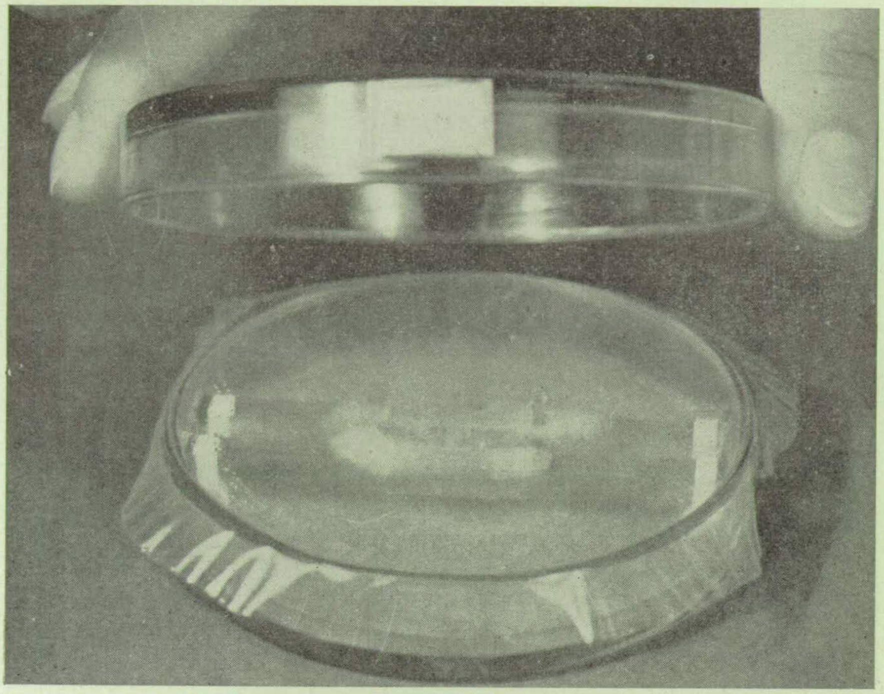


Fig. 3

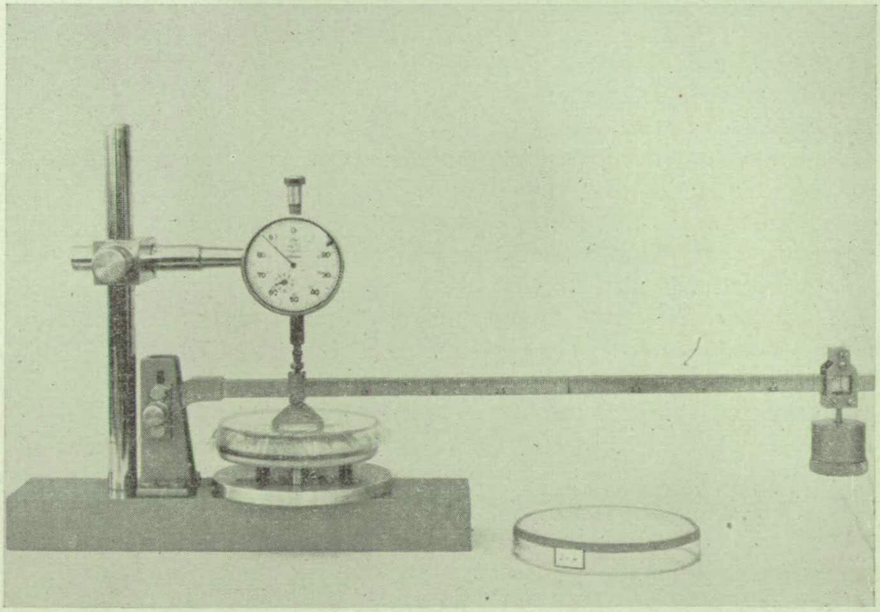


Fig. 4

that the lid can be removed when desired without hazard of infection in the fungus culture and the plastic can be loosened enough for the forces applied on it to be integrally transmitted to the specimens during the test for measuring their deflections.

We have observed that this plastic has no disturbing effect on the development of the fungus ; on the contrary it seems to create good conditions for its growth inside the Petri dishes, possibly because it avoids to a certain extent the evaporation of the water contained in the culture medium and that produced by the oxidation of wood substance during the fungal attack.

The bending test is carried out on an apparatus essentially made up of a simple lever acting on a yoke by means of which two forces of about 0.5 kg. are applied separately to each piece at points 25 mm. apart, and one deflectometer graduated in hundredths of a millimetre to measure the deflection of the specimens (fig. 4). This operation

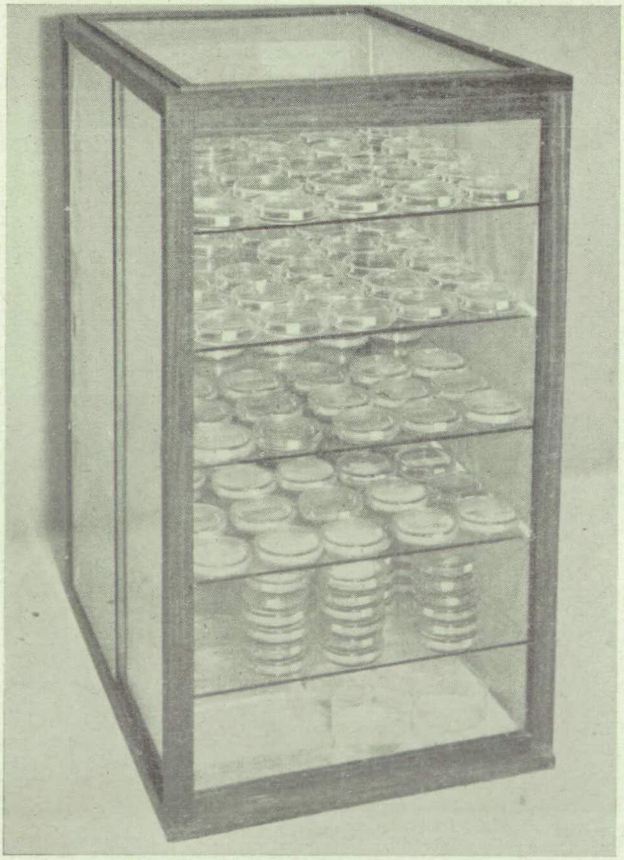


Fig. 5

can be repeated at intervals, for instance weekly, as we did in the tests mentioned in this report, or only at the beginning and at the end of the test, and in this case the method does not call for more operations than those necessary in the loss of weight method, with the advantage of being quicker and more significant.

The duration of exposure to fungal attack need be only one month, because at the end of this period of time the variation of deflection in those pieces affected by the fungal attack is already significant as can be seen in the curves obtained in the tests referred to later.

In "Laboratório Nacional de Engenharia Civil" the pieces usually remain exposed to fungal attack for two months.

The Petri dishes are kept in a chamber with a 90 per cent. relative humidity in a room at 24° C. (fig. 5).

Results Obtained

In figs. 7 and 8 are shown the results obtained with the deflection method in the study of (a) the effectiveness of a wood preservative of the water soluble type, and (b) the natural durability of different kinds of wood against fungi respectively.

1. *Study of effectiveness of wood preservatives*

Small wooden beams of Scots pine (*Pinus silvestris*) with the dimensions of 5 × 5 × 82 mm. impregnated with different concentrations of a mixture of salts (2·5 per cent., 1·25 per cent., 0·63 per cent., 0·25 per cent., 0·13 per cent. and 0 per cent.) were used. All these pieces after treatment were left in the air during two weeks to allow the preservative to be fixed on the wood fibres. At the end of this time, they were separated in three groups with four pieces for each concentration and for each fungus to be used in the test. One group remained exposed to the air for a further four weeks to represent treated timber used inside buildings and not exposed to rigorous conditions of temperature and humidity (doors, planks, etc.). Another group, in which only the 2·5 per cent. and 0 per cent. concentrations were used, was exposed, for four weeks to various cycles of temperature alternating from 50° C. to about 20° C. It should represent impregnated timber generally subjected to severe conditions of heat in the buildings, as it happens in the roof structures particularly during the warmest months of the year. The third group, with the same composition as the second group, was subjected, also for four weeks, to various cycles of temperature of 50° C. alternated with an immersion in water at a temperature of about 20° C. It should reproduce treated timber applied outdoors that is submitted to the direct action of sun and rain.

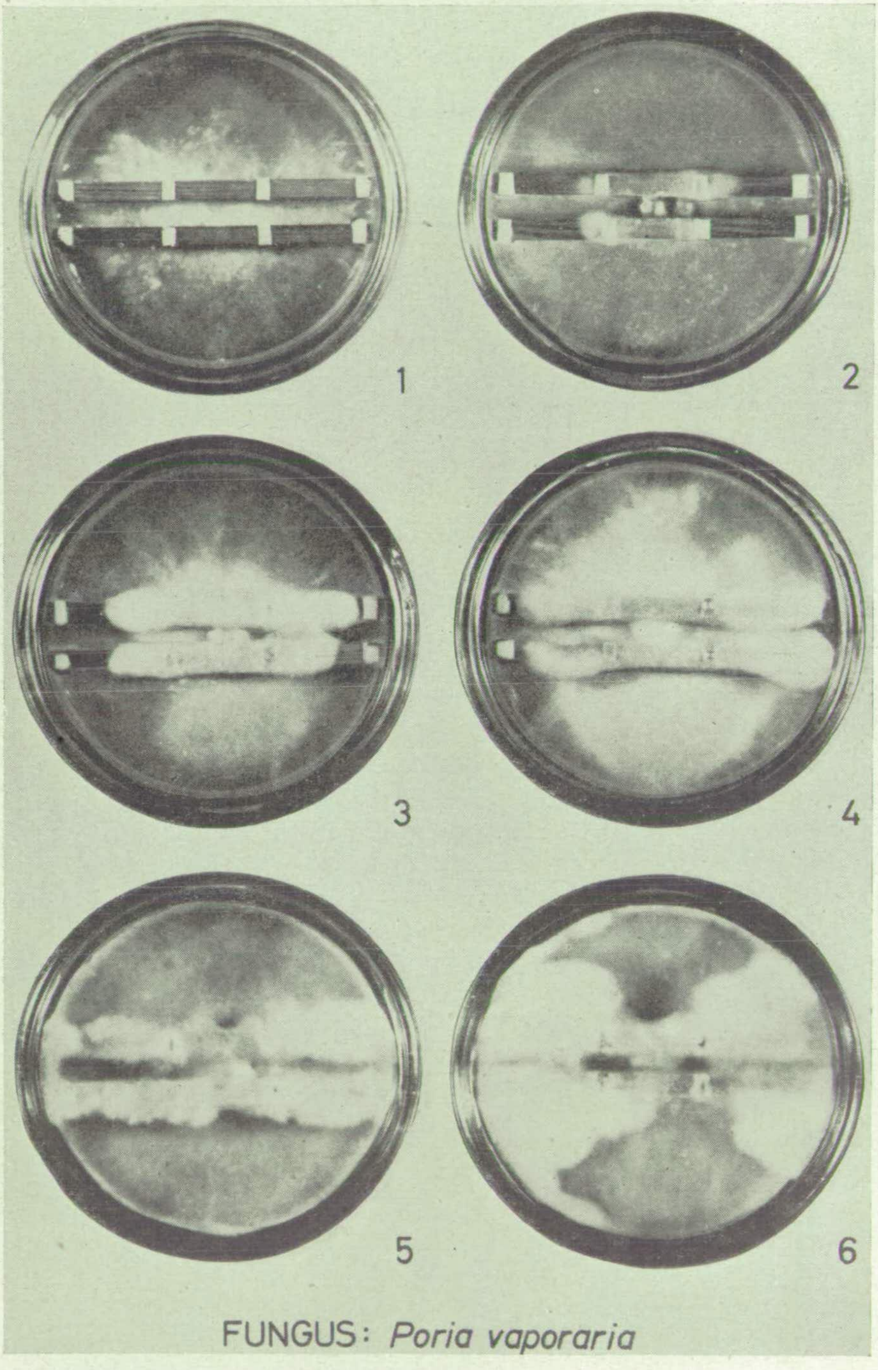


Fig. 6

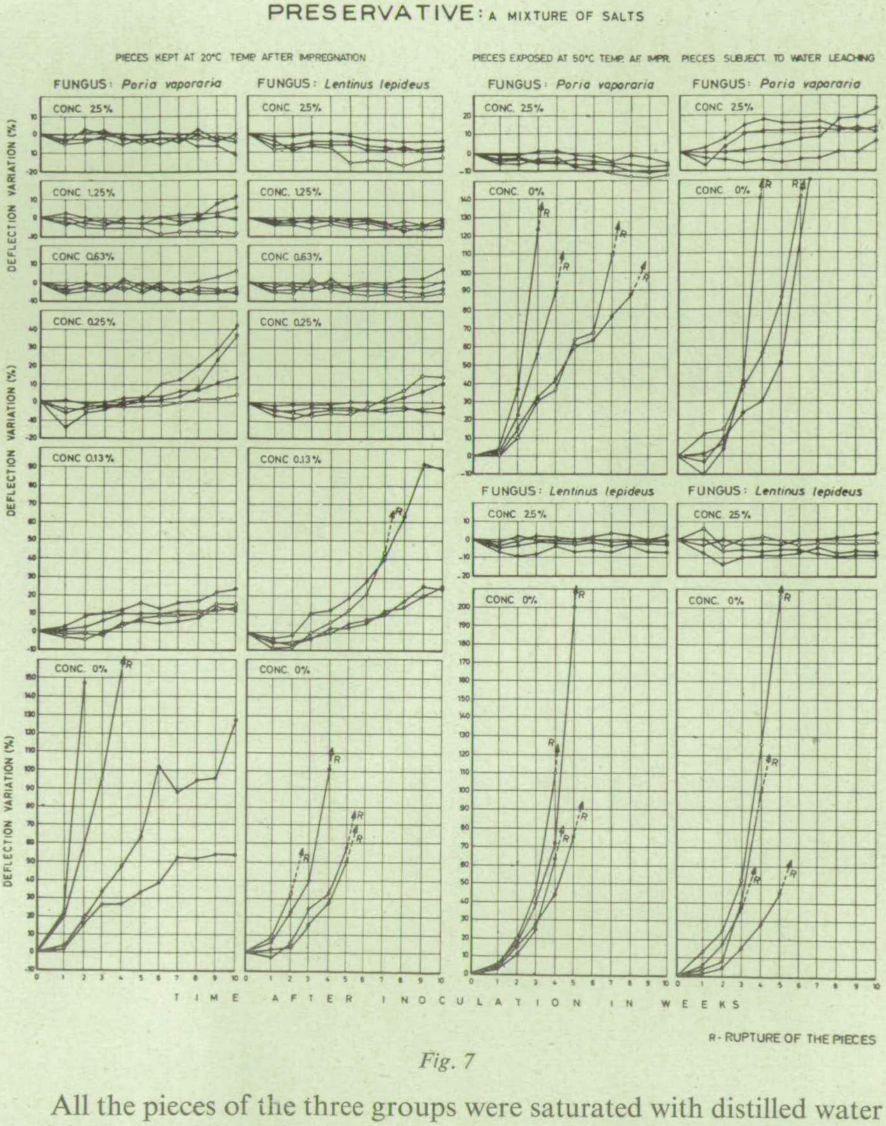


Fig. 7

All the pieces of the three groups were saturated with distilled water and introduced in pairs in sterilized Petri dishes 10 cm. in diameter as was shown at fig. 2.

A volume of 20 cubic centimetres of malt-agar culture medium was used for each of those vessels, and the inoculation with the fungi employed in the test—*Poria vaporaria* and *Lentinus lepideus*—was made as soon as the culture medium cooled down.

At fig. 6 are shown different aspects of the attack of *Poria vaporaria* on the pieces treated with weak concentrations of the preservative under test.

The deflections of the different pieces were measured weekly and the variations caused by the fungal attack, expressed as a percentage of the initial deflections, were plotted in graphs like those shown at fig. 7. On the left of this figure the evolution is represented of the attack on the pieces that were not submitted to any severe treatment after impregnation. The results obtained with the pieces that were exposed, after impregnation, to heat or to heat followed by water leaching for studying the permanence of the preservative are shown on the right.

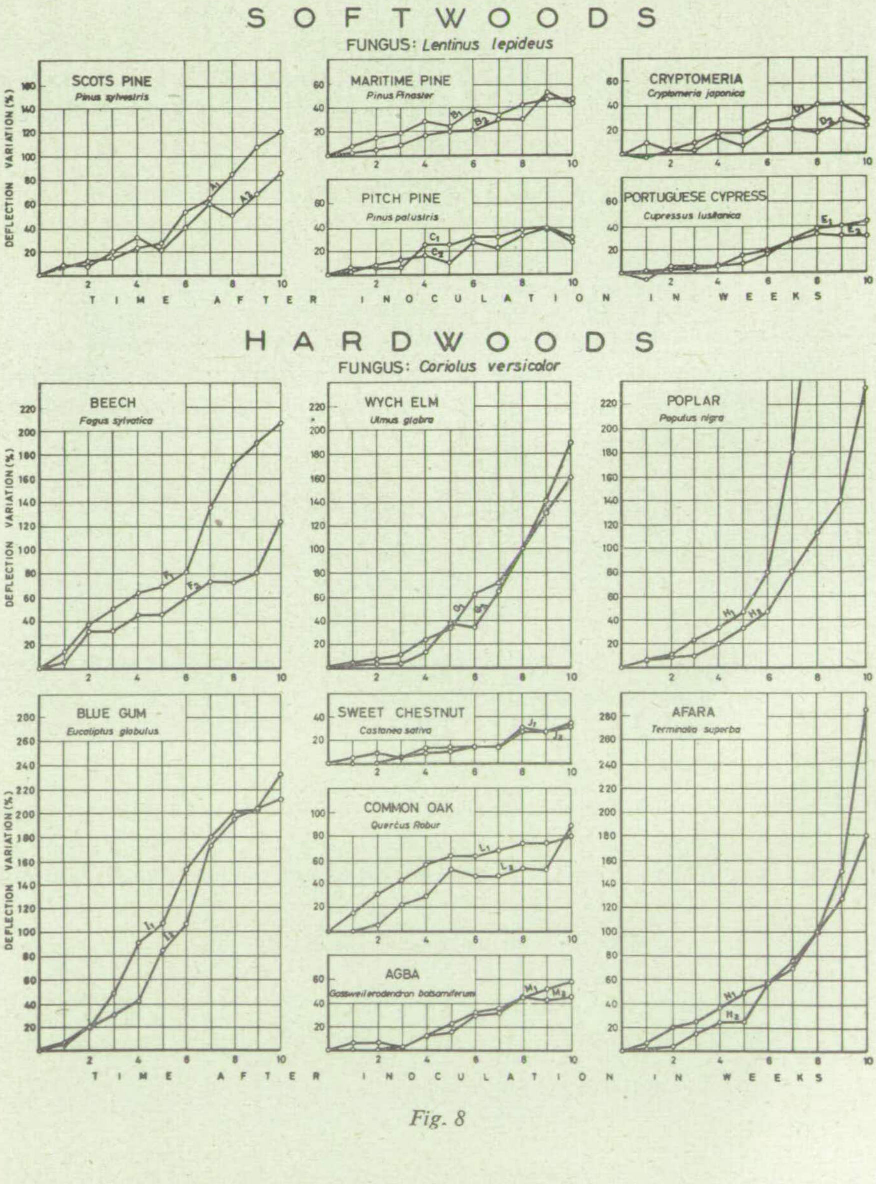


Fig. 8

The following conclusions can be drawn from these graphs:

(i) Pieces kept at a temperature of 20° C. after impregnation

(a) For the concentrations of 2·5 per cent., 1·25 per cent. and 0·63 per cent. the pieces were not attacked by the fungi. We can note a tendency for a decrease in the deflection variation as the time of exposure progresses, both with *Poria vaporaria* and *Lentinus lepideus*. This tendency can be the result of a decrease in the moisture content of the pieces due to water evaporation;

(b) For the concentration of 0·25 per cent. the pieces were clearly attacked by both fungi, which is shown by deflection variations of an order of magnitude of 40 per cent. with two of the tested pieces;

(c) For the concentration of 0·13 per cent. the attack is clearly more intense particularly in the case of *Lentinus lepideus*, with which values of about 90 per cent. were obtained at the end of the test;

(d) For the 0·0 per cent. concentration pieces (control pieces) remarkable values of deflection variation were obtained. In the majority of cases, fracture of the beams was attained before the fourth week.

(ii) Pieces exposed to heat after impregnation

(a) With a concentration of 2·5 per cent. the pieces suffered no attack whatever from either of the fungi. As previously, a tendency is observed towards a decrease in the deflection values, due perhaps to the reason given above;

(b) What was said under (d) above also applies here.

(iii) Pieces subjected to water leaching

(a) With a concentration of 2·5 per cent. a definite attack was observed by *Poria vaporaria*, while the pieces exposed to *Lentinus lepideus* showed no attack. This means that the preservative was partly washed out. The curves for *Poria vaporaria* seem to show that only the outer layers of the pieces were affected by the water leaching, as the attack showed a tendency to remain constant from a certain point onwards;

(b) As previously, remarkably high values of deflection variation were obtained for the control pieces.

2. *Study of the natural durability of different kinds of wood*

The deflection method seems also very adequate for studies of natural durability of wood. In effect it allows the progress of fungal attack inside the pieces to be followed from the beginning of the test and during all the time it is taking place.

We suppose it can even detect irregularities on the depth progress of the fungus in the wood, due to such factors as differences in density (springwood and summerwood), in moisture content of the various layers, etc. We have tested with it a lot of timber species against fungi and at the fig. 8 are shown the results obtained for different kinds of softwoods and hardwoods, subjected respectively to *Lentinus lepideus* and *Coriolus versicolor*.

The tests were carried out as was indicated before for the study of the effectiveness of wood preservatives, the pieces employed (two for each kind of wood) having the same dimensions (5 × 5 × 82 mm.).

No comments are needed on the graphs presented as they are self-explanatory, however we would remark that some of the curves seem to show an influence of the summer growth ring (as a denser wood) on the development of the fungal attack.

From the graphs, Table I was prepared in which are given in addition to the mean deflection variation obtained 10 weeks after inoculation, the theoretical thickness Δs of the layers around the pieces considered as completely destroyed by the fungal attack on the different species of wood. The curve of fig. 9 was employed to transform the deflection variations into Δs values.

Comparative Analysis of the Loss of Weight and Deflection Methods

1. *Sensitivity*

(i) Theoretical interpretation

In the publication referred to at the beginning of the introduction to this report we have presented the mathematical formulae that relate the deflection variation and the weight variation with the intensity of the attack on a wooden piece, expressed by the thickness of the layers of wood that are successively destroyed during the exposure to fungal attack.

Assuming that the piece is completely surrounded by the fungus mycelium and that the decomposition of the wood takes place uniformly on all its faces and consequently in depth too, these formulae have the form:

TABLE 1

	Species of wood	Fungus	Pieces	Deflection variation at the end of 10 weeks (%)	Mean deflection variation (%)	Theoretical thickness △s of wood destroyed by the fungus (mm.)
SOFTWOODS	Scots pine	*Lentinus lepideus*	A_1	120	103	0.41
			A_2	85		
	Maritime pine		B_1	46	44	0.22
			B_2	42		
	Pitch pine		C_1	29	30	0.16
			C_2	31		
	Cryptomeria		D_1	28	25	0.14
			D_2	22		
	Portuguese cypress		E_1	30	37	0.20
			E_2	44		
HARDWOODS	Beech	*Coriolus versicolor*	F_1	206	165	0.55
			F_2	124		
	Wych elm		G_1	160	175	0.57
			G_2	190		
	Poplar		H_1	>234	>234	>0.65
			H_2	234		
	Blue gum		I_1	234	222	0.63
			I_2	210		
	Sweet chestnut		J_1	33	32	0.17
			J_2	30		
	Common oak		L_1	80	84	0.36
			L_2	88		
	Agba		M_1	58	52	0.25
			M_2	45		
	Afara		N_1	285	233	0.65
			N_2	180		

(a) For the deflection variation:

$$\triangle f = \frac{bh^3}{(b-2\triangle s)(h-2\triangle s)^3} - 1 \quad \ldots\ldots(1)$$

(b) For the weight variation:

$$\triangle p = \frac{\pi_s - \pi_r}{\pi_s} \times \left[1 - \frac{(b-2\triangle s)(h-2\triangle s)}{b.h}\right] \quad \ldots\ldots(2)$$

in which:

b and h — are the sectional dimensions of the piece before fungal attack;

π_s and π_r — are the specific gravities of the wood in the sound and rotten conditions respectively;

$\triangle s$ — is the thickness of a theoretical wood layer completely rotten, such that its effect on the mechanical properties of the piece under bending test is equal to that of the thickness actually attained by the gradual attack of the fungus.

The equation (1) shows that the variation in deflection due to fungal attack is related to the *fourth power of the thickness* $\triangle s$, *of the layers of wood which are being destroyed.*

The equation (2) shows that the variation in weight due to fungal attack is related to *the second power of the thickness* $\triangle s$ of the layers *of wood that are being destroyed.*

Having presented the expressions which define the variation in deflection $\triangle f$ and the variation in weight $\triangle p$ due to fungal attack on a small wooden beam, we can now interpret what happens in a particular case.

Consider a Scots Pine beam (*Pinus sylvestris*) with a cross section 5 × 5 mm. and a moisture content about 30 per cent., freely supported at its ends and subject to fungal attack.

The expressions (1) and (2) become in this hypothesis:

$$\triangle f = \frac{5^4}{(5-2\triangle s)^4} - 1$$

$$\triangle p = \frac{\pi_s - \pi_r}{\pi_s} \left[1 - \frac{(5-2\triangle s)^2}{25}\right]$$

Assuming that the depth of fungal penetration into the wood is practically a linear function of the time, at the end of equal periods of attack, t, 2t, 3t . . . , there will be layers of destroyed wood of thickness $\triangle s$, equal to, say, 0·1, 0·2, 0·3 . . . mm. respectively.

Supposing that the beam is subjected to a bending test using the loading device shown in fig. 4, it will be possible, by means of the formulae of the Strength of Materials, to calculate the values of the corresponding deflections before the fungal attack and at the end of each of the periods considered, and, by expression (1), their variation $\triangle f$, expressed as a percentage of the initial deflection obtained with the sound wood, (for which $\triangle s = 0$).

To each value $\triangle f$ there will be a corresponding value of weight variation $\triangle p$, expressed as a percentage of the initial weight of the piece, which can be determined by means of the expression (2), and from the knowledge of the constant $k = \frac{\pi_s - \pi_r}{\pi_s}$. Now, assuming that the fungus in question destroys the wood to such an extent that the variation of its specific gravity as referred to π_s is about 50 per cent. from the sound condition to one of advanced decomposition, the value of *k* will be: $k = 0{,}5$.

Table II shows the values of $\triangle f$ and $\triangle p$ determined for the hypotheses which have just been presented.

TABLE II

$\triangle s$ (mm.)	$\triangle f = \frac{5^4}{(5-2\triangle s)^4} - 1$ (%)	$\triangle p = 0{,}5 \times \left[1 - \frac{(5-2\triangle s)^2}{25}\right]$ (%)	$\frac{\triangle f}{\triangle p}$
0.0	0.0	0.0	0.0
0.1	17.7	9.3	4.5
0.2	39.6	7.7	5.2
0.3	66.8	11.3	5.9
0.4	100.9	14.7	6.9
0.5	144.1	18.0	8.0
0.6	199.7	21.1	9.5
0.7	272.1	24.1	11.3
0.8	367.7	26.9	13.7
0.9	496.0	29.5	16.8
1.0	671.6	32.0	21.0

With the data given in this Table we can plot the curves of deflection variation $\triangle f$ and weight variation $\triangle p$ as functions of $\triangle s$ (fig. 9), as well as those which relate $\triangle f$ and $\triangle p$ (fig. 10), the latter giving a comparison of the sensitivity of the two methods when applied to pieces of wood with dimensions of the same order of magnitude as those considered.

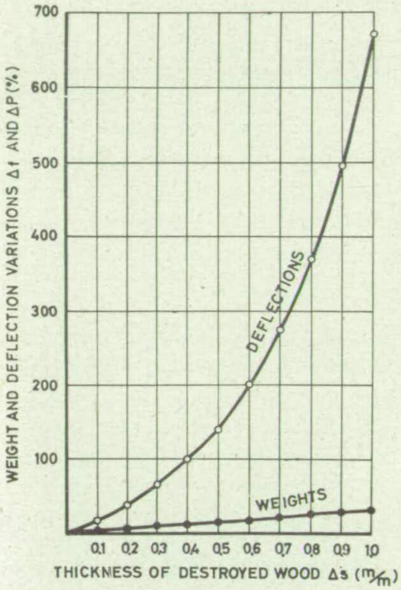


Fig. 9

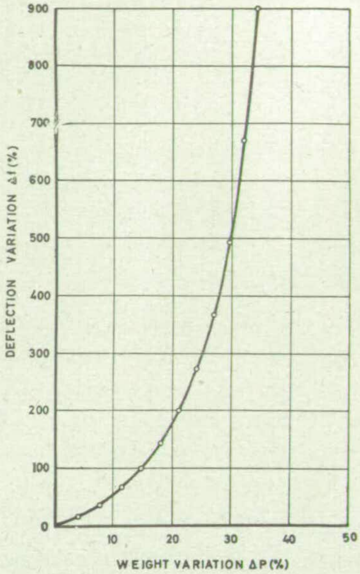


Fig. 10

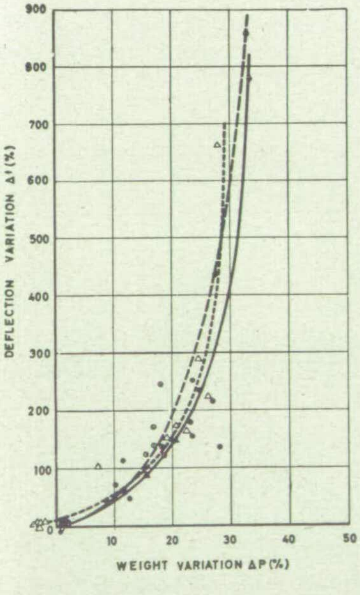


Fig. 11

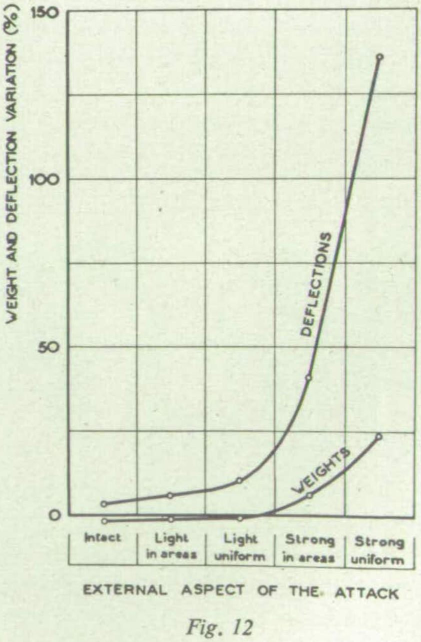


Fig. 12

The following conclusions can be drawn from Table II and these curves:

— The deflection variation is considerably larger than the weight variation, at any phase of decomposition of wood.

— The deflection variation is sensitive even in the initial stages of the attack, which is not the case with the weight variation, as will be seen in the following chapter, and we believe this to be a decisive advance on the latter method. In fact a few days after beginning of the test it is possible to determine the degree of decomposition that has already taken place in the wood.

As the deflection method allows the measurement of the deflection to be made without disturbing the fungal attack, we can determine at any time, a week after inoculation for instance, the deflection variation and estimate the thickness of the theoretical layer of wood already destroyed by the fungus, by means of the curve of fig. 9.

— The ratio $\frac{\triangle f}{\triangle p}$ between the deflection and weight variations increases as the attack progresses. In other words there is an acceleration of the effect of fungal attack on the deflection variation as the decomposition of wood increases in depth. It appears to us that this feature is one of the greatest advantages of the method we are presenting for testing wood preservatives and for studying the natural durability of wood against fungi. In fact there is the possibility of further increasing the sensitivity of the attack by using pieces of smaller cross section than that considered, which could be of value, for example rapidly to obtain data about the decomposition of the wood of certain hardwoods, which are rather resistant to fungal action and for which the loss of weight method would demand a long test period.

(ii) Practical confirmation

Fig. 11 shows three graphs relating the deflection variations with the weight variations, which were plotted from data obtained experimentally employing both methods for a number of pieces treated with weak solutions of two wood preservatives. The points situated near the intersection of the axes correspond to control pieces, placed on a culture medium without fungus and which consequently did not undergo any variation in weight or deflection.

Comparing this curve with the curve of fig. 10 it can be seen that there is satisfactory agreement between the values of $\triangle f$ and $\triangle p$ as determined theoretically and by means of tests, which upholds the hypotheses adopted in the deduction of the expressions for $\triangle f$ and $\triangle p$ which were presented.

2. *Significance of the results*

Protecting wood against the action of fungi and xylophagous insects by means of preservatives aims at maintaining this material in a satisfactory condition of conservation during the life of the building in which it is used; in other words, it is to contribute as much as possible to the length of life of the building. Thus it seems logical that the test for evaluation of the fundamental characteristics of the preservatives—toxicity and permanence—be made in such a way that it effectively measures any property that is directly related to the concept of safety; in other words, that it gives an exact idea on the degree to which the product protects the mechanical characteristics of wood during the time it serves in a given structure. Now the strength of a member of treated timber can be affected by such factors as the chemical action of the preservative employed, the enzymatic action of the fungi against which the product is applied, etc.

Let us analyse each of these factors separately.

As to the first, it is conceivable that a chemical product can confer immunity to wood against insects, fungi, etc., and at the same time, through reaction with the cell walls it may to a greater or lesser degree change them in such a way as to reduce appreciably their mechanical characteristics.

Alliot (1926) studied the effect of certain acids on the strength of some woods and reached the conclusion that this effect was to make the wood more fragile, and consequently affect more directly the capacity of the wood to withstand shock.

Mörath (1933) also carried out some interesting experiments on the study of this influence, and arrived at the conclusion that Pine and Spruce, after being treated with acids or alkalies with a pH between 3 and 7 and 7 and 11 respectively, for a moisture content above 30 per cent., showed a loss of bending strength of about 10 per cent. and that for Oak and Beech, treated in the same way this loss was about 30 per cent.

On the other hand Waksman (1931) showed that the creosotes are practically inert in relation to wood, not having any effect on its strength.

As to the second of the actions mentioned—fungal attack—its effect, if the product does not confer the necessary immunity to the wood, will be similar to that previously referred to, though as a rule much more intense. In fact, the result of the action of those destructive agencies on the wood is the decomposition of the cell walls. This decomposition always causes a reduction of the strength of the material, more or less considerable according to the type of wood, the fungus considered, the environmental conditions of temperature and relative humidity and the duration of attack. Particularly in an advanced stage of rot the wood loses practically all its strength for withstanding the various loads to which it is subjected, that is, it fractures, even with very low stresses developed in it.

There have been a number of investigators who have carried out tests on fungus attacked woods with the object of studying their mechanical behaviour. Among those who, in the first place, occupied themselves with this problem, we should mention von Schrenk (1899), Abbott (1915), Colley (1921), Baxter (1925), and Longyear (1926). The last mentioned, who appears to be the first to publish results of systematic tests on pieces exposed for different periods to fungal action, sought to relate the observed loss of weight in wood with the decrease in its strength, and he reached the conclusion that before any significant variation in weight can be detected, the mechanical strength has already been considerably reduced.

More recently Cartwright, Findlay, Chaplin and Campbell (1931) and Cartwright, Campbell and Armstrong (1936) also carried out important tests on the variation of strength in wood exposed to fungal attack. Their principal conclusions can be summed up as follows:

— The bending strength of pieces of wood of *Picea sitchensis*, subject to decay by the fungus *Trametes serialis*, decreased after a two weeks' attack by 15 per cent., while weight variation only became detectable at the beginning of the fourth week.

— Impact bending strength was the mechanical property most affected by fungal attack. Results obtained on pieces of *Fraxinus excelsior* exposed to the fungus *Polyporus hispidus* showed a reduction of this property of about 20 per cent. after a two weeks' attack. At the end of 12 weeks the reduction was 90 per cent.*.

— The bending strength for the above wood and fungus decreased about 15 per cent. at the end of 12 weeks and about 28 per cent. at the end of 28 weeks.

Other investigators, besides those referred to, have interested themselves in this problem, as for example Liese and Stamer (1934), Scheffer (1936), Trendelenburg (1940), Scheffer, Wilson, Luxford and Hartley (1941).

Their conclusions as to the influence of fungal attack on the properties of wood are identical with those already given, that is, they agree that the strength properties depreciate rapidly with fungal attack, the toughness being the most affected.

* Trendelenburg, as a result of this effect, and as a means of accelerating the rate of the tests, proposed (1940) a method for determining the degree of attack, which consisted in measuring the decrease of strength to withstand shock, instead of the decrease in weight, of the pieces of wood exposed to fungal attack. These pieces were dried in an oven for 7 hours at 100° C. before and after the attack. The decrease in the mechanical property in question was measured by comparison of the results obtained in control pieces of sound wood and those exposed to attack.

It is clear that the results quoted regarding this influence are not absolute. They obviously depend on the species of wood, on the fungus considered, on the form and dimensions of the test pieces, etc., and it is easily understandable that, for the same intensity of attack per square centimeter, the smaller the volume and the greater the surface exposed to the fungus, the greater this influence will be. Pieces with small dimensions in cross section and large length are consequently the most suitable for detecting the extent of fungal destruction.

From what has just been said it is possible to conclude that the deflection method, based on the determination of a mechanical characteristic of wood treated with the preservative to be studied under the attack of a fungus will give an overall indication of the degree of protection which this product confers on the wood.

As to the weight method, the remarks we have made, the experiments to which we have referred (those of Longyear, Scheffer and other investigators) and the conclusions of Gaumann (1930), about the loss of weight as a measure of the decomposition brought about by fungal attack, appear to demonstrate clearly that it is of little significance, not only because it measures a physical property which cannot give any clear idea as to what is happening inside the piece but also because it has a low sensitivity, particularly in the first stages of the attack.

Fig. 12 shows two curves which, we believe, demonstrate what we have said on the two methods being compared.

The ordinates give the variation of weight and deflection and the abscissae, in a conventional scale, give the various degrees of attack, characterised by the external aspect of the pieces at the end of the testing time. The various points on these curves were obtained from a number of about 300 pieces, from which only those showing foreign fungal growths were eliminated.

The following conclusions can be drawn from this figure:

1. — For the pieces which remained intact and which corresponded to the commercial concentration of the preservative there was a small increase in deflection, which may be explained by a destructive effect of the product on the cell walls of the wood, and a slight increase in weight which we believe is due to the absorption of soluble contents of the culture medium by the wood, because the pieces in this test were put in contact with it.

2. — For pieces with light patchy attack or light uniform attack and therefore necessarily affected by the fungi, the loss of weight method does not show any attack, contrarily to what happens in the deflection method which clearly shows it.

3. — Only in cases of pronounced attack in patches does the loss of weight become measurable, for which stage the deflection method shows variations of about 40 per cent.

4. — For a uniform heavy attack the difference between the two methods is still much more evident.

3. *Factors influencing the results.*

Let us analyse each of the factors which can introduce variations in the results of the tests on wood preservatives obtained by the two methods.

(i) Moisture content of the wood

It is known that when the fibres of wood are saturated with water the mechanical characteristics are not affected by any additional moisture content to any practical degree. It can be concluded, therefore, that the influence of this factor on deflection can be ignored, because the pieces are tested at a moisture content generally greater than that which correspond to the fibre saturation point ($H \simeq 30$ per cent.). This condition, however, is essential for the fungal attack to progress satisfactorily.

With regard to loss of weight, however, the moisture content is doubtless one of the major factors which make the interpretation of results difficult and which introduce errors.

In fact, as the equilibrium moisture content of wood varies considerably with the environmental conditions of temperature and relative humidity, it will always be necessary to refer the weights to a well defined value of this parameter, which can be achieved by drying the blocks at a temperature in the neighbourhood of 100°C. This technique, however, has its drawbacks which are analysed below:

As the temperature of 100°C. would alter or could alter the preservative to be tested, the blocks which are to be exposed to the fungal action cannot be dried in the oven after being impregnated.

Hence it will be necessary to overcome this difficulty for the initial weight. For this, the technique generally followed in European laboratories is to dry the blocks first, weigh them, and then impregnate them and weigh them again to determine the amount of solution absorbed.

From the knowledge of the concentration of this solution, the amount of preservative absorbed by the blocks can be determined by calculation and consequently the value of the correction to be made on the dry weights obtained before impregnation.*

* The English and German standards adopt this correction for products of low volatility and only for solutions which contain more than 1 per cent. of the product, when it is soluble in water and more than 2 per cent. when it is soluble in oil.

This technique, as it demands the drying of the blocks at 100°C. for some hours (18 in the English Standard) before the test, will alter the chemical constitution of the wood to a certain extent, will modify the impregnation conditions relative to those encountered in industrial processes of treatment, in which the pieces are impregnated in an air dried condition, will complicate the test with corrections of the values of initial weight and will also introduce variables in the results.

(ii) Evaporation of the preservative.

When dealing with highly volatile preservatives a greater complication arises. For strong concentrations of these products, at the end of three or four months, there will be an appreciable loss of weight in the blocks.

As concerns the deflection method, this loss will not interfere with the test, but with regard to the loss of weight method, such influence can be very significant. Hence the standards which are based on this method include the use of *correcting blocks* inoculated in a culture medium without fungus, which, at the end of the test and after being dried in an oven, will permit (not without the introduction of appreciable errors due to variation of results which are obtained when using these blocks) the determination of the mean quantity of the product which volatilized and consequently the correction of the final dry weight of the pieces exposed to fungal attack.

Conclusion

The test presented in this report for studying the effectiveness of wood preservatives seems to offer some advantages in relation to the loss of weight method. These can be summarised as follows:

It is more sensitive, more significant and does not lead to the variables that necessarily affect the results obtained with the loss of weight method which are due to the use of correcting blocks. Moreover it allows the fungal attack to be easily followed during the test without disturbing its development; it can give useful indications about the progress of the fungal attack in depth; it permits in a certain measure to know whether the moisture content in the pieces subjected to test falls to a value less than 30 per cent., because in this case a decrease in deflection will be observed. It can be applied also to pieces taken from timber industrially impregnated outside the laboratory, because the knowledge of the initial dry weight is unnecessary, which is not the case when the loss of weight method is employed. Finally, as the pieces need not be put in the oven at the end of the test, they can be used again, if necessary, for confirmatory tests or for studying the permanence of the wood preservative.

Discussion on Paper 6

The CHAIRMAN (Mr. B. Hickson): Mr. President, Ladies and Gentlemen, taking the Chair for Mr. Mateus from Lisbon is a very great privilege and pleasure because I have had the opportunity of seeing him in his own Institute in Lisbon and seeing his work some three or four years ago. He graduated in civil engineering in the Instituto Superior Técnico in Lisbon, and has subsequently worked in the Technical Services of Lisbon Municipality on problems of construction of low cost dwellings, being particularly interested in the use of timber which is plentiful and cheap in Portugal. Subsequently, in 1947 the Laboratory for Civil Engineering was founded in Lisbon on a national scale by the Ministry of Public Works and Mr. Mateus was invited to organise a department of timber research. This was the first time that the country of Portugal had undertaken this class of work. While engaged on this work he has naturally studied wood, its protection and preservation, and has also closely studied methods of carrying out tests.

His paper which has been in your hands—and I hope some of you have had time to study it—defines and describes a method of testing timber that had been subjected to timber preservative treatment and fungus attack as an alternative method to the well-known Kolle flask or soil test method of testing of fungus growth. He has his apparatus here and he will describe it to you when he has given his speech. I have discussed it with my colleagues in my company and we believe there is quite a future for this novel approach to testing wood preservatives and timber because we think that it may, if it can be proved, give quite an added advantage in the laboratories for testing work and save a great deal of bench space and man-hours in this way in which one has to do short-term tests continually.

With those particular remarks, I will now introduce Mr. Mateus who has a few additional words of introduction to his paper and who will then be ready to answer questions.

Mr. T. J. E. MATEUS: First of all, on behalf of the Laboratório Nacional de Engenharia Civil, and in my own name, I would like to thank the British Wood Preserving Association for having given me this opportunity to present a paper at its Convention. I feel much honoured to be present here among the most distinguished technicians and industrialists of England, in the field of wood preservation.

I am also very grateful to Mr. B. Hickson who, after a visit to my laboratory in Lisbon two years ago, made possible my attending for the first time one of the B.W.P.A. meetings in this charming city of Cambridge, and in this very same room. It was this meeting, from which I keep unforgettable impressions, that allowed me to get in touch with so renowned English technicians as Dr. Findlay, Dr. Fisher, Mr. Savory, Mr. Nevard, Mr. Price, and Mr. Cook, to mention only some of them.

Regarding the subject of my paper, I would point out in the first place that it is quite possible that my Latin make-up has made me to stress unduly the results obtained with my method and to over-estimate its usefulness to study the effectiveness of preserving products and the natural durability of wood. I hope that the English mind, always careful and prudent in its affirmations, may forgive me! I trust it will be so, as I find myself that the method in its present stage still has defects in spite of my efforts in these latter years to develop it. It is necessary indeed to improve some details such as the dimensions most adequate for the beams, the best type of vessel for the fungus growth, the supports of the beams, the loading system, etc.

I trust, that in the discussion that will follow, you may give me suggestions on these different questions.

I do not intend to give you details on the presentation of the method, as these you may find in my paper. I shall only briefly describe the essential aspects of the technique followed.

We have *here* the apparatus for bending tests in use at my Laboratory in Lisbon. It is the apparatus referred to in my paper and serves to measure the deflections of wooden beams subjected to fungal attack.

This apparatus is composed of a device that enables a certain load to be applied to the small beams and of a dial gauge in which the deflections, corresponding to the different stages in the development of the fungal attack, are read during the test.

Fig. 4 shows in detail the different pieces that make up the small testing machine.

I have *here* also one Petri dish of the type employed in tests to study the effectiveness of preservatives and the natural durability of woods against wood-rotting fungi.

In this type of dish, reproduced in Fig. 3, two small supports for the beams are glued. These are different from those presented in my paper which I did not deem entirely satisfactory. They consist of earthenware pieces, made specially for this purpose, that allow two specimens to be placed side by side. Their unit price is negligible, as it amounts to about 1/20th of the cost of each culture vessel.

After placing the beam in the grooves of these supports, its upper face lies slightly below the level of the rim of the under portion of the

Petri dish. Thus the plastic disc that is placed against this rim and is glued from outside at a few points of the vessel surface so as to remain slightly loose, allows the cap to be removed without infection hazards and to submit the specimens to bending test, whenever required.

This test, very quick and easy to perform, allows one to follow the development of the fungal attack in the wooden pieces. By means of the Strength of Materials it is possible to determine the cross-section corresponding to the different deflections observed and consequently the thickness of wood that, in theory, should be considered as wholly destroyed by the fungus. The curve of deflection variation presented in Fig. 9 of my paper was determined this way.

The specimen dimensions are such that the bending stresses induced by the applied force, before any wood destruction is observed, are much below the limit of proportionality of the material. As, however, the cross-section of the beam is small, an attack, even slight, on its surface is enough to induce a decrease in the moment of interia, rather considerable in percentage, and consequently to increase the deflection.

For a concentration of the preservative that effectively protects the wood or for woods not susceptible of attack by the fungus, no sensible deflection variation will be observed. On the contrary, whenever fungal attack takes place, the deflection increases during the test all the more quickly, the lower the concentration of the product, in the case of preservative testing, or, in the case of natural durability test, the more susceptible of attack is the wood.

In Fig. 7 of my paper, the results obtained in the test of a water soluble type preservative can be seen. Some comments on the curves obtained were already presented, but I believe it would be interesting to say something else about them, for a better interpretation of the results. In the first place, regarding the pieces kept at 20° C. after impregnation, for which different concentrations of the product were considered, it should be noted how the method discloses the different behaviour of the treated wood under the two fungi used. The attack is conspicuous with a concentration of 0.25 per cent., both in regard to *Poria vaporaria* or to *Lentinus lepideus*. As for the concentration of 0.13 per cent., although the product confers a certain protection (compare this with the curves obtained for untreated specimens), the development of the attack undoubtedly shows that the protection is insufficient, particularly in what concerns *Lentinus lepideus*, for which deflection variations of 90 per cent. were observed and in one case even the rupture of the beam.

Finally, what seems to show most clearly the value of the method is the observation of the development of the attack on the control pieces with a concentration of 0 per cent. In the case of *Lentinus* *lepideus*, the progress of the attack is remarkable, as in a few weeks, it caused the rupture of 4 specimens, in contrast with the inalterability of strength observed in the beams protected with concentrations of 2.5 per cent.

For the other testing conditions "Pieces exposed to 50° C. after impregnation" and "Pieces subjected to water leaching," in regard to which only the 2.5 per cent. and 0.0 per cent. concentrations were tested, the difference in the results is also remarkable.

In Fig. 8 the results obtained in a study of the natural durability of different woods, are presented. The fungi used were *Lentinus lepideus* for softwoods and *Coriolus versicolor* for hardwoods.

These results disclose the widely different behaviour of the various species tested. In order of decreasing natural durability, as determined by the tests, we have:

Softwoods:	*Hardwoods:*
Cryptomeria	Sweet Chestnut
Pitch pine	Agba
Portuguese cypress	Common oak
Maritime pine	Beech
Scots pine	Wych elm
	Blue gum
	Afara
	Poplar

Ladies and Gentlemen: I end here my comments on the paper.

Thank you very much for the attention you have kindly paid to me.

Owing to the difficulties I have with your language, I should be grateful if you could speak distinctly and not too fast when putting queries on my paper. Thank you very much indeed.

The CHAIRMAN: I should like briefly to give my own opinion about Mr. Mateus' work. This is a new approach for a short-term test. It does not replace, in dealing with timber preservatives, service records and long-term testing, but if it is successful in accelerating the rather heavy work which still takes some six to eight months on fungus testing with timber, I am sure it will be a great contribution in the future. It will, of course, only apply in certain cases to institutions, organisations and firms which have fungus-testing laboratories, but even from the little that I have seen of his work, I believe it may be a very valuable contribution to our future research work.

With that I will throw the Meeting open for questions.

Mr. E. H. NEVARD: I would like once again to thank Mr. Mateus for giving the Paper. As you may know, I had the privilege of looking at this apparatus when Mr. Mateus was here last, and even at that stage I thought that this was something which would be a very valuable contribution to this Association. I am particularly interested in the possible effect it may have on the laboratory testing of soft rots. Many of you may know that even under laboratory conditions it is very, very difficult indeed to get any appreciable weight loss with soft rot attack on soft woods. One can get it relatively easily under practical conditions. I do feel that this may be the means of detecting attack which we know but cannot prove to be there. I wonder if Mr. Mateus has already tried it with soft rots using this technique?

Mr. T. J. E. MATEUS: Not as yet, Mr. Nevard.

Dr. W. P. K. FINDLAY: I should first like to offer Mr. Mateus my congratulations, both on the delivery of his paper and on the very great deal of work which he has put into the development of this apparatus. When he first described it, I thought it would be a useful method for research. Now I think he has developed it further, and it has become a method which could be used for routine testing. Personally I am looking forward very much to carrying out some tests by this method.

Referring to the point Mr. Nevard has made, one of the fungi we shall include in this test will be *Chaetomium*, which is responsible for one form of soft rot.

I would like to ask Mr. Mateus what method he used for leaching small test specimens. Their small size makes leaching very much easier than in the standard test pieces which we use in the British Standard method. What method do you use for leaching?

Mr. T. J. E. MATEUS: I use at present in my Laboratory a method similar to that described by D.I.N. Standard which is the German method.

Mr. E. H. NEVARD: The German Standard method?

Mr. T. J. E. MATEUS: Yes, the German method for leaching tests. But I always make three groups of pieces treated with the preservatives under test that are subjected to different conditions: One of them as I refer in my Paper, is maintained, before the exposure to the fungal attack, at the room temperature; it represents the treated timber which is applied inside buildings. The second group is concerned with the pieces that are employed in roof structures in Portugal, where high temperatures are observed in Summer; it is subjected to a temperature of 50° C., alternated with the room temperature. The third group is for leaching tests and represents impregnated timber which is subjected in Nature to the direct action of rain. It is only for this group that I employ in my Laboratory the German Standard.

Dr. W. P. K. FINDLAY: Perhaps some members are not familiar with that D.I.N. Standard. Could you just very briefly describe what it involves?

Mr. T. J. E. MATEUS: Yes. The method involves the impregnation under vacuum of the pieces with distilled water at room temperature. The operation begins on a Monday at nine o'clock and is carried out for four weeks, the water being changed twice a day during that period, except on Saturday and Sunday, for which the flasks containing the pieces are maintained free from water till Monday morning. For leaching tests and also for the pieces which are kept at room temperature (first group referred) as for those which are subjected to 50° C., I employ special flasks which can be seen in Fig. 13. They have a cap with a

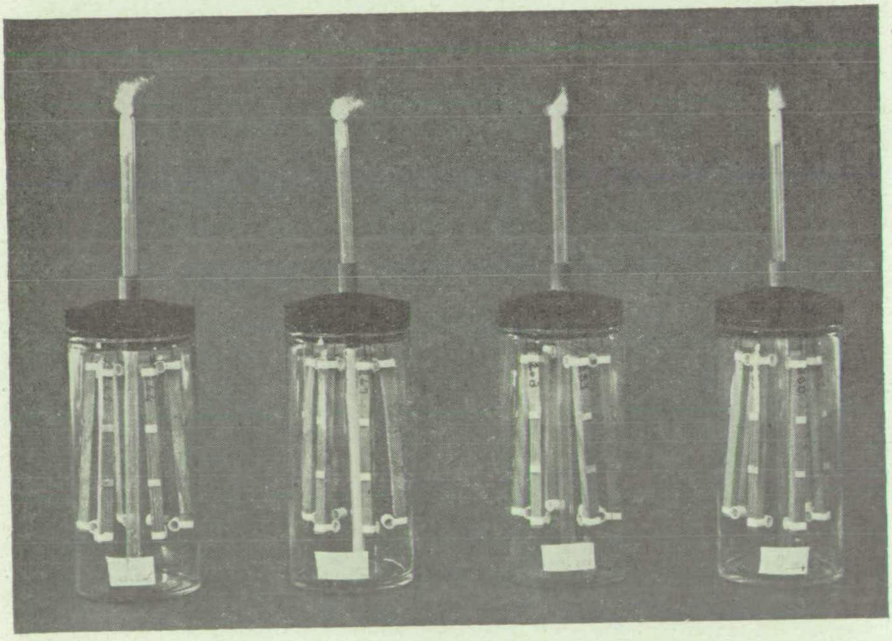


Fig. 13.

glass tube in it, through which the water can be introduced or removed without danger of infection during all the operations which are carried out before putting the pieces inside the Petri dishes with the fungus culture. The impregnation of the pieces with the preservative under test is also carried out in these flasks. The caps, from which the pieces are suspended, can be loosened for allowing the water or the preservative to evaporate after the liquid is removed in the course of such operations. This is the method employed at present in my Laboratory, but I must say that the leaching tests referred to in my Paper were not carried out according to the D.I.N. Standard, as I do nowadays. In those tests the flasks with the pieces were filled with distilled water at room temperature for a certain period and afterwards maintained free from water at a temperature of about 50° C. during the same period. The alternated operations were repeated in the course of four weeks.

Dr. D. McNeil: The first thing I would like to say in regard to this Paper is congratulations to the British Wood Preserving Association for inducing Mr. Mateus to come all the way from Lisbon to give his paper.

Secondly, I do think that Mr. Mateus deserves very warm congratulations indeed on this paper. I think myself it is brilliant in conception, in execution and, if I may say so, in expression. I am saying these things not simply as a courtesy to a representative of our oldest ally but because I sincerely feel this way.

It seems to me that in any work of this nature, where one is trying to evaluate agents against natural organisms, one of the most important things is to have an accelerated test which will correlate with results in practice. I think my friends at the F.B.I. would agree that our present methods of soil/wood testing, agar dishes and so on leave a very great deal to be desired. They are, I think, as our Chairman has said, very tedious and, as far as I can see, the results are not all that they might be. I do think that this particular test offers a new and very interesting possibility, particularly since the time required for these tests will be so greatly reduced, the volume of test results will be so greatly accelerated, and the possibility of noting the correlation between these tests and actual practice service records will be so much favoured.

There are two points I would like to make on the Paper. One is a question and the other is a suggestion. The position is, as I understand the test, that two exactly similar beams treated with the same concentration of preservative are placed in the same Petri dish, and I wondered whether Mr. Mateus would give us some idea of the repeatability of the results between his two duplicate specimens.

Secondly, I wondered whether the test might be improved if, instead of having two exactly similar beams, a control beam and a treated beam were placed in the same dish and the results were expressed as a ratio of the strength between these two beams over the period of time.

Mr. T. J. E. Mateus: With reference to this question, I must say that we do find a little dispersion in the results, of course, because it is quite difficult in every case to choose two pieces similar in all aspects. We can choose, for instance, the same rate of growth and the same straightness of grain. We can employ pieces with the same absorption of product, the same retention of preservative and so on, but we find a little difference because the method is a biological method and has the peculiarities of a biological method. In my Paper, from the curves obtained with the tests of natural durability, for instance (Fig. 8), you can get an idea of this dispersion. I chose the pieces carefully in such a manner that all the aspects—grain, rate of growth and so on—were the same. Notwithstanding the observed dispersion, sometimes there is a good concurrence in each pair of curves which were obtained from two pieces put side by side in the same vessel.

I think the improvement you suggested is a very good one, because in this way we can compare in the same conditions one piece treated with the preservative with another untreated one (control). However, I have one doubt about this in that I can have for instance, pieces impregnated with strong concentrations of a volatile preservative beside unimpregnated pieces (control), and I am not sure if the product does not influence the conditions of the fungal attack on the control beam. This, I suppose, is an important point. For non-volatile products of course, your suggestion is very interesting.

Mr. R. A. BULMAN: Mr. Chairman, I cannot let the opportunity go by without adding to the remarks made previously on how excellent this Paper is and how greatly we are indebted to Mr. Mateus for coming along and letting us have the advantage of his personal comments as well as the information in the Paper.

In the Paper, Mr. Mateus mentioned a period of one month as giving a good indication of the effects of the decay. That may very well be true when comparing any piece of timber treated with any preservative with untreated controls. But when it comes to comparing two preservatives of a fairly high standard, then I suggest it is quite probable, although not certain, that in a relatively short period of one month there will be no noticeable difference between the results obtained. It seems very likely that the test would have to be continued for two months, or possibly three, or even more, in order to show the differences between two or more high-class preservatives. I wonder if Mr. Mateus has any results which illustrate that point.

Mr. T. J. E. MATEUS: I generally register the results and plot them in the graphs after a month, but I always keep the pieces in the dishes for a longer time, say two or three months. It is possible to do this because the method is not destructive, as you know. We can prolong the test as long as necessary, because at the end of the test—whatever the period happens to be—the samples will be in the same test conditions as they were at the beginning. In my Laboratory we continue the test for a period of two or three months, because in the present phase of the development of the method we must collect as much information as possible about the test. Till now I have tested some products but I do not have results in sufficient quantity to be able to reply to your particular question.

Mr. G. GOBERT: Mr. Chairman, I cannot let the opportunity go without congratulating Mr. Mateus on a very excellent paper, and the disarming way, the personal charm, with which he put over his comments and the excellent way in which he is coping with the questions. I would like to ask several questions. Firstly, is anybody in Portugal manufacturing your little machine? In other words, is it available to be purchased by manufacturers of preservatives in this country?

Mr. T. J. E. MATEUS: *This* machine was designed by me and built in a workshop we have in the Laboratório Nacional de Engenharia Civil. This one is the second that we have built. No firm is manufacturing this apparatus at present in Portugal.

Mr. G. GOBERT: I would advise, Sir, take out a patent on it.

Mr. T. J. E. MATEUS: Our laboratory can supply this apparatus on request.

Mr. G. GOBERT: May I be first on the list, please?

My second point, Sir: the extreme value to mycologists is the fact that tests with diluted preservatives can be done relatively quickly.

Another point which is very important from the preservation industry's point of view is the testing of sap-stain fungi with your apparatus. Until now it has been believed that they do not appreciably weaken the timber, except by detracting from the appearance of the timber. I would be very interested to learn whether or not you have actually carried out any tests with timbers containing sap-stain fungi.

Mr. T. J. E. MATEUS: I have not made any tests relating to sap-stain fungi.

Mr. G. GOBERT: Finally, Sir, soft rot is a subject which has been very much discussed, not only today but yesterday as well, and it will be discussed again. There is a point of great dispute on one soft rot fungus which I would like to have tested, namely *Trichoderma viride*. On the Continent, this is believed to be a wood-destroying fungus.

Mr. J. G. SAVORY: Mr. Chairman, Mr. Mateus, I would like to follow up Mr. Gobert's remarks by asking you a few more questions about the nature of your tests.

Firstly, I am very pleased to hear that you are willing to offer blueprints of your apparatus to anyone who would like them.

Secondly, I would like to know what is the nature of the plastic cover that you use over your Petri dish. Is it available in this country, what thickness do you use, and so on?

The third point is a question relating to the tests. Do you have any difficulties with the drying out of your Petri dishes during the test and, if so, after what period?

Fourthly, have you carried out comparative tests on white and brown rot fungi on the same timber?

I think that is enough questions for the moment. I would like to add my commendations to the others which have been offered; in particular I should like to congratulate Mr. Mateus on the neat method by which he has adapted the German Standard test, so that he does not have to wade through a puddle of water every morning when he goes into the laboratory!

Mr. T. J. E. Mateus: It is quite a common type of plastic, Mr. Savory, such as is used in refrigerators for wrapping vegetables. It is quite a common or garden plastic. I did not quite understand what you meant with regard to the drying out of the Petri dish.

Mr. J. G. Savory: The difficulty is that in general the agar put into the Petri dish dries out after about six weeks. Dr. Findlay has just pointed out to me that you maintain your incubator at 90 per cent. relative humidity. Is that sufficient to prevent the drying out of the Petri dishes?

Mr. T. J. E. Mateus: Yes, I believe so, because the plastic is effective in keeping out the water, and it does not permit the easy exit of the water vapour. The fungal cultures maintain themselves in a fresh condition for five or six months afterwards, do you understand? . .

Mr. J. G. Savory: Yes, Sir.

Mr. T. J. E. Mateus: It is because the relative humidity of the chamber is high and the plastic prevents the evaporation of the water to a certain extent, of course.

Mr. J. G. Savory: Do you ever have contamination troubles by the growth of moulds on the plastic itself?

Mr. T. J. E. Mateus: The plastic discs are sterilised beforehand with alcohol. Before I put them on the lower part of the Petri dish, I pass the discs in front of a flame in order to evaporate the alcohol. I use this method of sterilisation because, of course, I cannot put the discs in an oven.

I have not done any tests with the same species of timber and different fungi.

Mr. J. G. SAVORY: That, of course, would be quite an interesting test to carry out, as your method is so sensitive, and you should be able to confirm the differences in the behaviour of the two types of fungi that other people have already commented on.

Mr. J. St. G. SPROULE: Could I ask Mr. Mateus whether, with specimens which are well rotted, there is any permanent distortion or deformation and if so how this affects the accuracy of his method?

At board, Mr. T. J. E. MATEUS: This is an important question. During the test the cross-section of the beam changes, not like *this*, of course, but theoretically like *this*. We can always consider a theoretical section corresponding to the deflection variation observed. In the beginning of the test the stress induced in the beam by the applied load is below that which corresponds to the limit of proportionality of the wood, in the stress-strain diagram. In an advanced stage of the attack the cross-section of the piece is greatly reduced and, therefore, the stress induced during the bending test will be increased, in such a manner that it will be greater than the limit of proportionality of the material. We attain the phase of great deformation. As the modulus of elasticity of wood decreases with the stress above that limit, when we study the relationship between the deflection variation and the time of attack, the curves present a deviation from the axes of deflections and this is, I believe, an advantage of the method, because an acceleration of the effect of the fungal attack results from this fact. When we find, for instance, at the end of two or three weeks a curve like those presented in Fig. 7 of my Paper for the same time, we can be sure that the attack is going on quickly. In this case the decrease of the modulus of elasticity which took place above the limit of proportionality of the wood, contributed to the increase of deflection.

I hope I have answered your question . . .

Mr. J. St. G. SPROULE: Mr. Chairman, I probably worded my question rather vaguely. I was merely interested in whether there was an actual distortion in rotted specimens. If, for instance, the profile of a specimen was such that the centre was higher than the ends owing to distortion, then it would really have a greater strength with which to resist any deformation.

Mr. T. J. E. MATEUS: In general we do not find deformations like that. We always standardise the apparatus and we refer all measures to this initial standard, but, of course, if a deformation or distortion of the beam takes place in the course of the test we can have an arch effect in the stiffness of the piece. Nevertheless I think it will be negligible and can be ignored.

I have never found this distortion.

Mr. F. F. Ross: This is not important really, Mr. Chairman, but, as many people will know, we have a certain interest in soft rot. I just wanted to say that I have no questions but I have one criticism of this Paper: it is a rather fundamental one and it concerns the date—I wish he had produced it four years ago!

Mr. R. A. Bulman: Mr. Chairman, I should like to go back to Mr. Sproule's query, and to refer to some of the graphs wherein, if I understand them correctly, some lines appear below the zero line. That I conclude indicates a gain in strength, and I wonder whether those lines showing that gain below the zero line do come about because of the phenomenon that Mr. Sproule suggests, namely bending. Is there any relationship between them?

Mr. T. J. E. Mateus: No. I suppose the reason why certain lines are below the zero line is because of the initial adjustment of the system. There are perhaps some . . .

Mr. D. V. Clift (Interpreter): It is a question of adjustment of the machine, to be taken up in the machine.

Mr. T. J. E. Mateus: Not in the machine, in the system, in the pieces, because the ends of the pieces must have a certain adjustment, initial adjustment. We sometimes find peculiarities and I think this is the cause.

Mr. G. Gobert: Mr. Chairman, I believe I read Mr. Mateus' Paper correctly in saying that you maintain the moisture content of your timber above the fibre saturation point; in other words, above 30 per cent. moisture. It is my experience with timber that it does not warp with fungal attack when it is above 30 per cent. moisture. Do you maintain that moisture? Is it still above 30 per cent. at the end of your test?

Mr. T. J. E. Mateus: Yes. In this method it is important that the moisture content of the wood is maintained above the fibre saturation point, or near the fibre saturation point, because these are the conditions under which the fungus can attack the timber.

At Board. The method can also give some information because if we find a decrease in deflection, we must observe the change of humidity and we must conclude that the moisture content in the pieces is below the fibre saturation point.

Another reason is that it is only above the fibre saturation point that the mechanical properties of wood and consequently the deflection are not affected by the humidity.

It is therefore important that in this method the moisture is nearly at or a little above, the fibre saturation point.

M

Mr. D. M. SPRANKLIN: One small suggestion I should like to make is that the aluminium plates, bearer plates, should be replaced by a material which could be certain to be inert under variable conditions of pH. which may occur using organic salts as preservatives.

Mr. D. V. CLIFT (Interpreter): These are porcelain now.

Mr. D. M. SPRANKLIN: Aluminium protection plates on the surface of the wood must be replaced by a truly inert material.

Mr. T. J. E. MATEUS: Yes, I am of your opinion, and this is a good suggestion, because, of course, the aluminium can affect the product as chemical reactions can take place between the aluminium and the preservative.

The CHAIRMAN: Ladies and Gentlemen, I am afraid that I shall have to bring this session to an end because a film is being shown before lunch.

It is quite evident from the number of questions that have been put to Mr. Mateus what interest there is in the future possibilities of this work. I am impressed myself at the clarity, in spite of his language difficulties, with which Mr. Mateus has attempted to answer and deal with the comments and questions, as well as by the fact that he is so honest as to admit that his work is by no means finished. He wants to perfect it and further it, and I am sure some of the comments that have been made this morning will be helpful to him and to other laboratory investigators in improving this method of test so that it can be of greater use to the laboratory investigators all over the world.

On behalf of the Association I would like to express our very greatest thanks to our speaker today for coming all the way from Lisbon, for making the great effort necessary to present his paper in his very excellent English to a room full of people and for the way in which he has dealt with and answered all the questions.

(7) THE PRESERVATION OF TIMBER IN WATER COOLING TOWERS

by F. F. Ross, M.A., B.SC. and M. Jocelyn Wood, B.SC.(HONS)
(*Central Electricity Authority*)

1. Introduction

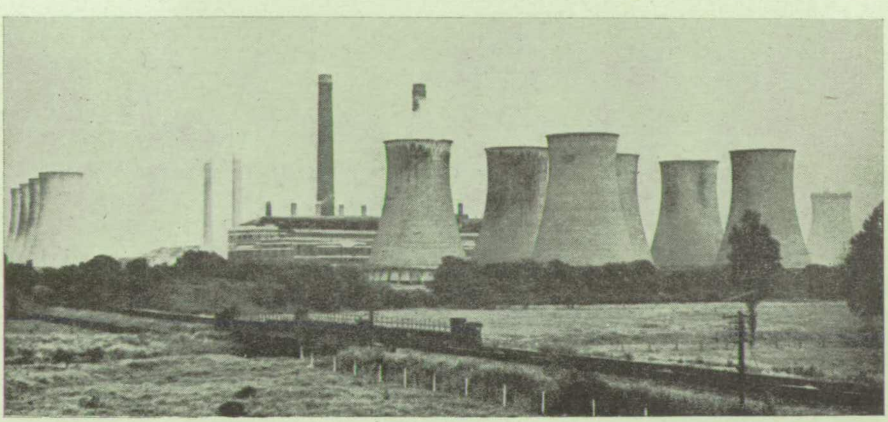
AT the present time the Central Electricity Authority has in service some 415 cooling towers capable of cooling a total of 450 million gallons of water per hour. Some of these installations are recent but some towers commissioned 30 to 50 years ago are still in use after various repairs or replacements of timber.

The electrical industry also uses timber poles for transmission of overhead lines and a certain amount of timber immersed in water for coal wharves and jetties. Timber poles formed the subject of a paper by K. L. May to the 1956 Convention and they will not be further referred to here. Marine timber, however, exhibits certain parallels in the problem of preservation with cooling tower packing, and much of what has been learned in the case of cooling towers will be applicable to marine timber in spite of the fact that different wood destroying organisms are involved.

2. Construction of Cooling Towers

Nearly all the Authority's towers are of the natural draught type without fans. The outer casing of such towers serves as a chimney to cause an upward flow of air through the packing. The older towers have wooden cases but practically all towers of this type built since 1935 are large and have concrete envelopes. Plate I shows the installation at Hams Hall Power Station where there are 11 such towers capable of cooling over 40 million gallons per hour (800,000 U.S. gallons per minute).

PLATE I. *Cooling tower installation at Hams Hall Power Station, near Birmingham.*



The packing inside a large tower is 15-20 ft. deep with the water distributed over it at a height of about 30 ft. above ground. The complete stack inside the envelope consists of the following parts:

Uprights, *columns* or *posts* which may be of timber or concrete.

Bearers or *rails* which are horizontal and which may also be made of timber or concrete.

The *packing* proper which consists usually of timber; this is all of small sections which are called *slats*, *laths* or *louvres* according to shape.

The *distribution* system, consisting of wooden troughs which allow the water to fall through holes on to splash plates or of asbestos piping carrying spray nozzles. (In some small towers metal piping is used and some American manufacturers use wooden *piping*).

The *mist eliminators*, which consist of two layers of wooden louvres; these are placed above the sprays to catch water droplets which would otherwise be carried upwards and out of the tower.

The cooling of the water is accomplished partly by transfer of heat from the water to the air, but for the most part by evaporation of some of the water. For both purposes a large area of contact between the water and the air is required. This necessitates a large area of packing carefully designed to achieve efficient air-water contact. Wood is a favoured material because of its cheapness, its strength and the ease with which it can be cut to the desired shapes. In an endeavour to obtain the maximum surface from a standard of timber small sections are used for the packing; for example, 3 in. × ½ in. and 4 in. × ½ in. rectangular section; 4 in. × 1 in. slit diagonally; 2 in. × 2 in. and 1½ in. × 1½ in. slit diagonally, and 3 in. × 1 in. cut at an angle of 45°.

In a large tower of the concrete envelope type the packing and mist eliminators together may amount to about 60 standards for each million gallons per hour of water circulating and the Central Electricity Authority must be using somewhere around 4,000 standards (8 million board feet) of timber a year for new towers and for repairs in old ones.

3. Types of Deterioration.

The following distinct types of damage are recognisable in cooling tower timber:

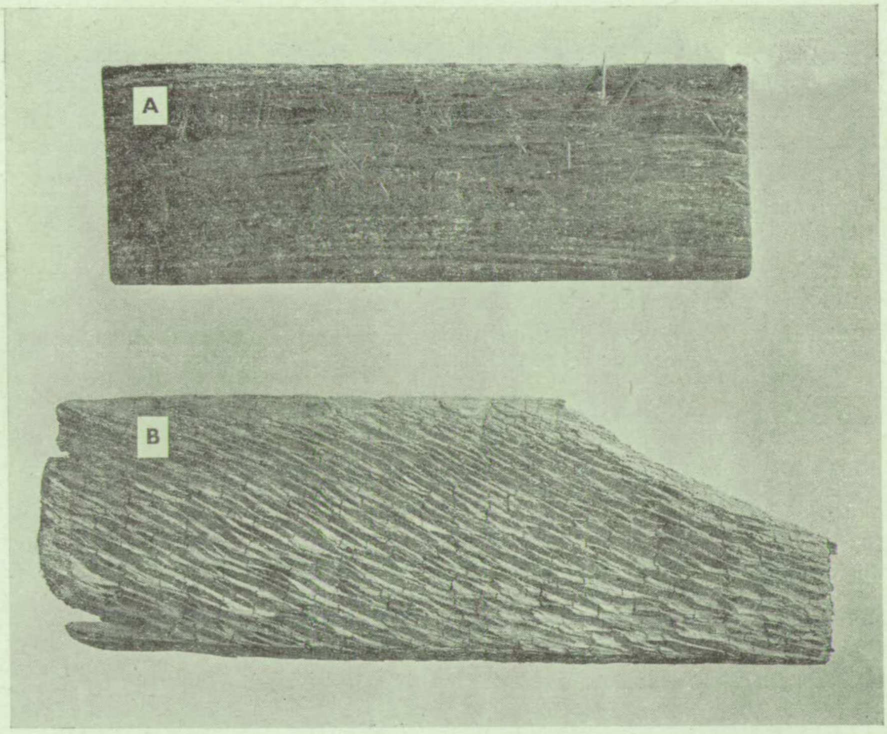
(1) Mechanical damage.
(2) Attack by salt crystallization.
(3) Attack by alkali.
(4) Attack by chlorine.
(5) Degradation near iron fixings.
(6) Attack by staining fungi.
(7) Basidiomycete attack.
(8) Soft rot.

3.1 MECHANICAL DAMAGE

It can be said that there are only two types of mechanical damage to cooling tower packing; one is due to the formation of ice and the other to the formation of scale, both of which may damage the structure by sheer weight. There is now believed to be no mechanical effect of the water itself or of grit or diatoms contained in it. Erosion of the wood only occurs after it has lost all of its strength and even then the rotted spongy residue will remain in place (as shown in Plate VIII) unless it breaks up and flakes off due to contraction on drying.

Another type of damage in the mechanical category has occurred in America if induced draught towers are used for emergency purposes only; in a hot dry climate the wood may shrink to such an extent as to loosen the joints so that there is excessive vibration if the draught fan is turned on before the wood has been well soaked.

PLATE II. (*a*) *Effect of salt crystallization on Scots Pine* (*Gt. Britain*).
(*b*) *Suspected alkali attack on* Sequoia (*dried specimen from California*).



3.2 SALT CRYSTALLIZATION

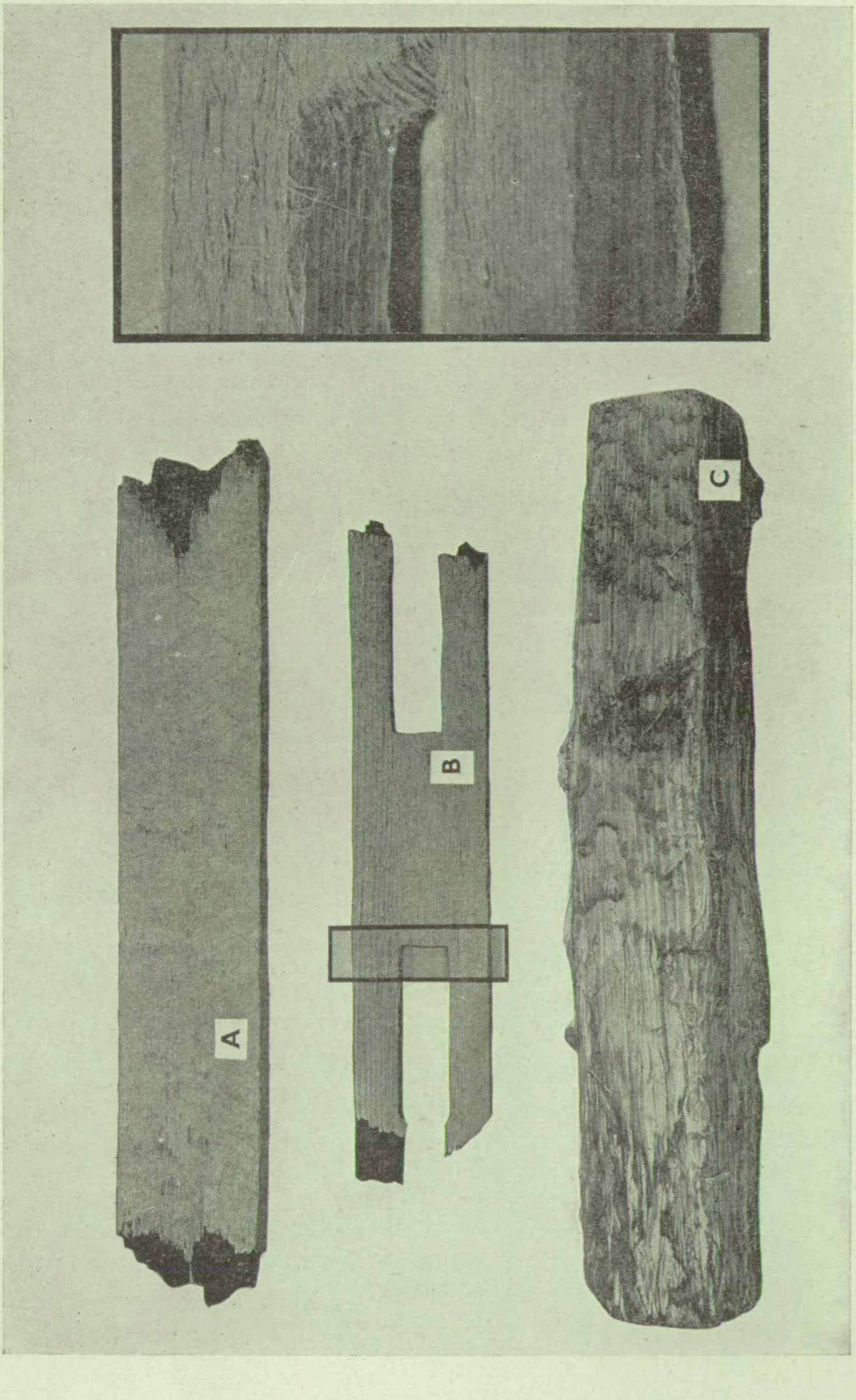
A very obvious form of timber deterioration is one which occurs on the outside timbers, the wood being broken up into coarse fibres which stand out from the surface. This has been seen in Britain on the outside of wooden shell towers (Plate IIA) and is quite common in the U.S.A. It was formerly thought to be associated with excess alkali in the water but is now believed to be due simply to the evaporation of water in the wood tissues; the subsequent growth of crystals from the salts naturally present in the water seems to force the fibres apart. This only occurs on external timbers where evaporation can take place, and it is therefore easily seen. It looks alarming, but since it does not affect interior timbers and since those destroyed are easily replaced when necessary, it need not be considered.

3.3 ALKALI ATTACK

Towers which are operating on cooling water softened by base-exchange are likely to suffer serious degradation of the timber if the raw water is high in bicarbonate hardness. Some carbon dioxide is lost and the remaining solution of sodium carbonate concentrates as the water evaporates. Even if care is taken to ensure that the circulating water is kept below pH8, a high pH may occur on such parts as mist eliminators, as a result of evaporation. No example of this has occurred in C.E.A. towers but a case was reported recently from some towers at an oil refinery. The effect on the wood is one of de-lignification, leaving the wood pulpy. Some peculiar effects may be observed on drying (Plate IIB). The effect occurs from the surface inwards so that the interior of a piece of wood may be sound even when it has been considerably thinned. It was suggested to one of us by the California Redwood Association that Californian redwood (Sequoia) which is continually wet, does not deteriorate from alkali attack unless there is also an oxidising agent (such as chlorine) present. The majority opinion in America does not, however, uphold this view.

3.4 ATTACK BY CHLORINE

Chlorine is commonly used in cooling water circuits to prevent the growth of slime on the tubes of heat exchangers. Small cooling towers in which the packing is exposed to daylight may also suffer from the growth of algae. If this is not prevented, masses of such growth may break away and block up distribution orifices or the tubes of heat exchangers. Various algicides such as chlorine, pentachlorphenol, or "cuprose" (copper citrate), have been used to kill this growth. This problem has chiefly been troublesome in America. It does not occur to any extent in natural draught cooling towers where the packing is enclosed in a light-excluding chimney.


A
B
C

The cheapest algicide is chlorine and only too often it has been used to excess. Timber which is undergoing attack by chlorine has the surface bleached and broken up into fine white silk-like threads (Plate III). It is not known what concentration of chlorine can be tolerated without damage to the wood. It has been suggested by the Cooling Tower Institute in the U.S.A. that concentrations exceeding 1 ppm. should certainly be avoided, but it may be that any free chlorine or hypochlorite will attack the wood and that it is merely a question of degree. On the other hand, chloramine equivalent to 0.5 ppm. chlorine has been maintained for health reasons in the sewage effluent used at one power station in England, and the timber (*Pinus sylvestris*) shows no deterioration after five years.

3.5 DEGRADATION NEAR IRON FIXINGS

Samples have been seen of fairly large timber sections which have decomposed in the vicinity of iron bolts or fixings. This is believed (Campbell 1952) to be of a purely chemical nature, being a type of catalytic oxidation of the cellulose.

3.6 STAINING FUNGI

Some pieces of wood have been seen which are darkened but not much weakened. Californian redwood in cooling tower service readily suffers attacks of this nature, even where soft rot is not evident, although the Forest Products Laboratory at Madison suggest that fungi of the same type as those causing soft rot may be involved. The attack is fairly rapid, penetrating the wood at five or ten times the rate normally observed for soft rot. The loss of strength is not serious and can probably be neglected.

3.7 BASIDIOMYCETE ATTACK

Lentinus cyatheformis, *Poria nigrescens*, *Poria oleraceae* and other basidiomycete fungi sometimes establish themselves in cooling towers. They are more likely to be found in larger members such as supports or parts of the troughing which are not continuously flooded with water. Plate IV shows an example in the mist eliminator in a four-year-old tower in Britain. This form of attack is common on Californian redwood in the Gulf area in the U.S.A. and has been confirmed in Tennessee. Cooling towers constitute a new environment and we ought to be prepared to expect a spread of these fungi as opportunities for infection increase.

PLATE III (*left*) (a) *Mild Chlorine attack on* Sequoia (*Arizona*); (b) *More severe chlorine attack on* Sequoia (*California*); (c) *Serious attack on* Pinus (*Gt. Britain*); Inset: *Enlargement of* (b) *to show fibres.*

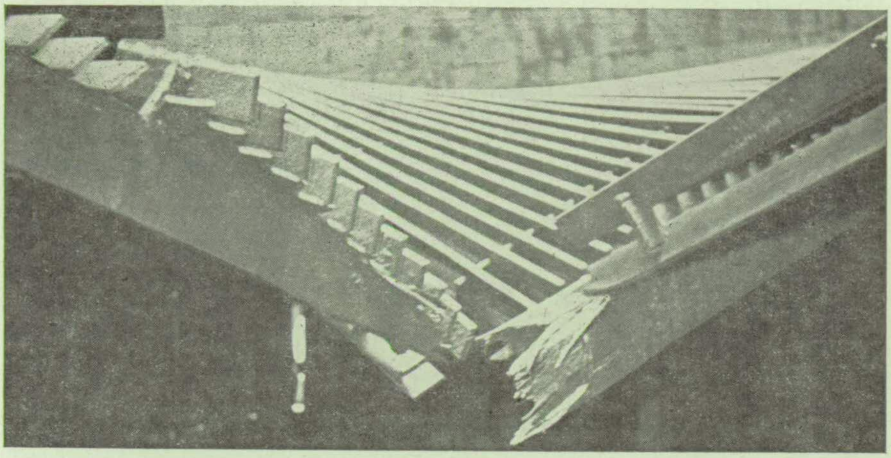


PLATE IV. *Collapse of Scots Pine eliminator after four years' service, due to attack by* Poria *(Britain).*

Samples of large timbers have been seen in which the interior only has disintegrated. The most likely explanation is that such timbers were infected before use and the outside has become too dry (e.g. in house construction) or too wet (in cooling towers) for fungal growth there also.

3.8 SOFT ROT

This is a recently recognised form of biological attack on wood.

4. Soft Rot

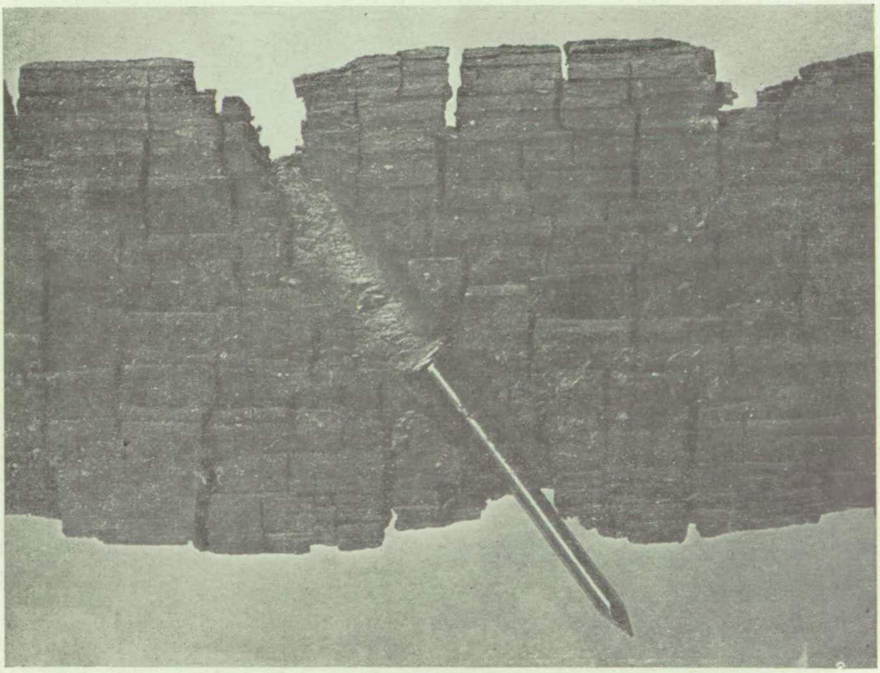
4.1 DISCOVERY OF SOFT ROT

Interest in cooling tower timber preservation was quickened in 1946 when the packing of a tower collapsed after being in service only seven years. Such breakdowns were at first considered to be due to some form of chemical hydrolysis of the wood coupled with mechanical erosion by the water or the grit suspended in it. In 1948 the Forest Products Research Laboratory reported to this effect in respect of some samples from another power station. In May, 1949, however, the F.P.R.L. reported discovery in packing timber of microfungi not hitherto recognised as wood destroyers, and asked for co-operation in the investigation. In 1950 a survey was made by one of us of the towers in use in the Electricity Authority. From the data obtained on 48 towers or groups of towers it appeared that the average life was about 17 years, with some towers failing in under 12 years and others lasting more than 20. Many of the premature failures were ascribed to poor design, such as in the method used to fix the bearers to the uprights, and could not be directly ascribed to deterioration of the substance of the wood in the packing. However, within about 20 years the laths or slats usually became so thinned that the packing had become inefficient and it was economical to replace it. Further work by the F.P.R.L. confirmed that this surface decomposition of packing timbers is brought about by microfungi (Findlay and Savory 1950).

4.2 FUNGI RESPONSIBLE FOR SOFT ROT

The "soft rot" fungi usually attack the surface of the wood, destroying the cellulose of the cell wall as the attack progresses slowly inwards; this leaves the wood surface soft when wet, cork-like and covered with shrinkage cracks when dry (Plate V). Laboratory investigations with *Chaetomium globosum* on beech were undertaken. This fungus was chosen because of its common occurrence and ease of culture (Savory 1955). It has not, however, been shown whether this particular species is responsible for most of the damage to Pinus under cooling tower conditions. Several species of the Ascomycetes are involved. All of them appear (from the limited work which has been done) to behave similarly. They may assist one another, or be competitive, or follow each other in successive waves. Different groups attack different woods. For instance, the fungi which most readily attack *Sequoia* appear from preliminary investigations at Madison to be species of Bispora.

PLATE V. *Typical appearance of advanced soft rot in* Pinus sylvestris, *after drying out. The piece has been scratched with head of* 1 *in. nail.*



On the grounds of the different fungi involved, the California Redwood Association has expressed some doubts about a type of test in which different species of wood are put into towers constructed wholly of *Sequoia*.

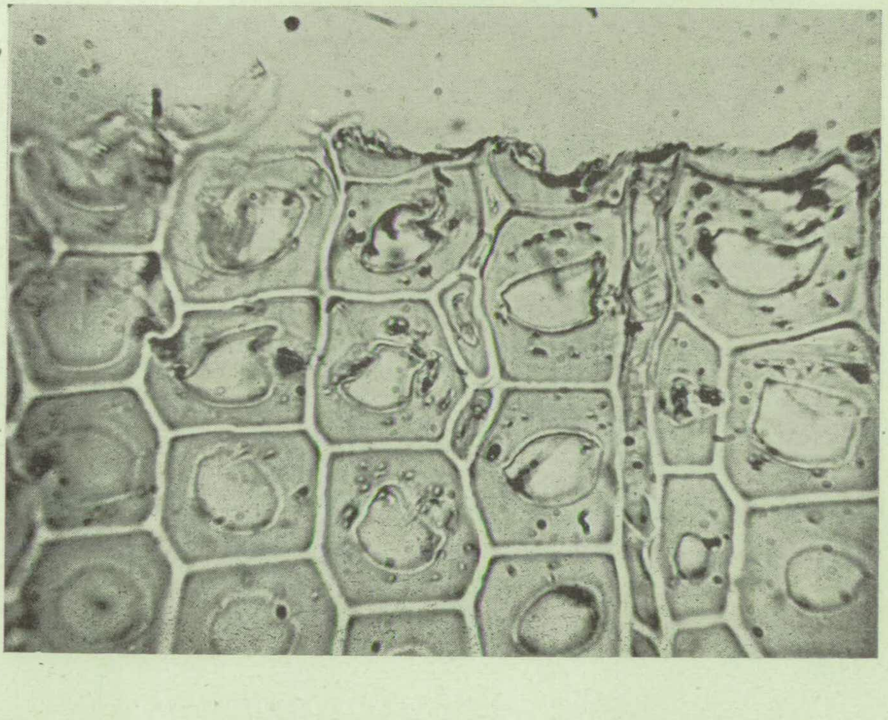
4.3 RATE OF ATTACK

Techniques were developed for measuring the rate of attack under working conditions. It was found to be of the order of 0.01 in. per year. In a six weeks' laboratory test such a rate produces negligible weight loss although incipient attack can be observed miscroscopically (Plate VI). For quantitative tests beech was therefore selected because it is rapidly attacked and can be easily impregnated with preservatives.

Sometimes the rate of attack under working conditions is less than 0.01 in. per year and sometimes it is very much more. Possible factors in this variability that have been considered are:

(a) Wood species
(b) Position in the tower
(c) Closeness and direction of grain
(d) Heartwood or sapwood
(e) Water composition
(f) Operating schedule
(g) Protection by masking

PLATE VI. *Transverse section of Scots Pine* 19 *days after inoculation with* Chaetomium globosum



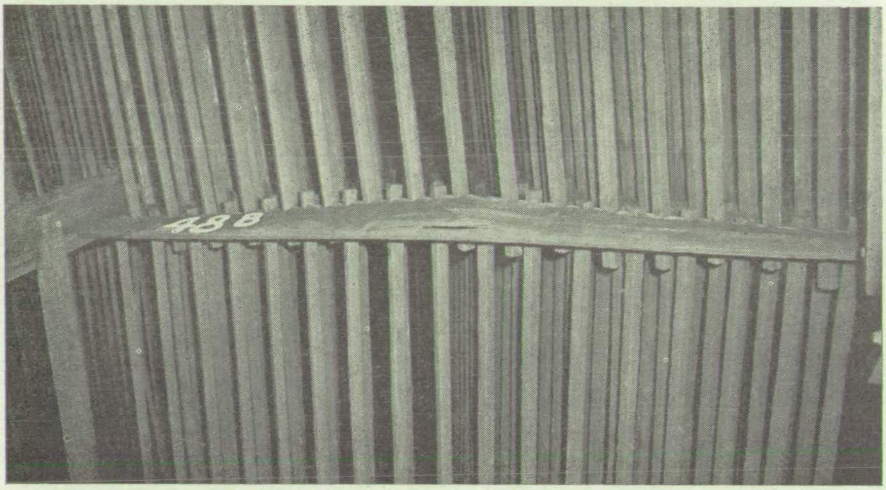


PLATE VII. *Condition of* 1 *in.-thick Douglas Fir bearer after* 5 *years' service.*

(a) *Wood Species*

A study was made of statistically random samples from untreated timber slats that were to be replaced after seventeen years' service in one cooling tower. Although the wood was stated to be all Scots pine the 240 pieces examined consisted of 141 of spruce, 68 of Scots pine, 19 of hemlock and 12 of Douglas fir. Scots pine was clearly shown to be better than spruce. The few pieces of Douglas fir appeared to be no better than spruce, and sometimes this timber is attacked rapidly (see Plate VII). One of us has observed rapid attack of Californian redwood in the U.S.A. and a rate of 0.06 in. per year has been reported from Australia. It should be borne in mind, however, that the ability of a timber to take preservatives may be more important than the resistance of the untreated wood.

(b) *Position in the tower*

In the packing, which is continually wetted, no significant variations have been observed in Britain in rate of attack between top and bottom, windward and leeward, North and South. Different conditions obtain for mist eliminators and inlet louvres and, as would be expected, differences in attack between these and the packing are observed.

(c) *Closeness and direction of grain*

The theory had been advanced that timber with the annual rings close together, i.e. slow grown timber, would be attacked less rapidly than timber with open grain structure. No evidence for this was found in the species referred to in (a) above. The California Redwood

Association does not consider there is such an effect for *Sequoia* either. However, an effect of grain direction was found for Scots pine such that, if all the slats in the tower examined had been of Scots pine with the grain in the preferred direction a life of 30 years instead of 17 could have been expected. Unfortunately this is of no industrial significance. It would be impracticable to build a tower with all the timber so cut and so placed in position as to present the preferred grain direction to the water.

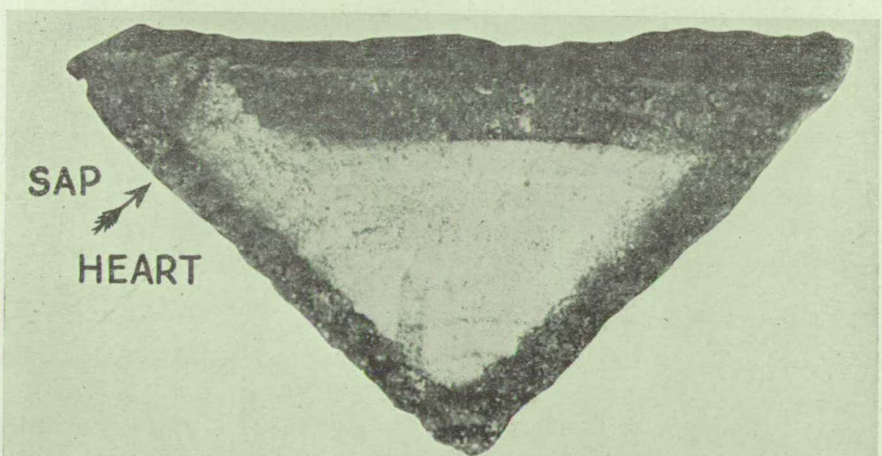
(d) *Heartwood and Sapwood*

Surprisingly it has been found that with Scots pine the attack proceeds equally into heartwood and sapwood. This is well shown in Plate VIII.

(e) *Water Composition*

Towers are used on all kinds of water and with varying degrees of recirculation of the same water. There is some evidence that towers operating with water containing a high proportion of some types of industrial wastes and in which this water is many times recirculated, are subject to more rapid decay than towers in other conditions. But there are exceptions to this and, in particular, the effluent from sewage works does not seem to encourage timber decay. Some observations on the presence of nutrients in the water might seem to support Savory's laboratory work on nutrients (Savory 1955) but there are too many complicating factors to justify any conclusions. Sometimes impurities in the water, such as oil or oil products, may have a preservative effect. Chloramine has already been referred to.

PLATE VIII. *Cut from nominal* 2 *in.* × 2 *in. stock this timber was still giving service after* 25 *years when sampled in* 1954, *despite destruction of the wood substance to a depth of about* ¼ *in. and substantial internal attack by soft rot fungi.*



(f) *Operating Conditions*

A further complication is the continuous or intermittent use of the tower. Only in extreme cases has any effect been noted. If the timber is never allowed to dry, the rotted material may remain in place instead of flaking off (Plate VIII). If the timber is only occasionally wet and is thoroughly dried in between, then soft rot may be absent. This has been observed at a power station in South Wales and at one in Denver, Colorado. In addition, many of the open-type cooling towers without mechanical draught seen by one of the authors in the U.S.A. in the summer of 1956 were free from obvious soft rot. Some of them were as much as 30 years old. Small towers associated with summer air-conditioning also have a long life.

(g) *Protective Coatings*

It has been observed that timber coated with scale or firmly bolted to another piece does not suffer severe soft rot. One case that seems to be of this nature is at a British power station downstream of a steel works. Here the timber has been coated with a deposit of iron oxide and only microscopic traces of soft rot have been found in it. This gave rise to suggestions to protect the wood by means of a film of wax or bitumen. Tests were made but only partial success was obtained.

4.4 PREVALENCE OF SOFT ROT IN COOLING TOWERS

Apart from the few exceptions noted, soft rot has been found on packing timber in every British power station cooling tower over 6 months old that has been examined. This includes a number of towers commercially treated with Celcure and some treated with Tanalith U.

Despite the examples of old towers in the U.S.A. that have apparently escaped attack by soft rot, M. W. Larinoff (1956) showed that maintenance costs had remained fairly constant (when expressed as percentages of original tower cost) over a period of ten years or so, and there is no doubt that soft rot attack is more widespread in Californian redwood towers than is yet realised. For example, one of us was directed especially to a large cooling tower installation at a power station in California to observe the absence of soft rot, and discovered its undoubted presence (Plate IX).

5. Remedies Against Timber Deterioration

5.1 CHEMICAL DETERIORATION

The best, and probably the only cure for alkali attack is to eliminate the alkali. For softening the water to prevent scale a lime softening plant, as at some British power stations, may be substituted for base-exchange zeolite treatment. Acid may be added to reduce excess alkalinity in softened water, or may be used in accordance with Langelier's Index to prevent scale formation with water that is not softened. Attack by chlorine can be cut to an acceptable level by reducing the total amount of chlorine. Since less than 0.5 ppm of chlorine is probably ineffective against algae the best method of reducing the chlorine is to reduce the time for which it is applied. Continuous chlorination is rarely necessary.

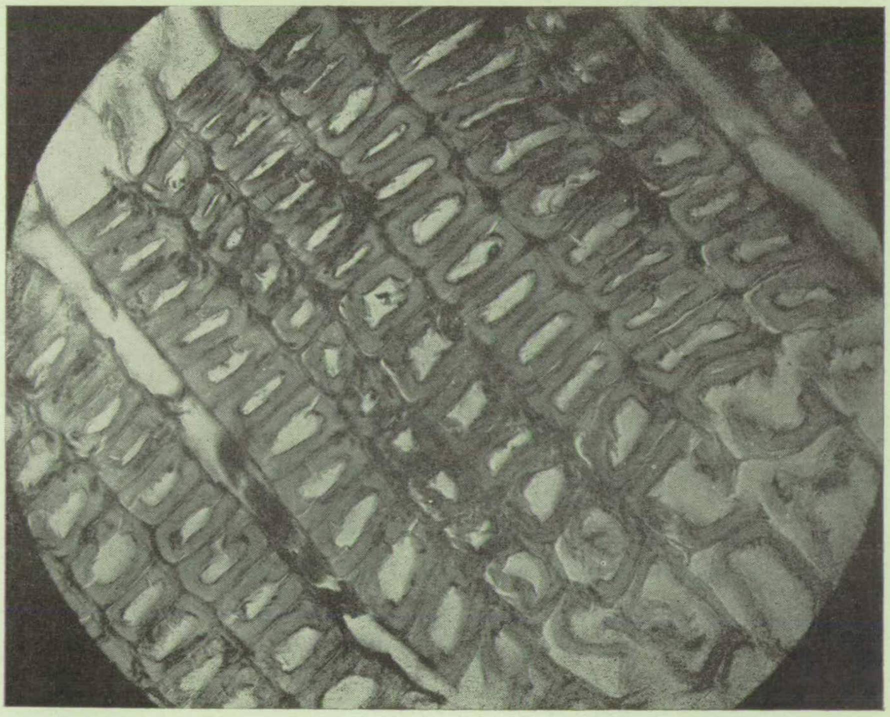
5.2 FUNGAL DECAY

There are several possible approaches to the problem of fungal decay. One is to treat the wood. Another is to treat the water. Perhaps one can find a timber species that is resistant, or some other material that is not subject to rot. Or the slow rate of soft rot can perhaps be allowed for in the initial dimensioning of the wood.

(a) *Treatment of the water*

Continuous treatment of the water is out of the question. The only fungicide that is cheap enough to consider is chlorine and this probably damages the wood chemically at any level at which it prevents

PLATE IX. *Soft rot in* Sequoia *(from a cooling tower in California).*



fungus growth. On the other hand it may only be necessary to kill off the fungi at frequent intervals. Some consultants in the U.S.A. advocate the use of occasional heavy doses of sodium pentachlorphenate or other water-soluble fungicides for the purpose. It is probable that chlorine could be used similarly with equal effect without too much harm to the wood. A dosage of 2 ppm of chlorine might, if maintained continuously, destroy the timber in a year. If used for only one hour every two days it might take 40 years to destroy the timber while preventing fungal growth. This suggestion arises from an observation made at a power station in California where such a chlorination schedule was being used. The timber in the flooded zone showed no sign of rot and negligible chlorine attack, whereas the inlet louvres and mist eliminators were badly affected by soft rot.

(b) *Use of Timber other than Scots Pine*

As reported by Savory (1955) nearly all hardwoods suffer from soft rot much more readily than does Scots pine. As a result of laboratory tests only greenheart appeared to be promising. The Colonial Development Corporation predicted that greenheart in the sizes required could, if there was sufficient demand, be supplied at a price only slightly higher than that for Scots pine. The wood is difficult to cut and may warp. It was considered worthwhile to experiment with it at a time when no satisfactory treatment of Scots pine seemed to be available. Sizeable portions of packing have been put into three towers with different types of water.

Of the softwoods, pitch pine has long been known for its resistance to decay. Some tests have been made with pitch pine from the West Indies.

(c) *Use of Materials other than Wood*

At a time when it appeared that there was no commercially available preservative for timber, a search was made for other materials: asbestos sheeting is in use in both Britain and Germany; this is successful but requires more care in water distribution and a different type of packing. Glass strips can be made in the same shape as one type of wood slat and such strips of glass have been used to replace a few standards of wood in one tower. The experiment was made on this scale to determine the cost and handling difficulties of a packing of this type. It seems that glass will not be able to compete with treated wood if the treatment to be described is as successful as is now confidently expected. There are three power station cooling towers in Britain in which the packing is entirely of concrete; this stands up well to ice formation but is expensive.

(d) *Dimensioning the Timber*

Since the average rate of soft rot attack is so slow it is attractive to consider whether, by making the timber sections initially larger, an economic life for the packing could be achieved. This applies particularly to structural members of which it is required merely that they shall remain capable of the mechanical duty required of them; for such members, say pieces with a minimum dimension of 2 inches or more, the initial increase in section does not add a high proportion to the cost. It does not apply at all to mist eliminators which must maintain their exact shape if they are to remain effective. For laths in the packing, if it could be guaranteed (which it cannot) that they would maintain their shape as in Plate VIII, the question would be merely one of economics. The smaller the initial timber section, the greater is the cost of an increase in thickness to allow for rotting. Further, one cannot predict what the rate of attack will be. The arguments for timber preservation are therefore strong and it is now recognised that this is the economic solution.

(e) *Preservation of the timber: theoretical*

It is fundamental that a preservative to be applied to wood under marine or cooling tower conditions must be completely insoluble in water if it is to remain effective for more than a few years. In a cooling tower a cubic foot of timber may be washed in a week with between 1,500 and 100,000 lb. of water, depending on the degree to which the same water is recirculated. A preservative present in the wood at the rate of 1 lb. per cubic foot and soluble in water to the extent of only 10 ppm can theoretically be lost from thin sections in one to seventy weeks.

There is much evidence to show that, to be toxic to fungi or marine borers, a preservative substance must to some extent be soluble in water. For example, Roe (1956) reported tests against marine borers with a wide range of copper, silver, lead, mercury and other metal compounds. Those that were toxic leached out, and those that were resistant to leaching were non toxic. Vind (1956) also described the method of attack on creosoted wood by *Limnoria tripunctata*; the burrows are parallel with the surface and it seems that this particular species has some resistance to creosote and eats away the surface wood from which the more toxic constituents have been leached out.

Analysis of cooling tower packing in Britain treated with Tanalith U showed a loss of over 90 per cent. of dinitrophenol after a few years, and observations by the Marley Company in the United States have indicated that pentachlorphenol is completely lost in about two years. Dr Heiks of the Battelle Memorial Institute has suggested that the fixation of toxic organics might be improved by dissolving them in a medium which is itself non-toxic but is insoluble in water, such as a heavy oil; being much more soluble in the oil than in the water they will remain in the oil.

In order to preserve wood from attack by fungi it is not essential to kill off the fungus if in some way it can be prevented from using the wood as food. Finholt (1952) has described tests in which organic molecules too large to enter the fungal hyphae nevertheless prevented growth, perhaps by inactivating enzymes secreted by the fungus. Creosote may contain substances capable of acting in this way, which are at the same time sufficiently insoluble in water to be resistant to leaching under cooling tower conditions. It is of proved value as a preservative for marine timbers.

Creosote has long been used in the outer timber casings of cooling towers, the creosote being re-applied by spraying every 5 or 10 years; this timber is normally wet on the inside and exposed to the weather on the outside. Creosote has also been used for large internal structural members but engineers have been reluctant to use it for the packing as well because of fears that the water would become contaminated. These fears may be groundless, but the fact remains that there is very little experience with creosote as a specific against soft rot in timber of small section. Savory (1955) records that 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.

(f) *Preservation of timber: experiments*

In view of the many possible ways in which timber might be preserved, anything was worth trying. In the summer of 1954 tests were undertaken in collaboration with one of the preservative manufacturers. A large number of pieces with different treatments were incorporated into the packing of a new tower at Skelton Grange Power Station. The timber was in five replicate batches, intended for removal at intervals up to several years if necessary. The individual pieces were marked by a coded pattern of drilled holes. The first batch was removed after 6 months and examined microscopically for soft rot. Gross deterioration of Scots pine is not to be expected in such a short time, but with the aid of the microscope any incipient attack is clearly visible (see Plate VI). The indications were clear. Those pieces treated with creosote or with water-borne salts containing a high proportion of copper showed no sign of attack. Wax coatings and the organic preparations tried had failed, although a sample with both organic preservative treatment and a wax coating to restrict leaching was free from attack. Examination of a second batch after 18 months confirmed these findings.

The Cooling Tower Institute (1953) reported the commencement of a series of tests in which small panels or frames were placed in the packing and eliminator zones of a number of towers. Four different species of wood and eight different treatments were used. The frames have been examined at intervals for evidence of deterioration visible to the unaided eye, i.e., no microscope work has been done. In 1956 it was possible to report that four of the treatments showed promise, and it may be assumed that these were in the same categories as those found in the British experiments. There have been some failures even with the best treatments; the reason for this is now apparent by comparing the salt loading used for the C.T.I. tests with that now recommended for soft rot protection.

The frame technique is a useful one which has been adopted in Britain for tests of other preservatives which have from time to time been proposed.

6. Development of an Effective Treatment

6.1 TYPE OF PRESERVATIVE

The tests at Skelton Grange and in the laboratory were encouraging. It seemed that effective preservation should be attainable with preservatives containing inorganic copper, despite the failures with Celcure as commercially applied. Hickson's Timber Impregnation Company continued the programme of research on which they had embarked when the cooling tower problem became apparent, and developed a new preservative called "Tanalith C." This is a copper chrome arsenate preservative which contains a higher proportion of toxic constituents than the related water-borne products Ascu and Greensalt. It is also commercially available in the form of an easily handled and easily soluble dry powder. Hicksons began to test "Tanalith C" in a tower at Kilmarnock soon after the installation of the Skelton Grange test-pieces. Because of the rapid attack of untreated wood at Kilmarnock, proof of the success of this preservative quickly became available. Since the reorganisation of the electrical industry in April, 1955, the South of Scotland Electricity Board has willingly co-operated in the continued use of the Kilmarnock towers.

The copper chrome and copper chrome arsenate preservatives become fixed in the wood by an interesting chemical reaction. Part of the chromate is reduced by natural constituents in the wood to chromic, which is a change from an acidic to a basic radical. In consequence there is a rise in pH which causes the precipitation of insoluble basic salts. The salts then remain in an insoluble form, resistant to leaching by water, until dissolved by enzymic fluids secreted by fungi or the digestive juices of animals such as insects or marine borers.

6.2 CONDITIONS OF APPLICATION

Under experimental conditions, in the laboratory or in the field, the copper chrome and copper chrome arsenate preservatives worked. Moreover, they were resistant to leaching. And yet the commercial treatments with Celcure had failed to give protection. This had to be explained before further progress could be made.

The misleading concept is that of net dry salt retention expressed as lb. of preservative per cu. ft. of wood. Preservative treated timbers can only be compared on this basis if they have been completely and uniformly penetrated. To prevent soft rot attack a certain minimum loading of the wood substance round the outside of every piece is necessary. For a given species of timber this can best be achieved by penetration with a preservative solution of specified strength. The volume of solution absorbed and the resulting gross loading will depend on the depth of penetration and in particular upon the proportion of sapwood and heartwood.

The sapwood of Scots pine will readily absorb up to four gallons of solution per cu. foot; 50 per cent. of sapwood may be expected in cooling tower packing timber. Faced with the difficulty that cooling tower packing readily absorbed two gallons or more of solution and that no more than about half a gallon could be recovered on final vacuum, commercial treaters had no way of treating timber with only 0.5 lb. of copper chrome salts cu. ft. except that of reducing the strength of the solution to allow for an absorption of $1\frac{1}{2}$ gallons. A solution strength of 3.3 per cent. was therefore used; this was less than the 4 per cent. found in the Laboratory to be the minimum needed to inhibit fungus growth. With such a treatment giving limited absorption the heartwood was scarcely touched.

Hicksons carried out research work to determine the optimum treatment schedule for Scots pine to ensure satisfactory penetration of the solution into the heartwood in cooling tower packings. Complete penetration of the heartwood is not required, but a complete treated "skin" of at least several cells deep is essential. Their findings form the basis of the specification adopted.

6.3 THE RECOMMENDED TREATMENT

Satisfactory penetration of the heartwood can be achieved by specified conditions of time, temperature and pressure of application. Such a treatment will inevitably give complete penetration of sapwood provided the original moisture content was reasonable. The total amount of solution absorbed by a given charge then depends to a large extent upon the proportion of sapwood in it. This is quite independent of solution strength, but upon the solution strength depends whether the wood which is penetrated will be preserved.

After comparative tests in the laboratory of Celcure and "Tanalith C" the C.E.A. decided to accept both preservatives at the same solution strength. With the minimum indication at 4 per cent., and with the aim of being certain of having sufficient preservative still in the wood after 20 years, a solution strength of 5 per cent. was specified. The complete specification is given as an appendix (Page 25). It should be noted that clause (vii) "It is expected that with the above treatment cycle the net dry salt retention will not be less than 1.25 lb. per cu. ft." means very little more than "It is expected that Scots Pine for cooling tower packings will consist of about 50 per cent. of sapwood."

A charge consisting of 100 per cent. sapwood would take up about 4 gallons i.e. 2 lb. of salts per cu. ft. A charge of mainly heartwood pieces, or of large timbers of which a quarter of the total volume was penetrated, would take up only 1 gall. i.e. 0.5 lb./cu. ft. Both treatments would be in accordance with the specification and in both cases the protection against soft rot would be similar, and adequate.

6.4 COST OF TREATMENT

The cost of the salts is an important part of the cost of treatment and there has been commercial justification for quoting on a basis of pounds of salts per cu. ft. of timber. But it will now be seen that this is deceptive, and that the dimensions of the pieces to be treated and the proportion of sapwood in them must be taken into account.

In considering the economics of treating the packing of cooling towers, the cost of replacement is not the sole consideration. If a tower packing collapses (or becomes inefficient) the cost of unscheduled outage (or of increased fuel consumption) of the plant dependent upon it may, with modern large plant, run into many hundreds of pounds a day. This cost is incurred by the additional coal which has to be burned in old inefficient generating plant in order to make up for the electricity which the modern efficient plant is unable to generate. The modern plant would require less than 30 tons of coal an hour to generate 60,000 kilowatts whereas an old plant may need over 50 tons per hour for the same electrical output.

The cost of treatment adds about 25 per cent. to the cost of the unsawn timber and perhaps 10 per cent. or 12 per cent. to the cost of the installed packing. It is an even smaller proportion of the cost of a complete tower and is considered to be a worthwhile investment. Scots pine treated in accordance with the specification which is attached as an Appendix, is expected to last for 25 years or more, i.e., as long as other power station equipment such as turbines.

7. Further Considerations

7.1 TREATMENT OF STRUCTURAL MEMBERS

Soft rot of Scots pine in cooling towers proceeds slowly. Under average conditions a structural member, such as an upright or bearer, with a minimum dimension of 2 in., may still be expected to have $1\frac{1}{2}$ in. of sound wood after 25 years, and may still be able to do its duty. It is of interest in this connection that soft rot does not proceed at the same rate where a timber surface is protected by being clamped securely to another piece of timber, so that the joints will not loosen as rapidly as might be feared. Protection from soft rot is therefore regarded as unnecessary for structural members, providing these have a minimum dimension of 2 in. Premature failure of cooling tower packings has occurred in the past however when bearers of only 1 in. thickness have been used. After a few years these may be so weakened that they warp and allow the packing to fall (see Plate VII). This is therefore not regarded as a sound method of construction unless such bearers are made of Scots pine and are treated to prevent soft rot.

There remains the danger that structural members may suffer from basidiomycete attack, especially the species of *Poria* (see Plate IV). To eliminate this risk it is advisable to treat such timbers with preservative at a level which, while not necessarily being effective against soft rot, will be good enough to prevent the growth of Basidiomycetes.

7.2 TREATMENT OF SPECIES OTHER THAN SCOTS PINE

A Treatment Schedule for Scots pine has been worked out and is considered satisfactory. Similar treatments have not so far been published for other species such as Californian redwood or Douglas fir, the two timbers principally used in the U.S.A. Douglas fir is more difficult to impregnate and Californian redwood cannot be treated at the high pressures which Scots pine will stand because of the possibility of "collapse." It is for this reason that the Authority has specified that only *Pinus sylvestris* shall at the present time be used in its towers for those parts small enough in section to require soft rot protection.

Not only the treatment schedule but also the optimum solution strength may be different for timbers other than Scots pine. Experimentally one might aim in the first place for penetration of at least 1/16 in. into all exposed surfaces and a salt weight per unit weight of treated wood in this zone (a pointer to solution strength with woods of different densities) of perhaps 4 per cent. However, this is only meant as a suggestion, and experience must be the guide. Using the microscope, field tests can indicate the success or otherwise of a particular preservative treatment within only a few months.

7.3 DOUBLE DIFFUSION TREATMENT

The Forest Products Laboratory at Madison have developed a process termed "Double-diffusion" by which wood which is already well saturated with water is treated first with a saturated solution of copper sulphate and secondly with a saturated solution of sodium chromate. Other salts can be substituted for copper sulphate, and in practice the treatment is best applied to timber after it has been in cooling tower service for six months or longer. This treatment is now available in the United States as a commercial service. A cooling tower is taken out of service and copper sulphate solution is pumped over the packing, collected in a temporary trough in the basin and recycled for several hours until the major part of it has been absorbed. This is then followed by a sodium chromate solution. So far, it has only been applied to towers in which soft rot has been found to be actively developing. One of us was able to inspect some of these towers, including one which had been so treated four years previously. There was no doubt that the timber had been suffering from soft rot but it appeared that this had now been completely arrested and the surface of the wood appeared to have a sound skin. The mechanism of absorption of salts by sound wood is not fully understood but the success of the application to wood which already shows signs of soft rot needs no explanation; it has already been observed that the soft residue left by the soft rot fungi readily takes up certain salts from the water and surprisingly high contents of manganese as well as copper have been found in the rotted portions of wood from untreated cooling tower slats.

For some of the timbers which are difficult to impregnate under pressure, double-diffusion treatment *in situ*, after one or two years service, may prove to be a satisfactory alternative. In Britain, however, the chief interest lies in the possibility offered of extending the life of hundreds of existing towers which have been inadequately treated or not treated at all.

7.4 OTHER PARTS OF THE COOLING SYSTEM

Cooling towers are installed for the purpose of cooling water which, in turn, is used in heat exchangers for cooling oil or chemicals or for condensing steam. The owner of the plant is interested as much in the maintenance of this other equipment as he is in the maintenance of the cooling tower. It would be true to say that in most instances he is much more interested in this other equipment and neglects the cooling tower entirely. Cooling water circuits in most power plants are designed for long life and are built of corrosion resistant materials such as concrete, cast iron, brass or cupronickel alloys. Heat exchangers in many other industries are often constructed of cheaper materials, such as mild steel, which require protection from corrosion by the cooling water. Chromates are sometimes added to the cooling water to minimise corrosion, together with polyphosphate to reduce scale-formation. Both scale and corrosion can be certainly prevented by the use of chromate and orthophosphate together, but then the pH of the water must be kept below 7 to keep the phosphates in solution. This raises the danger of leaching out the salts in the wood. It is established that this can be done by means of acid, as simple chemical considerations would predict. In one case a company in the United States that advises clients on water treatment analysed a low-pH, high-phosphate circulating water for copper after double-diffusion treatment of the timber. Copper was found for a period of several weeks. Although present to the extent of less than 1 ppm initially and gradually falling away, it was considered to be highly objectionable from the point of view of corrosion control. In this connection it should be remembered that with the separate application of copper and chromate in the double-diffusion procedure the relative proportions are not under the same exact control as is the case with pressure impregnation. Both preservatives now accepted by the C.E.A. have been scientifically blended for maximum fixation. With double-diffusion, some initial bleeding of one constituent might not be unexpected. The evidence of Hurst (1956) that timber could in a laboratory test be destroyed by *Lenzites trabea* after 3 years' service subsequent to double-diffusion treatment is of little help here. The pH of the water is not reported, nor is it clear whether in the test the fungus was given access to an interior surface.

If the leaching of copper should be significant in particular circumstances one possible solution is to use zinc instead; although zinc is less effective than copper against most of the soft rot fungi it may be useful, and the Forest Products Laboratory at Madison is carrying out investigations along these lines.

At the same time it must be stated that the strength of acid necessary to extract the salts is not known. Laboratory leaching tests with distilled water in contact with the atmosphere, having a pH of about 5.0 due to carbon dioxide, have been reported as showing negligible leaching. A sample of wood from the station referred to in paragraph 4.3 (g) as being downstream of a steel works was analysed and found to be free from copper. This was attributed to acid from the steel works effluent. Analyses of further samples from the same tower, however, have shown as much copper as is present in timbers from many other towers—insufficient to prevent soft rot, but showing no evidence of loss. The first piece analysed was probably a piece of heartwood which had not been impregnated by the treatment schedule at that time in use.

If it should be established that low pH circulating water does indeed extract copper which has been truly fixed in the wood, then timbers subject to such leaching action may perhaps be effectively preserved by intermittent heavy chlorination, as already suggested.

8. Summary and Conclusions

1. Timber in cooling tower packings does not suffer erosion and need not suffer from chemical breakdown if the water is not either too alkaline or continuously chlorinated.
2. Scots pine used for cooling tower packings can be protected against biological decay by the treatment specified in the Appendix. By appropriate treatment other species can probably be protected with the same preservatives.
3. Timber so protected is a satisfactory material for cooling tower packing for which long life is desired.

Acknowledgments

The F.P.R.L. mycologists have been unfailing in their guidance and assistance throughout this investigation. The research staffs of the manufacturers of water-borne preservatives have freely made available to us the results of their own investigations. In the U.S.A. the Forest Products Laboratory, the Cooling Tower Institute, the California Redwood Association, two manufacturers of cooling towers, and representatives of wood preserving interests helped F. F. Ross with friendly reception and exchange of information when he was attached to the United Kingdom Scientific Mission in 1956. Assistance has also been given by several Station Superintendents and Divisional Officers of the Central Electricity Authority, by whose permission this paper is published.

CENTRAL ELECTRICITY AUTHORITY

SPECIFICATION FOR THE PRESERVATION OF TIMBER PACKING IN COOLING TOWERS

1. General

The impregnation of the timbers is to be strictly in accordance with this specification and no departure is to be made in the methods of treatment as laid down.

2. Preparation of Timber for Treatment

The timber to be impregnated shall be Baltic redwood of a suitable quality at a moisture content not exceeding 25 per cent. before treatment. It shall be bundled in such a manner as to permit ease in handling and allow access of the solution to the flat surfaces of the timber.

All timber must be fully machined and cut to size before treatment. No ripping or shaping may be carried out after treatment is completed.

3. Preservative Solution

Either of the preservative salts Celcure or Tanalith C.

The preservative salts shall be dissolved in water to give the appropriate solution strength.

4. Method of Treatment

The timber shall be loaded into suitable pressure cylinders and impregnated with the preservative by the vacuum and pressure process, using the following treatment cycle (a) at a minimum pressure of 180 lb./sq. in.

Where the maximum available pressure is less than 180 lb./sq. in., but not less than 150 lb./sq. in., treatment cycle (b) shall be used.

Treatment at a pressure lower than 150 lb./sq. in. is not acceptable.

(a) *Minimum Pressure* 180 *lb./sq. in.*

(i) *Initial Vacuum*

The initial vacuum shall be 25 in. Hg. for a minimum period of 15 mins. but may be extended at the discretion of the plant operator.

(ii) *Flooding Pressure Cylinder*

Whilst still holding the initial vacuum the cylinder shall be flooded with preservative solution.

(iii) *Pressure Period*

Immediately after flooding, the pressure in the cylinder must be raised and held at not less than 180 lb./sq. in. for a period of 90 minutes from the time maximum pressure is reached.

If the specified absorption is not reached in this time then the pressure of not less than 180 lb./sq. in. shall be held for a further period of 30 mins. to give a total pressing time of 120 minutes.

(iv) *Final Vacuum*

A final vacuum of 25 in. Hg. shall be drawn and immediately released.

(v) *Solution Strength*

The solution strength shall be not less than 5 per cent., i.e. 5 lb. of salts to 10 gallons of water.

(vi) *Absorption*

The net absorption shall be not less than 2.5 gallons/cu. ft., except as allowed in Clause 4 (a) (iii).

(vii) *Net Dry Salt Retention*

It is expected that with the above treatment cycle the net dry salt retention will be not less than 1.25 lb./cu. ft.

(b) *Minimum Pressure* 150 *lb./sq. in.*

(i) *Initial Vacuum*

The initial vacuum shall be 25 in. Hg. for a minimum period of 15 mins. but may be extended at the discretion of the plant operator.

(ii) *Flooding Pressure Cylinder*

Whilst still holding the initial vacuum the cylinder shall be flooded with preservative solution.

(iii) *Pressure Period*

Immediately after flooding the pressure in the cylinder must be raised and held at not less than 150 lb./sq. in. for a period of 180 mins. from the time maximum pressure is reached.

If the specified absorption is not reached in this time then the pressure of not less than 150 lb./sq. in. shall be held for a further period of 60 mins. to give a total pressing time of 240 mins.

(iv) *Final Vacuum*

A final vacuum of 25 in. Hg. shall be drawn and immediately released.

(v) *Solution Strength*

The solution strength shall be not less than 5.5 per cent., i.e. 5.5 lb. of salts to 10 gallons of water.

(vi) *Absorption*

The net absorption shall be not less than 2.25 gallons/cu. ft., except as allowed in Clause 4 (b) (iii).

(vii) *Net Dry Salt Retention*

It is expected that with the above treatment cycle the net dry salt retention will be not less than 1.25 lb./cu. ft.

References

CAMPBELL, W. G. (1952). Chapter 17 of "Wood Chemistry" Vol. 2 by L. E. Wise and E. C. Jahn.

COOLING TOWER INSTITUTE (1953). Summary report of Technical Sub-Committee No. 3 on Cooling Tower Wood Maintenance.

COOLING TOWER INSTITUTE (1956). Technical Sub-Committee No. 3; Interim report on the study of Wood Maintenance for Cooling Towers.

FINDLAY, W. P. K. and SAVORY, J. G. (1950). Breakdown of timber in water cooling towers *Proc. VII Int. Bot. Congr.*, 315.

FINHOLT, R. W., WEEKS, M. and HATHAWAY, C. (1952). New theory on wood preservation. *Ind. Eng. Chem. Vol.* 44. 101.

HURST, E. H. (1956). Why cooling towers decay—how to prevent. *Petroleum Engineer, Sept.* 1956.

LARINOFF, M. W. (1956). Cooling towers for steam-electric stations: selection and performance experiences. *Amer. Soc. Mech. Eng. Ann. Mtg. Paper* 56-*A*-59.

ROE, T. (1956). Performance tests of heavy metal compounds as marine borer inhibitors, *Amer. Soc. for Testing Materials Pacific Area Mtg.* 1956. *Paper No.* 95.

SAVORY, J. G. (1955). The role of microfungi in the decomposition of wood. *B.W.P.A. Fifth Ann. Conv. Record.* 3.

VIND, H., MARAKOA, J., CASEY, JOAN and HOCHMAN, H. (1956). The importance of the local borer species in specifying agents for protecting wood from marine borers. *Amer. Soc. for Testing Materials Pacific Area Mtg.* 1956. *Paper No.* 96.

Discussion on Paper 7

The CHAIRMAN (Mr. T. Gabriel): Mr. President, Ladies and Gentlemen, as you know, this Paper is by Mr. Ross and Miss Wood both of the Central Electricity Authority. I was extremely happy when I was asked to take the Chair at this session because I feel I can say without any fear of contradiction that they probably know more about the troubles to which a cooling tower is subjected, and more about the ways and means of combating those troubles, than anyone in Great Britain, possibly in the world.

Both Mr. Ross and Miss Wood had their early schooling in Scotland about 25 miles apart. I am telling you this because being myself 90 per cent. Sassenach, I just cannot resist trying to pronounce the name of the town in which Miss Wood had her early schooling. Mr. Ross had his early schooling at Moffat, and Miss Wood at a place which is spelt H-A-W-I-C-K, and I understand is pronounced "Hoik."

On leaving his primary school Mr. Ross went to St. Edward's school and then to Merton College, Oxford, gaining first-class honours in chemistry. After graduating, he spent nine years with the British Coal Utilisation Research Association doing research work on many problems, such as new ways of burning coke and so on. Then he finally joined the C.E.A. in 1950, where a great part of his work has been on the cooling tower problem about which you will hear today. He is also doing valuable work on the use of water, coal, oil etc. in power stations.

Miss Wood, after early schooling, went to St. Andrew's University, obtaining post-graduate honours, specialising in mycology. She joined C.E.A. in the year after Mr. Ross, 1951, and has since then concentrated on research into fungal attack on cooling tower timbers and has studied micro-biological problems.

Mr. Ross has been clever enough, today, like a good cricketer, to bring a long stop with him. If any really hard questions slip through, he has Miss Wood at hand to do the retrieving.

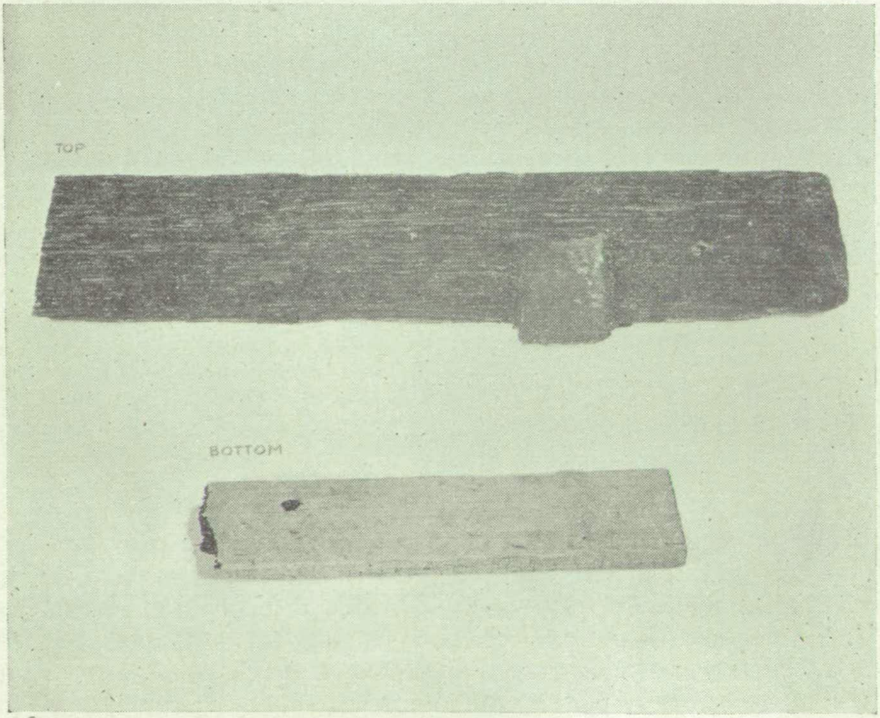
Mr. Ross has asked me to mention that he will start by showing some slides, and when question-time comes he will answer the questions as they are put. It now only remains for me to call on Mr. Ross and welcome an Oxford man to Cambridge.

Mr. F. F. Ross: Thank you, Mr. Chairman. This series of slides is intended to illustrate the importance of cooling water in the generation of electric power, the amount of generating plant we are having to build each year to keep up with the demand, and the actual construction of cooling towers. I have some photographs of the towers in which we have inserted experimental packings, including glass. And here we have a view, taken from the superintendent's office window, of a group of old towers, the packing of one of which was reliably reported by the engineer who was in charge at the time to have been treated with creosote; for verisimilitude there was the corroborative detail that a large amount of froth was produced which blew over into the adjoining bakery and ruined a batch of cakes! The present superintendent could find no record of the treatment, so we collected my original informant from his new power station several miles away and had him point out exactly which tower it was. My hopes of a ten-year-old service record with creosote were dashed when we found that the packing had never been treated, but I like the story as illustrating how rumours can grow into facts.

My final picture shows one of the frames, similar to those used by the Cooling Tower Institute in California, which can be laid on top of the packing in a cooling tower of which the behaviour is known, in order to test a preservative treatment. In this connection I should like to refer you to the Paper by Mr. E. A. S. Price in the May 1957 issue of "Wood," and to support the suggestion he makes that selected cooling towers may make excellent testing sites. We should be pleased to assist anyone who wished to make use of this alternative to the graveyard or sea-burial.

Referring to paragraph (f) in section 4.3 the suggestion we have made here about drying does not account for all cases of the absence of soft rot; the Forest Products Laboratory at Madison have suggested that Californian Redwood may be immune from soft rot unless it has been subjected to the action of water containing free chlorine. The California Redwood Association are of the same opinion, and so far as we know the theory may be sound.

PLATE X. *Specimen showing protection by adjoining pieces of wood. Top—Pinus—Great Britain. Bottom—Sequoia—Indiana.*



With regard to the next paragraph of the Paper on protective coatings, I have some specimens here on the table which show the effect of an adjacent piece of wood. Where this piece was held in a "V" notch its original dimensions have been preserved. The same phenomenon can be seen in this piece of *sequoia* from the United States where it was fixed against another piece of wood and there has been some protection from soft rot (Plate X).

On the question of the permanence of double diffusion treatment, I have a letter from Mr. D. R. Baker of the Marley Company in which he tells me that the tests made by Hirst to which we have referred in the Paper (paragraph 33), were by mistake conducted on a piece of wood which had not in fact received treatment. Some replacements with untreated timber were made in the tower concerned after the double-diffusion treatment, and it was one of these pieces which was tested. Samples of treated and untreated timber from this tower were taken on the occasion of Mr. Price's visit a few weeks ago and are here on the table before you.

Finally I should like to say something about Plate VIII. The arrow is slightly misplaced, but in any case the Plate does not show clearly what we intended it to show. It is one of the difficulties of producing a Paper like this that unless you make your photographic records for eventual publication as you go along, you may lose the opportunity. This photograph was taken recently from another section of the original piece of wood, but it is now too dried up. I do assure you that when it came fresh into the laboratory we tested for heartwood and sapwood and looked with surprise and astonishment at the division; the depth of penetration of gross soft rot was exactly equal on both sides of this demarcation line. We shall have to ask your indulgence in accepting this picture as an illustration of the type of observation which we made but which we failed to record at the time. Thank you, Mr. Chairman.

The CHAIRMAN: Mr. Ross is now willing to receive questions.

Mr. G. GOBERT: I should like to take the opportunity of thanking Mr. Ross and Miss Wood most profusely for a very interesting Paper as well as for some excellent photographs.

In his written Paper there are only two products mentioned as being suitable for the protection of timber in cooling towers. I understand, however, that in addition to these two products there are, in fact, other materials which are understood to be even more effective and which are likely to become commercially available very soon. It is, of course, gratifying to see that such a great public authority as the C.E.A. can work so closely with industry in solving its problems. The members of this Association will remember Dr. Liese of Freiburg University who prepared a Paper for the B.W.P.A. Convention in 1955 on soft rot. I had an opportunity of discussing Mr. Ross' Paper with Dr. Liese who naturally found it very interesting. He was very sorry that he could not be here today but he has allowed me to ask one or two questions on his behalf and make the following comments. His research into the failure of timber in telegraph poles and cooling towers has shown that there are numerous micro-fungi causing soft rot. It is extremely rare to find all these fungi present in one and the same situation. As many fungicides are not effective against all micro-fungi, Dr. Liese wondered whether field tests in only a few cooling towers could be conclusive on the universal efficacy of certain preservatives.

Dr. Liese mentioned that the period of field trials, namely 18 months, appears to be very short on which to presume that 25 years of protection is given.

Lastly, Dr. Liese would like to ask the following questions. Have experiments been carried out to determine whether timber can absorb the large quantities of salt specified without affecting the strength of the timber or its physical structure?

The CHAIRMAN: I am sure Mr. Ross will do his best to answer those questions but I am convinced you could take the rest of the time on them.

Mr. F. F. ROSS: I will try to answer very shortly. The deduction of 25 years' life or more from quite short-term field tests is a case of (a) plus (b) equals (c). The first fact is that the type of preservative we have decided to use stays in the wood; this has been shown by analyses of timbers that have been in cooling towers for many years; what was originally put in is still there; unfortunately it was not enough to stop soft rot. The recent tests have shown that if we put in enough, then we will prevent soft rot. If the preservative is known to stay in the wood and there is enough there to stop soft rot initially, then there should be prevention of soft rot for many years to come.

With the question of strength, I am not really concerned. I do not know whether impregnation with water-borne salts reduces the initial strength of the timber, but if there is such an effect it is small. From our point of view what matters is the strength after 20 years or more. I think the question was answered this morning by someone who said it is far better to start off with something which is 10 per cent. weaker than new timber and end up with something which is 200 per cent. stronger than unpreserved timber would be. I feel sure that is the right way to look at it.

Mr. T. M. SCARFFE: Might I ask Mr. Ross if it is true that had this experimental work not taken place, and had not the problem of soft rot been resolved, there would have been a very great danger of timber being eliminated as a material for cooling tower construction?

Mr. F. F. Ross: There is still that danger. I do not speak for the C.E.A. as regards what they are going to use to make their cooling towers. The design branch is experimenting with asbestos and there are people in the C.E.A. who believe that asbestos packing has many merits which a timber packing cannot have even when preserved. All I can do is to report that, in my opinion, a preserved timber is a satisfactory material for cooling towers for which we require a long life.

Mr. E. A. S. Price: I would like to ask a question of the joint authors of this Paper relating to the reference to soft rot attack in redwood towers. The whole question of soft rot in cooling towers, ground contact or elsewhere, seems to me to be dependent largely upon the rate at which the soft rot is occurring. The rate at which it occurs will indicate whether one can afford to ignore that soft rot or whether it is commercially significant. My question to the joint authors of this sub-section is, what in fact was the rate of soft rot occurring in this Californian Redwood? Have you got information on this subject?

Mr. F. F. Ross: I agree with Mr. Price that by itself this picture does not show that anything serious was happening. What it does show is that the serious deterioration evident in this particular piece of wood was in fact soft rot. I brought back several specimens of timber from America showing various kinds of deterioration, and in some of them Miss Wood could find no evidence of soft rot. Among the specimens on the table here this small piece is almost invisible inside its envelope, and Mr. Price may not have seen it. If anyone would like to look at it afterwards I am sure he will be satisfied that the rate of deterioration in this tower—which was only about 18 months or two years old—is really quite serious. I showed this piece to Mr. D. R. Baker in Kansas City and to Dr. Duncan of the Forest Products Laboratory; neither of them wasted any time on it, being satisfied it showed typical soft rot. In other words, we took this picture because of what appeared to be gross soft rot, not to find out whether there were signs of initial attack.

Mr. A. C. Oliver: I noted in some of your photographs, Mr. Ross, that we saw some older cooling towers which were constructed of timber and then newer ones of concrete. Would it not be possible with the new techniques of lamination to develop a cooling tower entirely of timber including the shell and the packing as well?

Mr. F. F. Ross: It might be possible if you could make it heavy enough not to blow away and stiff enough with the very large radius of curvature to stand up without a network of internal bracing which would cause resistance to the flow of air, but I do not think it makes much sense. The concrete is only about four and a half inches thick. The place to re-establish confidence in timber is in the columns, bearers, walkways and handrails. Handrails in particular must remain sound and strong for as long as they have the appearance of being safe; some cutting is required on the job, and the best solution would be to ensure that they are made from completely permeable wood that is treated through and through. So far, timber treated to ordinary commercial specifications has not stood up any better in cooling towers than untreated timber, and the first step, before talking about wooden shells, must be to re-establish confidence in timber by adequate treatment.

Mr. P. GRINDELL: It seems to me that for the columns one might very well use round timber where the depth of impregnation can really be given; that should give fairly satisfactory service. As to bearers, I think it a little doubtful that we could use round wood. I do not know whether Mr. Ross might comment.

Mr. F. F. ROSS: I do not see the merit of using round timber. There is a lot of fabrication to be done on it, with bearers bolted to it at intervals and other stays at right angles to these It is more complicated than a telegraph pole which just has a few crossbars at the top.

Mr. P. GRINDELL: To continue on the same subject, I see no difficulty in bolting and staffing on round timber. It is done very widely in North America in the construction of jetties. You are still dealing very largely with sapwood which can be fully impregnated; it can be prepared before it is treated, and, therefore, I do not see any reason at all why round timber should not be used.

Mr. F. F. ROSS: There may be something in your suggestion, and no doubt the manufacturers of cooling towers will take note of it.

Mr. J. G. SAVORY: Mr. Chairman, I should like to compliment Mr. Ross and Miss Wood on the excellent way in which they have set out the different factors that arise inside a water cooling tower. I know myself how extremely difficult it is to sort out the various factors. I should like to attempt to answer one of Dr. Liese's questions, namely that of infection in the towers. I wonder if Mr. Ross would agree with me that a water cooling tower is a most efficient spore-washing apparatus, and that if there are any fungal spores in the atmosphere they would readily be collected and brought into contact with the surface of the timber.

Mr. F. F. ROSS: Yes, I certainly do agree. We have done a fair amount of work on the changes which take place in the analysis of the water in cooling tower systems, and there is no doubt that they are an efficient way of cleaning the atmosphere.

Mr. E. A. S. Price: Could I refer Dr. Liese to a publication of the Bell Telephone Monograph published in 1952 by R. C. Ecclestone on Pole Strength Tests. In this a considerable amount of testing of a preservative called greensalt impregnated to one pound per cubic foot was carried out, and his findings were that far from weakening the timber in any way, there was an indication that it in fact strengthened it.

I would also like to comment on the other point as to whether a sufficiently large number of investigations have been carried out as regards different sites of testing. The Cooling Tower Institute of America has been carrying out tests for the last five years and recently issued a confidential report which I believe Mr. Ross has seen. I have not seen it myself, but I am given to understand that the results in that report very closely parallel the kind of performances and behaviours that we are getting in this country.

Mr. F. F. Ross: Yes, I have seen the report, and I can assure the meeting, Mr. Chairman, that the results being obtained in America do largely confirm what we have found here.

Mr. R. A. Stock: Is there any evidence that the incidence of soft rot is increasing?

Mr. F. F. Ross: Perhaps Mr. Savory would like to say something on that point, but I am sure the answer is 'No.' There have been more cooling towers in recent years, and therefore more soft rot perhaps, but cooling towers are only one place. You can find soft rot wherever you look for it, if you know what to look for. If you ask this question about *Poria* in cooling towers in 3 or 5 years time you may get the answer yes, although I hope not.

Mr. J. G. Savory: Although there has been an increase in the number of observers of soft rot, I do not think there has been any other increase.

Mr. F. G. Broughall: This paper is primarily concerned, of course, with the large cooling frames which are a prominent feature of electricity stations. However, I think we must not forget that a cooling frame is today an essential part of many industrial organisations, and very often its capacity there is not what we anticipate is held on an electricity station. Consequently the dismantling of one of these frames—very often the timber exterior—is perhaps a more serious problem than on an electricity station. If one works at one cooling tower it can be a very serious matter.

I have had some very amateurish experience of the decay of timber in industrial cooling frames, a decay which at that time was associated with hydrolysis. I gather from Mr. Ross' paper that hydrolysis is not considered to be a serious factor in the decay of timber, but I think perhaps the statement under Section 4.1 is not really definite on this point. I would like confirmation.

The second point on which I should like just a little more information—it does not concern preservation—is on the condition of the water. Reference is made to alkalinity arising from high bicarbonate waters, to the chlorine content of the water and, of course, on many industrial concerns, the control of the cooling water is nothing like as precise as I trust it is on an electricity station. The control of algae is also a serious problem, and perhaps rather indiscriminate use is made of chlorine in an attempt to control the algae in industrial frames.

We have found chlorine treatment is not always effective, or it is perhaps only effective for a short time, and then a switch has to be made to something like copper sulphate or some other copper salt. What exactly is the effect of the condition of the water on the development of soft rot in these timbers? I have in mind particularly the use of complex phosphates for scale control which results in high alkalinity of water. Is the use of phosphate from that point of view to be deprecated?

Mr. F. F. Ross: On the question of hydrolysis I am prepared to say that with ordinary cooling water it is negligible or non-existent. On your other question about water composition, we made a survey of about 50 towers with treated and untreated timber, and obtained as much information as we could about the water. Electricity power stations take whatever water they can get, from sewage effluent to drinking water to muddy rivers, and provided it causes no corrosion or other trouble, the water is not analysed although routine checks of hardness and pH may be made. From Mr. Savory's work, I should expect high nitrate and phosphate content in the water to favour decay, but there is really no evidence of this in practice. At two stations where soft rot proceeds at above average rate the nitrate and phosphate figures seem to be quite low.

Mr. R. V. Tipler: Do I understand from Section 4.2 that *Chaetomium* is used as a laboratory guide to the possible efficacy of treatments for the control of soft rot? If so, are you satisfied that this is a valid organism? Other organisms, including *Trichoderma*, are mentioned in Mr. Mateus' paper, and *Chaetomium* may be more easily controlled by fungicides than some other fungi.

Mr. F. F. Ross: Here is where I call on the longstop. Miss Wood, Mr. Savory or Dr. Findlay may be able to comment.

Dr. W. P. K. Findlay: We regret very much that we cannot carry out laboratory tests on a nice range of soft rot organisms, but the indications are that the laboratory results obtained with *Chaetomium* bear a reasonable relationship to what occurs in practice. I do not want to say any more at present, but I do agree that field tests are most essential.

Mr. F. F. Ross: I should like to add that Mr. Price's work shows a close correlation between field tests and the laboratory tests with *Chaetomium*. We may just have been lucky, but a research worker who is not sometimes lucky is a bad research worker.

The Chairman: The time being what it is, Gentlemen, if Mr. Ross has nothing further to say, I am sure you would like me on your behalf to thank Mr. Ross and also Miss Wood for a most interesting Paper.

SUMMARY OF CONVENTION PAPERS

By
W. E. VESEY, M.B.E., A.C.A.,
(*Christie and Vesey, Ltd.*)

Introduction

Mr. President, Ladies and Gentlemen, it is my privilege today at the closing session of this year's Convention, to make some comments on the papers which have been presented. They have covered various aspects of timber preservation and have, in my opinion, maintained the standard attained in previous years. Some have undoubtedly broken new ground, introducing to delegates aspects of the subject of timber preservation which have not before been considered at our Conventions, and one may say that, on the whole, the field covered by the authors is as wide, or perhaps wider, than in past years. While it is possible to present such instructive papers year by year, there would appear to be no cause for supposing that the Conventions arranged by the Association are not serving a most useful purpose or for contemplating the extension of the period intervening between one Convention and the next.

As an Accountant engaged in the Timber Trade and Wood Preserving Industry, I am certainly no expert in Timber Technology, and therefore my remarks must of necessity be those of a layman seriously interested in the papers which have been presented and "having obtained all the information and explanations I required" I submit my comments.

Paper No. 1

"An account of Marine Borers with Special Reference to Breeding," by Professor J. E. G. Raymont, is one I venture to say, that the B.W.P.A. is fortunate in having the privilege of publishing for the first time, in the Convention Record.

It contains information by no means readily accessible to delegates and members and being at any rate partly based on unpublished research, is likely to have a wide interest for some considerable time to come among marine biologists and dock and harbour engineers, not to mention shipwrights responsible for the maintenance of wooden ships.

It will come as a surprise to delegates lacking a knowledge of marine fauna that there are several species of shipworm in British waters, of which two are of real economic importance, and more particularly to learn of their varied reaction to the temperature and salinity of the sea water around our coasts. All delegates will, I am sure, wish me to tender their thanks to Professor Raymont for his interesting and informative paper, and to express the hope that as the results of the research still in progress bring new facts to light, he will favour us with another paper on the subject at some future date.

Paper No. 2

"Timber Preservation from the Point of View of the Architect," by Mr. Eric Bird, appealed to me because of its very practical, down-to-earth approach to the subject, and further, by reason of the direct evidence from the Questionnaire which it contained, giving the opinions of a number of architects of standing.

One wonders whether architects generally have as intimate an acquaintance with publications of F.P.R.L., T.D.A., and B.W.P.A. as would be desirable. Apart from this, however, I think most delegates will have found the paper both interesting and instructive and worthy of study as opposed to mere perusal. The author, as most of us know, is an architect of wide experience and in addition, as evidenced by his paper, possesses a large fund of common sense. These together, have resulted in an approach to the subject of the preservation of building timbers which is somewhat novel and refreshing, as well as being helpful.

It is of interest to note Mr. Bird's observation that so often an architect has to "build down to a price," which among other economies may mean using untreated timber instead of preserved timber.

His pleas for more information in trade and technical literature on the costs of treating timber and on the latest scientific developments are ones which members of the industry will no doubt study carefully.

Arising from the discussion, it is very obvious that there is a real necessity for more information on fire retardants and it is to be hoped that the Committee preparing the Association's publication on Fire Retardants will redouble their efforts in order that this information be made available to the public as soon as possible.

Paper No. 3

"Some Observations on British Standard 913 of 1954—Pressure Creosoting of Timber," by Mr. N. A. Richardson, opened with some brief historical references to past practices both in this and other countries. It reminded delegates that, although there have been numerous specifications for creosote, the earliest dating back to 1865, nearly a century ago, there was no British Standard for the pressure creosoting process itself until 1940. This B.S. 913, as users of creosote are well aware, was revised in 1954 and is still the only British Standard Specification for a timber preservation treatment. A careful perusal of Table I is interesting as indicating the changes in the opinion of users as to what the limits of the various fractions of a good creosote should be. The paper proceeds to the analysis of B.S. 913 clause by clause, with such comments on each as will lead to a fuller understanding of its aims and objects. The need for adequate seasoning prior to impregnation is again very rightly, emphasised, for in the preservation industry the old adage about the incompatibility of oil and water can never be overlooked without undesirable results, ensuing. The reminder of the effect of temperature on the viscosity and consequently on the penetrating power of creosote is also timely. The paper, one foresees, is likely to be carefully filed for future reference, particularly in connection with the training of operators of plants.

Arising from the discussion of the paper, it is pleasing to note that it matters not how often a paper on pressure creosoting of timber is presented, there is always some discussion and something new to learn about this, the oldest method of pressure treatment of timber.

Paper No. 4

"In situ Treatment of Building Timber for the Control of Wood-destroying Insects and Fungi," by Mr. S. A. Richardson sheds light on a facet of wood preservation infrequently touched on, at any rate with anything approaching thoroughness, in scientific or technical papers or the press. The paper deals with the subject in an essentially practical manner and if it has no other effect, an unlikely contingency, it will serve to dispel the idea that *in situ* treatment is an easy way of making money quickly, and may prevent "would-be" money-makers from embarking on a career with quite inadequate knowledge and equipment. It is to be hoped that it will come to the notice of church authorities and architects to whom is entrusted the very responsible task of maintaining the fabric of ecclesiastic and public buildings in a satisfactory state of repair.

It is a paper which I have found extremely interesting and one which is easily understood. I thank Mr. Richardson for the most able way in which he has presented this paper.

Paper No. 5

"The Compatibility of Wood Preservatives and Glues," by Mr. A. J. Bune, introduced for discussion an aspect of timber preservation which is of considerable economic importance and which has not previously been considered at any of the B.W.P.A. Conventions. Perhaps the publicity given to the subject by the paper and the discussion which followed will encourage further research on the problems associated with it. Obviously results of past attempts to develop a suitable technique have at times been conflicting, and the sooner it is possible to determine the cause of this, so removing doubts as to the results of the various methods, the better will it be for both manufacturers and users of plywood and other forms of laminated wood. The author of the paper has undoubtedly been at pains to tap various sources for the information he has given in it and the thanks of the Association are due to him for having presented the paper, so directing attention to an aspect of timber preservation which promises to assume added importance in the future.

Paper No. 6

"A mechanical Test for Studying Wood Preservatives," was presented by Mr. T. J. E. Mateus, Chief of the Timber Section of the National Laboratory of Civil Engineering, Lisbon. On behalf of the Association, I should like to state that the Association was very pleased to receive this paper from Portugal and always welcomes the introduction of papers from overseas. This paper was particularly welcome both as throwing light on the trend of development in timber testing and as describing a test which, so far as I am aware, has not yet been adopted in this country. The author acknowledges, however, that an approach was made some years ago at Princes Risborough to the determining of the possibility of following the progress of decay by its effects on some of the strength properties of the test pieces. The choice of resistance to static bending, is amply justified by the sensitivity of the test and the facility with which it can be carried out. The paper will undoubtedly be read with interest, not only by scientists in this country, but by those in lands overseas where the technology of timber is given serious consideration.

On your behalf I would like to thank Mr. Mateus not only for preparing the paper but also for coming here to participate in our discussions.

In addition I would like to add my personal congratulations to Mr. Mateus for the way in which he answered the questions arising from the discussion and also to thank Mr. Clift for his services as interpreter.

Paper No. 7

"The Preservation of Timber in Water Cooling Towers," by Mr. F. F. Ross and Miss M. Jocelyn Wood of the Central Electricity Authority, carried a step further our knowledge of the factors influencing the incidence and development of the so-called "soft-rots," particularly Ascomycete fungi of the family *Chaetomiaceae*. The first feature of the paper which struck me was the table of its contents at the beginning, and the careful tabulation of the items therein, making reference to any particular section very easy. The subject matter was full of interest, from the description of the construction of a cooling tower at the outset, to the Summary and Conclusions at the end. The list of references will, I have no doubt, be useful to members interested in soft rots and the "Specification for the Preservation of Timber Packing in Cooling Towers" of the Central Electricity Authority was a valuable appendix, proving an authentic source of reference henceforth readily available to members of the Association who may be called upon to treat cooling tower timber. It is clear that much water will flow under London Bridge before research on this particular group of fungi is complete and perhaps we may hope for other equally interesting papers in the future as new facts come to light.

I should like to congratulate Miss Wood and Mr. Ross on the presentation of their slides in Technicolor.

That concludes my summing up Mr. President, Ladies and Gentlemen, and I thank you for your attention.

1957 Convention Record

THE PRESIDENT: I am sure you would all wish me to thank Mr. Vesey for the excellent summary of papers which he has presented to us and also for the care and trouble he has taken throughout the Convention in preparing it.

As this is the last official session of the Convention, I would also like to express our thanks to the authors of papers, those who took the Chair at the various sessions, all those who have participated in the discussions, Mr. E. H. B. Boulton and members of the Convention Committee, the staff of the Association, those members of the staff of the University Lecture Rooms who have helped us and to the two ladies who have taken down a record of our deliberations. All have played an important part in ensuring the success of the Convention.

MR. BERNARD HICKSON: Before we close, Mr. President, I am sure that all delegates would wish to join with me in passing a personal vote of thanks to you for all that you yourself have done to make the Convention such a pleasant and interesting one. We are all deeply grateful to you.

B.W.P.A. CONVENTION, 1957

(Alphabetical List of Delegates and Visitors)

A

Name	*Company or Organisation.*
Adams, H. C.	Ministry of Transport & Civil Aviation
Allen, T. C.	Admiralty
Alliot, H.	Xylochimie, Paris
Ady, C. J.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
Ashburner, S.	Ministry of Works
Ashley, P. J.	Calders Ltd.
Ashley, S. D.	Calders Ltd.
Arnold, W. P.	Koppers Co. Inc.
Atkinson, W. R.	West Dock Timber Co. Ltd.

B

Bates, L. A.	Area Electricity Boards
Bassham, J.	May Gurney & Co.
Bayley Butler, Prof.	Biotox Ltd.
Bayley Butler, Mrs. A.	Biotox Ltd.
Benstead, C. R.	St. Catharine's College
Bick, J.	Kiln Owners' Association
Biek, L.	Ministry of Works, Ancient Monuments
Bird, E,	Building Centre
Boocock, D.	Standardised Disinfectants Co. Ltd.
Boyle, C. B.	Silexine Paints Ltd.
Boyne, C.	Architects Journal
Boswell, B. T.	Ministry of Supply
Boulton, E. H. B.	Pestcure Ltd.
Boulton, E. H. B., Mrs.	Pestcure Ltd.
Bowlby, V. R. S.	Calders Ltd.
Brekke, K. P.	Nyegaard & Co. Oslo
Broughall, F. G.	Midland Tar Distillers Ltd.
Brown, J. R.	Federated Home Timber Associations
Brown, D. H. M.	North of Scotland Hydro Electricity Board
Bruce, W. E.	British Wood Preserving Association
Bulman, R. A.	Cuprinol Ltd.
Bune, A. J.	Aero Research Ltd.

C

Carey, C. E.	South Eastern Gas Board
Carr, E.	Post Office
Carr, H.	Jewson & Sons Ltd.
Carter, H. J.	North Thames Gas Board
Cottell, N.	Pirelli & General Cable Co.
Cherry, Mr.	Leicester, Lovell & Co. Ltd.
Christensson, A.	Boliden Mining Co. Ltd.
Clift, D. V.	Christie & Vesey Ltd.
Clark, L.	Black Sluice Drainage Board
Clarke, S. H.	Fire Research Station
Clark, R. H. E.	South Eastern Tar Distillers Ltd.
Clark, V. R.	Railway & General Ltd.
Clayton, D. W.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
Cook, C. D.	Hickson's Timber Impregnation Co. (G.B.) Ltd.

Cooper, R. C.	Jewson & Sons Ltd.
Cotton, K. E.	East Suffolk & Norfolk River Board
Cornish, A. W.	Private Member
Cox, H. A.	British Wood Preserving Association
Cunnington, W. G. . .	Midland Electricity Board
Cridland, J.	Canusa Ltd.

D

D'Abrumenil, C. H. . .	Pyman, Bell & Co. Ltd.
Davies, J. M.	James Davies (Timber) Ltd.
Davies, J. C. S.	James Davies (Timber) Ltd.
Diaper, Mr.	Eastern Electricity Board
Dodd, A. H.	Cobra (Wood Treatment) Ltd.
Donnelly, G. V. . .	Timber Development Association
Douglas, J.	Christie & Vesey Ltd.
Dowsett, A. J.	Timber & Plywood
Downing, O.	Imperial Chemical Industries
Downing, F. S. Dr. . .	Plant Protection Ltd.
Dowson, T.	National Coal Board

E

Eades, B. W.	V. A. Luck Ltd.
Eagle, A. J.	Eastern Electricity Board
Earwaker, W. H. . .	Burt, Boulton & Haywood Ltd.
Edgett, C.	British Columbia Lumber Manufacturers
Evans, G. C. Dr. . .	St. John's College
Evans, D. J.	Ministry of Supply

F

Fenner, R.	Albi-Willesden Limited
Findlay, W. P. K. Dr.. .	Forest Products Research Laboratory
Fisher, R. C. Dr. . .	Forest Products Research Laboratory
Fothergill, R.	National Sawmilling Association
Friend, H. G.	Christie & Vesey Ltd.

G

Gabriel, T.	Gabriel, Wade & English Ltd.
Garratt, M.	Gabriel, Wade & English Ltd.
Glass, H. M. Dr. . .	British Standards Institution
Gibson, W.	National Coal Board
Gobert, E. G.	Protim Ltd.
Gobert, Gerald	Gallwey Chemical Co. Ltd.
Gould, A. W.	South Eastern Gas Board
Green, N. S.	Celcure Ltd.
Grindell, P.	Burt, Boulton & Haywood Ltd.
Greenham, R. G. Harvey .	English Joinery Manufacturers' Asssn.
Gregory, J.	John Gregory & Sons (Timber Merchants) Ltd.

H

Hampson, M.	North Welland Int. Drainage Board
Haigh, F. R.	Yorkshire Electricity Board
Harris, A. C.	South Wales Electricity Board
Harrison, J. L.	Edinburgh University
Haryott, J. Capt. . .	Ministry of Supply
Hayes, R. T.	United Coke & Chemicals Co. Ltd.
Heron ,P.	Monsanto Chemicals Ltd.

HICKSON, B.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
HILEY, B. A. E.	Mouchel & Partners
HILL, E. H. Dr.	Ministry of Supply
HOEK, M.	Gebr. van Swaay
HOGG, W.	Pyman Bell & Co. Ltd.
HOLLAND, Mr.	Eastern Electricity Board
HOULTON, C. M.	Borax Consolidated Ltd.
HORN, D. F.	South Western Electricity Board
HUTCHISON, L. G. O.	Calders Ltd.
HUTCHISON, W. K.	South Eastern Gas Board
HUXTABLE, W. H.	Coal Tar Research Association
	J
JEFFERY, A. H.	Timber Technology
JEWSON, J. H. Col.	Jewson & Sons Ltd.
	K
KEMP, C. N.	South Western Tar Distilleries
KING, G.	National Coal Board
KING, C. W.	British Transport Commission
KINTON, T. L.	Prince Regent Tar Co. Ltd.
KLEM, G. G.	Norwegian Forest Research Institute
KNIGHT, J.	Calders Limited
KUNESCH, A. M.	Film Cooling Towers Limited
	L
LANE, M. J. R.	Normanby Park Tar Supply Co.
LAY, A. P.	Church Commissioners
LEVY, J. F.	Imperial College
LINDSEY-RENTON, J. P.	Protim Limited
LEWIS, R. J.	Post Office
LOWSLEY, L.	Forest Dept. Kenya
	M
MACCORMACK, D. M.	British Tar Confederation
MCKENZIE, D. T.	H. Newson Sons & Co. Ltd.
MAY, F. G.	Timber Development Association
MAY, K. L.	Area Electricity Board
MANTON, R.	Jewson & Sons Ltd.
MARSHALL, R. P.	Coalite & Chemical Products Ltd.
MATEUS, T.	Laboratorio Nacional de Engenharia Civil
MILLS, Mr.	Leicester, Lovell & Co.
MCNEIL, D. Dr.	Coal Tar Research Association
MONTGOMERY, D.	Borax Consolidated Limited
MOORE, P. J.	E. Sherry Ltd.
MORRIS, H. G.	Eastern Electricity Board
	N
NAIRN, P.	'Wood'
NELSON, R. E.	Ministry of Supply
NEVARD, E. H.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
NEWTON, A. H.	Shell Petroleum Co. Ltd.
NICHOL, C. W.	Celcure Ltd.
NICHOLSON, F.	Pyman, Bell & Co. Ltd.
NIGHTINGALE, A. G.	British Transport Commission
NORRISH, R. G. Prof.	University Dept. of Physical Chemistry

NUNES, J. I. De Matos .	M. D. Falconer Lda., Lisbon
	O
OLIVER, A. C.	Timber Development Association
ONARHEIM, Erik	Nyegaard & Co. Oslo
	P
PARKE, R. B.	U.S.A. Embassy
PAYNTER, M. W.	National Federation of Box and Packing Case Manufacturers
PAY, T.	Eastern Electricity Board
PHILPOT, D.	John Bland & Co. Ltd.
PORTWAY, D. Col.	St. Catharine's College
POTTER, F. M.	Scottish Tar Distillers Ltd.
PRATT, J. Davidson	Association of British Chemical Manufacturers
PRICE, E. A. S.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
PRIOR, E. N.	Ministry of Fuel & Power
PROUDFOOT, M. Miss	British Wood Preserving Association
PERRY, R.	Bensley & Co.
PACKER, T.	Bensley & Co.
	R
RAYMONT, J. E. G. Prof.	University of Southampton
RAY, W. C.	Eastern Electricity Board
REYNAUD, C.	Xylochimie, Paris
REECE, Phillip O.	Timber Development Association
REECE, S. H.	Cobra (Wood Treatment) Ltd.
RICHARDSON, N. A.	Association of Tar Distillers
RICHARDSON, S. A.	Richardson & Starling Ltd.
RICKARDS, M.	Phoenix Timber Co. Ltd.
RIDING, F. N.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
ROBINSON, D. W.	Robinson Dunn & Co. Ltd.
ROBINSON, T. G.	Robinson Dunn & Co. Ltd.
ROBINSON, Stanley	Midland Tar Distillers Ltd.
ROBINSON, F. E. S.	Christie & Vesey Ltd.
ROBERTSON, M.	Eastern Electricity Board
ROBERTS, J. D.	Wm. Gimson & Co. Ltd.
ROBSON, F. P.	Armstrong, Addison & Co. Ltd.
ROSS, F. F.	Central Electricity Authority
ROTHWELL, W.	British Railways
ROWLAND, W. E.	J. L. & F. Wilkinson Ltd.
ROWBOTHAM, J. A.	Canusa Ltd.
ROWDON, H. E.	Cuprinol Ltd.
RUHEMANN, F. A.	Private Member
	S
SADLER, J.	Crosby & Co. Ltd.
SAVAGE, L.	Timber Trade Federation of U.K.
SALMON, M. N.	Hickson's Timber Impregnation Co. (G.B.) Ltd.
SAUNDERS, A. G. Major	Prince Regent Tar Co. Ltd.
SAUNDERS, W. R.	Midland Tar Distillers Ltd.
SAWYER, P. R.	H. S. Sawyer & Sons
SAWYER, R.	H. S. Sawyer & Sons

SCARFFE, T. M. . . .	Calders Ltd.
SCOTT, H. W. . . .	Chemical Trades Journal
SCOULER, A. . . .	National Coal Board
SCHOFIELD, J. . . .	Burt Boulton & Haywood Ltd.
SHAW, J.	Watts & Sons Ltd.
SHIVAJI, S. . . .	Ascu Wood Products, India.
SISLEY, C. . . .	Cuprinol Ltd.
SLOGETT, T. H. . . .	Plymouth & Oreston Timber Co. Ltd.
SARTAIN, G. L. . . .	Ministry of Works
SMITH, D. N. . . .	Forest Products Research Laboratory
SMITH, W. E. . . .	E. A. Posts & Telecommunications
SPOONER, J. L. . . .	Spooners (Hull) Ltd.
SPRANKLIN, D. M. . .	Burt Boulton & Haywood Ltd.
SPROULE, J. St. G. . .	Monsanto Chemicals Ltd.
STAKE, Leif . . .	Henry Johansen Ltd.
STEVENS, T. . . .	Celcure Ltd.
STOCK, R. A. . . .	London County Council
STUBBS, J. M. . . .	Hickson's Timber Impregnation Co. (G.B.) Ltd.
	T
TARGETT, H. J. . . .	Burt Boulton & Haywood Ltd.
TAYLOR, F. . . .	National Coal Board
TATLOCK, V. . . .	Architectural Press
TEIGEN, Jens . . .	Henry Johansen Ltd.
THOMPSON, R. . . .	National Coal Board
THORNTON, J. . . .	Hickson's Timber Impregnation Co. (G.B.) Ltd.
TILLBROOK, G. H. . .	Eastern Electricity Board
TIMSON, J. S. . . .	Calders Ltd.
TIPLER, R. V. . . .	Imperial Chemical Industries Ltd.
	U
URMSTON, F. . . .	Hallam, Ramsay & Co. Ltd.
	V
VANDER-STRAETON . .	Aero Research Ltd.
VESEY, H. J. . . .	Christie & Vesey Ltd.
VESEY, W. E. . . .	Christie & Vesey Ltd.
VOSPER, G. R. . . .	Tar Residuals Ltd.
	W
WADE, G. S. . . .	Gabriel, Wade & English Ltd.
WARD, W. . . .	Standard Telecommunications
WAKELIN, J. . . .	Watts Sons Ltd.
WALLACE, E. M. Dr. . .	Celcure & Chemical Co. Ltd.
WATERMAN, A. G. . .	Protim Ltd.
WELLS, F. W. . . .	Eastern Electricity Board
WESTON, G. . . .	British Standards Institution
WELCH, N. V. . . .	Timber Trades Journal
WHITE, C. S. . . .	Ramsey, Murray, White & Ward
WILDE, R. L. . . .	Protim Limited
WILLIAMS, P. G.. . .	Gabriel, Wade & English Ltd.
WILLIAMS, B. M. . .	Tar Residuals Ltd.
WOOD, M. J. Miss . .	Central Electricity Authority
	Y
YEO, H. C. J. Brig. . .	Burt, Boulton & Haywood Ltd.
YERBURY, F. R. . . .	Building Centre

Printed by MERRITT & HATCHER LTD., London.