M E Rhodes

DEPARTMENT OF SCIENTIFIC & INDUSTRIAL RESEARCH

Nov. 1953

FOREST PRODUCTS RESEARCH

BULLETIN No. 1

DRY ROT IN WOOD

Fifth Edition

LONDON: HER MAJESTY'S STATIONERY OFFICE

1952

TWO SHILLINGS NET

PUBLISHED BY HER MAJESTY'S STATIONERY OFFICE
To be purchased from
York House, Kingsway, LONDON, W.C.2 423 Oxford Street, LONDON, W.1
P.O. Box 569, LONDON, S.E.1
13a Castle Street, EDINBURGH, 2 1 St. Andrew's Crescent, CARDIFF
39 King Street, MANCHESTER, 2 Tower Lane, BRISTOL, 1
2 Edmund Street, BIRMINGHAM, 3 80 Chichester Street, BELFAST
or from any Bookseller
1952
Price 2s. 0d. net

S.O. Code No. 47-68-1-52*

M E Rhodes

DEPARTMENT OF SCIENTIFIC & INDUSTRIAL RESEARCH

Nov. 1953

FOREST PRODUCTS RESEARCH

BULLETIN No. 1

DRY ROT IN WOOD

Fifth Edition

LONDON: HER MAJESTY'S STATIONERY OFFICE
1952
TWO SHILLINGS NET

THE Director of Forest Products Research is prepared to consider applications from timber merchants, or others connected with the timber-using professions and industries, for investigations, at an agreed fee, pertaining to the identity, seasoning, mechanical and physical properties, durability and preservative treatment and working qualities of timbers.

So far as the programme of research permits, the service of the officers is available for advisory work, for which no charge is made unless considerable time is occupied in preparing the reply, or travelling or the carrying out of experimental work is involved. Applications for tests or advice should be addressed to the Director, Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

FOREST PRODUCTS RESEARCH
BULLETIN No. 1

DRY ROT IN WOOD

5th Edition

BY

K. ST.G. CARTWRIGHT, M.A., D.I.C.

AND

W. P. K. FINDLAY, D.Sc., D.I.C.

LONDON: HER MAJESTY'S STATIONERY OFFICE
1952

6th ed. 1960. 4/-

CONTENTS

PART I

FUNGI CAUSING DRY ROT IN WOOD

PART II

THE DETECTION AND PRACTICAL TREATMENT OF DRY ROT

PART III

PRECAUTIONS TO BE TAKEN IN THE USE OF TIMBER IN NEW BUILDINGS TO PREVENT OUTBREAKS OF DRY ROT

PREFATORY NOTE

It is generally agreed that dry rot in the woodwork of buildings has become very much more prevalent during the past decade, mainly as a result of neglected maintenance during the war years. Judging from the number of enquiries still being received at the Laboratory, the problem has become one of considerable magnitude. In view of the scarcity and high price of softwood and the need to use building labour to the best advantage, it is most important that owners should, in their own as well as in the national interest, do everything possible both to prevent unnecessary outbreaks of dry rot and to eradicate the trouble when it does occur before it becomes extensive.

The 4th Edition of this Bulletin having become exhausted, in spite of repeated reprintings, it has been decided to issue a new edition, which has been thoroughly revised, particularly in the section dealing with the sterilization of infected walls.

As in previous editions, the information in Part III has been largely supplied by officers of the Building Research Station of the Department, to whom the authors wish to express their thanks.

F. Y. HENDERSON,
Director

Forest Products Research Laboratory,
Princes Risborough,
Aylesbury,
Bucks.

January, 1952.

DRY ROT IN WOOD

Part I

FUNGI CAUSING DRY ROT IN WOOD

INTRODUCTION

Though timber is inherently a naturally durable material it is liable even in buildings to become decayed if it is exposed for any length of time to damp conditions. Such decay is caused by the action of wood-rotting fungi ; bacteria which are so important as a cause of disease in man and animals play little part in the decomposition of wood.

Dry rot is a popular term used to describe the decay of timber in buildings which finally leaves the wood in a dry friable condition. More precisely the term is used to describe the decay caused by fungi which have water-conducting strands, by means of which they can spread into surrounding relatively drier timber from the original focus of infection taking moisture along with them. In this country one fungus, *Merulius lacrymans*, the Dry Rot Fungus, is outstandingly important as a cause of true dry rot in buildings.

Wet rot is a term used by builders and others to describe the decay which attacks timber in very damp situations where there are no visible growths of any fungus present. Actually it is almost invariably due to decomposition of the wood by some species of wood-rotting fungus, since exposure to water even for a prolonged period does not cause rot in the absence of fungal growth.

Extensive damage to the woodwork of buildings and to furniture may also be caused by the attack of wood-boring insects popularly known as "woodworm".

DISTINCTION BETWEEN DAMAGE BY INSECTS AND FUNGI

Since the treatments to be adopted in eradicating wood-boring insects and dry rot are widely different, it is essential to be able to distinguish between the two types of damage. In buildings, beetles generally attack the drier wood, although their moisture requirements may vary for different species of insects; the damage occurs mostly in roofing timbers, panels or in furniture. With the exception of the Powder-post beetle they generally confine their attack to old wood that has been felled many years.

Fungi, on the other hand, attack wood in a moist condition, so that decay often originates in cellars, embedded joist ends, window sashes and behind skirting boards (*cf.* p. 15). Wood damaged by insects can be recognized by the presence of narrow tunnels excavated by the small curved white larvae ("worms") which bore their way through the wood. These tunnels are filled with wood dust (frass) produced by the larvae during their boring: piles of such dust may frequently be seen on or beneath infested timber, and give a sure indication of the presence of living insects. On the surface of attacked timber exit holes are present, which vary in size according to the species of insect, and are caused by the mature beetles emerging from the timber in which, as larvae, they have completed their development.

Fungi causing rot never produce such tunnels, but eventually they cause the wood in which they are growing to shrink and to develop cracks which run both along and across the grain, thus breaking the wood up into square-edged pieces. Exit holes, characteristic of insect attack, do not occur when fungi alone are present, but as insect may frequently follow fungus attack, it is possible to find the characteristic features of both types of injury in one piece of timber. Wood attacked by fungi commonly shows some change of colour, usually becoming a darker brown; it loses its characteristic smell, becomes brittle, gives a dull sound when struck, shrinks and often warps. In addition an actual growth of fungus is usually visible on the surface of the wood.

STRUCTURE OF WOOD

In order to understand the way in which fungi attack and destroy wood, it is necessary to consider briefly the nature of this material.

The porous structure of wood is due to its being composed of minute tubular or fibrous elements. These so-called cells are tightly cemented together and it is their relative size and arrangement which give the characteristic grain and texture to different kinds of wood. The wood substance, which forms the walls of the cells and the solid framework, is composed chiefly of cellulose and a complex substance called lignin; it is hygroscopic and becomes moister or drier according to the condition of the surrounding atmosphere. In the standing tree and in freshly felled or "green" timber most of the cavities or cells in the wood contain free water; timber in this condition may have a moisture content of 100 per cent or more of its oven-dry weight. The point at which all the free moisture has disappeared, the cell walls being still fully saturated, is known as the "fibre saturation point". As the timber becomes still drier the cell walls themselves begin to dry out, and the timber gets harder and stronger. Fungi which decay wood obtain their food supply by breaking down and digesting this cell wall substance, but they cannot do this if the moisture content of the wood is much *below* this "fibre saturation point", i.e. much below 25-30 per cent of the oven-dry weight of the wood. Wood that has been thoroughly air-seasoned in the open contains 15-18 per cent of moisture and in a properly ventilated house this soon falls to 12 or 14 per cent or even lower where central heating is installed. Thus the wood in a well constructed building should always be well below the fibre saturation point.

STRUCTURE AND GROWTH OF WOOD-DESTROYING FUNGI

The wood destroying fungi in buildings belong to the large family called Basidiomycetes which includes such familiar plants as mushrooms and toadstools. These structures, which appear above ground, are the fruit bodies containing the reproductive parts and correspond to the flowers and fruits of the higher plants.

The vegetative part of a fungus consists of exceedingly fine tubes or hollow threads called hyphae, which grow in length by elongation of the tips. These tubes may be arranged loosely, or bunched, closely to form soft cushions. When

closely interwoven they may appear as dense skins, sheets, lumps, or long strings. It is through the interweaving of these threads that the large fruit bodies, which may be shaped like mushrooms or be flat and plate- or pancake-like, are formed. Countless numbers of extremely minute spores (which act in the same way as the seeds of higher plants) are produced on these fruit bodies, and every one (or in some cases a pair) of these spores can give rise to a complete new fungus plant. The spores of some fungi (e.g. the dry rot fungi) when dried may remain capable of germinating for several years.

FUNGI WHICH CAUSE DECAY OF TIMBER IN BUILDINGS

The majority of the cases of serious dry rot in this country are caused by the action of one species of fungus—*Merulius lacrymans* (Wulf.) Fr.—the Dry Rot Fungus. This fungus possesses certain characteristics which enable it to live and spread with rapidity in any damp building containing woodwork, and which render it difficult to stamp out. Other species of fungi occur on timber in houses: *Poria vaillantii* (D.C.) Fr. (*P. vaporaria* Pers.), the Pore Fungus, causes a decay similar to that of *Merulius*, but is less virulent in its attack; *Coniophora cerebella* Pers., the Cellar Fungus, is the cause of considerable damage where the wood is definitely wet, but its attack can be readily stopped if the wood is dried out. *Paxillus panuoides* Fr. is similar in its action to *Coniophora*, and can cause damage only in very damp wood.

The curative measures to be adopted in dealing with a case of dry rot largely depend upon the species of fungus which is present; it is therefore important to be able to recognize which of them has been responsible for the outbreak. The characteristics of the four fungi mentioned are described below, and for ready reference the most important points of distinction have been summarized in tabular form on page 13. It must be remembered that the appearance of the fungi and the type of damage which they cause to the wood depend to a certain extent upon the conditions under which the timber has been exposed to attack, and sometimes it may not be possible to recognize what species of fungus is present without microscopic examination. Where there is doubt whether *Merulius lacrymans* (i.e. the serious form of dry rot) is present, expert advice should be sought.

MERULIUS LACRYMANS (Wulf.) Fr. THE DRY ROT FUNGUS

Appearance.—When growing actively in still, humid air as in a damp cellar or in a coal mine, this fungus forms soft cushions of snowy white growth or delicate silky tassels; these growths quickly shrivel on exposure to dry air. Patches of bright lemon yellow colour appear on the mycelium* wherever its growth is checked, particularly when it is exposed to light. When the fungus is in active growth, it often produces drops of moisture, a characteristic which has given rise to its specific name of *lacrymans* (weeping).

When conditions are somewhat drier the fungus forms a skin or sheet over the surface of the wood; this is most frequently seen on the back of skirting or the underside of floor boards. The colour of the skin is a pearly or mouse grey, but usually patches of bright yellow occur and sometimes there are also tinges of lilac. (See Figure 1.)

* The term used to denote a mass of fungus growth built of numerous hyphae.

Strands.—A striking and important characteristic of the Dry Rot Fungus is its ability to form strands or strings which enable it to pass across inert substances like bricks or metal, and to spread from one piece of timber to attack any wood nearby. These strings vary in thickness from mere threads up to stout hard strands as thick as a lead pencil; they are capable of penetrating mortar and may sometimes be found in the middle of soft bricks. Thus they can readily pass through walls and are known to have penetrated stone walls 2 feet thick. By means of these strands the fungus can spread from room to room and from house to house. The strands contain special hyphae, modified to form vessels or veins, which serve to carry water and thus enable the fungus to transport water from the damp place where it has got a hold, to drier parts of the house, and so to attack moderately dry timber. The strands contain a reserve of food material, and even after the infected timber has been removed they are capable of renewing growth and infecting any newly intoduced wood. It is therefore of great importance to sterilize walls which have been in contact with dry rot, in order to kill these strands and thus prevent infection of the new timber (see Part II).

Fruit bodies.—After the fungus has been growing for some time in wood, which by this time is in a fairly advanced state of decay, it generally produces its fruit bodies (sporophores). In *Merulius* these are fleshy outgrowths which appear on the surface of the timber or brickwork, sometimes on an exterior wall or near a ventilator, more frequently on exposed woodwork in a room as on the surface of skirting or on a cornice (see Figure 2).

The fruit bodies vary in size from a few inches to a foot or more in diameter and may be shaped like pancakes or thick brackets. They are soft, but rather tough and, when young and fresh, have quite a pleasant "mushroomy" smell, but when old and decomposing may give rise to foul odours. The margin of the fruit body is white or tinged with lilac; the centre portion, when mature, is marked by a series of folds giving rise to wide pores or an irregular network of ridges, the characteristic of the genus *Merulius* (see Figure 4), on which are borne the rusty red spores which give the fruit body its characteristic colour. The shape of the fruit body depends partly upon the position in which it is growing, and, when on a vertical surface, the ridges may be elongated into points giving rise to the so-called "stalactite" form (see Figure 2). The spores are produced in enormous numbers, many millions of them may be shed from a single fruit body; sometimes when there are several large fruit bodies in a room, everything in it will become covered with a thick layer of impalpable, rusty red dust consisting solely of fungus spores. These spores blow about with the slightest draught and can be carried by insects and other vermin, so that infection may become widespread.

Appearance of decayed wood.—Wood thoroughly decayed by *Merulius lacrymans* has a characteristic appearance which, apart from colour, rather resembles that of charred wood. It is friable, light, and dry (hence the term "dry rot") and falls to powder under the fingers. Numerous deep cracks, running both along and across the grain, break up the wood into more or less cubical pieces (see Figure 3). The colour of the decayed wood is brown and it has lost its fresh or resinous smell.

There are usually some fungus growths visible on the surface of the timber, in the form of skins or strands; but when the exterior of the wood is dry and only the centre of the piece of wood is moist enough for fungus growth (as may occur in large beams the ends of which are embedded in a damp wall but which are otherwise exposed to the air) the decay may be entirely internal, and the beam may appear perfectly sound until collapse occurs or the condition is revealed by means of borings.

PORIA VAILLANTII (D.C.) Fr.* THE WHITE PORE FUNGUS

This fungus is one of the chief causes of decay in timber in damp coal mines. It occasionally occurs in houses, where it brings about a rot of the timber which closely resembles that produced by *Merulius*. The wood cracks up into cubes in much the same way and the growths on the surface of the timber are somewhat similar, but can readily be distinguished because they always remain white or cream-coloured, never showing patches of yellow or tinges of lilac. The strands are seldom much thicker than fine twine and remain flexible when dry. The fruit body, which is rarely seen in houses, is white and consists of an irregular plate covered with pores whose depth may vary from $\frac{1}{16}$ to $\frac{1}{2}$ inch; frequently there are a number of strands running off from the fruit body (see Figure 9).

Poria vaillantii and one or two other species of *Poria* which sometimes occur in houses can cause serious and widespread damage to timber if conditions are suitable, but they require more moisture in the wood for growth than does *Merulius* and, since they do not possess such well developed conducting strands can be much more readily eradicated from walls, etc.

CONIOPHORA CEREBELLA Pers. (C. PUTEANA (Schum.) Karst.) CELLAR FUNGUS

This fungus, which is of frequent occurrence in houses, only attacks timber that is definitely wet, consequently it is commonly found in cellars, roofs and bathrooms, in fact in any place where leakage of water is liable to occur. It frequently attacks flooring which has been laid directly on damp concrete and covered with an impervious covering.

The strands of this fungus are never thicker than stout twine; they are at first yellowish brown, but soon darken and eventually become brown or almost black (see Figure 6). Thick cushions or sheets of mycelium are never formed as they are by *Merulius*. At the most, small areas of thin yellowish skin are produced on the surface of the wood. The effect upon the timber is to cause it to become much darkened (sometimes almost coal-black), particularly near the surface, and to split mainly with longtitudinal cracks (see Figure 6). Decay caused by *Coniophora* is often largely internal and a thin unbroken layer of more or less sound wood conceals the rot.

The fruit body of *Coniophora cerebella*, which is a thin, irregular-shaped, olive brown plate or skin, covered with small lumps or pimples, is very common on many kinds of felled timber in the forest, but is comparatively seldom seen in buildings. It should be mentioned that the spores of *Coniophora*, which are widely distributed, germinate more readily than do those of *Merulius* and that given suitable, moist conditions, *Coniophora* is almost certain to make its appearance.

Since this fungus requires a fairly high moisture content in the wood for growth, and does not possess well developed conducting strands, its eradication

* The name *Poria vaporaria*, used for this fungus in a former edition, has been applied to a number of species, including the common *Poria* in buildings in this country, which should correctly be called *P. vaillantii*.

is much more simple than in the case of *Merulius*, as its growth will be checked at once if the timber be thoroughly dried.

PAXILLUS PANUOIDES Fr.

This fungus is similar in its action and general method of attack to *Coniophora cerebella*, though of less frequent occurrence. It occasionally causes quite serious decay in very damp situations, but may be readily checked by the drying out of the timber on which it is growing. It is also readily checked by antiseptics. The fine branching strands are yellowish, never becoming dark, and a rather fibrous, yellowish mycelium, which sometimes shows quite vivid violet tints, may occur on the surface of the wood. In an early stage of attack the wood is stained a bright yellow, and as attack proceeds this colour deepens, in the final stages becoming dark reddish brown. The fruit body, which is a dingy yellow becoming ochre beneath as the spores develop, is soft and fleshy and shaped rather like a fan or shell; the upper surface is slightly hairy and the lower marked by a series of ridges (gills) which bear the spores.

PHELLINUS MEGALOPORUS (Pers.) Heim (P. CRYPTARUM Karst.)

This fungus attacks, so far as it is known, only oak wood, and has been reported as the cause of serious damage in some old buildings, a notable instance being the Palace of Versailles. Wood thoroughly decayed by *Ph. megaloporus* is reduced to the consistency of whitish lint, leaving long fibrous strands; it is easily crushed by slight pressure, but does not crumble to powder as does wood destroyed by *Merulius*.

The fruit body consists of a thick, tough plate or bracket of a dull fawn or biscuit colour, on which a rather darker pore surface appears.

This fungus is able to grow well at high temperatures (up to 100°F.) and must be regarded as a dangerous wood destroyer.

An exactly similar type of decay in oak may be brought about by *Poria medulla-panis* Pers., but for practical purposes it is unnecessary to distinguish it from that caused by *Ph. megaloporus*.

LENTINUS LEPIDEUS Fr. (L. SQUAMOSUS Schroet.)

This species, which is one of the principal agents of decay in railway sleepers, telegraph poles and wooden paving blocks, occasionally occurs in buildings where wood has become wet owing to leakage of water. It causes a brown cubical rot of the wood. The fruit bodies are mushroom-like, rather tough, woody and brownish, with the gills running down the stem. When the fruit bodies occur in ill-lit parts of a building they are usually abortive, assuming abnormal forms; often the cap is entirely lacking, the fruit body consisting only of branched, cylindrical, white, light- or purplish-brown outgrowths several inches long (see Figure 7). The fruit bodies and wood decayed by the fungus have, when fresh, a characteristic strong, aromatic smell. Control measures should be adopted as for *Coniophora*.

PORIA XANTHA Lind.

Poria xantha is frequently found causing decay of the woodwork in greenhouses. The fruit body consists of a thin, sulphur-yellow layer of pores which, when growing on a vertical surface, may develop into thickened, lumpy patches. It causes an active brown cubical rot.

TRAMETES SERIALIS Fr.*

Occasionally timber affected by "dote" in the form of brown pockets or pipes of decay may be discovered in a newly erected building. This type of decay is found particularly in Douglas fir and other timbers which have been imported from Canada or the U.S.A. in an insufficiently seasoned condition, and have been then stacked in solid piles with inadequate ventilation. Decay caused by *Trametes serialis* is sometimes difficult to detect when the timber is damp, and only becomes obvious when the wood dries out. This fungus will continue to spread and rot the wood only so long as it remains damp, and will cease activity as soon as the wood is dried out. If, therefore, small isolated patches of "dote" of this type are discovered in well ventilated timbers, such as roofing rafters, no action need be taken.

A large number of different species of fungi have been recorded as causing decay in buildings. Some of these are fungi which cause heart-rots of standing trees in the forest and which are introduced into buildings in wood cut from diseased logs containing portions which, though apparently sound, harbour incipient decay. Should moisture reach such infected wood the fungus may continue its growth and decay the whole piece in which infection was present. Such fungi, however, are not at all likely to spread on to surrounding woodwork and set up serious dry rot. Again, in wet exposed situations, such as window sills where spores blown from outside sources may germinate, quite unusual species may be found causing decay.

CONDITIONS NECESSARY FOR FUNGUS GROWTH

The conditions under which growth of fungi can occur may be listed as follows:—

(1) A supply of food material from which the fungus can derive its nourishment.
(2) A suitable temperature.
(3) A supply of moisture.
(4) A sufficient amount of oxygen for the respiration of the fungus.
(5) The presence of some infection, in the form of spores or mycelium, which will act as a seed or a germ from which the fungus can develop.

Growth of fungi and the development of dry rot can only take place if each of the conditions mentioned above is satisfied. Control of dry rot, therefore, should involve rendering as many of the above conditions as possible unfavourable for fungus growth. These will now be considered in turn.

FOOD MATERIAL

In the case of wood-destroying fungi, the usual food material is obviously wood, but most of them can feed, or at any rate live for considerable periods, upon other materials having a similar chemical composition, such as paper, straw, etc., and it is therefore advisable to have as little of such material in contact with woodwork as possible. A soil rich in humus can also support many of these fungi (see page 17).

Where it is not possible to render the other conditions unfavourable for

* A number of closely allied species of fungi have in the past been called *Trametes serialis*. *Poria monticola* Murr. is probably the commonest of these, causing dote in imported Douglas fir.

fungus growth (e.g. where timber is bound to get damp) the food material should be *poisoned*, i.e. the timber should be treated with a wood preservative to render it immune from attack.

TEMPERATURE

The majority of fungi are able to grow at temperatures ranging from freezing point to a little below or above blood heat—but the rate of growth depends very largely upon the temperature. Growth is extremely slow at temperatures just above freezing point, it becomes increasingly rapid as the temperature rises to the optimum and then the rate becomes very slow again as the maximum is reached.

Coniophora cerebella, for example, grows four times as fast at 75°F. as it does at 50°F. A temperature well above the maximum for growth, if maintained for sufficiently long, will kill any fungus, but many fungi are extremely resistant to heat, particularly when in a dormant condition in dry wood, and can resist for many hours temperatures far above their maximum, e.g. temperatures up to only a little below boiling point. The sterilization of infected timber by means of heat is, therefore, a lengthy process, as the high temperatures must be maintained long enough to ensure that the heat has penetrated to the inmost part of the wood, which must then be kept for many hours at that temperature to ensure killing any fungus present. (See page 20.)

Though the growth of fungi ceases at temperatures near to freezing point, yet they are very resistant to cold, and no temperatures experienced in this country would kill fungi growing in wood.

Merulius lacrymans grows within a rather limited temperature range and is unable to develop at temperatures above 80°F.* It is not, therefore, present in very warm coal mines or in the tropics. It can, however, make good growth at low temperatures, and causes serious damage in cold stores only a few degrees above freezing point.

Speaking generally dry rot fungi are able to grow actively at all the temperatures commonly met with in domestic buildings. Increase of temperature, if it also means increase of ventilation, will dry out a house and so help to prevent decay, but if the timber remains damp it will merely increase the rate of decay. This point should be borne in mind when it is proposed to put additional heating in a building infected with rot; increased ventilation to the timber should always be provided at the same time.

MOISTURE AND AIR

In practice, these factors are the most important that we have to consider in connection with the fungal decay of timber, since an outbreak of dry rot in a building is invariably due to the timber being damp. The moisture requirements of different fungi vary somewhat and depend to a certain extent upon the particular timber on which they are growing, but generally speaking, as soon as timber contains more than 20-25 per cent (of its oven-dry weight) of moisture it becomes liable to attack by *Merulius lacrymans;* and timber which is at the "fibre saturation point," i.e. which contains 25 to 30 per cent of moisture,

* It may be noted as a matter of interest that *Merulius lacrymans* ceases to grow at a temperature many degrees below that of the human blood so that it cannot possibly grow inside human beings and thus as a parasite directly cause disease. A house heavily infected with dry rot is necessarily damp, and for that reason may be unhealthy and it has been suggested that a few people may be allergic to the spores of the fungus.

is liable to attack by most wood-destroying fungi. The optimum moisture content of wood for their growth lies around 40 per cent, but this varies for different fungi and different timbers.

Wood completely saturated, that is, when the cell spaces in the wood are entirely filled with water, is quite immune to fungus attack because it contains no air; fungi like most other organisms require a certain amount of oxygen for their growth and respiration. A familiar illustration of this fact is the durability of the butts of posts embedded in waterlogged soil or submerged in water; decay always taking place "between wind and water" where the wood is damp but not water-logged. The still existing remains of wooden galleys which have been submerged since Roman times, and the foundations of prehistoric lake dwellings may be cited as further proofs of the fact that completely water-logged timber does not decay. Though this method is made use of in the storage of timber kept submerged in log ponds, it scarcely comes into consideration in buildings. Occasionally, owing to leakage of water, timber in a house may become soakingly wet so that *Merulius* is unable to attack it, yet there is usually a large surface exposed to the air and this may be decayed by fungi, such as *Coniophora* and *Paxillus*, which prefer timber in a moister condition than does *Merulius*.

Some of the fungi which cause active rotting of timber actually produce water by chemically splitting up the carbohydrates in the wood; *Merulius lacrymans* is particularly active in this way and renders timber on which it is growing considerably moister; this in its turn stimulates growth and so the process goes on. It is for this reason and on account of the conducting strands that a well established, vigorous attack by *Merulius* is so difficult to check by ventilation and drying out alone.

Thus, since it is extremely important to ensure that dry rot fungi do not become established in the timber, its moisture content should always be kept below 20 per cent of the dry weight. The precautions to be employed in building, which will ensure this, are discussed in Part III of this bulletin.

SPREAD OF DRY ROT FUNGI

Dry rot fungi may be spread either by contagion or by infection. Consider first the spread of fungi by contagion, that is, by the actual growth of the fungus from an infected piece of wood on to adjoining sound timber. This is the general method by which dry rot spreads throughout a house, by actually growing through pieces of wood and over adjoining brick or metal work to adjacent timber. It is the ability to spread over surfaces on which it is not feeding that makes *Merulius lacrymans* such a dangerous pest. Under favourable conditions it can travel many feet in a few months and under very bad conditions may eventually reach every piece of timber in a house. *Poria vaillantii* has a similar method of growth though its powers of spreading are not so great. Timber infected with dry rot may be introduced into a building in a number of ways:—

1. The timber may have been in an infected condition when it was first built in the house, having become contaminated either by spores or by contact with decayed wood in the timber yard; and it is, therefore, important to see that timber is obtained only from well kept yards.
2. Dry rot fungi may be introduced with timber which has been used to effect some repair or addition to the structure.

3. Firewood, which is not infrequently obtained from houses affected with dry rot, may be stored in a damp cellar or outhouse and there develop active dry rot, which spreads into the rest of the building.

Infectious spread of dry rot is due to the dissemination of the spores of decay-producing fungi which are produced in enormous quantities, and which, owing to their lightness and very small size, become blown everywhere. These may possibly be introduced with coal, for in many coal mines the pitwood is covered with fungi and their spores may be present on the coal. It is, in fact, safe to say that if timber be kept in a moist condition suitably placed for fungus growth, one or other of the wood-destroying fungi will make its appearance sooner or later, however carefully infection may be excluded. Fortunately, *Merulius lacrymans* is seldom if ever found out-of-doors and its spores, which do not always germinate readily, are therefore not so generally dispersed as are those of some other fungi, such as *Coniophora cerebella*. In order to limit the spread of *Merulius lacrymans* in this country it is extremely important that everything possible should be done to prevent the spores and mycelium of the fungus becoming distributed.

Tools used when working with wood affected by dry rot may become infected with spores or fragments of wood, and should be sterilized by wiping over with a rag dipped in an antiseptic such as creosote.

RESISTANCE OF TIMBERS AND OTHER ORGANIC BUILDING MATERIALS TO DRY ROT

Any timber, however perishable, is completely immune to the attack of dry rot fungi so long as it remains *perfectly dry*, and the following remarks must be taken as applying only to timber which contains sufficient moisture for fungus growth.

Timbers vary enormously in their resistance to fungus attack; some, such as poplar and beech, may be reduced to powder in a few months by fungal decay, whereas others, like teak and greenheart, can resist attack for many years. Again, while certain fungi are able to attack only certain kinds of timber others can destroy most timbers at least to some degree. *Merulius lacrymans* can attack timbers ranging from soft coniferous woods to durable hardwoods, such as oak and mahogany. Considering only the timbers commonly used for constructional work in this country, it may be said that given favourable conditions for fungus growth they can all be severely attacked by *Merulius lacrymans.*

The heartwood of Scots pine (Baltic redwood, red deal, etc.) is much more durable than the sapwood, and therefore, if sapwood is used in ground floor construction, it should receive preservative treatment. This distinction in durability is shown by practically all timbers in which there is a heartwood well marked off from the sapwood by a difference in colour, and is particularly noticeable in oak. Further, there is great variation in the durability of different samples of the same timber; for instance, a slow-grown, close-ringed, resinous sample of a coniferous timber such as pine or spruce will exhibit much greater resistance to fungal attack than a quick-grown sample of the same timber.

Few of the timbers commonly used in this country can be relied upon to resist the attack of dry rot, and untreated timber should never be used for replacements in situations where there is risk of subsequent dry rot infection.

On the other hand sapwood and timber of non-durable species, if thoroughly treated with a good wood preservative, are as resistant to decay as the most durable species, and even after allowing for the cost of treatment, will usually be found cheaper than the more durable woods.

In certain special instances, however, where any form of treatment of the timber may be undesirable, it may be wished to use a timber which is naturally resistant to dry rot and for this purpose choice may be made from the following: Canadian western red cedar (*Thuja plicata*), opepe (*Sarcocephalus diderrichii*), afzelia (*Afzelia* sp.), kokrodua (*Afrormosia elata*), teak (*Tectona grandis*), iroko (*Chlorophora excelsa*), "Rhodesian teak" (*Baikiaea plurijuga*), jarrah (*Eucalyptus marginata*) or (but somewhat less resistant) well seasoned oak heartwood.

The durability of *plywood* depends on two factors—the resistance of the wood to decay and the resistance of the adhesive to moisture and to decomposition by micro-organisms.

In the so-called exterior grade of plywood, synthetic resin adhesives resistant to moisture and microbial decomposition are used, but the veneers themselves are not usually treated with wood preservative and the plywood as a whole is not immune from dry rot, although it will not delaminate even after prolonged exposure to damp conditions. The decay resistance of plywood of this type may therefore be regarded as similar to that of the wood from which it was made. If plywood is used to replace wood which has been attacked by rot, it should invariably receive preservative treatment.

Under no circumstances should "interior" grade of plywood be used in any situation where it is likely to remain damp for any length of time. The practice of covering damp walls with plywood or matchboarding without getting rid of the dampness in them is a frequent cause of dry rot.

Wall boards made from defibrated wood, sugar cane bagasse, and similar cellulosic materials, are readily attacked by dry rot if exposed to persistently damp conditions. Some proprietory brands of wall board of this type have incorporated in them a preservative which renders them resistant to decay and attack by white ants. Hardboards are generally less readily attacked than the softer, more porous types but they do rot under bad conditions.

Building blocks and slabs made of wood wool and cement are being increasingly used for partitions and for acoustic insulation; this material, though resistant to decay, is by no means impervious to the strands of the dry rot fungus, and if it becomes saturated with water may slowly disintegrate as a result of fungal decay. Some types in which gypsum is incorporated with the cement lose their cohesion under the influence of moisture alone. So far experiments with preservative treatment of the wood wool have not shown that this increases the resistance of the block to attack. Probably the preservatives which have been used are rendered inactive by reaction with the cement.

OTHER FUNGI OCCURRING IN HOUSES

Occasionally fungi which are not injurious to timber and which should not be mistaken for a stage of dry rot may be found growing on or near woodwork in a building. These may be classified into :—

(1) Blue stain fungi.
(2) Mould-like growths.
(3) Other larger fungi.

BLUE STAIN FUNGI

Blue stain is caused by fungi which grow principally in the medullary rays of the wood and feed upon the contents of the cells, i.e. the starch, sugar, oils, etc., without destroying the cell wall substance. Consequently, they do not appreciably weaken the timber, and hence blue-stained wood, if seasoned properly, may be safely used where there is no objection to its appearance. Blue staining is not the first stage of any form of rot, but it does indicate that timber has been kept fairly moist for some period and, therefore, that it has been exposed to conditions favourable to the development of decay-producing fungi. For this reason blue-stained wood should always be examined carefully for traces of "dote". In any case "blueing" is a clear indication of the presence of sapwood.

MOULD-LIKE GROWTHS

Many kinds of mould will grow on damp timber; usually they appear as a soft cobwebby film or patches of green or blackish powder, irregularly scattered over the wood. The appearance of mould is a sign that the timber is damp and steps should be taken at once to increase the ventilation and dry it out, lest dry rot should develop.

OTHER FUNGI

Sometimes in a damp cellar species of fungi which live on soil will force their way up between stone flagging. The commonest of these belong to a genus called *Coprinus*, which possess conical toadstool-like fruit bodies that at first are white or brownish, but soon dissolve into a sort of black inky liquid. They do not seriously decay timber and cannot set up dry rot, but are indicative of dangerously damp conditions.

Occasionally small, soft, rather gelatinous fungi, cup-like in form, appear on damp plaster work. These fungi, commonly called "Elf Cups", which measure one or two inches across and may be dull brown or purplish in colour, belong to the genus *Peziza*. They are harmless to timber and will not reappear once the plaster becomes dry.

Sometimes enquiries are received as to the source of small deposits of black powder, which looks like finely ground carbon, on roofing rafters and other timbers which have been in a damp condition. This powder has been found on examination to consist of large numbers of the minute spores of a slime fungus (Myxomycete), such as *Fuligo* spp., which does not cause decay in timber.

TABLE FOR DIAGNOSIS OF FUNGI CAUSING DECAY OF TIMBER IN BUILDINGS

Fungus	Effect on the wood	Strings on the surface of the wood	Other growths on the surface of the wood	Fruit Bodies
Merulius lacrymans	Rotted wood shrinks and becomes split up into cubical pieces by deep *cross cracking*. Generally occurs in damp not *wet* positions.	Strings grey, sometimes as thick as a lead pencil, becoming brittle when dried.	In damp, dark places, soft white cushions; in drier places, thick silver-grey sheets or skins usually showing patches of lemon yellow and tinges of lilac.	Fleshy, soft, but rather tough; shaped like pancakes or brackets. Spore bearing surface, yellow to red brown, with wide pores or labyrinthine ridges and furrows. Margin white.
Poria vaillantii (and other related species of *Poria*)	Rot similar but less widespread than that produced by *Merulius*. Several species of *Poria* occur in houses, all requiring more moisture than *Merulius*.	Strings white, seldom thicker than stout twine, remaining flexible when dried.	White or cream coloured sheets and growths, never showing coloration.	Shaped like sheets or plates, white in colour. Spore bearing surface, white, showing numerous minute pores.
Coniophora cerebella	Causes darkening of the wood and longitudinal cracking, cross-cracking not usually visible on the surface. Usually found in very damp situations where there has been leakage of water.	Strings, slender, usually thread-like, at first yellowish, soon becoming deep brown or nearly black.	Ocasionally very thin skin-like growths.	Sheet-like in shape. Fertile surface greenish to olive brown, bearing spores on many minute pimples.
Paxillus panuoides	Causes a characteristic yellow discoloration in the attacked wood, which finally becomes red brown.	Very slender, yellow but eventually brownish yellow.	Rather hairy or woolly, dull yellow, sometimes pale-violet in colour.	Fleshy, fan- or shell-shaped, stalkless. Spore bearing surface with radiating ridges (gills), at first yellow, then ochre.
Lentinus lepideus	Causes an internal brown cubical rot. This fungus and the attacked wood have a characteristic strong aromatic smell.	None.	Only present occasionally. Purplish brown felted woolly sheet.	Normal form, shaped like a mushroom with radiating gills beneath, tough and woody. Frequently abortive forms occur without a cap and consisting only of cylindrical branching out-growths.
Trametes serialis (*Poria monticola*)	Causes "dote" in the form of isolated small pockets of brown rot. Eventually may cause general brown cubical rot. Usually found only on timber imported from America.	Slender, white, much branched.	Only developed under very damp conditions, soft white, cotton woolly, sometimes with dark brown patches.	Seldom seen in houses; consisting of thin plates or broad thin teeth forming wide pores.

Part II

THE DETECTION AND PRACTICAL TREATMENT OF DRY ROT

GENERAL

When dry rot is either suspected, or has been discovered in a building, a thorough investigation should be made in order to determine both the extent of the attack and the nature of the fungus.

When dealing with large or important buildings it may be advisable to prepare a detailed report, illustrated by drawings and photographs.

IDENTIFICATION OF FUNGUS

Since the treatment to be adopted depends largely on the species of fungus present, it is important to identify the fungus causing the rot. If after reading the descriptions given in Part I there is still doubt as to the identity of the fungus, samples of infected timber with specimens of fungus attached should be selected and submitted to an authority for identification. All such samples should be carefully packed in waterproof paper so that their moisture will be retained.

It is not safe to assume that only one species of fungus is present. In some instances, two or more kinds may be found attacking the same piece of timber.

The drastic treatment recommended below for the eradication of dry rot need only be adopted when *Merulius lacrymans*, or a similar fungus is present. Where *Coniophora cerebella* alone is present, removal of the affected woodwork, and its replacement with treated wood, will suffice, *provided the source of dampness is removed.* But less drastic measures should only be adopted when the rot has been shown to be due to less virulent fungi than *Merulius*.

DETERMINATION OF THE EXTENT OF DECAY

Since the Dry Rot Fungus is able to travel considerable distances, and even to penetrate through brickwork and grow behind plaster, it is important that the full extent of the attack should be determined so that no infected timber remains which can give rise to a subsequent outbreak. Frequently the fungus may be found to have travelled up a wall behind the layers of plaster from the ground to the first floor and has there attacked the timbers. In one instance, which may be quoted as of somewhat unusual character, the fungus travelled (in the form of a string or cord) along the flange of a rolled steel joist for a distance of more than 10 feet. It had its origin in timber near one end of the joist, and was eventually able to attack the timber at the other end although there was no timber in between upon which it could feed. (*Cf.* page 4.)

All fungus should thus be traced until its origin and the limit of attack has been ascertained; all hidden timbers within the suspected area should be uncovered so that their condition may be known.

The parts of a building in which dry rot attack is most likely to occur are

cellars, ground floors, lavatories, roofs, etc. The positions most liable to be affected are:—

(*a*) *Floors.*—Boards and skirtings (unventilated wood floors covered with linoleum or rubber carpet are susceptible to attack, especially ground floors and those directly on concrete). Joists, beams and wall plates, especially where they come into contact with an outer wall.

(*b*) *Walls.*—Timbers buried in the wall (known as bond timbers) or for the purpose of fixing panelling, etc. Battens and laths in plaster, especially on outer walls; lintels over door and window openings. Match boarding or panelling, especially on outer walls.

(*c*) *Door frames.*—Especially the lower ends where in contact with steps.

(*d*) *Windows.*—Especially the sill; the lower ends of the frame and sash; the window board.

(*e*) *Roofs.*—Gutter boards and bearers under lead, zinc or copper coverings; the rafters, especially where they rest on a plate bedded in an outer wall.

SIGNS OF DECAY

Apart from clearly recognizable signs of attack such as the appearance of fungus growth, or the collapse of infected woodwork, the following are indicative of the presence of dry rot:—

(1) A damp, musty smell which, if the growth be vigorous, may become offensive.

(2) A warping of the surface of woodwork.

(3) The development on the surface of the timber of a network of cracks running parallel to and across the grain (see Figure 5)—not usually shown on a painted surface.

(4) The presence of a fine, rusty red powder (consisting of fungus spores) which may be deposited throughout the room.

TESTS FOR SOUNDNESS OF TIMBER

Practical tests for determining the soundness of timber:—

(*a*) Drive into it a sharp pointed tool. If the timber is rotten the tool will enter easily and can be withdrawn without effort; if sound the pointed end will meet with resistance, the wood fibres will grip it and some effort is required to withdraw it.

(*b*) Striking the timber with a hammer. If in good condition a ringing note will be given out; if decayed the sound will be dead and dull.

(*c*) In timbers of large size, drill small holes with an auger. The shavings can be withdrawn separately for each inch in depth, to be put on one side and examined for evidence of fungus. Cavities in the heart of a timber can be detected by means of this test.

CAUSES OF DECAY

A careful examination should be made in order to ascertain possible defects in the structure that have led to the development of dry rot, particular attention being paid to:—

A. Source of the dampness originally responsible for the outbreak, e.g. from soil, from percolation through walls or roof, from condensation or from the use of insufficiently seasoned timber.

B. Source of the infection.

A. SOURCE OF DAMPNESS

The most probable sources of moisture are:

(1) *Capillary rise of moisture from soil*

(*a*) Absence of a damp-proof course in exterior walls, sleeper walls, or below solid floors.

(*b*) Presence of earth above level of damp-proof course, thus rendering it inoperative.

(*c*) Bridging of cavity in double wall by means of mortar droppings.

(2) *Percolation and leakage of water*

(*a*) Porous wall surfaces.

(*b*) Defective gullies, drains.

(*c*) Leaky gutters and defective down rain-water pipes, particularly when the latter are embedded in the wall.

(*d*) Leaks in slates or tiles or lead flats.

(*e*) Leakage from plumbing damaged by frost.

(3) *Condensation*

(*a*) Poor or no ventilation under floors owing to absence of air bricks or to their having been blocked by soil, vegetation or additions or alterations to buildings. Frequently ventilation is poor under hollow floors which adjoin solid floors, unless pipes are laid under the latter to ensure a through current of air.

(*b*) Absence of concrete over the site.

(*c*) In buildings where the atmospheric humidity is high, condensation may occur on the roof unless this be well insulated.

(*d*) Panelling on a cold wall may become damp because of insufficient ventilation behind it.

Before proceeding with repairs or replacements, it is necessary that such defects should be made good and the source of the moisture eliminated.

It must be noted that fungus may grow out again after structural defects, such as those mentioned above, have been made good. Though the saturated timber may dry out, it may still contain enough moisture for the fungus to continue growth if it is well established.

B. SOURCE OF INFECTION

The principal sources of infection by which dry rot can gain entry to a house have been mentioned on page 9.

FIG. 1. SEVERE CASE OF DRY ROT IN MATCHBOARDING CAUSED BY *Merulius lacrymans*

Note the sheets of mycelium, the strands penetrating into the brickwork, the warping of the boards and the fruit bodies of the fungus

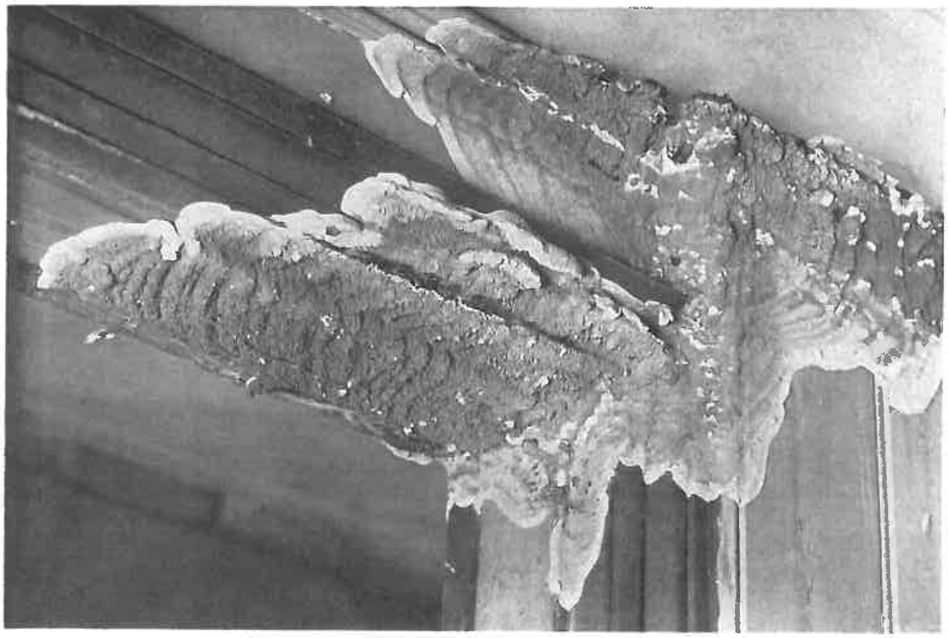


FIG. 2. LARGE FRUIT BODY OF *Merulius lacrymans* AT THE TOP OF DOORWAY

Enlarged photograph of fruit body shown at top right of Fig. 1

FIG. 3. *Merulius lacrymans.* PORTION OF JOIST ATTACKED BY DRY ROT WITH TWO FRUIT BODIES ATTACHED

Note the deep cross cracking, splitting the wood into cubes, and the sheets of mycelium

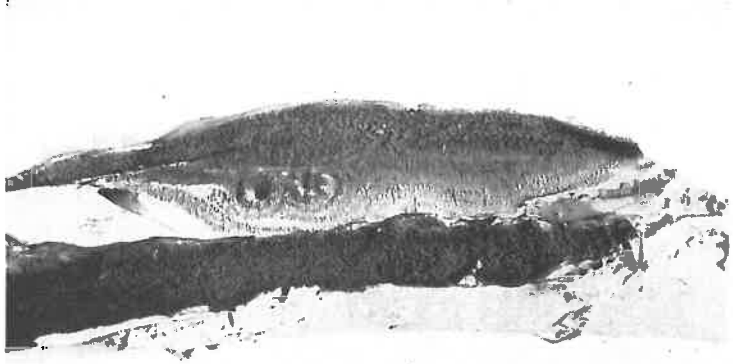


FIG. 4. *Merulius lacrymans.* FRUIT BODY SHOWING STRUCTURE OF FERTILE SURFACE ON WHICH SPORES ARE BORNE

Note the variation in shape of the shallow pores and the labyrinthine folds

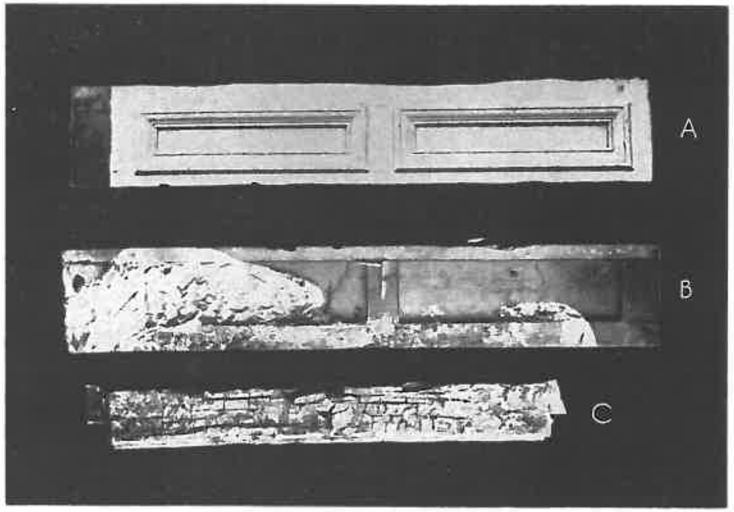


FIG. 5. *Merulius lacrymans*

A. FRONT PANEL SHOWING NO SIGNS OF DAMAGE
B. BACK OF *same* PANEL SHOWING FUNGUS SKINS
C. WOOD ATTACKED BY DRY ROT SHOWING CROSS CRACKS

FIG. 6. *Coniophora cerebella.* PORTION OF DECAYED FLOOR BOARD

Showing fine blackish strands and longitudinal splitting

FIG. 7. *Lentinus lepideus.* FRUIT BODIES FROM A BUILDING
One normal specimen with cap bearing gills beneath, the rest abortive consisting only of elongated stalks

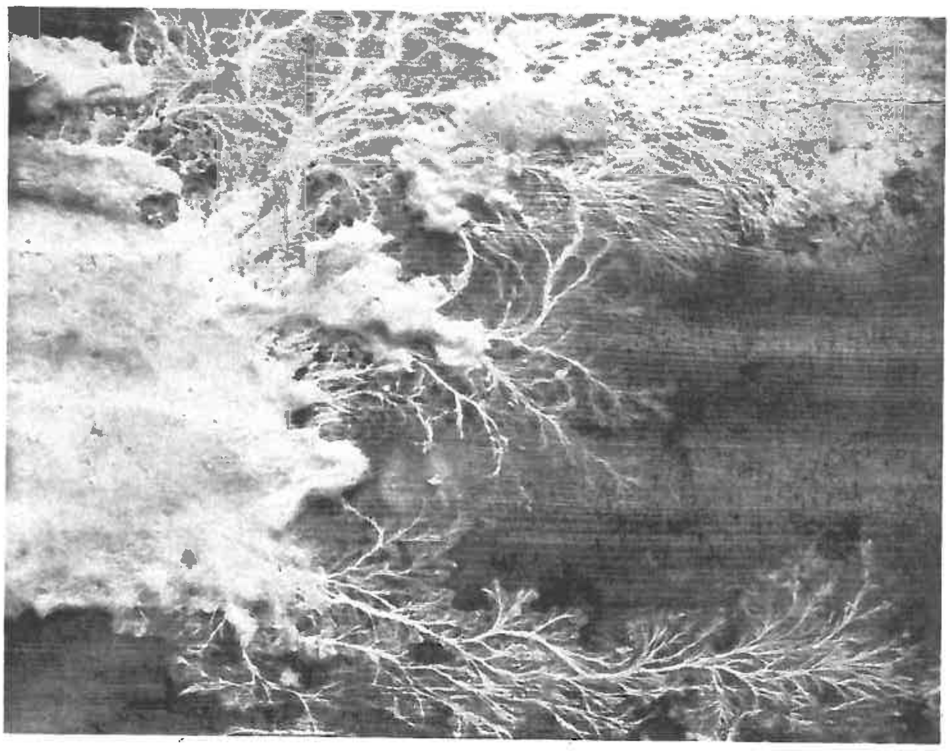


FIG. 8. *Poria vaillantii:* MYCELIUM IN FORM OF SHEETS AND STRANDS ON A BOARD

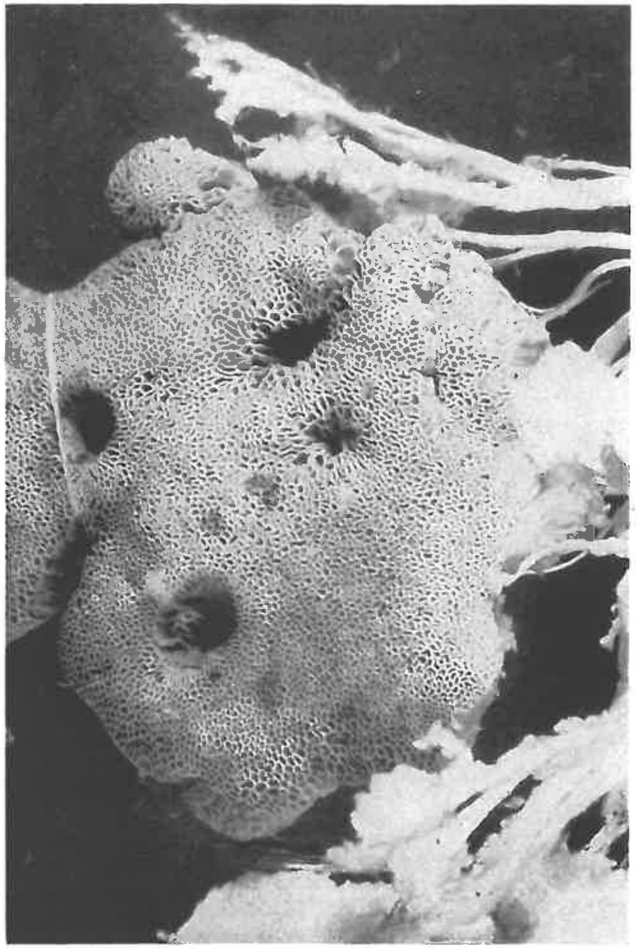


FIG. 9. *Poria vaillantii.* FRUIT BODY FROM TIMBER IN COAL MINE
Note the fine round or angular pores of the *white* fertile surface

Decayed timber buried in soil is another possible source of infection. The spores and mycelium of the fungus can exist in the soil for considerable periods and may develop and spread up over brickwork on to the timber. This source of infection should be particularly guarded against when building upon a site previously occupied by other buildings.

Old wood shavings and sawdust, either left accidentally or as pugging under floors or elsewhere, may encourage the outbreak of dry rot.

CAUSES OF INCREASED PREVALENCE OF DRY ROT IN WAR TIME

Dry rot became more widespread during the war for the following reasons:—

(1) General neglect of upkeep owing to shortage of labour and materials; e.g. the blocking of rain-water pipes with leaves, etc., was a frequent cause of wet walls and consequent dry rot.

(2) Alterations to buildings for A.R.P. purposes, such as erection of sand-bag revetments, which bridged the damp-proof course and caused dampness in walls; closing of sub-floor ventilators to proof rooms against poison gas; introduction of timber strutting into damp basements, etc.

(3) Air raid damage, which admitted wet into buildings, especially fires caused by incendiary bombs, during which large volumes of water were used in fire fighting.

(4) Absence of owners or tenants of property, especially in evacuated coastal areas. This often meant that the house was shut up, with consequent restriction of ventilation and no heating.

(5) Bursting of water pipes owing to insufficient heating of buildings or failure to empty water system before house was left unoccupied.

REMEDIAL MEASURES

GENERAL RECOMMENDATIONS

It is not possible within the scope of this Bulletin to make detailed recommendations concerning structural repairs which may be necessary. Each case must be dealt with on its merits, but the following precautions should be taken when carrying out repairs:—

(1) All decayed timber should be removed, cutting away for about a foot into sound wood beyond the point at which the timber is visibly affected. Particular attention should be paid to the removal of embedded pieces, such as fixing blocks, which are decayed.

(2) As far as possible, no new timber should be allowed to come into contact with brickwork which has been infected with fungus. Where it is unavoidable that the new wall plates and joist ends should touch the exterior walls, they should be bedded on bituminous felt which should also be brought up round the sides or ends, so that nowhere does the timber come in actual contact with the brickwork.

(3) All unnecessary woodwork should be eliminated from the replacements, e.g. ornamental cornices, picture rails, etc.

(4) Built in timbers, such as lintels, which have decayed should be replaced by concrete or steel. Decayed wooden skirting in basement rooms should be replaced by a cement skirting. In basements where the walls are damp and infected with fungus, it may be preferable to replace decayed window frames by steel ones, if pressure-treated timber is not available.

(5) Where decay is localized at the end of a beam or joist, and the rest of the member is perfectly sound, it is often possible to splice on a new end consisting of treated timber, held in position by means of steel plates bolted on each side.

(6) New woodwork used for replacements, in addition to being well seasoned, should be thoroughly treated with a preservative, particular attention being given to joist ends and to any portions which are to come in contact with brick or stone work. The under-sides of floor board should be twice coated with preservative.

(7) Ample ventilation should be provided to all spaces under floors and between panelling and walls.

(8) When carrying out repairs to a building of historic importance all carved or moulded work should, as far as possible, be retained. This may necessitate the adoption of special methods of repair and of preservation, involving sterilization by heat or chemicals of the woodwork to be retained.

REMOVAL OF DECAYED TIMBER AND FUNGUS

All decayed or unsound timber should be burnt immediately after removal and not be sold as firewood. It is not advisable to re-use wood that appears to be sound but was part of a decayed piece, except in special cases, such as in a rafter where the decay is generally localized at the foot.

All fungus growth on brickwork or similar surfaces should be carefully removed and burnt.

All dust and dirt (which may contain spores of fungus) should be removed as far as possible from the surfaces of walls and from beneath the floors.

STERILIZATION OF WALLS INFECTED WITH MERULIUS LACRYMANS

After all the decayed timber has been removed it is necessary to sterilize the surfaces of adjoining brick or stonework with which it has been in contact. Almost invariably it will be found that when growths of the Dry Rot Fungus are present on the brickwork its strands have penetrated for some depth into the wall. If the walls are not effectively sterilized this fungus may grow out after repairs have been carried out and attack the new woodwork.

It is always difficult to ensure that the strands of Dry Rot Fungus which have penetrated to some depth into brickwork are rendered harmless but the following procedure should be effective when the source of dampness can be removed and the wall dried out and kept dry in the future.

(1) Strip the plaster from the wall for so far as any fungus threads are found in it.

(2) Heat the surface of the brickwork by passing over it the flame from a powerful blow lamp or flame gun slowly and repeatedly until it becomes uncomfortably hot to the touch.

(3) Apply one of the following fungicides freely to the surface, working it well into the joints, from which any loose mortar should previously have been raked.

(I)	Magnesium silico-fluoride.	8 oz. to gallon of water.
(II)	Sodium pentachlorphenate.	8 oz. „ „ „ „
(III)	Sodium fluoride	6 oz. „ „ „ „
(IV)	Copper sulphate	3 oz. „ „ „ „

(Note that solutions of (I) and (IV) are corrosive to metals and must be handled accordingly.)

If the antiseptic solution is applied by spraying, the operatives should be provided with some form of respirator to avoid inhalation of the spray particles, for most fungicides are in some degree poisonous.

In severe cases where dampness is likely to persist in the walls and the strands have penetrated deeply, the treatment outlined above cannot be relied on effectively to eradicate the infection, and an attempt should be made to impregnate the affected portion of the wall by drilling into it a series of ½ in. holes, 6-9 in. deep, at the upper limit of the infected area into which the fungicide can be poured. The holes should be spaced about 2 feet apart horizontally and vertically in staggered rows and should slope down into the wall. They can be filled through funnels (bottles with bottoms cut off make convenient vessels) or the fluid can be lead through bungs by tubing from douche cans supported at a slightly higher level. The treatment should be continued until fluid appears from holes cut at the bottom of the infected area.

After "irrigating" the wall in this way it must be left to dry out before redecoration is attempted, as efflorescence of soluble salts is likely to develop; if it does, the salts should be brushed (*not* washed) off.

While this irrigation treatment is undoubtedly effective if carried out systematically by experienced workmen it is laborious and involves the introduction of large amounts of liquid into the wall which has then to be dried out. Complete sterilization of brickwork, if the heat can be applied for sufficiently long to the surface to heat the wall *throughout* its thickness to a temperature above 130°F. in special circumstances, can be effected by applying electric hot plates to the walls for periods up to 12 hours or more or by employing an oxy-acetylene flame. The use of the latter must be applied with caution to avoid the risk of fire and of damage to the wall itself.

Recent investigations have shown that under laboratory conditions the application of a fungicidal paint or plaster based on zinc oxychloride cement can effectively prevent the emergence of *Merulius* growths from infected brickwork. It is thought that this treatment should prove an effective method for preventing any infection developing from walls permeated with fungal strands, but further experience in the practical applications of this material must be obtained before this opinion can be confirmed.

STERILIZATION OF TIMBER

Sound woodwork around the decayed portions which have been cut away should be treated with wood preservative to sterilize the surface and to kill any spores that may be present on it.

In the ordinary way, *all* the infected woodwork should be removed, but in special cases it may be necessary to retain portions of the woodwork which are known to contain infection. For instance, in the case of a main beam which would cost a very great deal to replace, and which is only slightly affected at one end, the affected end may be treated by boring into it a number of holes at an angle to the grain, and repeatedly filling these with preservative or with a paste made of preservative salts, which will slowly diffuse out and form a barrier against the further spread of the fungus. It must be emphasized that there is always a risk attached to leaving any infected wood in a building, and expert advice should be sought before this is done.

Carved and valuable ornamental woodwork which can be removed from the building can be sterilized by heating it in a drying kiln. Six hours at a temperature of 130°F. in a humid atmosphere should suffice to sterilize even thick timbers infected with *Merulius lacrymans*. Sterilization of whole buildings by means of heat has sometimes been attempted, and while this method is fairly successful in killing insects in roofing timbers, it is difficult to attain sufficiently high temperatures in the parts of the woodwork most likely to be affected by rot, i.e. the embedded joist ends and wall plates, and until further experience is available, the method cannot generally be recommended against dry rot.

WOOD PRESERVATIVES

Wood preservatives may be classified into three general types, each of which has its own particular usefulness under special circumstances, i.e. the precise kind of preservative to be used depends on the situation in which it is to be employed.

All good wood preservatives should be highly toxic towards wood-destroying fungi, and reasonably permanent in the wood. For a more detailed description of the various types of preservatives, reference should be made to Forest Products Research Record No. 17. The British Wood Preserving Association's Circular No. 2, "The Preservative Treatment of Building Timber," also contains information about preservatives suitable for use in buildings.

(a) *Tar oil preservatives*

For the preservation of all external timber, except that which is to be painted, creosote can be recommended. It is also very useful for the preservation of wall plates, ground floor joists, etc., but it should not be used where there is a risk of its "bleeding" through paintwork or into plaster, nor should it be used in rooms where food is to be stored, as it may cause tainting. The smell of tar oil preservatives is fairly strong, and is objectionable to some people, but is not unhealthy.

Creosote should be ordered to conform to the British Standards Specification (No. 144—Creosote for the Preservation of Timber). It should preferably be applied hot, at a temperature of about 140°F., and at least two coats should be given.

There are a number of proprietary tar oil preservatives which can be used if desired, instead of creosote. Some of these have the advantage that they are cleaner and of less pungent odour than creosote. Instructions as to their use are issued by the respective manufacturers.

(b) *Water soluble preservatives*

Most water soluble preservatives are liable to be washed out if the treated wood is exposed to the action of the weather—they should therefore only be

used on wood which is protected against the weather by being under cover or coated with paint. For the preservation of building timbers they have certain advantages over the tar oil preservatives:—

(1) Wood treated with a water soluble preservative may be painted as soon as it has dried.
(2) They are odourless.
(3) They do not "creep" and cause stain in plaster work.
(4) They may be obtained colourless if desired.

One of the most effective and economical of the water soluble preservative salts is sodium fluoride, which is used in the form of a solution made by dissolving 6 oz. of commercial sodium fluoride (obtainable as a crystalline powder) in 1 gallon of water. These proportions will give a 4 per cent solution. It should be applied by means of a brush, every effort being made to ensure penetration into cavities and cracks. At least two coats should be given. If desired, this solution can be coloured by the addition of a few crystals of Vandyke Brown.

It is sometimes desirable where there is a risk of the treated timber coming into direct contact with foodstuffs, as in a cold store, that the preservative should not be of a poisonous nature. For such cases a solution of borax made by dissolving 8 oz. of borax in a gallon of warm water may be used.

Of the other non-proprietary preservatives magnesium silico-fluoride is one of the most effective. It is colourless and will not stain timber, brickwork or plaster, but it will attack metal and glass and must be mixed in a wooden tub. The solution (5 per cent) is made by dissolving ½ lb. of this salt in 1 gallon of cold water. Two coats should be given.

There are on the market a number of highly effective proprietary water soluble preservatives. In general it may be said that those known as the "fluor-chrome" and "copper-chrome" types are effective and resist leaching well.

Corrosive sublimate (mercuric chloride) at a strength of 1 part in 1,000 parts of water has been successfully used in the past for sterilizing infected brickwork, but its use is not recommended as it is intensely poisonous to human beings and therefore requires great care in handling.

Zinc chloride is not sufficiently toxic to fungi unless applied by a pressure process and if used in too strong a solution it will itself attack wood.

Copper sulphate (blue vitriol) is moderately effective against the fungi which cause dry rot, but as it is corrosive to metals, is not generally recommended for use on timber.

(c) *Solvent type preservatives*

In recent years wood preservatives have been developed, consisting of a toxic substance such as pentachlorphenol or copper naphthenate dissolved in an organic solvent such as white spirit or solvent naptha, so that when the solvent evaporates the toxic principles remain in the wood. If the active principle is present in sufficient quantity this type of preservative may be very effective.

The undermentioned substances have sometimes been used for the preservation of timber in buildings, but are not recommended:—

Sulphate of iron (green vitriol), which is corrosive to metals, common salt and lime wash, which are not sufficiently toxic to fungi. Organic compounds such as carbolic and acetic acids and formalin should not be used as they evaporate quickly and soon disappear entirely. Antiseptic soaps and household disinfectants are useless.

ACTION OF PAINT

A film of good-quality paint on seasoned wood acts as a more or less waterproof coating as well as a mechanical barrier to fungus spores reaching the wood, and a good priming of paint on the backs of window frames, etc., is a very useful protection. On the other hand, when high gloss paint is applied to damp wood, it may be a source of danger, retarding drying out of the wood and providing conditions suitable for the development of fungus which may gain access to the unpainted portions of the woodwork, as, for example, through the backs of door and window frames in contact with brickwork; or through cracks which may develop in the paint coating because of the shrinkage of the wood on drying.

METHOD OF APPLYING PRESERVATIVES

All timber which is to be treated with preservative must be free of dust and dirt, and it is essential that it should be in an air-dry condition before any preservative is applied.

Brush application is the most convenient method of treating timbers *in situ* and wall surfaces, except where they are of large area, when spray application may be more rapid and economical.

In severe cases of dry rot where the fungus has penetrated deeply into the walls (which may be almost impossible to sterilize owing to their thickness and which may remain damp), it is recommended that timber, impregnated with preservative by means of pressure treatment, should be used for all replacements which are to come into contact with such walls. Where it is not possible to obtain timber impregnated under pressure the wood should be treated by the so-called open tank process, details of which are given in Forest Products Research Record No. 9, "Methods of applying Wood Preservatives. Part 1. Non Pressure Methods." Briefly, the process when using creosote, consists in immersing the timber in cold creosote, which is then gradually heated up to 180°F.-200°F. and maintained at this temperature for at least one to two hours. The creosote is allowed to cool, the timber being kept completely submerged during the cooling process. When the timber is too large to be completely immersed the ends are dipped in hot preservative and the other surfaces treated by brush application.

Water soluble preservatives can be applied in a similar way and details regarding the temperatures to be used, etc., should be obtained from the manufacturer of the product used.

TREATMENT AND PREVENTION OF DRY ROT UNDER EMERGENCY CONDITIONS

(a) *Treatment*

Under emergency conditions it may not be feasible to carry out repairs along the lines indicated above, owing to scarcity of labour and materials, and only "first aid" repairs may be possible. But it is essential at least to check the spread of the rot and, if at all possible, to eradicate it, so that when full repairs can be made there will be no risk of the fungus again breaking out. If dry rot is discovered in a building, and if for any reason proper repairs cannot be put in hand immediately, the following steps should be taken at once:—

(1) The source of dampness originally responsible for the outbreak should be sought out and dealt with so that any further access of moisture is prevented.

(2) All wood infected with the fungus should, whenever possible, be cut out and burnt. Where only one end of a long timber is infected, this should be cut away at a point 12 inches beyond the last visible signs of attack.

(3) It should be made certain that there is proper ventilation under the floors.

(4) The brickwork should be sprayed with an antiseptic solution, the treatment being repeated if further outgrowths of fungus develop later.

Delay in reinstatement of woodwork is actually an advantage, since it facilitates the escape of the moisture from the brickwork; moreover, any further development of the fungus can be detected at once, and any areas in which fresh activity is noted can receive a second dressing with antiseptic.

(b) *Prevention*

By far the greater proportion of dry rot outbreaks can be prevented, even under emergency conditions, if the simple precautions listed below are taken without delay when signs of dampness become evident.

(1) If floors have been saturated with water, all impervious coverings such as linoleum should be removed at once. Floor boards alongside walls should be taken up. If pugging is present and saturated with water this should be removed.

(2) Any débris on floors should be removed.

(3) Ventilators under floors should be examined, and if necessary opened or cleaned out. If ventilation under the ground floor appears poor, additional 9 by 6 in. airbricks, sited so that they give a through draught, should be inserted in the external walls.

(4) Any soil above the level of the damp-proof course should be removed.

(5) Rain-water pipes should be cleaned out and replaced if found to be cracked or punctured.

(6) Any leaks in the roof and guttering should be mended.

(7) Windows in the basement and upper floor rooms should be left slightly opened at the top.

(8) In unoccupied houses the water system should be emptied in addition to cutting off the main supply.

Owners of property, both in their own interests and in the interest of the nation when materials for repairs are scarce, should see that such precautions are taken at the earliest possible opportunity.

TREATMENT OF OUTBREAKS CAUSED BY CELLAR FUNGUS, ETC.

When it is established that the decay is of the type commonly known as wet rot, caused by *Coniophora, Paxillus* or *Lentinus*, less drastic steps are necessary to get rid of the infection than when *Merulius* is present. Since these fungi do not possess well developed water-conducting strands their attack is limited to the area which is damp. They do not penetrate into brickwork and the risk of persistent infection is therefore much less.

Provided that the source of dampness can be removed and the woodwork can be dried out and kept dry, further development of the rot is most unlikely. Of course, obviously decayed wood must be removed, but if the source of dampness has been traced and eliminated, there will be little risk of the rot spreading further even if some slightly affected timber be left *in situ*. If on the other hand dampness is likely to persist owing to the nature of the site or the absence of proper damp-proof courses, every piece of timber showing even traces of infection must be replaced with timber that has been thoroughly treated with a preservative.

Whatever fungus has been the cause of the rot, it is always advisable to treat with preservative existing sound timber left *in situ* and all new timber to be used in repairs. Sterilization of brickwork is really necessary only if *Merulius* is present and can safely be omitted when dealing with "wet rot", provided that the new woodwork receives proper treatment.

Part III

PRECAUTIONS TO BE TAKEN IN THE USE OF TIMBER IN NEW BUILDINGS TO PREVENT OUTBREAKS OF DRY ROT

THE VALUE OF TIMBER IN BUILDING

The intensive search during the last few years for substitutes for the traditional building materials has not so far shown any signs of producing a substitute for timber, the most adaptable of all the orthodox materials of construction. Timber does not deteriorate with time, for so long as it is protected against moisture it will remain sound and serviceable in a practically unchanged condition. In spite of its liability to attack by fungus and insect, its special properties and adaptability render it the most economical and efficient material for a large variety of building purposes.

SELECTION OF TIMBER

When selecting or inspecting timber for use in building construction, the aim should be to select sound, good quality, well-seasoned material. Wherever possible the conditions of storage should be ascertained and nothing allowed on the site which comes from a yard in which careless stacking or unclean conditions are tolerated, such as damp foundations or an accumulation of rotting waste (*cf.* page 9). All timber should be rejected which shows signs of unsoundness (e.g. timber showing signs of "dote" (incipient decay) or traces of heart rot which occurred in the living tree), as any such defect may pave the way for subsequent fungal attack in the building.

Since it has been shown that timber containing over about 20 per cent of moisture (based on its oven dry weight) is liable to attack by dry rot, care should be taken to ensure that no timber containing more than this amount is built into any part of the house where rapid drying cannot subsequently occur. For ground floor joists, wall plates, etc., no timber containing over 22 per cent of moisture should be admitted; and for rafters and similar timbers, the upper moisture content limit should never exceed 25 per cent.

PRECAUTIONS IN DESIGN AND CONSTRUCTION

Since it is the moisture content of the timber which is the really important factor determining whether or not fungus spores will germinate and fungi will develop and cause rotting of the woodwork, it is against penetration of dampness that precautions must be taken, and this should be the designer's first consideration.

As far as possible the use of built-in timbers surrounded by brickwork or masonry, and which cannot be adequately ventilated, should be avoided entirely. Bond timbers are but little used in modern buildings, but wooden lintels, embedded fixing battens, wooden fixing plugs, which are still commonly used, should always be thoroughly treated, preferably impregnated with a wood preservative *before* being built into the structure.

Whilst access of moisture is often the result of subsequent accidents to the structure, there is no doubt that a great deal of structural timber, which appears on paper to have adequate protection from damp, is in practice liable to become wet, with no opportunity for drying quickly afterwards. It must be emphasized that it is *persistent* dampness which leads to dry rot; fungal attack takes some time to become established, and occasional short periods of exposure are unlikely to give wood-rotting fungi a chance to become established. If, on the other hand, moisture reaches timbers from which it cannot readily get away, conditions suitable for the development of dry rot are liable to be set up.

The most vulnerable points in a structure are where the timber comes in contact with other materials of construction which are introduced into the building in a wet state, or which, although not really damp-proof and weather-proof, are employed as a protection against damp and the weather.

Wooden buildings with a good timber-frame construction are seldom attacked by dry rot when kept in good repair and well insulated from ground damp probably because no moisture penetrates beyond the outermost covering, and because the small scantling timbers employed are well placed for rapid drying; but the exclusion of moisture from walls constructed in brickwork or masonry is a more difficult problem.

DAMP PENETRATION THROUGH WALLS

Most of the traditional masonry walling materials have a porous, capillary structure, and if exposed to rain for a sufficient length of time will allow water to pass through to the inner face. Cases are known where there has been penetration of rain through brickwork as much as 4 feet in thickness, and penetration through a 14- or an 18-inch wall is quite common. The amount of the rainfall and the force of the prevailing winds, which tend to force the water through the wall vary greatly in different localities. Solid walls may suffice to keep out the rain on sheltered sites in localities where the rainfall is moderate, but it is very difficult to draw the line of demarcation between severe and moderate exposure. Even with carefully built walls, with relatively dense, impervious masonry units, there is a tendency for discontinuities to form between unit and mortar, especially in vertical joints, through which rain can penetrate rapidly. Because of the tendency for such discontinuities to form, dense cement mortars are not necessarily the most suitable materials for obtaining a dry wall, and with all but the most dense and impervious units, lime mortars or lime mortars gauged with a moderate amount of cement are to be preferred, as they tend to give a better bond with the unit.

There is no doubt that the continuous cavity is the most certain and reliable method of securing a dry wall, even under the most adverse conditions of exposure, for it provides a complete break in the capillary channels through the walls. Reasonable precautions are necessary to avoid bridging the cavity by mortar droppings, and careful detailing at heads and jambs of openings is essential (see Figures 10, 11).

Since it is generally recognized that the solid wall is liable to allow penetration of moisture, recourse is often made to cement renderings and stuccos to provide a weather-resistant cover. Actually, however, troubles with these are by no means unusual; cement renderings, in common with cement con-

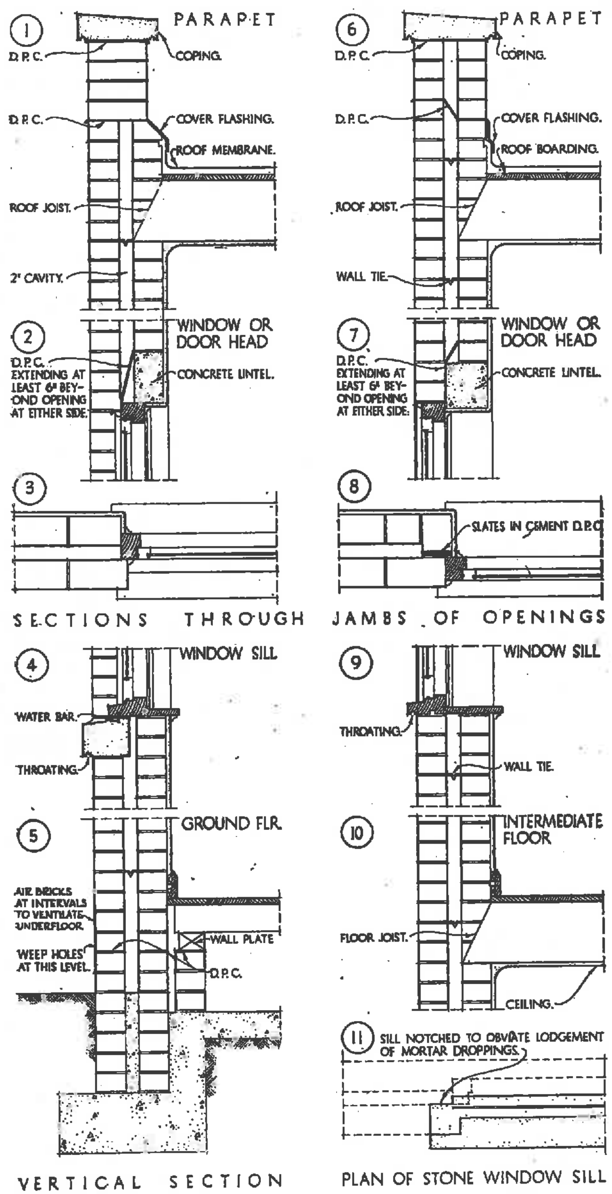


FIG. 10. GOOD CONSTRUCTIONAL DETAILS FOR CAVITY WALLS

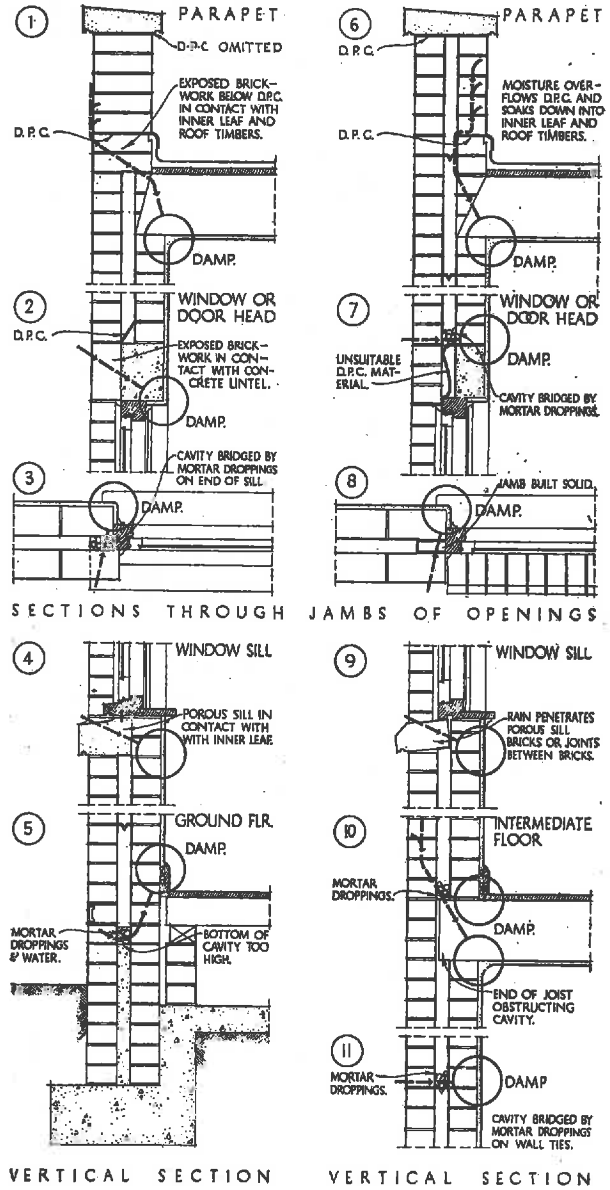


FIG. 11. BAD CONSTRUCTIONAL DETAILS FOR CAVITY WALLS

cretes and mortars, shrink as they dry, and this shrinkage is liable to lead to the formation of cracks. Once cracks have formed, a very bad condition arises; damp penetrates through the cracks, but evaporation is hindered when favourable weather conditions follow rain, and a badly cracked rendering may actually be worse than no protection at all. Cement-mortar rough-cast and pebble-dashed finishes appear to be less troublesome than the floated renderings. It may be that here shrinkage is taken up in a system of very fine cracks round individual pebbles, and the danger of moisture penetration is less than when the cracks are less numerous but larger.

Investigations described in Building Research Bulletin No. 16 show that softer and more porous renderings are less liable to the defects enumerated above than dense cement renderings. In actual permeability to moisture they are somewhat inferior to an uncracked dense cement rendering, but in practice moisture rarely penetrates the renderings and the backing except when there are cracks, and since these softer renderings are much less liable to cracking they actually give a much greater margin of safety. The mixes used depend upon the nature of the backing, the conditions of exposure and the finish to be applied. A mix of 1 part Portland cement 1 to 1½ parts of lime and 6-8 parts by sand by volume is most generally useful. One part of Portland cement, 2 parts lime and 8-9 parts sand may be used under conditions of moderate exposure.

The cement should conform to B.S. No. 12, 1940 (Portland cement) or B.S. No. 146, 1947 (Portland blastfurnace cement). Lime should be white or grey lime putty run from quicklime and well matured before use or white or grey hydrated lime conforming in either case to B.S. No. 890. 1940 (Building limes). Sand should conform to B.S. No. 1199, 1944.

Where a white or tinted finish is required, white Portland cement or coloured Portland cement should be substituted for all or part of the Portland cement. Other constituents as for undercoat.

Where the site is exposed to severe weather conditions the walls should be treated prior to application of rendering undercoat, with a slurry consisting of one volume of Portland cement to two and a half volumes of sand. The slurry should be thrown on with the trowel, in the thinnest possible coat which will just cover the wall. No attempt should be made to smooth this coat as the projection of the larger particles in the sand forms a valuable key for the rendering overcoat.

PARAPETS

The flat roof is being used to an increasing extent on houses very often in conjunction with parapet walls. This introduces certain difficulties if the joist end and wall plates supporting the roof are to be kept dry. Some details showing how the entry of damp through parapet walls can be prevented are given in Figure 13.

GROUND DAMP

From the point of view of dry rot development the efficiency of the damp-proof course is probably one of the most important factors. The tendency in recent years to economize by using inferior damp courses is culpable. All material used as damp-proof courses should, without exception, comply with the requirements of British Standard Specification No. 743—1951, which includes definitions for bituminous materials suitable for use in damp-proof courses, or B.S. No. 1067—1942 for pitch felt and No. 1097—1943 for mastic asphalt.

Whilst dealing with damp-proof courses, there is one very persistent type of failure which is worth mentioning. It is quite common to find that a break in the capillary path for ground moisture has been carefully secured by the insertion of a good damp-proof course, but at the same time that an alternative capillary path has been inadvertantly provided. This happens most frequently in the case of an internal partition wall with a hollow timber floor on one side and a solid concrete or tiled floor on the other (see Figure 12).

The section indicates the form of construction in question; the position of the damp-proof course is determined by the position of the timber plate, and, as a general rule, it will be found that the filling under the concrete floor is in contact with the wall above the damp-proof course. This provides a capillary path for ground moisture shown by the arrows in the diagram. If the building site happens to be a damp one, there is every likelihood that conditions will arise which will be favourable for dry-rot development.

For this reason it should be made a rule that all timber which is to be placed in contact with damp material or materials likely to become damp (even though it is not actually to be built in) should be treated with a preservative at least at the points of contact.

FLOORS

It is probable that by far the greatest number of dry rot fungus outbreaks originate in floors so that the treatment of the sub-floor area is of importance; a layer of Portland cement concrete is usually specified and is undoubtedly of value. Concrete, however, possesses a porous structure and can absorb a considerable amount of moisture by capillary forces so that if placed directly on damp ground the concrete will become saturated. The most practical method of breaking the capillary path of moisture to the surface concrete is by the provision of a layer of loose aggregate below the concrete, and for this purpose large ballast or broken dense brick is to be recommended but, in order to be effective, it is essential to ***eliminate the fine material.*** Hard core, consisting of broken brick in all states of the sub-division, with old mortar and other refuse, cannot be relied upon to prevent the rise of liquid water although it may make a good firm bed for the concrete. It should be realized, however, that in waterlogged sites the provision of this non-capillary layer under the concrete will fail in its purpose, since a "head" of water in the surrounding soil will cause it to act merely as a sump; in such soils it should obviously be employed in conjunction with sub-soil drainage.

Whatever precautions may be taken to prevent the capillary rise of moisture in the liquid form, the risk of water vapour moving up through the concrete remains unless a truly moisture-proof layer is either laid over the surface of the concrete or incorporated in it. Recent experiments with solid floors have shown that the incorporation of a bituminous layer in the site concrete greatly reduces the amount of moisture which can percolate through it in the gaseous form, and this type of damp-proof course (suitably linked up with the damp-proof course in the external walls) can be recommended for use in site concrete under suspended floors on any sites where the ground is known to be damp.

Ventilation of spaces below suspended floors.—With the utmost care which

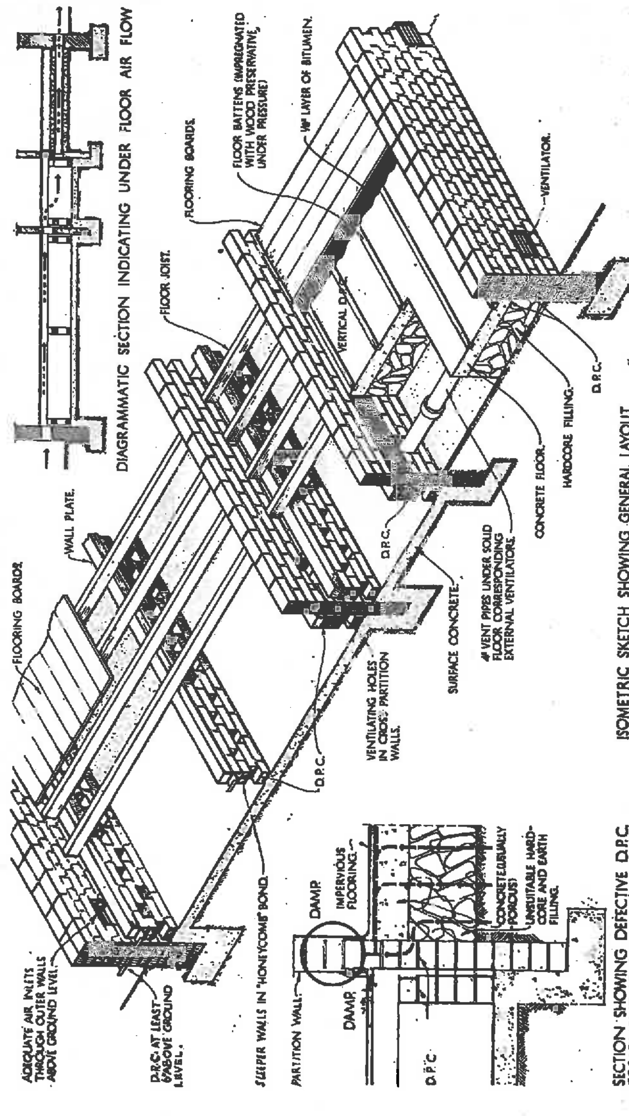
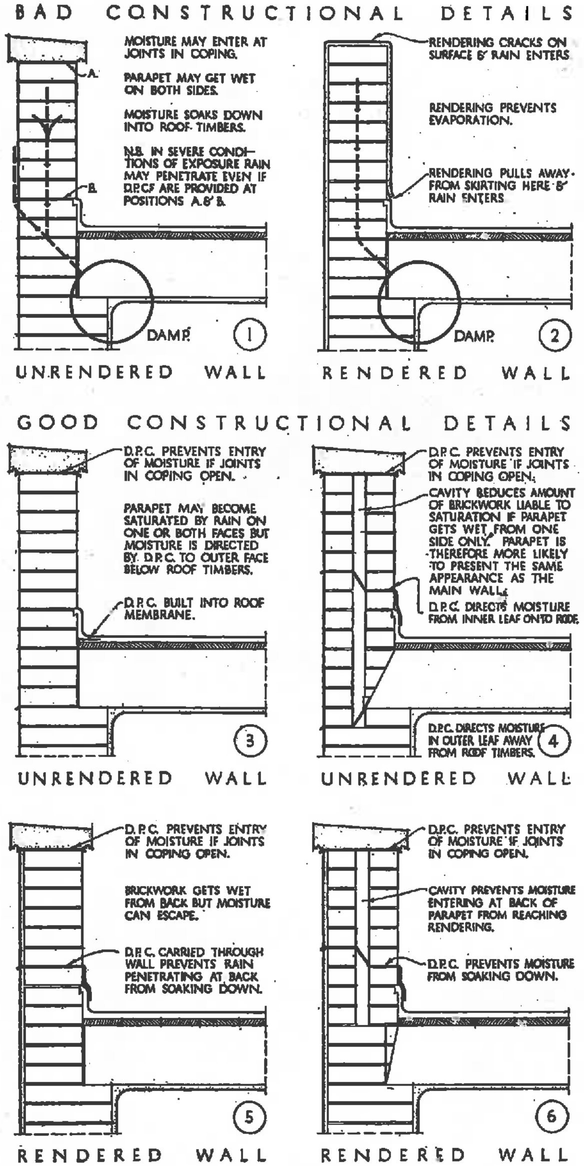


FIG. 12. DETAILING AT GROUND FLOOR LEVEL RECOMMENDED TO ENSURE ADEQUATE UNDER-FLOOR VENTILATION AND PREVENTION OF RISING DAMPNESS



NOTE: WEEP HOLES SHOULD BE PROVIDED AT FOOT OF STEPPED D.P.C.s IN EXAMPLES Nos 4 & 6.

FIG. 13. BAD AND GOOD CONSTRUCTIONAL DETAILS FOR PARAPET WALLS.

can be reasonably exercised, some moisture will probably be found to reach the surface of the site concrete, and where a timber floor is to be used, it is essential to provide adequate ventilation in order to ensure that the air below the floor is not constantly in a state approaching saturation.

The ordinary type of timber ground floor, consisting of boarding on joists with intermediate sleeper walls, affords opportunities for obtaining good ventilation. An aperture opening into an enclosed space cannot be considered adequate as a means of ventilation; it is necessary to ensure an *air current* below the floors right through the building. Where the ground floor planning is such that the air path is obstructed by solid floors it is desirable to provide ventilating ducts in the form of pipes laid below the solid floor, as shown in Figure 12. The air vents in both external and partition walls should be as large as possible (e.g. 9×6 ins.); if typical air bricks are examined it will be found that they often have a very small clear opening—as small as 3 square inches. In selecting air vents particular consideration should be given to the opening; this is even more important than their strength or finish.

In this connection British Standard Specification No. 483 for cast iron air bricks and gratings lays down the requirement that the total unobstructed area shall not be less than one-fifth of the total area calculated from the overall dimensions. Sufficient air bricks should be provided so as to allow at least $1\frac{1}{2}$ sq. in. open area per foot run of external walls. Sleeper walls should be honeycombed, and damp courses should be provided below plates.

It is desirable to place air vents rather higher above ground level than is the usual practice. Serious outbreaks of dry rot have been traced to the prac-practice of heaping up the soil of a garden bed against the wall so that in addition to covering the damp-proof course the air vents may be obstructed. Even if the air vents are uncovered they will obviously be less efficient if placed very closely to the ground.

The hearth presents a special problem in the ventilation of the sub-floor space. In a small room the projection of the hearth may lead to the formation of unventilated pockets on either side. The provision of a pipe below the hearth should eliminate trouble of this kind.

Construction of solid floors.—A great deal of dry rot has been experienced with wood floors laid directly on concrete, especially ground floors. The relative cheapness of a floor of this type compared with one consisting of flooring on joists, plates and sleeper walls may make its use attractive, but when this type of construction is adopted it is particularly desirable that its construction should be designed so as to prevent any moisture from the ground reaching the timber and persisting in it.

The concrete should be made as dense as possible. A thin layer of well-proportioned material will be immeasurably superior to the 6-inch layer of roughly deposited, insufficiently rammed and badly proportioned material which is only too common. At best, however concrete cannot be made truly impermeable and sufficient moisture may pass through it in the vapour form to render timber laid directly on it liable to attack by dry rot fungi. The provision of a really impermeable layer immediately below the timber is absolutely essential. Care should be taken to ensure that the impervious layer makes a water-tight joint (carried vertically if necessary) with the damp-proof course in the walls. As already indicated, bitumen is a convenient material to use for providing this impervious layer. A lightly brushed coating of tar, as is often used, is quite valueless. The kind of bitumen that should be used for this purpose can be indicated by reference to its hardness, defined by its "penetration-number" which should be between 40 and 50, or by its softening point which should be 50-55°C. Alternatively, a soft pitch of softening point 45-50°C. may be used. The bitumen, or pitch, should be poured hot and it should be regarded as essential to have a continuous layer which is nowhere less than ⅛ in. thick. To obtain this thickness at least 50-60 lb. (5-6 gallons) of bitumen, or pitch, per 100 sq. ft. will be required and considerably more, even up to 100 lb. per 100 sq. ft., will be necessary if the concrete surface is not smooth and level. If embedded wooden battens are used for fixing, they must be thoroughly impregnated under pressure with a wood preservative. Breeze concrete, which has been extensively used for this purpose, does tend to corrode the nails, but if this is covered with a good layer of bitumen into which the boards can be bedded, they should not work loose. There are certain other porous concretes which would be non-corrosive and probably offer a more permanent grip on the nails, but actual trial on a full scale would be required before any definite recommendations regarding these could be made. An alternative type of solid floor is one consisting of wood blocks, which, being more decorative does not call for a covering with linoleum or similar material. If the adhesive used for fixing down the blocks is of the right type and applied sufficiently liberally it will also act as a damp-proof course.

A compromise between the suspended and solid ground floor lies in the use of the type in which the flooring is fixed to wood bearers held by special metal grips partly embedded in the concrete. In such floors, particularly when these are laid on the ground, the surface of the concrete must be covered with a layer of bitumen and the bearers and the underside of the flooring should be creosoted, the former preferably by an impregnation process.

Information on the design of timber floors to prevent dry rot is summarized in Building Research Station Digest No. 1, 1948, and general information on laying of timber flooring in B.S. Code of Practice C.P. 201 (1951).

CONDENSATION

Condensation of moisture on the internal surface of the walls should be avoided as far as possible, as well as the penetration of moisture from the ground or from the exterior of the building. Other conditions being favourable, it is quite capable of providing sufficient moisture to bring about the germination of spores or the growth of fungi behind skirting boards, architraves and the like. The fundamental cause of condensation, which may be briefly summarized as a lowering to below the dew point of the temperature of the air in contact with the condensing surface, is fairly generally understood. But consideration of the various combinations of factors which may lead in practice to such a condition is complicated. Condensation troubles can be reduced by providing extra ventilation, or by the use of more absorptive surfaces, or by more heat-insulation in the walls. All these are factors which may be of assistance in preventing it. The case of the week-end cottage, lock-up shop, or other building for occasional occupation, is a particularly difficult one. Such buildings as these may be unventilated and unheated for appreciable periods and, despite all precautions in construction, they may be liable to heavy condensation under certain weather conditions. In buildings of this type the use of timber preservatives is especially desirable.

GENERAL OBSERVATIONS

Dry rot outbreaks in suspended floors in the upper storeys are considerably less common than in ground floor construction. Fungus attack on plates and joist ends, abutting on damp walls, is probably the more frequent trouble.

The omission of throating to sills, or of the weather moulds on doors exposed to driving rain, has been the cause of many local outbreaks of rot. The inadequate precautions taken to protect the timber bearers of parapet gutters from contact with damp material makes them a very frequent source of fungal decay. The use of wood bricks, rough grounds, slips and plugs for fixing purposes in buildings is dying but slowly, in spite of alternative materials (e.g. breeze bricks and cellular concrete) now available, while built-in wood lintels, wall plates, beams and joist ends are still the general practice. If it is particularly desired to use timber in such ill-ventilated situations, it should be thoroughly treated with an efficient wood preservative. The small extra cost involved will be amply compensated for by the extra security provided.

Care should always be taken to remove shavings, soil, and debris from surface concrete, as well as pieces of wood employed during excavation, and wooden forms for concrete work.

Linoleum or rubber carpeting can safely be laid on suspended floors if there is good ventilation underneath, but there may be a risk of dampness and rot developing when linoleum is laid on a solid ground floor. In any case, it is most important that linoleum should not be laid until the floors have had time to dry out thoroughly. Excessive washing of linoleum should be avoided as water may find its way through cracks and render the wood in the floors permanently damp. It is much better to keep it waxed and polished. On a suspended floor, it is better to leave a margin near the walls uncovered, but on a solid floor this is very little better than covering the whole area. In no case should linoleum be relaid on floors in which dry rot has already occurred.

When door or window openings are closed up, all built-in grounds, frames and linings should be removed. These are potential sources of fungus growth when sealed up, and they may provide a starting point for the attack on other timber in the structure.

Prefabrication of building units, which permits much of the work on the site to be carried out without the use of wet materials, may eliminate some of the risks of dry rot in new buildings. One of the difficulties in prefabricated construction is to obtain a satisfactory watertight joint between the units. In some types which we have seen, weatherproofing of the joints is affected by inserting a fillet or grouting of bitumen between the uprights of adjoining units. If a joint of this kind is to remain watertight, considerable care is needed in its workmanship, and it would generally appear desirable to insist on some form of jointing strip to seal the joints between adjoining units.

A careful scrutiny of constructional drawings, bearing in mind the ever-present danger of the incidence of dry rot in structural timber, may reveal many other situations in which conditions ideal for the germination of fungal spores or the growth of fungi are likely to develop. In figures 10, 11, 12 and 13 some of these danger points are shown and means for preventing the penetration of damp indicated.

Note.—Copies of Forest Products Research publications are obtainable from the Forest Products Research Laboratory, Princes Risborough, Aylesbury, Bucks., where enquiries relating to the use and treatment of timber may be addressed to the Director.

Printed in Great Britain under the authority of HER MAJESTY'S STATIONERY OFFICE
by C. Tinling & Co., Ltd., Liverpool, London and Prescot

(18274) Wt4432/369 K52 7.52 CT&CoLtd Gp500.

FOREST PRODUCTS RESEARCH PUBLICATIONS

BULLETINS :—

No. 18. Commercial Mahoganies and Allied Timbers (*Reprinted* 1949)	2s. 0d. (2s. 2d.)
No. 19. Beetles Injurious to Timber and Furniture (1940)	3s. 0d. (3s. 1½d.)
No. 20. Requirements and Properties of Adhesives for Wood (*Revised Edition* 1950)	1s. 3d. (1s. 4½d.)
No. 21. Flooring Hardwoods: their Wear and Anatomical Structure (1948)	1s. 9d. (1s. 10½d.)
No. 22. The Identification of Softwoods by their Microscopic Structure (1949)	2s. 6d. (2s. 7½d.)
No. 23. Flooring Softwoods: their Wear and Anatomical Structure (1949)	9d. (10½d.)
No. 24. The Protection of Buildings and Timber against Termites (1950)	2s. 6d. (2s. 7½d.)

SPECIAL REPORTS :—

No. 6. Swelling Stresses in Gels (*Revised* 1950)	1s. 0d. (1s. 2d.)
No. 7. The Elasticity of Wood and Plywood (1948)	2s. 0d. (2s. 2d.)

RECORDS :—

No. 3. Experiments on the Preservation of Mine Timber (*Revised Edition* 1949)	6d. (7½d.)
No. 9. Methods of Applying Wood Preservatives. Part 1. Non-pressure methods. (*Revised Edition* 1946)	1s. 0d. (1s. 1½d.)
No. 17. Wood Preservatives. (*Revised Edition* 1946)	6d. (7½d.)
No. 21. The Growth and Structure of Wood (1937)	1s. 3d. (1s. 4½d.)
No. 30. The Natural Durability of Timber (1949)	6d. (7½d.)

MISCELLANEOUS :—

Handbook of Home-Grown Timbers (*Revised* 1941)	2s. 0d. (2s. 1½d.)
Handbook of Empire Timbers (*Revised Edition* 1951)	3s. 6d. (3s. 9d.)
Handbook of Woodcutting (1946)	1s. 6d. (1s. 8d.)
Decay of Timber and its Prevention (1947)	12s. 6d. (13s. 2d.)
Solid and Laminated Wood Bending (1948)	5s. 0d. (5s. 4d.)
Hardwoods for Building and General Purposes (1951)	1s. 3d. (1s. 4½d.)

Prices in brackets include postage.

Copies can be purchased from H.M. STATIONERY OFFICE at the addresses overleaf.