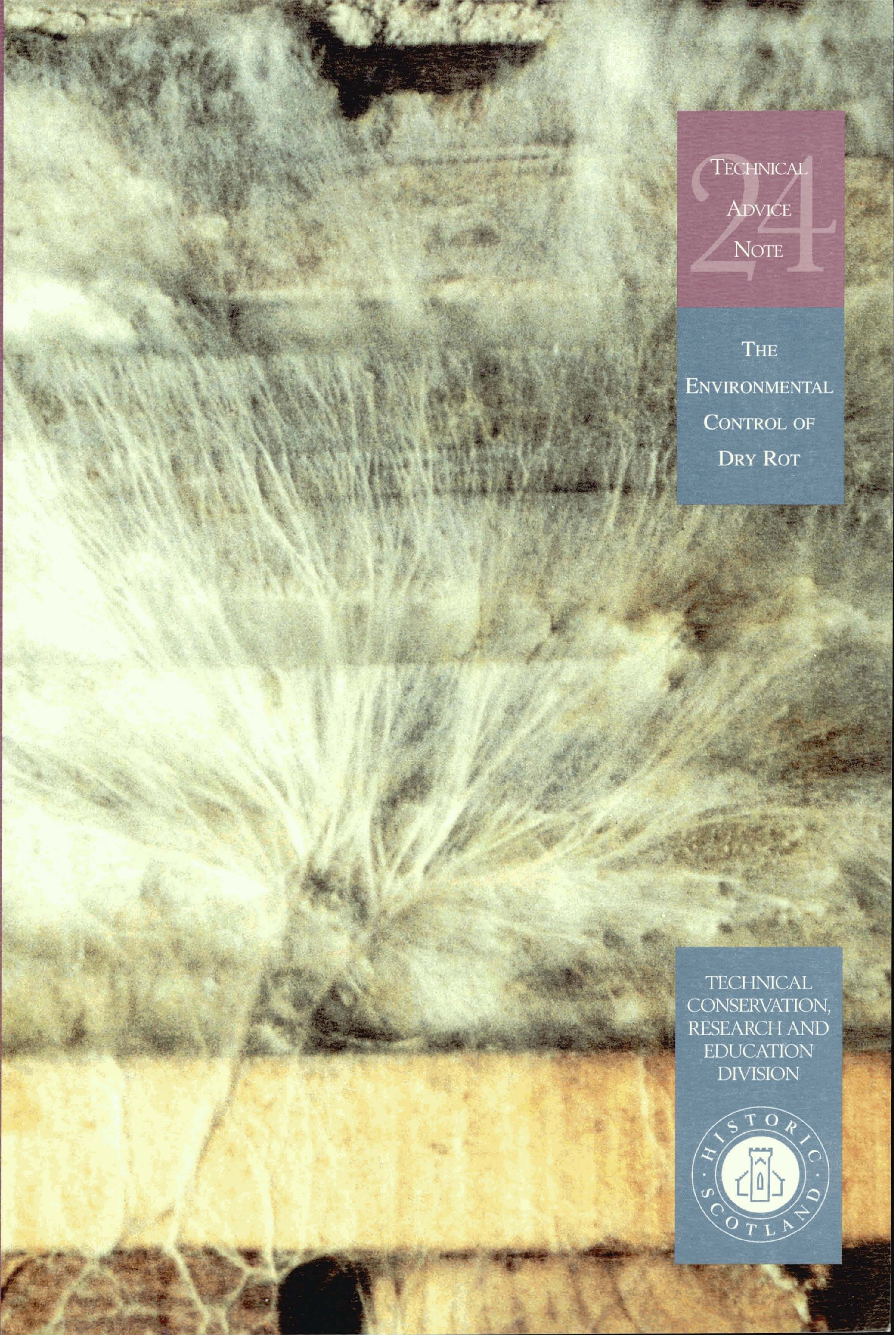

TAN 24

THE ENVIRONMENTAL CONTROL OF DRY ROT

Technical Advice Note 24

The Environmental Control of Dry Rot

Technical Conservation, Research and Education Division

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TECHNICAL
ADVICE
NOTE
24

THE ENVIRONMENTAL CONTROL OF DRY ROT

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We would like to offer special thanks to the residents of Keith Hall, Aberdeenshire for allowing us to feature their property as a 'Case Study'. Keith Hall is an excellent example of the practices and procedures described in this TAN and, after 10 years, the control methods applied to the Hall are still highly effective. Thanks also to Keith Moir of Squire Associates for giving us access to the documentation related to this case. Finally we would like to thank Geoffrey Hutton of H&REI for his thoughts on the treatment of Keith Hall and on environmental control of dry rot in general.

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FOREWORD

The principal themes running through Historic Scotland's series of Technical Advice Notes (TANs) can be summarised as the care and conservation of the built heritage, and the prevention of loss of historic fabric. Historic fabric is, by definition, comprised of traditional materials amongst which the use of timber has influenced the development of a wide range of building forms from pre-history to the present time.

With its unique strength in compression and tension timber remains the only material from which the majority of the elements of traditional buildings can be formed. However, being an organic material it is influenced by changes in environmental conditions, of which fire may be regarded as one extreme and water another.

Where water is present timber decay in the form of woodrot may result. Of the many types of decay it is undoubtedly dry rot – Serpula Lacrymans – which gives building owners and managers most cause for concern. Outbreaks often result in invasive methods of treatment, with the potential of further damage to the building.

With the aim of conserving historic fabric whilst rectifying dry rot outbreaks Historic Scotland commissioned the University of Abertay, Dundee to research the control and treatment of dry rot by environmental methods. Although the principles of environmental control have been understood for some time little scientific research has been carried out to validate the commercial treatment already available, albeit to a limited extent, in the United Kingdom.

As a companion volume to this TAN the completed research work by University of Abertay has been published under the title "Studies of the Domestic Dry Rot Fungus Serpula lacrymans with Relevance to the Management of Decay in Buildings". This TAN translates and expands upon the findings of that work and applies them in a practical way to the built heritage.

It is fundamental to the avoidance of timber decay that moisture should be excluded from the structure and fabric of a building. The research proved that restoration of good environmental conditions (with low levels of humidity and moisture content), together with adequate levels of natural ventilation, will stop the spread of woodrot.

High standards of building care allied to regular maintenance will offer the best assurance that building fabric remains in a sound condition. Thereafter good building management should prevent minor defects becoming major problems, and will keep repair costs down.

This TAN aims to respond to owners' and occupiers' concerns about dry rot in their buildings. It seeks to encourage those responsible for the care, conservation and management of historic, and contemporary, buildings to invite appropriate specialist advice when timber decay is found. It also aims to encourage the adoption of a more sympathetic, environmentally-sound approach to the resolution of dry rot outbreaks.

Ingval Maxwell
Director TCRE
September 2002

1 INTRODUCTION

There are a number of biological agents which can cause damage to timber in buildings. These include various insects and a range of fungi. The important fungal agents are divided into two types, those that cause 'wet rot' and the one, *Serpula lacrymans*, which causes what is known in the UK as 'dry rot' or 'true dry rot'. Dry rot is much more significant to the conservator than wet rot for a number of reasons, the most significant being that a) the dry rot fungus can cause extensive damage to timber in buildings and b) eradication of dry rot is, traditionally, a highly expensive process. This Technical Advice Note is devoted exclusively to issues associated with dry rot.

The 'dry rot' problem is familiar to most people in the UK and northern Europe, and estimates of the scale of the associated damage range from £100M per annum to over £400M. Much of this damage is in relatively small, modern constructions, but the dry rot fungus, *Serpula lacrymans*, is no respecter of age or quality and historic buildings are particularly susceptible to attack. This susceptibility is due to a number of factors including a) lack of knowledge (historic buildings may be harder for practitioners and owners to understand, i.e. their construction may be complex and include features no longer commonly used), b) financial (funds for repair and maintenance may be problematical), c) change of use (sealing up draughty, but essentially sound buildings, may promote the development of decay conditions) and d) materials (some materials used in historic buildings are particularly susceptible to decay – BUT ONLY IF THE APPROPRIATE CONDITIONS DEVELOP). These factors, when associated with a general lack of awareness about how dry rot develops, seem to lead almost inevitably to the development of timber decay.

Conditions which favour the growth of the dry rot fungus are not those that we would wish to develop in our buildings. Indeed they are associated with bad human health as well as the development of dry rot, i.e. elevated moisture levels, lack of ventilation, and stagnant air. When these conditions occur within the 'lived-in' areas of a building we normally rectify them. When they occur under floorboards, in roof spaces or behind lath and plaster walls there is a tendency to ignore them, or at least not to seek them out. The result is often the development of dry rot. However a major theme of this TAN is that it is very rare for dry rot to develop in the total absence of indicative signs and, if the practitioner or owner is aware of the tell-tale signs and does something about them, serious problems can be avoided. And the problems caused by dry rot can certainly be very serious, and complete destruction of the timber elements of a building is a possibility. Whilst this can take years to develop, it can be stopped very quickly by the simple methods described in this TAN.

Because of the prevalence of timber decay in buildings, and particularly the potentially devastating effects of dry rot, the degradation of timber in buildings is often considered to be an inevitable process. To prevent this process conventionally requires drastic remedies associated with the use of fungitoxic chemicals and extensive rebuilding. This perception of timber decay in buildings has arisen in the UK for a large number of reasons, foremost amongst these is a desire to seek a permanent solution to the potential problems associated with timber decay. Coupled to this view is an industry standard that originally developed at a time when building managers and owners were facing substantial repair problems, i.e. after World War II, during a period when, of necessity, little attention was paid to the long term needs of both buildings and their occupants. Rapid solutions, which could be implemented quickly and which minimised the effects of inevitable (at the time) lapses in routine maintenance, were required.

In recent years this philosophy has been challenged from a number of viewpoints:-

a) It is now recognised that timber degradation in buildings is not an inevitability if building fabric is maintained in a sound and dry condition, and also that the decay of timber is invariably associated with elevated levels of moisture.

b) The most problematic fungus in buildings, the dry rot fungus *Serpula lacrymans*, is now recognised to be a rather sensitive organism with very little tolerance for unfavourable environmental conditions.

c) It is becoming obvious that decay of timber in buildings is an inevitability if moisture levels in timber become elevated: therefore the most appropriate way of preventing decay is to eliminate sources of moisture. Treating timber (and other building components) with potentially toxic agents that may reduce their susceptibility to decay is only a partial, and temporary, solution.

d) Both the general public, and practitioners alike, are starting to request more specific solutions to problems of timber decay, solutions that tackle the long-term issues of general decay problems and not ones which simply look at a particular incident and 'solve' it.

e) Both the public and practitioners have a growing awareness of the potential detrimental effects on the environment of treatment chemicals and their solvents. This has led to a desire to reduce the reliance on chemical-based treatments of dry rot.

These challenges have resulted in a change to the industry-standard proposed by the BWPDA (British Wood Preservers and Damp-Proofers Association) with a reduction on the reliance on chemical treatments. However a new set of companies has now developed whose strategy for dry rot control is centered around passive manipulation of the built environment with the use of chemicals treatments only being specified in highly specific circumstances. To understand the different philosophies of treatment being promoted it is necessary to have a holistic, 'knowledge-based' approach to dry rot and other timber problems of buildings.

The new companies offer 'environmental control' remedies to timber decay and, in particular the problem of dry rot (see Appendix G). These companies challenge the normal industry standard as promoted in the U.K. by the BWPDA, and it is timely now to evaluate the foundations of their claims. Despite the current interest in it, environmental control is not a new concept. It was first suggested over 60 years ago that the best way to prevent dry rot was to ensure that environmental conditions in a building remain unfavourable to the development of *S.lacrymans*. However this information became ignored (temporarily) as non-holistic, often chemically-based, approaches to the 'dry rot problem' developed.

This Technical Advice Note (TAN) aims to inform those responsible for the management of historic buildings of the reasons why timber problems develop; the questions that need to be asked of any prospective remedial treatment; the process to be instigated to prevent reoccurrence of problems in the future; and of the overriding importance of regular building maintenance. Most of the guidance offered in this TAN has been gleaned from research undertaken by the authors and from the extensive literature that has accumulated over the last century regarding dry rot. Additional information comes from a questionnaire-based survey undertaken by the team which analysed the knowledge base of practitioners involved in dry rot management and from discussions with practitioners in Scotland and beyond.

Primarily this TAN concerns itself with issues associated with dry rot and its causative organism, the fungus *S.lacrymans*. However the recommendations with regard to dry rot are in most cases also applicable to other types of fungal decay in buildings. Dry rot has the potential to be a particularly serious problem when conditions within poorly maintained buildings may become very similar to the natural environment of the causative organism. This, coupled with other features of *S.lacrymans* which will be described later, means that special care must be taken when dealing with outbreaks of dry rot. However the nature of this special care is no different from that needed to control or prevent other types of fungal infestation.

The principal message from this TAN is that prevention is better than cure. Some guidelines regarding prevention will be discussed and the authors are preparing a fully evaluated Risk Management procedure to assist in the prevention of dry rot. Further information may be available in due course.

2 TIMBER IN BUILDINGS

2.1. Introduction to the fungal life cycle

Fungi are ubiquitous organisms whose role in the Biosphere is to degrade and recycle living and dead organic matter e.g. via the carbon and nitrogen cycles. Without fungi our forest floors would be covered in undecayed leaves and fallen branches; in such an eventuality nutrients, specifically organic molecules, trace metals, nitrogenous compounds, etc., would not be returned to the soil for reuse by living trees and growth of trees and other plants would cease. So whilst fungi are often considered a nuisance, because of the degradative effects they can have on man-made products, their presence in the ecosystem is vital.

Fungi are dimorphous, or polymorphous, organisms. They can occur in more than one form. The basic building block is the fungal hypha. This is a cylindrical tube or filament that secretes enzymes (biological catalysts) and other chemically active compounds in order to digest the surrounding organic material, the products of which can be reabsorbed and utilised by the whole organism. Nutrients can be transported around the network of hyphae, that collectively form the mycelium, and mobilised by the fungus when needed. The function of the mycelium is essentially to explore for and accumulate nutrients to permit growth. Fungal mycelia sometimes grow and spread widely, for example the largest organisms known are mycelia of certain forest pathogens which may be kilometres in diameter – much larger, for example, than a blue whale. Eventually a fungus may run out of potential nutrients, or become stressed in some other way, which is when the organism may show its dimorphic nature by changing its form. A typical result of this would be the development of sexual structures known as fruiting bodies that produce spores. These spores can be transported by natural means (wind, water, etc.) to distant sites and initiate new infections. Fruiting bodies are probably the most well-recognised form of fungal growth and may be found in buildings where dry rot has developed; mushrooms and toadstools are the most familiar examples. Many other fungal forms are found, for example strands, which are built up from contiguous hyphae, as well as non-sexual sporulating structures. Each of these has a specific role to play in the life cycle and survival of an individual organism. The different growth forms that an individual fungus can display, directed by prevailing environmental conditions, allow arrival (spores, mycelium), exploitation (decay, by

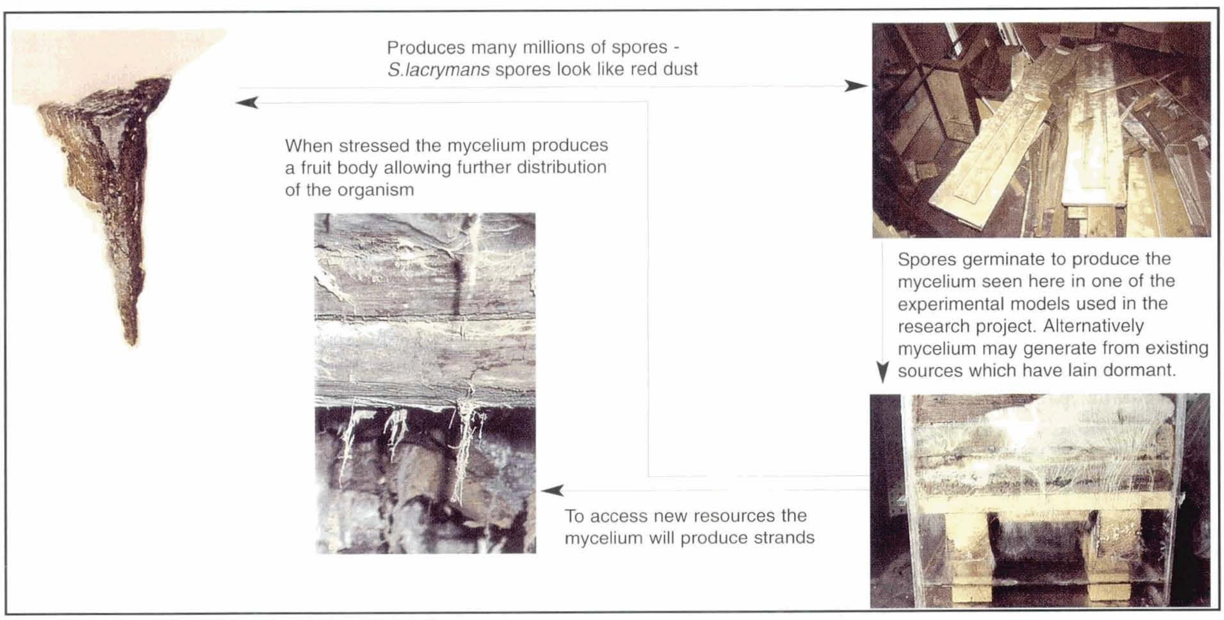

Illustration 1. The life cycle of the dry rot fungus
The three main stages in the life cycle of the dry rot fungus are illustrated in the diagram. Germination of a ***spore*** *results in the formation of an individual hypha which grows, divides and branches to form the* ***mycelium*** *of the organism. In order to improve communication over distances, and in particular to transport nutrients, individual hyhae may coalesce to produce strands. In times of environmental stress, for example lack of further nutrients or the introduction of ventilation, the mycelium may produce a* ***fruit body****, also known as a sporophore or basidocarp. The genesis of fruit bodies is by no means fully understood.*

mycelium), consolidation, exploration (rapid mycelial/ strand growth), survival (spores, mycelium) and exit (spores, mycelium). These different growth forms can even exist at the same time in different regions of the same individual mycelium.

There are many species of fungi found in buildings, the most damaging as far as timber decay is concerned are those of the subdivision Basidiomycotina known as the basidiomycetes. The most destructive of the basidiomycetes found in buildings is the dry rot fungus *S. lacrymans*. Why this organism is so destructive will be discussed later in this section.

2.2 Fungal degradation of wood

2.2.1 The microorganisms causing decay

Timber decay specialists recognise a number of different types of wood decay caused by microorganisms including soft rot, white rot and brown rot. Other types of decay, notably that caused by bacteria, occur to timber in wetter, harsher environments, such as in ground contact outdoors, but these are not a major problem in buildings. Soft rot, caused by a range of different fungi, is of limited importance to building conservationists as it only occurs in very special circumstances for example in water logged archaeological finds. So the building specialist need really only be concerned with white and brown rot. Both these types of rot are caused by basidiomycete fungi (so called because they produce their spores on a particular type of structure called a basidium – the fungal fruit body is essentially an enormous collection of basidia). White-rot may also be caused by ascomycete fungi (not discussed in this text). To understand the difference between white and brown rot a short description of the molecular structure of wood is required.

Table 1: Some basidiomycete fungi found in buildings

The most destructive type of fungi found in timber in buildings are those from the basidiomycete group. There are a number of such organisms and, in the context of buildings, they are divided into two groups, the dry rot fungi and wet rot fungi. The difference in these groups is really based on two things, a) dry rot fungi tend to grow on wood that has a lower moisture content and b) dry rot fungi are more persistent because they exist both in timber, which is relatively easy to dry out, and masonry, which is often much more difficult. The only dry rot fungus of significance to this TAN is ***S. lacrymans****, for a description of other organisms which can be considered in this group the reader is recommended to consult Bech-Andersen (1995) or Bravery et al (1992).*

Latin Name	Common Name/ type	Characteristics
Serpula lacrymans	The 'true' dry rot fungus (DR)	Rusty red fruit body Strands, brittle when dry White/grey mycelium with pink/lemon tinges
Coniophora puteana	Cellar fungus	Fruit body olive green/brown – rarely seen Strands, black or brown Cream/brown dark coloured mycelium
Coniophora marmorata	Cellar fungus	Similar to *C.puteana*
Poria spp	White Poypores	White/cream lumpy sheets or plates –many minute pores (hence the name) Thin strands, flexible when dry (c.f. dry rot) White or cream sheets or ferns
Phellinus contiguous	White rot	Rare/ ochre to dark brown with pores Strands do not occur Mycelium – brown tufts
Donkioporia expansa	White rot	Plate or bracket fruit body/ layers of pores/ light brown No strands/ yellow to red/brown mycelium with yellowish brown exudate Associated with death watch beetle
Pleurotus ostreatus	Oyster fungus	White mycelium/ no strands/ grey/fawn mushroom with white gills
Asterostroma spp.	White rot	Light coloured sheets of mycelium Thin/white/rough/flexible (when dry) strands Non-descript fruit body
Fibroporia vaillantii	'Mine' fungus	White mycelium which may resemble *S.lacrymans* Strands are NOT brittle when dry May overgrow masonry like *S.lacrymans*
Paxillus panuoides	Brown rot	Dirty yellow fan + yellow gills to fruit body Thin strands Soft/hairy/woolly dull yellow mycelium

2.2.2 The molecular structure of wood

Wood is composed of cells made up from a range of different types of molecule but there are three major types of polymeric macromolecule namely lignin, cellulose and hemicellulose. Lignins are amorphous, high molecular weight, highly branched polymers whose function is to provide rigidity to wood. They also provide wood with its durability since the complex lignin molecules are very difficult to degrade (e.g. there are at least 15 different types of chemical bond to be broken during decay). Cellulose, by contrast, has a relatively simple structure being composed of large regular polymers of glucose molecules linked by a single bond type. Cellulose molecules are arranged into microfibrils which are carefully orientated and give wood its high tensile strength. Cellulose is also the main constituent of other materials, such as paper and cotton, and is unfortunately rather susceptible to decay. Normally the cellulose in wood is surrounded by lignin, which reduces its accessibility to decay fungi and hence improves its durability. The third type of macromolecule, the hemicelluloses are a heterogeneous class of polymers containing a range of different sugar molecules in addition to chains of glucose molecules. The function of hemicelluloses is not fully understood though they may enhance the structural integrity of the cellulose and partially shield it from decay enzymes. The hemicelluloses are themselves susceptible to fungal degradation and indeed their destruction may be the first stage in the biodeterioration process. Essentially wood has been described as a 'series of holes surrounded by nutrients'. Whilst the nutrients themselves may require degradation before they can be utilised their metabolic value, particularly the value of the glucose component of cellulose, is very high. Access to these nutrients is via the 'holes' or vessels within the wood.

2.2.3 White and brown rots

White rot is caused by fungi which degrade all the macromolecules of wood, brown rot by fungi which do not degrade lignin. The residue left after the action of a brown rot fungus is a brown amorphous substance, rich in lignin, and which gives the rot its descriptive name. Whilst the lignin is not substantially degraded by a brown rot fungus, it is modified and this modification is probably necessary to allow access to the cellulose, the main nutrient of the brown rot fungus. In fact the first action of a brown rot fungus may well be lignin modification. Generally the main fungal decay problems found in buildings are caused by brown rot fungi though some white rot organisms, for example *Phellinus contiguous* and *Asterostroma* spp. do cause some more minor difficulties in buildings. A full description of all the types of fungal decay, and indeed fungi, found in buildings is well beyond the scope of this TAN and the interested reader is directed towards the excellent texts noted in the bibliography. The information given in Table 1 will act as an initial guide.

White and brown rots are themselves divided into wet and dry rots caused respectively by wet and dry rot fungi. Wet rot fungi contain both white and brown rotters, all dry rot fungi cause brown rot. There are a large number of wet rot organisms including *Coniphora putena*, *Fibroporia vaillantii* and *Paxillus panuoides*. The range of dry rot fungi is more limited and includes *S. lacrymans*, *Serpula himantioides* and *Leuocogyrophana pinastri*. Of these by far the most important in buildings is *S. lacrymans* which is often called, in the remedial treatment trade, the 'true dry rot fungus', or more simply the 'dry rot fungus'. Indeed, in any but the most technical of publications, it is normally safe to assume that the phrase 'dry rot' refers simply to the decay caused by *S.lacrymans*. The nomenclature here, as in many areas of mycology, can be obscure and it is recommended that to avoid any ambiguity the latin name of *S.lacrymans* should be used when referring to the dry rot fungus. The actual difference between the wet and dry rot fungus relates to two aspects of the organisms, first the dry rot fungi tend to decay wood at lower moisture contents than the wet rot organisms and second the wood tends to be left in a dry state after attack by a dry rot fungus. In addition the dry rot fungi can, to a limited extent, transport water from once source to another and because of this, once established, *S.lacrymans*, tends to be persistent and spread.

However, it must be understood that to initiate decay both types of organism require wood containing more moisture than would be normal in a well designed and maintained building. It will be emphasised throughout this TAN that:

- **wood with a normal moisture content (i.e. a moisture content not elevated by incoming rain water, leaky pipes or excessive condensation) will not be attacked by either a wet or dry rot fungus and**
- **in a well managed building dry rot should never occur, problems start when management of a building is faulty.**

Factors which allow the development of dry rot are detailed in Table 2.

Table 2 Factors controlling the development and growth of the dry rot fungus in buildings

Factor	Ideal for the fungus	Prevention
Water source	Ingress of water from external environment, internal pipes, condensation	Good building maintenance, regular inspections, adequate ventilation
Wood moisture content	If greater than 20% timbers are at risk, if greater than 60% timbers likely to be safe from dry rot but not from other degradative organisms	Keep wood moisture levels below 20% - this should not be an issue in well maintained buildings
Masonry moisture content	An issue if timber penetrates damp masonry	Prevent direct contact between timber and damp masonry
Humidity	RH greater than 90%	Do not allow high humidity to develop
Air movement	Stagnant air	Effective draughts in wall cavities, etc
Building management	Ineffective	Effective – the dry rot fungus should not occur in well-managed buildings
Temperature	Constant temperature – 4-24°C	High temperatures (>24°C) will kill the fungus

The factors controlling the development and growth of the dry rot fungus are detailed in Table 2. Each of these factors will be discussed in further detail in other sections of this TAN together with information on how to avoid those factors that result in the development of optimal growth conditions for the fungus.

2.3 *Serpula lacrymans,* the causative organism of dry rot

The history of *S.lacrymans* in buildings goes back many centuries. It first became recognised as of economic importance in the UK in the 17th Century when ships of the Royal Navy were decomposing faster than they could be built, culminating in the case of the Queen Charlotte, launched in 1810, which cost far more to repair in 1812 than she had to build two years before. The damage to the ship was almost certainly caused by *S.lacrymans*. The causative organism of these early attacks is sometimes recorded as *Boletus lacrymans* though by the 18th Century the organism had been more formally named as *Serpula lacrymans*. For a few years the name *Merulius lacrymans* was used but in recent decades a return to name *Serpula lacrymans* has occurred. It seems probable that the name of the organism will not change again in the future, however the reader is advised to be aware that name changes could occur.

Now *S.lacrymans* has developed an unenviable reputation as the cause of one of the most expensive and destructive problems associated with timber in buildings. To understand why the organism can cause such destruction it is necessary to understand a little about the physiology of the organism and about its natural environment.

2.3.1 The physiology of S.lacrymans

The dry rot fungus is a typical basidiomycete organism which exhibits a number of morphs (see Illustration 1), viz. **hyphae** which together form the fungal **mycelium,** a well developed system for the formation of strands (which the organism uses to transport moisture and nutrients from one site to another as well as for internal communications within the organism), **fruit bodies** which may vary in size from a few centimetres to one or two metres in diameter and **spores** which are about 5x10 µm in size. Contrary to popular belief, the problem stage as far as the property manager is concerned is the mycelial stage. At this point the organism is actively decaying timber and seeking out new sources of nutrient/ moisture. At some point, perhaps because of stress (e.g. through repair to a building and a change of environment or because there is no further timber to degrade) or perhaps because sufficient biomass has developed the fungus seeks to transfer itself to a new site. This process is usually achieved by the formation of a fruiting body that produces and disperses spores. The number of spores produced runs into billions and consequently there are undoubtedly some spores in the air that we breathe all the time. Trying to avoid infection of wood by any means other than preventing the development of the environmental conditions which would allow spore germination to occur is therefore certain to fail.

2.3.2 Conditions for the germination and growth of S.lacrymans in buildings

Decay caused by *S.lacrymans* will be initiated either by the activation of mycelium or from the germination of a spore. The exact conditions in buildings required for successful spore germination have not been fully evaluated; however a source of free moisture is undoubtedly essential, as is the correct pH (acidic), temperature and relative humidity (RH). Spore germination is probably a rather infrequent event, which is just as well given the huge numbers of spores that any one fruit body may produce. Germination of spores produces a rapidly developing mycelial mass which itself produces a range of enzymes and other

Table 3 Determining if the dry rot fungus is alive or dead

Features of a Dry Rot attack	Viability
Mycelium fluffy and 'cotton wool-like'	Organism is certainly alive
Mycelium flat and grey and looking like sheets of thin material	Organism is probably no longer actively growing
Mycelium dark yellow/ brown	Organism is dying or dead.
Does the outbreak smell of 'mushrooms'?	At least part of an outbreak may be alive
Area of attack associated with elevated moisture levels and stagnant air	If the answer to both of these is no then the organism is almost certainly not active.

reactive chemicals. These modify lignin and degrade cellulose and hemicelluloses initiating the decomposition of wood.

During this process excessive acid is produced and the non-woody components of buildings, notably masonry and plaster, produce an ideal mechanism for neutralisation. As might be expected, dry rot is less of a problem in buildings made solely, or largely, of wood. However changing the material within such buildings can cause difficulties as was found in the 1980s when the addition of 'mineral wool' insulation to buildings in Scandinavia resulted in various outbreaks of dry rot. As might be expected dry rot is rare in wooden ships, the problems of the early British Navy may well have been caused by the use of lime as ballast.

2.3.3 Identification of dry rot and determination of viability

Identification of the dry rot fungus on site is relatively easy though a detailed description of methodology used is not within the scope of this TAN. For further information the reader is referred to the excellent text '*Recognising wood rot and insect damage in buildings*' by Bravery, Berry, Carey and Cooper (published by the Building Research Establishment (1992) – ISBN 0 85125 535 3). This text includes a series of flow diagrams which can be used to identify a wide range of wood decay fungi including *S.lacrymans*. Disputes regarding identification do occur from time to time and these can be readily resolved either by microscopy or by modern molecular methods.

The salient identification features for *S.lacrymans* are shown in Table 1. However, the visual appearance of fungi is not static and the white fluffy nature of *S.lacrymans*, as typically seen when the organism grows under laboratory conditions, is soon modified in buildings by tinges of salmon-pink, lilac and or lemon yellow. The pink/ lilac colour is probably caused by the accumulation of transition element metal ions, the mechanism of the yellowing is unknown but it represents a stress defence mechanism which indicates that optimal growth conditions no longer exist for the fungus. As the fungus becomes more stressed its colour may change from lemon yellow to brown and grey as melanins are produced. At this stage the organism will no longer be viable and indeed, in the laboratory, viability can be estimated by colour change. This is, however, unlikely to be a sufficiently robust measurement to be used in the field but colour changes can indicate that control methods are working.

Illustration 2. Lush growth at a wood/ masonry interface Unlike most other wood decay fungi found in buildings the dry rot fungus has an absolute requirement for both nutrients from the wood and metal ions extracted from masonry (see Appendix F – Bibliography). Because of this the organism grows in a particularly luxuriant way around wood/ masonry interfaces. This is particularly well seen at the rear of lath and plaster or walls and ceilings.

Determining whether or not an outbreak of dry rot is alive can be difficult. Salient observations are shown in Table 3.

Despite these indications determining if dry rot is dead or alive is an imprecise business though diagnostic tests may become available in the next few years based on ATP or ergosterol measurements (both of these substances are transiently produced by live fungi), dye discolouration tests or electronic noses which can detect specific fungal volatiles. Trained dogs (as used by Hutton and Rostron Environmental Investigations Ltd and in Denmark) can give guidance, also by detecting fungal volatiles, but their reactions need to be evaluated by trained handlers. Of course, whether or not an outbreak is still alive is irrelevant if the conditions which support growth remain. In such conditions it will just be a question of time before an active growth of the dry rot fungus is initiated either from extant live material or from a new source.

Of course development of the fungus will not happen in timber of low moisture content unless moisture can be transported to it. It is generally considered - though difficult to measure precisely - that moisture levels in wood need to be over 20% (weight for weight) before dry rot can develop from mycelial inocula and 30% from spore inocula. This is not much higher than the moisture level found in seasoned wood (around 12-16%) but nevertheless it is a level that should not occur in a well maintained building. At low moisture levels, water in wood is intimately associated with wood fibres. As moisture levels increase above 20% enough water is available in the woody cell wall to allow degradative enzymes to operate and above around 25% moisture levels 'free' water is present. The point at which free water becomes available is termed the 'fibre saturation point' and it varies slightly from timber to timber. It is as well to be aware that, for the purposes of evaluation of risk of timber decay in buildings, precise moisture measurements in wood are of less importance than changes and trends within buildings. However any wood which contains moisture levels above the fibre saturation point is definitely at-risk

2.3.4 The natural environment of S.lacrymans

Dry rot caused by *S.lacrymans* is found throughout the UK, in most of Northern and Central Europe and in temperate sites in southern Europe, in parts of Asia and Australasia but rarely in the Americas. However *S.lacrymans*, is found only within buildings in almost all of these regions and substantiated reports of its growth in the 'wild' (i.e. the external environment) are rare. Strangely perhaps, given its rampant nature in buildings, the organism seems rather innocuous in its natural environment suggesting there may be unidentified factors limiting its growth in nature. One such factor could be the presence of competing microorganisms, another could be the relative environmental sensitivity of *S.lacrymans*.

Illustration 3. The Himalayan environment
*The natural habitat of the dry rot fungus appears to be the foothills of the Himalayas. Finds have been made by the group at the University of Abertay Dundee in conjunction with Dr Jagjit Singh, then of H&REI in the vicinity of Narkanda in Himachal Pradesh (India). Understanding the natural environment of the organism, and why this is so restricted, will assist in the development of new environmental protocols for controlling, and preventing, the growth of **S.lacrymans** in buildings.*

Illustration 4. Surface coatings may mask the destruction of wood Trying to discover dry rot attacks by looking for decayed wood is an inappropriate strategy as the attack will often not appear on the visible surface of wood. In the case shown severe decay has developed under what was, until recently, an intact paint surface. The cracking across the grain is well illustrated.

Illustrations 5 a) and b). The appearance of wood after dry rot attack
The final stages of a dry rot attack are typified by the appearance of cuboidal cracking, both along and across the grain. In addition the wood develops a uniform brown character and a friable texture. Often the wood may be dry to the touch, however during active decay the wood will have had an elevated moisture level.

Illustration 6. Growth of the dry rot fungus around a metal object
The dry rot fungus is often found in association with metal objects. There are probably two reasons for this, i) the fungus requires ferrous ions to decay wood and ii) condensation occurring around the metal object will assist in the wood decay process.

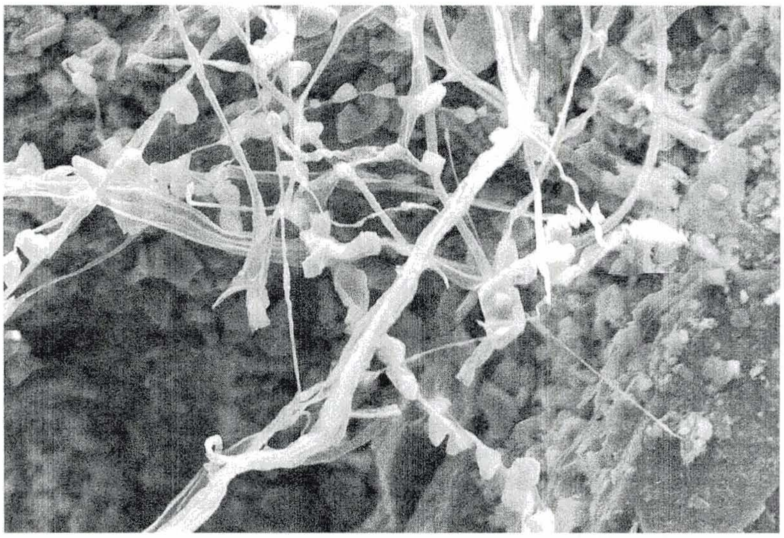

Illustration 7. Photomicrograph of the dry rot fungus growing on sandstone
Mycelium of the dry rot fungus are seen to be coated with crystals which are composed of calcium oxalate. The fungus extracts calcium from the surface of the sandstone, but in such minute amounts that the integrity of the stone does not appear to be compromised. The study illustrated in this Figure was, undertaken with the assistance of Dr Maureen Young of the Masonry Conservation Research Group at The Robert Gordon University, Aberdeen.

There is no doubt that there is a strong similarity between the natural environment of the dry rot fungus (on shaded, damp coniferous timber), and the environment that CAN develop within our buildings. However it is the presence of moisture that is the crucial element in the development of dry rot.

Without elevated moisture levels the environment within buildings is very unfavourable for the growth of the organism.

2.3.5 Examples of damage caused by S.lacrymans

As detailed above the dry rot fungus reduces wood to a brown residual amorphous mass which contains mainly modified lignin. Unlike the damage caused by wet rot organisms, the surface of wood is decayed as well as the interior; in addition distinctive cracking across the grain develops (cuboidal cracking). The identification of rot causative organisms by the appearance of degraded wood can be difficult and the reader is referred to specific texts produced to aid in identification. A glossary of terms associated with dry rot is given in Appendix E.

3 CONTROL OF *SERPULA LACRYMANS* IN BUILDINGS

3.1 Introduction

With a knowledge of the growth requirements of *S.lacrymans* it should be obvious that the dry rot fungus should not prosper in the environment within buildings. That it does is testament to the problems that can develop in buildings due to defective maintenance or inappropriate use. The most common method for treating dry rot over the past few decades has concentrated on removing the fungus, and any infected wood, and producing a chemical environment toxic to the organism. However *S.lacrymans*, like all other organisms, is sensitive to its environment and it should be possible to disable the organism by more simple environmental manipulation (environmental treatment/ control). Despite the popularity of chemical treatment based systems, studies on environmental control of *S.lacrymans* were relatively well advanced before World War II. Subsequent to this remedial treatment and control became the preserve of chemically-based methodologies. Such methods became the 'conventional' treatment method for dry rot. This chapter looks at a range of methods for the control of the dry rot fungus as well as reporting on experimental evidence and observations on the effectiveness of environmental control.

3.2 Conventional treatment of dry rot

In the UK around 40% (by value) of remedial treatments for dry rot are carried out by members of the trade organisation, the BWPDA or British Wood Preserving and Damp-Proofing Association. It is probable that the majority of treatments (by number) are carried out by small companies with no specific allegiance to BWPDA but who may use some, or all, of the BWPDA approved techniques. The BWPDA produces a Code of Practice for remedial treatment of dry rot which suggests practices should be used as the basis for satisfactory treatments. There is no doubt that the Code of Practice is successful; however a number of aspects of the work of remedial companies may cause problems and these can be listed as:

a) the difficulties of undertaking complete surveys of buildings, particularly complex historic buildings, to ensure that all causes of dry rot outbreaks are fully identified,

b) the use of chemical preservatives to try to ensure that fungi do not regrow and

c) the policy, of some companies, of removing sound timber up to 1 metre away from a decay site on the grounds that it may contain live fungus.

It is of great significance that the BWPDA states at the outset of its guide to treatment of fungal decay that:

"All active fungal attacks result from the presence of excess moisture in a building and the identification and rectification of the cause of this dampness and drying out of existing dampness must be regarded as the fundamental part of a successful overall treatment."

Illustration 8. Conventional dry rot treatment
Conventional dry rot treatments may be very destructive and are not appropriate for the types of repair required in historic buildings or buildings with historic interiors. In this illustration the loss of original fabric is well seen. Note also the 'cutting back' of plaster by at least 1 metre on the party wall and loss of the decorative cornice .

3.3 Introduction to environmental control

In the last decade a small number of companies have developed a philosophy which does not advocate the use of chemicals in the treatment of dry rot. These companies are effectively supporting the BWPDA statement in section 3.2 and using it as a basis, not just for prevention of dry rot, but also for its treatment. This type of treatment has led to the introduction of the term '*environmental control*'. One of the major objectives of this TAN is to promote environmental control methods that are effective in the treatment of dry rot, founded on a large body of experimental work and practical experience. In addition, the TAN is designed to inform readers about the true nature of the dry rot fungus. With this knowledge practitioners will be able to make effective evaluations of potential treatment methodologies and not be forced, whether by ignorance or panic, to opt for any particular type of treatment. In this way it is hoped that best practice in the treatment scenario can be improved, thus preserving historic fabric and reducing the loads of anti-fungal chemicals in buildings.

Environmental control can be defined as: "the exploitation of the environmental sensitivity of the dry rot fungus for its treatment" – both for preventative and remedial purposes. The justification for such an approach depends upon a number of beliefs and observations such as:

- the causative organism of dry rot, *S.lacrymans*, is, like any other organism, sensitive to its environment
- the environment within buildings is not necessarily a suitable environment in which the organism can flourish
- the reasons why dry rot occurs in buildings are related to elevated moisture and humidity levels, and
- the conditions which allow the development of dry rot normally occur because of poor building management or inappropriate design or use.

Environmental control companies therefore base their methodologies on precise identification of moisture sources, the introduction of conditions in buildings which will not allow growth of dry rot, and the adoption of rigorous maintenance schedules. Whilst there can be little doubt that prevention of dry rot can be achieved by these methods, these alone, may not be adequate as a remedial treatment. In order to determine the potential effectiveness of such methods the environmental sensitivity of actively-growing *S.lacrymans* needs to be determined, as does its ability to regrow in environmentally-treated environments following failure of maintenance practices.

In summary:

- The strategy used by *Traditional Remedial companies* assumes that dry rot will develop in buildings, so the companies attempt to produce a metabolically-toxic environment which does not allow the fungus to grow: – **chemical control**
- The strategy used by the new *Environmental Treatment companies* acknowledges that dry rot is not inevitable in buildings, and uses a variety of simple physical procedures designed to prevent the fungus from growing:– **environmental control**

3.4 The scientific and physiological basis of environmental control

Are the fundamentals of environmental control correct? Certainly *S.lacrymans* is sensitive to its environment and it can be inactivated in the laboratory by air drying, removal of moisture, removal of nutrients and by reduced, or particularly by elevated, temperatures. Indeed the last of these, temperature control, has been used in Denmark as a method for treatment of dry rot, though its application has been infrequent. The optimal temperature for growth of *S.lacrymans* is about 22°C, however it is rapidly inactivated, and indeed killed, by temperatures only a little in excess of this. Heating whole buildings to temperatures of 40-50°C can therefore be an effective method for inactivating the organism. Fungal spores are not so sensitive and, since they are everywhere, heat treatment can only ever be successful if associated with control methods designed to remove excess moisture.

Removal of nutrients can be mimicked in the timber of buildings by the addition of boron-based preservatives to wood, as these appear to inhibit digestion of wood macromolecules. This is in marked contrast to most wood preservatives which actively poison the degrading organisms rather than just starving them.

In fact, as will be seen from this TAN, *S.lacrymans* turns out to be rather more sensitive to its environment than a number of other wood decay fungi. Despite this finding *S.lacrymans* has developed a reputation as being very difficult to eradicate and highly persistent. This reputation has developed because of the unique ability of the dry rot fungus to spread throughout the affected building. Indeed a single outbreak of *S.lacrymans* can, in time, degrade many of the internal wooden components of a building environmental conditions permitting. Wet rots are much more restricted in their activities and hence easier to treat. The spreading property of *S.lacrymans*, whilst intensely annoying to the building manager, is in fact common in fungi.

3.5 Perceptions and myths

Why does *S.lacrymans* have such a notoriety? Why is its remedial treatment much more stringent than that of the other wood decay fungi? In addition, why is it able to cause so much damage before it is discovered? There are many answers to these questions but amongst them must be that:

- lack of understanding of dry rot resulting in an undeserved fear of the organism
- if left unattended there is no doubt the dry rot fungus can do major damage to buildings because of its ability to translocate moisture and nutrients which allow it to explore unfavourable substrates with a view to locating further nutrients
- because it grows in non-woody materials, e.g. rubble walls, removing the timber from a decaying environment will not automatically remove the fungal mycelium, and new timbers can be at risk
- typically *S.lacrymans* grows in hidden areas of buildings, under floors, in roof spaces, behind lath and plaster walls so its effects are often not seen until it has done its damage –and, finally,

• the fear of the organism makes individuals irrational regarding its management, and instead of solving potential problems at an early stage they may be left to become worse – i.e. until overt damage has been done by which time decay will often be extensive.

3.6 The fundamentals of an environmental control process

To an extent, any method for controlling dry rot other than simply removing the organism relies on environmental control. Chemical treatment produces an unfavourable environment by introducing overt toxins which either kill the dry rot fungus (fungitoxic chemicals, e.g. creosote or copper/ chrome/ arsenic) or starve it (fungistatic chemicals, e.g. boron based preservatives). An alternative system termed 'Biological control' alters the biological environment within which the dry rot fungus is growing – like using ladybirds to kill greenfly. However, 'Environmental' control concentrates on two specific natural control parameters, namely the availability of free water and of high humidity levels. By preventing the former and reducing the latter, environmental control aims to prevent growth of, and if already present kill, the dry rot fungus. In its 'purest' form environmental control, or 'passive control' would not introduce any external controls to the environment within buildings other than those that are based upon moisture and humidity manipulation. Is this a realistic proposition?

The Historic Scotland/ University of Abertay Dundee research partnership, which produced the background data for this TAN, was designed to answer this question by the development of suitable experimental procedures. Other answers to the question will come from practitioners in the field. The evidence in this TAN, and in the associated research report, is designed to allow better assessment, by the reader, of the claims of the various types of remedial treatment companies. The underlying strategy for environmental control is detailed in Illustration 9.

3.7 Research results and the practitioner

Confirmation of the effectiveness of environmental control of dry rot comes from observation of buildings that have been treated in this way, for example the Case Study on Keith Hall, Aberdeenshire (Appendix A) and other practical experience. Experimental observations on environmental control were undertaken on models of parts of buildings kept in a carefully controlled environment. The details of the models, and the data from them can be found in the associated Historic Scotland Research Report. Many of the observations from these models are of relevance to the practitioner as they are observations that are also found in buildings. For example:

- environmental control should cause rapid changes in the morphology of the dry rot fungus. Areas of a building where environmental changes are not induced can be expected to retain actively growing *S.lacrymans* if conditions are otherwise appropriate,
- the dry rot fungus is not just found in contact with wood,
- the dry rot fungus can appear in many different forms,
- look for dampness when surveying for dry rot, shriveled and discoloured mycelium is unlikely to be active,
- expect the masonry parts of buildings to dry slowly, and allow for this in the specification of the repair,
- deafening material within floors can affect decay, the most important parameter being the size of particles, and its water holding capacity,
- all potential water 'reservoirs' need to be carefully removed to fully control the dry rot fungus,
- fruit bodies indicate stressful environments but this may only be because all available wood macromolecules have been metabolised,
- wood must not be placed in intimate contact with damp masonry unless precautions are taken,
- great care must be taken when placing moisture probes in buildings – the causes of dry rot are often much easier to spot than the rot itself, and
- replace moisture sensors if they remain damp for extended periods (over 1 month).

With regard to the environmental treatment of dry rot the results of the research study indicate the following:

- reduction of humidity in buildings, by the opening up of airways, can rapidly reduce the ability of the dry rot fungus to grow and degrade timber,
- timber within infected walls is probably still subject to decay, though this would be limited to those areas of the timber in intimate contact with the wall,
- the introduction of new wood into walls will result in decay if the moisture from the wall is able to enter the wood and the wood is not chemically protected in any way. Putting new timber next to old, partially decayed material will not cause problems if ventilation is maintained,
- areas of buildings where ideal conditions for dry rot development exist will support the growth of *S.lacrymans*, even if connected portions of the fungus are being severely stressed elsewhere
- walls tend to retain higher moisture levels than timber, though increases in moisture levels in walls do not necessarily lead to rapid, spontaneous development. However growth of the dry rot fungus will occur eventually, and
- the design of moisture sensors is important and they must be replaced if moisture levels within the surrounding building materials are allowed to obtain at high levels for extended periods.

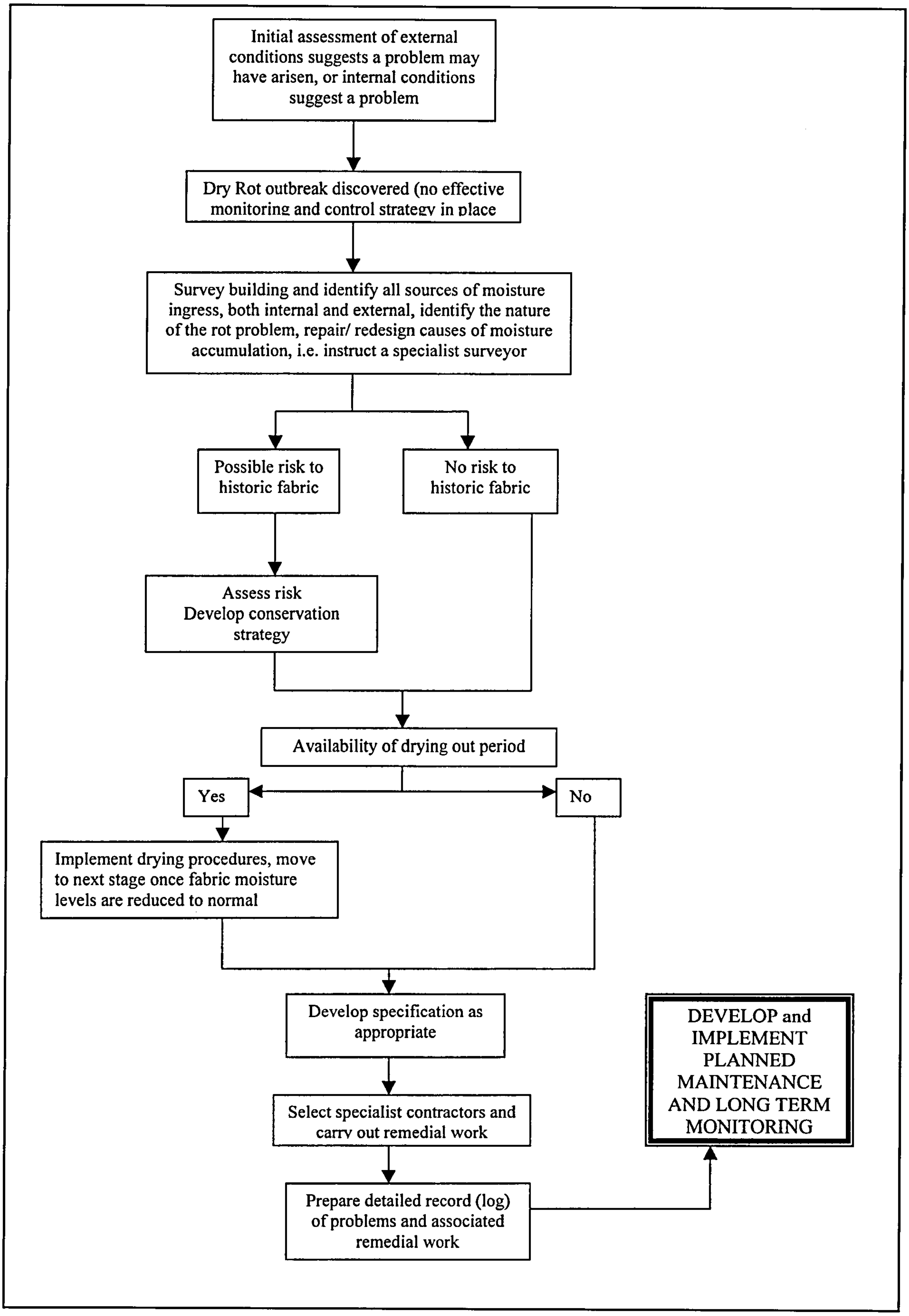

Illustration 9. The strategy of environmental control

4 ELEVATED TIMBER MOISTURE LEVELS: THE CAUSE OF DRY ROT

4.1 Introduction

Having understood something of the nature of the causative fungus of dry rot and its environmental control it is now time to turn the attention of this Technical Advice Note to building management and, in particular, the prevention and treatment of dry rot within buildings. Whatever the specific causes of an outbreak of dry rot in a building the basic requirement is elevated levels of moisture in timber components. Without this there is no risk of dry rot. What is more, the occurrence of elevated moisture levels in building components should not happen, and when it does happen it is almost always accompanied by tell-tale signs. Signs, which if interpreted correctly by the practitioner, will normally allow prevention of dry rot outbreaks and, failing this, will certainly reduce the impact caused by the dry rot fungus.

There is a great temptation by some remedial treatment companies and building owners/ managers to treat the symptoms of dry rot rather than trying to understand, and rectify, the building defects that have allowed moisture levels in timber to increase. It is a crucial tenet of the environmental, holistic approach to dry rot management that all moisture sources in a building should be identified.

So what are the main reasons for elevated moisture levels in buildings and what are the potential sources of moisture and what are the common defects in buildings which allow moisture levels in timber to rise? Essentially there are three main reasons why moisture levels increase:-

- defective rain water handling (including transfer of water from ground sources to the building fabric)
- defective plumbing
- condensation.

The most significant of these is the first and most of this chapter concentrates on defective rain water discharge systems.

4.2 Moisture in buildings

Whilst this Technical Advice Note is concerned with dry rot it should be recognised that all the sources of moisture identified here will be equally capable of providing sufficient moisture to promote the development of a range of wet rots such as cellar rot (*C. puteana*) and mine fungus (*F. vaillantii* also known as *Antrodia vaillantii*).

As the prerequisite for the dry rot fungus to become established in a building is for the timber to have a moisture content in excess of 20%, it must be therefore the case that a defect, or defects, will be present in the building if dry rot develops. Such defects may occur in the building fabric, in the drainage system (rainwater or soil and wastewater disposal), water supply and water-using appliances or in the relationship of the ground floor level to the external ground. These defects may arise as a result of poor design of building detail, poor quality construction or inadequate building maintenance. Where defective construction allows water to come into contact with timber, the maintenance of a high timber moisture content is encouraged when there is a lack of air movement around the affected timber as a result of inadequate ventilation. The relationship between building design, maintenance and ventilation is explored in Illustration 10 which attempts to assess the factors responsible for high moisture contents in timber.

In some instances the source of moisture within a building may be apparent immediately and can be rectified easily. However, in many cases the identification of the cause of high moisture content of timber may be rather more complex due to the interaction of a number of factors. To identify correctly the sources of dampness requires a good understanding of building construction and building pathology. This, in turn, means the ability to assess critically and holistically the mechanisms and effects of water penetration into the fabric of a building. It also requires experience and understanding of the performance of critical building details and materials over a period of time so that change in performance can be identified and remedial action taken.

The primary cause of a building failure that permits moisture access to timber is essentially a failure of specification or construction during building, or of maintenance of the fabric in a sound condition throughout the life of the building. In the case of design and construction, this may be because of a lack of knowledge and understanding of the principles of construction or a lack of skill or care during the original construction. In the case of poor maintenance, the potential for human failure is more acute and a lack

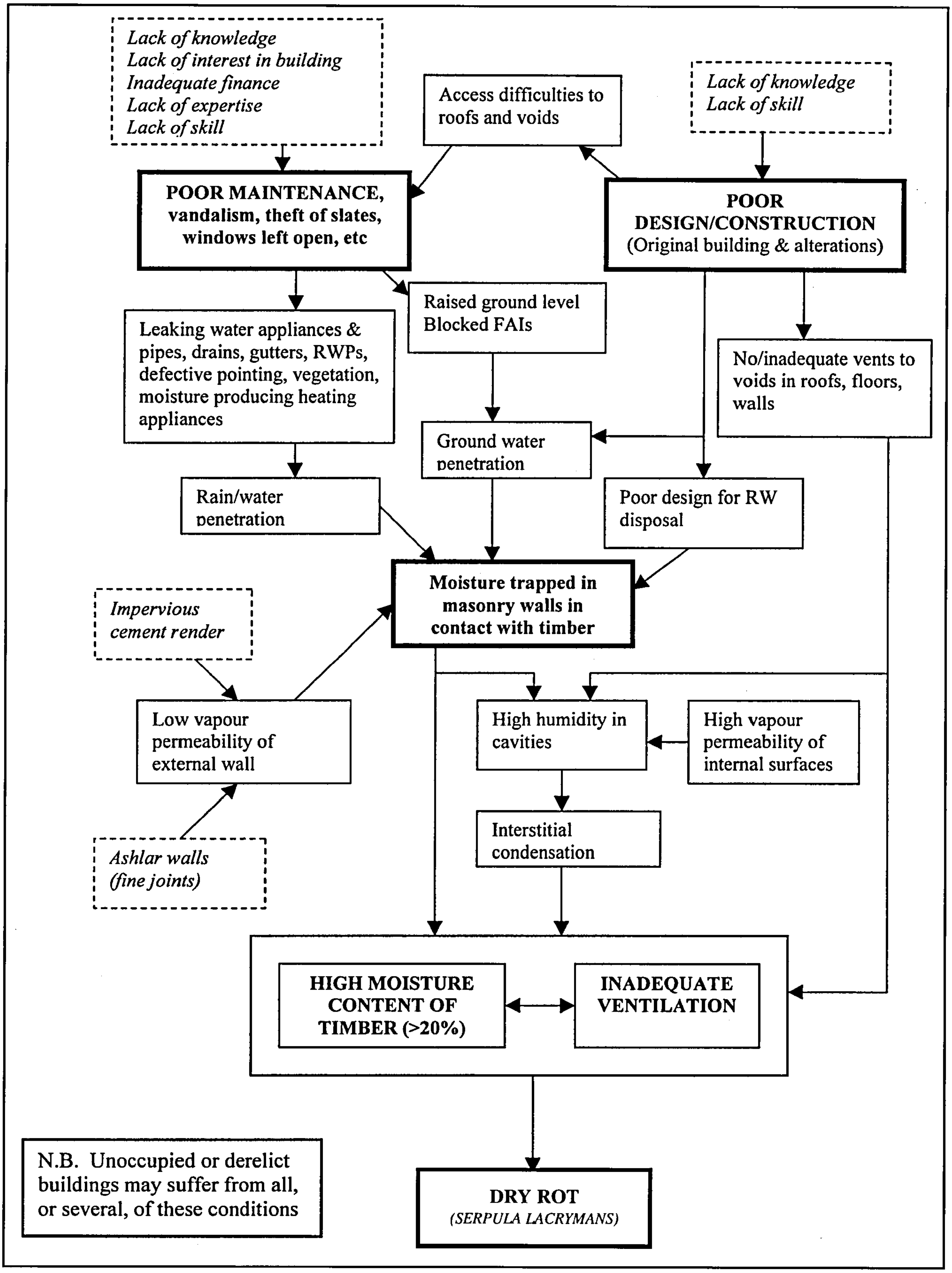

Illustration 10. Analysis of sources of high moisture content in timber.

of knowledge and understanding of building detail may be compounded by a lack of appreciation of traditional forms of construction materials and methods on the part of both building professionals and maintenance trades-people. Improving the knowledge base of building owners will also help to prevent difficulties. Difficulties can arise due to a failure to understand building maintenance requirements. A better understanding of these needs will encourage owners to identify problem areas whilst repair bills are still minimal. The form of some leaseholds may also be a contributory factor. For example, where a building is leased on the basis of repairs being undertaken by the leaseholder there is usually little incentive for the leaseholder to ensure that the building is being properly maintained externally. Finally a general lack of knowledge and understanding of the dry rot fungus, *S.lacrymans*, compounds all these other issues.

Early detection of points of water ingress into a property, or of excessive condensation, is thus the single most important factor in any dry rot prevention strategy. However, for detection to occur there must be regular and competent inspection of the building to identify, as early as possible, any changes to the building fabric. Fortunately, unless there has been a sudden and catastrophic failure due to a storm, for example, most building defects develop relatively slowly over a period of months or years and an informed inspection can detect an emerging problem, which can then be monitored. Annual or biannual inspections of critical areas are normally adequate for most situations.

4.3 Sources of moisture

As the potential routes of water penetration into a building are numerous, and many are also building-specific, this Note will not attempt to provide information on all possible sources but will focus rather on a limited number of typical potential problem areas associated with Scottish traditional buildings. An analysis of these problems will provide the reader with the ability to assess the evidence available on particular buildings so that appropriate remedial action can be implemented. It was identified in Chapter 2 that the need for a source of calcium for the growth of the dry rot fungus, usually from lime or cement mortar, means that the dry rot outbreak in a property will normally occur where the timber is adjoining such a source. It is for this reason that the genesis of a dry rot attack will often be in timber in the vicinity of a masonry wall or concrete floor. This, in turn, means that wall-roof and wall-floor junctions are particularly vulnerable to moisture penetration and thus to dry rot attack. A factor to bear in mind when analysing a dry rot attack is that, in a poorly maintained building, there is likely to be more than one site of water penetration which will mean that dry rot outbreaks may be located at a number of points within the building. All points of water ingress must therefore be investigated and rectified.

In addition to identifying the initial source or sources of water ingress, it is important to understand the processes by which water can move through the building fabric from the initial ingress point. In addition to vertical and horizontal movement on wall surfaces, moisture will move down and through a porous wall by both gravitational and capillary forces. Any impervious surface which impedes the downward movement of water, for example a granite lintol, will encourage a build-up of moisture in the wall at that point and may therefore cause an increase in the moisture content of timber joists, beams, dooks, grounds and other timber in contact with the wall. An assessment of the likely spread of moisture on and within a masonry wall will provide valuable evidence to help identify possible sites of dry rot attack.

Traditional masonry wall construction in Scotland, whether ashlar or rubble build, will be of substantial thickness and will have a core composed of smaller filler stones with comparatively large volumes of lime mortar or clay binding the stones. It is also possible that quite large voids will be present. Diagrams of typical wall constructions are shown in Illustrations 11, 13, 14, 18 and 21. Each of these constructions has the potential to retain large volumes of moisture within the core area, with a comparatively slow rate of evaporation due to the moist Scottish climate. The degree of permeability of the external surface will have a significant impact on the rate of evaporation. A wall rendered with a dense cement mortar, or constructed of granite ashlar with fine joints, will be highly impermeable and therefore tend to trap moisture within the core.

In addition to the penetration of rain and ground water into the fabric of the building, the effect of water vapour generated within the building can be an important factor in raising the moisture content of timber. In this case, it is the effect of water vapour moving into the construction, because of a vapour pressure differential, and condensing on surfaces within the wall or roof that are below dew point temperature, which is the most significant feature. This phenomenon creates the effect known as interstitial condensation. In the context of dry rot, metal-covered roofs, and basements, can be particularly vulnerable locations.

4.3.1 Defective roof drainage

The features of a building that are responsible for the majority of dry rot attacks are those associated with the collection and disposal of rainwater, especially the roof drainage arrangements. When assessing the potential risk of a dry rot attack associated with roof drainage, it is perhaps worthwhile to consider the concept of risk in this context. Risk is defined as:

Risk = Hazard Frequency x Hazard Consequence

Hazard Frequency is related to the incidence of water penetration, which is a function of numerous features including:

- overall roof design and degree of complexity,
- design and detail of rainwater disposal arrangements,
- selection of materials for components (risk of corrosion, thermal movement characteristics),
- adequacy or otherwise of roof maintenance,
- suitability of replacement materials and details, and
- standard of workmanship achieved.

Hazard Consequence is the repercussion of the hazard that results in a moisture content of timber raised above the critical threshold level. The ultimate hazard consequence is the destruction of timber by the dry rot fungus.

From the above, and as a general rule, the more complex the roof form the higher the risk of water penetration and therefore of the occurrence of dry rot. Unfortunately, the limits of the available technologies and of architectural design mean that many larger historic buildings have roofs that are complex due to the limited spanning capabilities of the roof forms used. In addition, modifications and extensions to historic properties are common and often further complicate the roof form. Inevitably, the result is the introduction of features that can increase risk, particularly when design or maintenance are inadequate. Typical features are:

- valley gutters,
- parapet gutters,
- large roof areas draining to small drainage hoppers and eaves gutters,
- large roof areas draining to small flat roofs (especially those with a perimeter parapet wall)
- raised skews,
- slated or tiled roofs with low pitches,
- internal rain water pipes contained within ducts (or otherwise hidden), and
- sheet-metal covered roofs (flat and pitched) and related interstitial condensation.

The following examples and illustrations attempt to analyse the mechanisms of water penetration and movement at selected details.

4.3.1.1 Parapet gutters

Illustrations 11 and 12 show a typical example of a parapet gutter situation that resulted in a dry rot attack. The points to note in Illustration 12 are:

(a) The very low pitch to the slated roof, together with missing and slipped slates and poorly constructed eaves course will encourage water to penetrate below the slates.

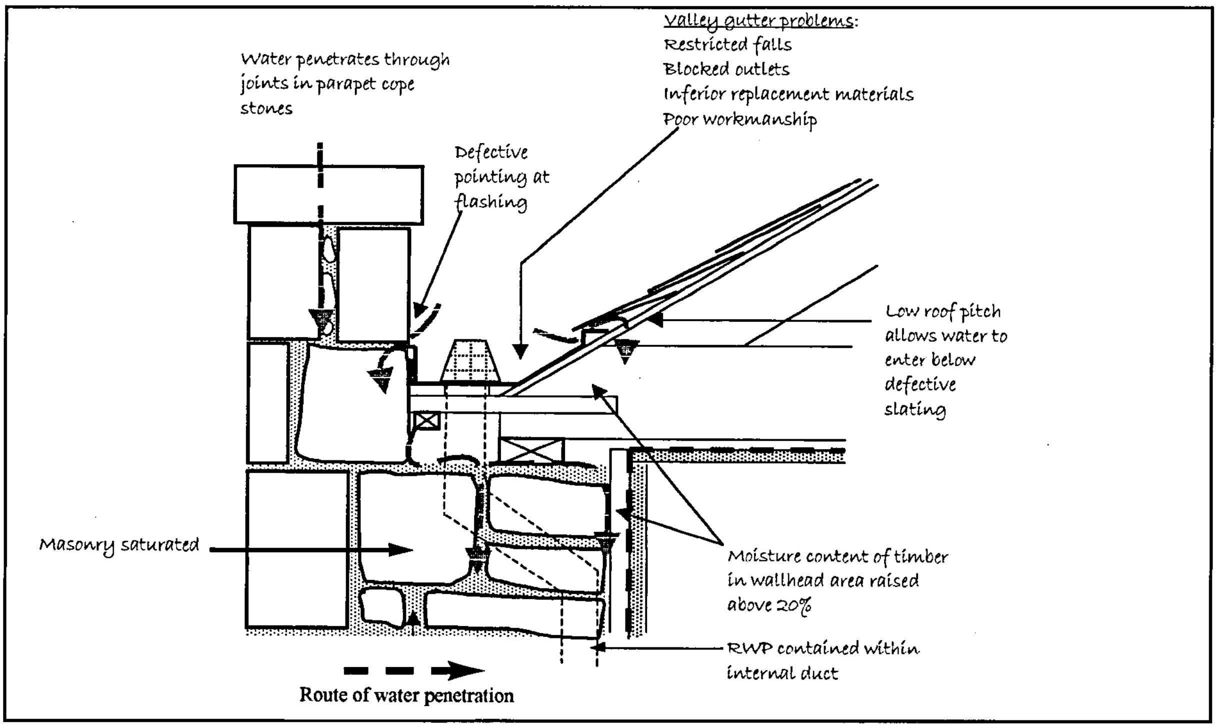

Illustration 11. Detail at a parapet gutter showing possible routes for water ingress.
The illustration shows the numerous problem areas associated with a parapet gutter and indicates the need a) for frequent monitoring of performance and b) for high quality repairs.

Illustration 12. Poorly maintained parapet gutter responsible for dry rot attack. Poor maintenance, substandard materials, missing and slipped slates, inadequate falls and a choked outlet led inevitably to an associated dry rot attack in this property.

(b) The parapet and associated gutter are a potential source of water penetration. The mechanism of this water penetration is demonstrated in Illustration 11.

(c) The generally poor standard of repairs to the roof and gutter.

(d) The parapet gutter, which was originally constructed in lead but laid to inadequate falls, has been repaired using bituminous felt. There have been subsequent attempts to seal leaking joints. Note also the build-up of debris in the gutter which further restricts water flow.

(e) The rain water outlet is of inadequate size and therefore prone to frequent blockage.

(f) Shrinkage of cement mortar fillet above the lead flashing allows water to penetrate behind the flashing.

(g) As the mortar in the joints of the parapet cope age and shrink, water can penetrate below the cope in the absence of a DPC.

The outcome of these deficiencies is that water can penetrate into the wall structure below the parapet and below the gutter thus raising the moisture content of any timber in contact with the wet wall surfaces.

4.3.1.2 Problems at a skew

Illustration 13 is a cross section through a skew tabling at the verge of a slated roof. The detail shown is characteristic of the treatment at this location and is responsible for numerous dry rot incidents in adjoining timber, especially towards eaves level where moisture will tend to concentrate. The normal routes for water penetration are through the joints in the skew cope stones and at the mortar fillet. A particular problem is when the fillet has been formed from cement mortar, which then shrinks and permits ready access of rain water into the construction. A common repair of this detail is to replace the mortar fillet with a lead secret

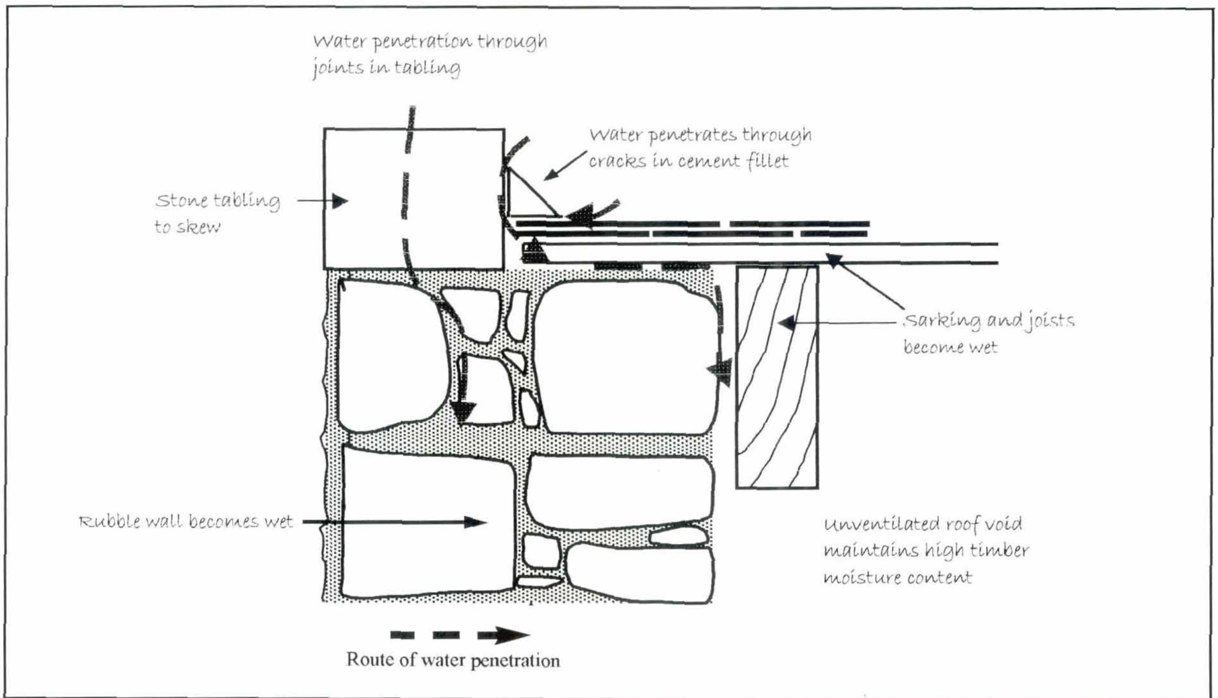

Illustration 13. Routes for water penetration at a skew.

gutter and lead flashing dressed over the top of the cope stone where a visible lead downstand may be deemed acceptable. Alternatively the lead capping may be dressed into a chase cut into the top surface of the skew stones, set back from the outside face.

4.3.1.3 Other gutter problems

There are many different wall head details that use eaves gutters to collect and direct rain water to downpipes fixed to traditional masonry walls. These eaves gutters are a frequent source of water penetration into masonry walls, usually as a result of lack of maintenance leading to a range of defects such as those identified below:

(a) Defective gutter brackets allowing the gutter to sag, joints to open and water to run down the wall face.

(b) A build-up of debris, particularly at outlets that encourages the growth of grasses, weeds and woody plants, which then obstructs drainage to the outlets forcing the water to discharge down the wall face.

(c) Many of the classic sandstone terraces use a box gutter arrangement such as that as shown in Illustration 14. Rainwater downpipes are often fixed within a recess in the external stonework or within a duct on the inside wall surface. In either case, maintenance can be difficult and the wall can become saturated in the event of water leakage at failed pipe joints.

(d) Snow and snow melt water can defeat most constructions unless snow is physically removed or melted by a gutter heating system.

Gutter problems may be also due to poor design, poor workmanship and inadequate maintenance. Gutters are frequently undersized and poorly laid with optimistic falls. Vernacular buildings with open eaves, freely dripping, may cause fewer problems as run-off is evenly distributed, splash water can evaporate and there is no concentration of water to penetrate should hopper heads and downpipes fail.

The maintenance problems posed by access difficulties to roofs is demonstrated in Illustration 15. In this case a valley gutter on a Glasgow church roof is in a very inaccessible location between three steeply sloping roofs. Whilst the gutter appears to be of adequate width and laid to appropriate falls, the outlet from the roof has not been well designed and allows debris to collect and block the outlet. Because of access difficulties, clearing the outlet was ignored and resulted in water penetration at the wall gutter junction leading to an outbreak of dry rot.

4.3.1.4 Complex roofs

The problems posed by complex roof designs, contributing to dry rot problems, can be seen in Illustration 16. A number of features have contributed to water penetration and the development of dry rot.

(a) Internal valley gutter with inadequate falls.

(b) Shallow pitch roofs, poorly maintained (note slipped and broken slates).

(c) Poor quality repairs to the roofs around the cupola area, at ridges and ridge junctions, valleys and around the rooflight.

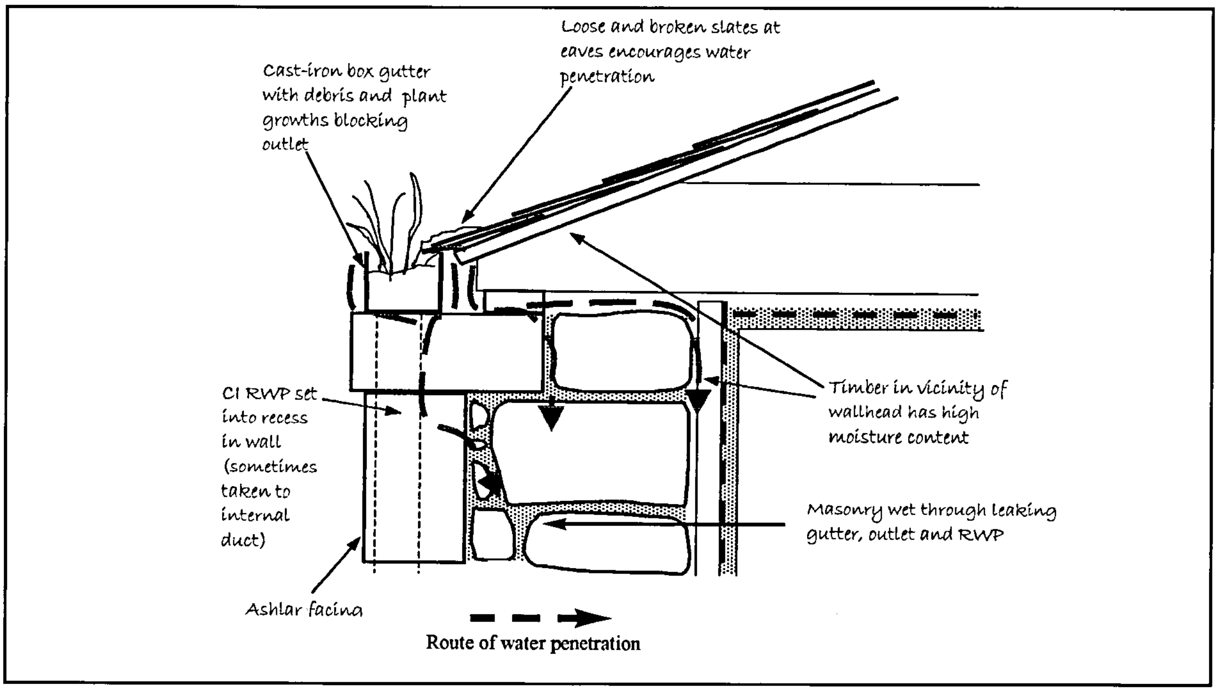

Illustration 14. Detail at eaves using a box gutter set on the wallhead. This arrangement allows ready access of water into the wall should the gutter become broken or blocked. The situation is often exacerbated by loose or broken slates which allow access of water to the wall plate and beam ends (in the first instance)

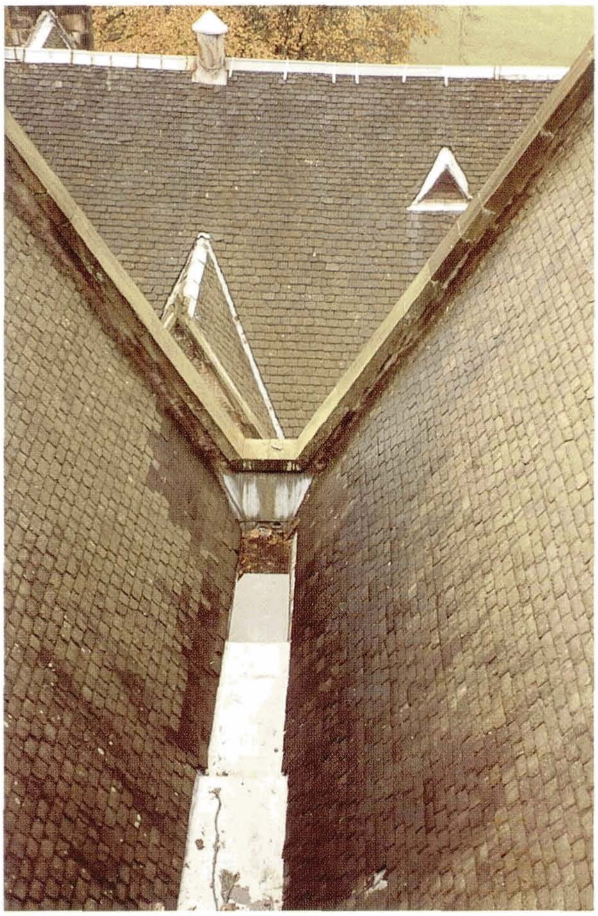

Illustration 15. Access to this internal valley gutter is difficult, leading to lack of maintenance and a dry rot attack.

*Illustration 16. A complex roof arrangement
Poor quality repairs, lack of maintenance, an internal outlet and inadequate falls have all resulted in water penetration to this property followed by a dry rot outbreak
It is likely that evidence of the water penetration was available long before the development of dry rot .*

However, whilst complexity and access difficulties may contribute to water ingress, it is the poor quality of repair work that is the primary cause of the dry rot attack in this instance.

A further example of roof complexity and difficult access is shown in Illustration 17. In this case, a comparatively large roof area drains to a single, hopper-type outlet which becomes easily blocked, leading to dampness and dry rot in the adjacent areas of the building. The original materials used are, however, of good quality.

A rather similar outcome to that shown in Illustration 17 may occur when a large roof area drains onto a smaller flat roof creating a flow rate to the flat roof outlets that are in excess of their capacity. This problem can be further exacerbated when the flat roof is contained within a parapet wall, or other upstand, and downpipes are placed inside the walls and are therefore not visible. The risk of undetected, long-term water leakage into the building and of consequent dry rot attack is thus considerable.

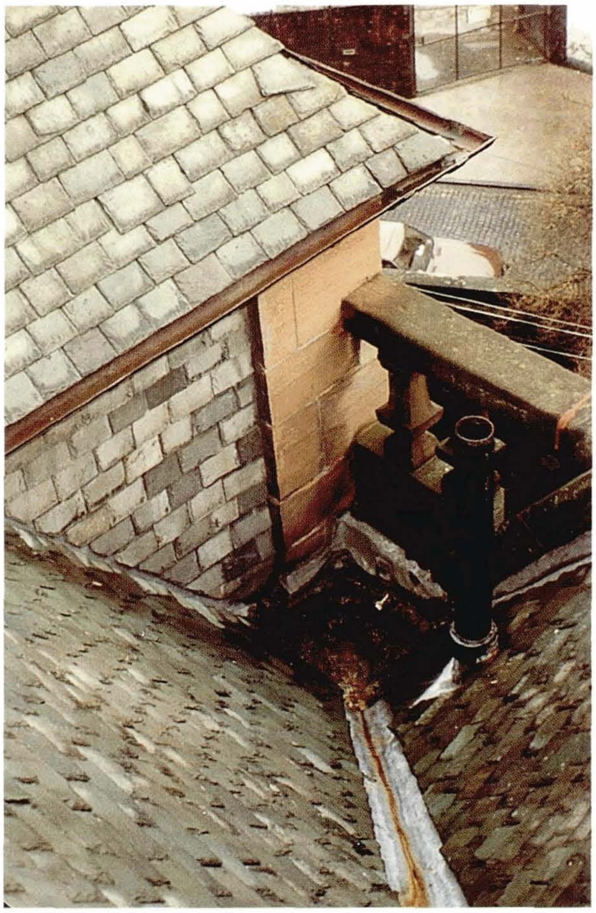

*Illustration 17. A blocked and inaccessible roof outlet.
Lack of maintenance combined with inaccessibility resulted in a dry rot attack in adjacent timbers.*

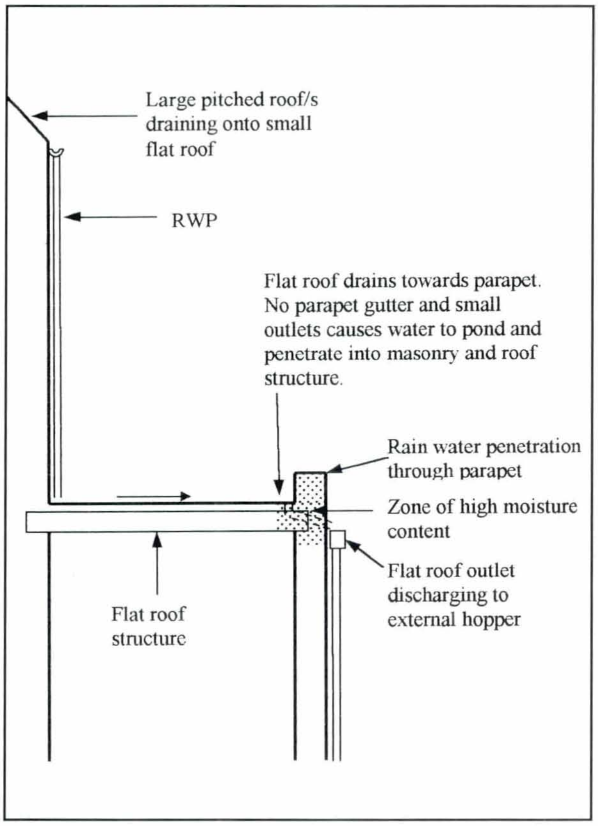

Illustration 18. Detail of rain water discharge at a flat roof.

4.3.2 Low vapour permeability of external walls

When the internal structure of a traditional masonry wall becomes wet, drying of the core is not easily achieved especially when the external surface has a high resistance to the passage of water vapour. Any constructional timber in contact with the wet wall is thus vulnerable to decay. A typical example of this problem, shown in Illustration 21, allows water to penetrate into the wall as a result of:

- defective roof drainage,
- features built into the external wall which restrict the downward flow of water and direct it into the wall and
- poorly-maintained external wall surface allowing excessive water to enter the wall.

In this example a dense cement render has been used as the external wall finish in place of a traditional lime mortar. The effect is to restrict considerably the rate at which water vapour can escape through the outer wall surface, thus helping to maintain a high moisture content in the wall. Under these circumstances any built-in timber, such as the timber lintols in this example, become vulnerable to dry rot attack. The small projection of the granite outer lintol beyond the line of the render allows water to collect and be diverted through shrinkage cracks between the granite and the render to the interior of the wall.

Illustration 19. Complex roof systems present serious challenges to the property manager A series of roofs at different levels drain to a single small outlet. The wall area around the outlet can get very wet when the outlet overflows and this is inevitable unless maintenance levels are high.

Illustration 20. A detail from Illustration 19. The concentration of downpipes in the corner can lead to wetting of the area. Water causing soaking of masonry at internal corners does not evaporate easily.

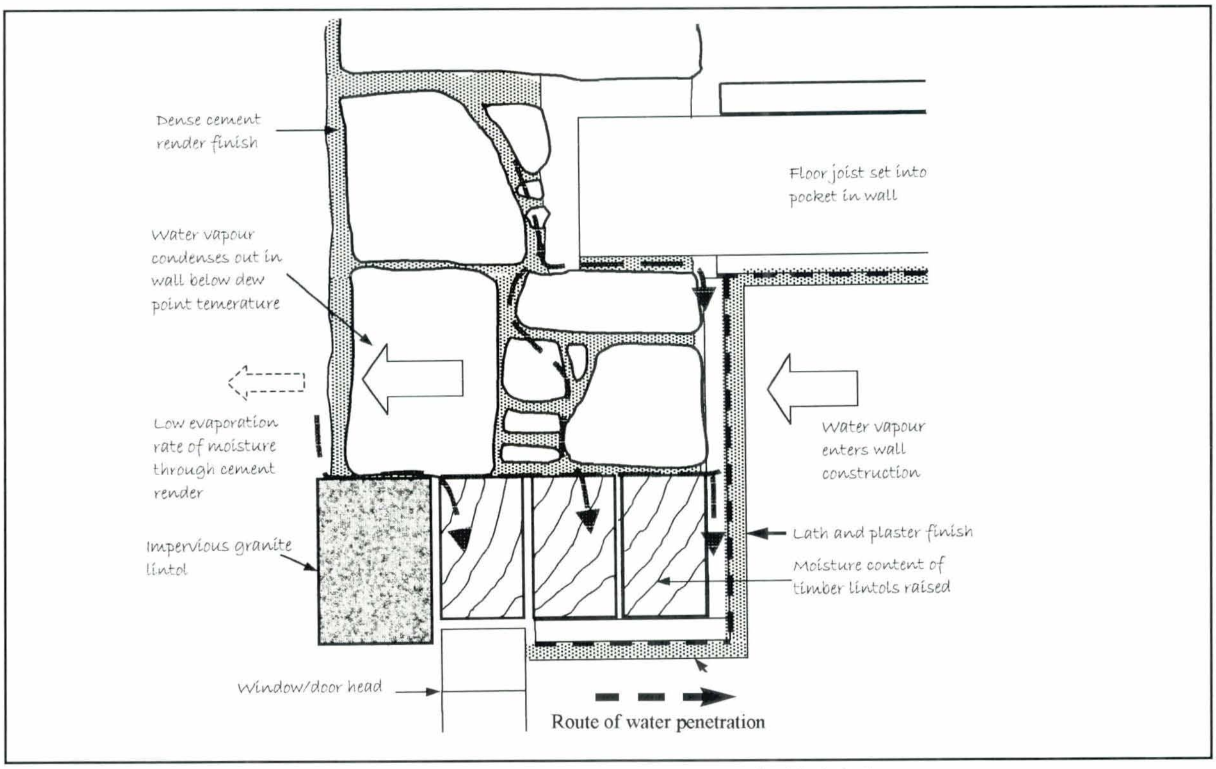

Illustration 21. Detail at window head showing moisture access routes to embedded timber.

4.3.3 Interstitial condensation

In a heated building the inside surface temperature is higher than the dew point of the ambient water vapour, which is moving into the construction as a result of a vapour pressure differential between inside and outside air. As the warmer air from inside diffuses into the construction and reaches surfaces, including pore-wall surfaces, where the structural temperature is lower than the dew point, water vapour condenses out on the surface as liquid water. The condition can be exacerbated when the external surface is a dark-coloured metal and is radiating to a clear, dark, cold sky. This can result in the external surface temperature being significantly below the ambient air temperature, thus increasing the interstitial condensation risk.

Illustration 22. A severe dry rot outbreak Dry rot outbreak at intermediate floor level resulting from external wall defects. Not the infected safe lintols and the badly degraded floor joists

As a contributor of moisture to the building fabric, interstitial condensation is more insidious than water penetration through defective construction because the latter should be revealed by a competent visual inspection. Condensation that occurs within the thickness of a wall is not immediately obvious, as there may be no evidence of dampness on internal surfaces. Whilst interstitial condensation is less likely to be the primary source of moisture than water penetration from an external source, this phenomenon can, however, lead to the moisture content of timber being raised above the critical level for long periods. The possible presence of interstitial condensation within vulnerable construction must therefore be given serious consideration. It is outside the scope of this Technical Advice Note to discuss the detailed mechanisms of interstitial condensation, but the example provided in Illustration 23 demonstrates how timber roof boarding supporting a metal roof covering can become damp enough to support dry rot. It follows that any enclosed space within a construction, where there is a marked temperature gradient through the construction and no air movement to evaporate condensed water, may be a potential site for dampness from this cause. There is no substitute for ventilation,

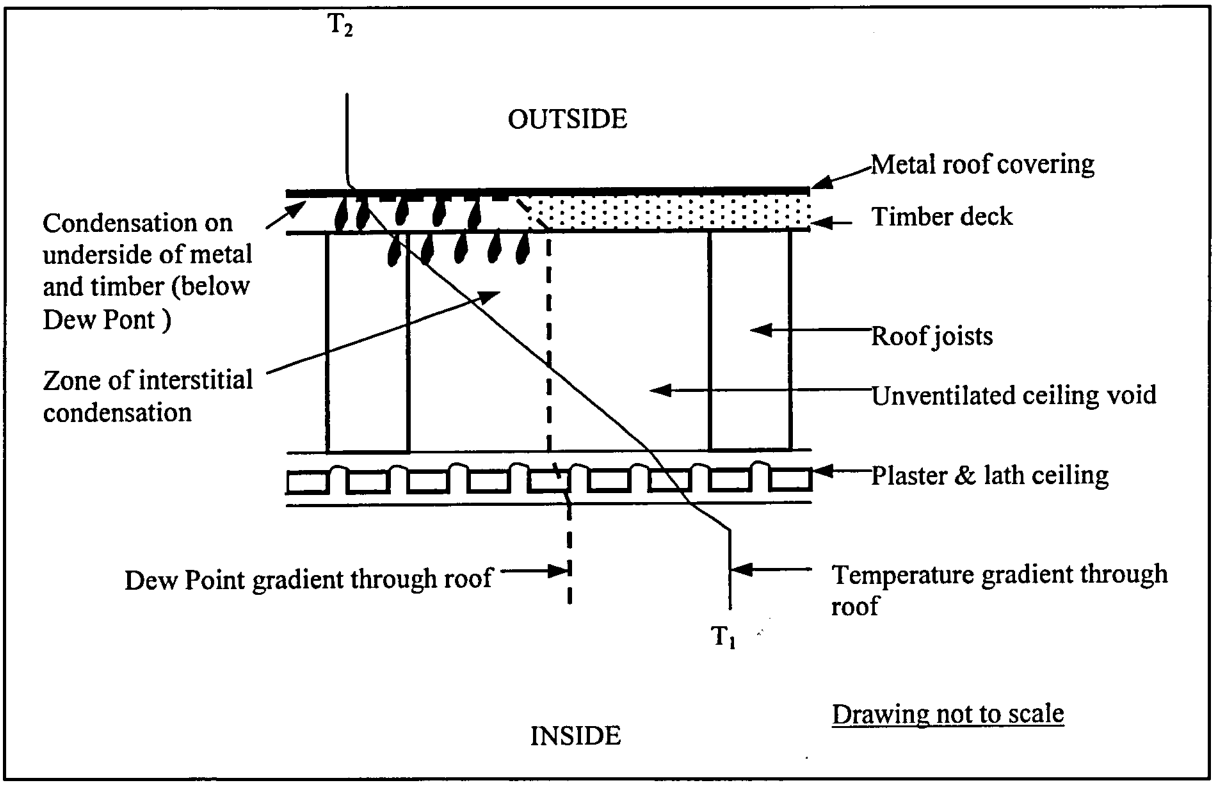

Illustration 23. Diagrammatic representation of the formation of interstitial condensation within a metal covered flat roof. 1. The point at which the structural temperature gradient crosses the dew point gradient is the point at which the structural temperature falls below dew point and condensation occurs. 2. Water vapour will condense out on surfaces that are below dew point, i.e. on the undersides of the sheet metal and the timber deck. 3. The moisture content of the timber deck and tops of joists may be raised above 20% and, where this occurs in contact with a calcium source, dry rot is possible. 4. Many older flat roofs lack sufficient ventilation to prevent condensation occurring. 5. Temperature gradients are indicative only and simply represent a temperature gradient between outside and inside.

vapour barriers can improve matters but they tend to be defective at some point and then merely concentrate moisture.

It is sometimes the case that ill-advised attempts to improve the insulation characteristics of flat roofs have led to insulation being placed in the roof voids, without either the addition of a vapour barrier (on the warm side of the insulation) or the ventilation of all roof cavities. To simply upgrade the insulation in this way will only serve to further increase the dampness of the roof space and increase the risk of wet or dry rot.

4.3.4 Moisture from the ground

Most historic buildings of masonry construction rely on the mass of the masonry to provide some resistance to the transfer of moisture from the ground. It should be noted that this transfer of liquid water can be both vertical and horizontal. The transport of water through porous materials depends on the pore structure of the material and therefore on the capillary suction caused by the water being drawn towards the pore walls. The height of water movement is governed by gravitational forces and the rate of evaporation from the wall, until equilibrium is reached when transfer from the ground (and downward flow of rain water) is balanced by evaporation losses. Therefore, maintaining a flow of air over the surface may cause a reduction in the moisture content of the pores adjacent to the exposed surface. This is the principle underlying the need to provide ventilation below suspended floors, to prevent timber in contact with the masonry from reaching a critical moisture content. In most situations relating to historic masonry buildings, it is likely that timber in contact with masonry walls at ground floor level will fall within the zone of rising damp, unless adequate ventilation is provided within the under-floor area to keep wall surfaces dry.

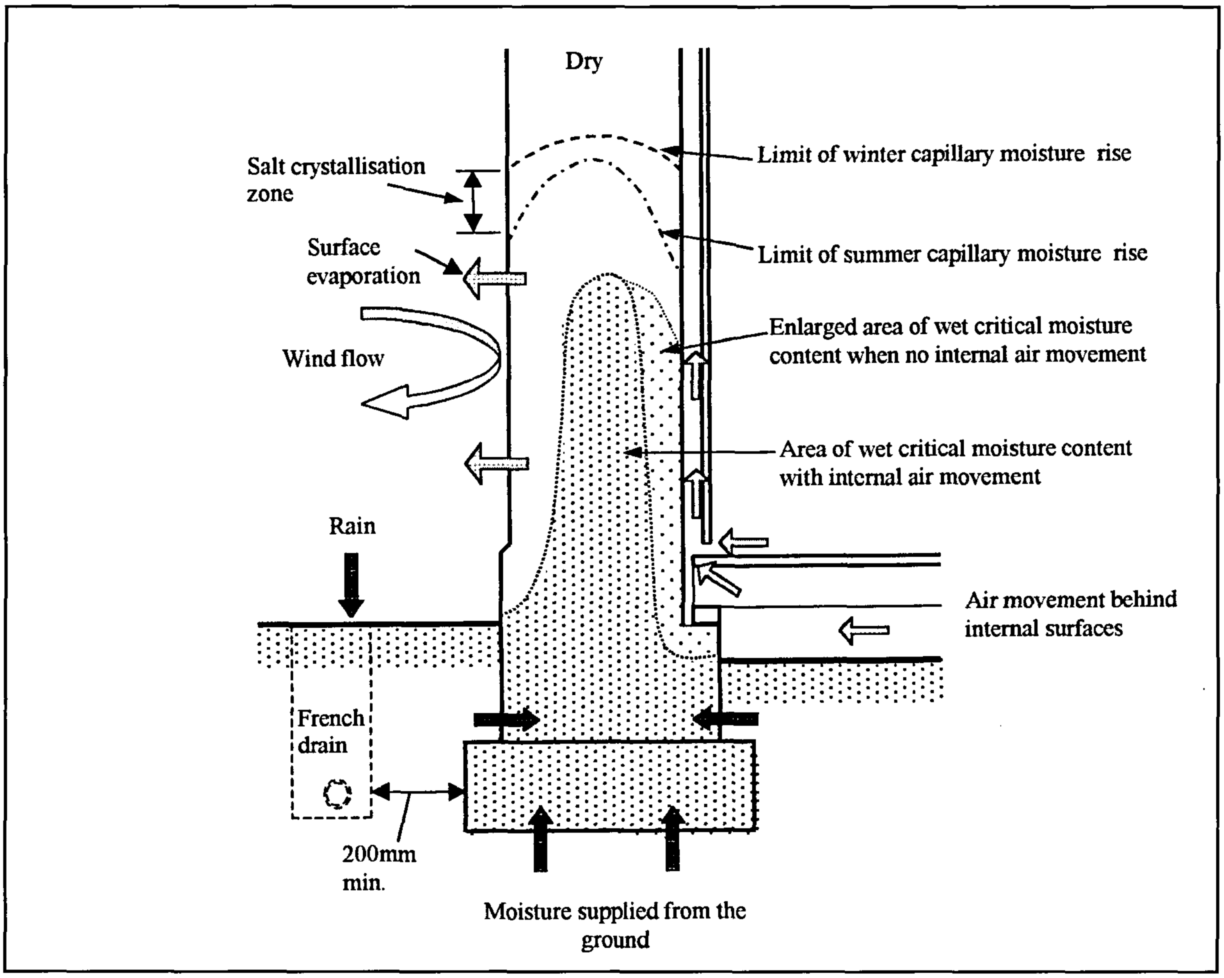

Illustration 24. Hypothetical representation of the effects of air movement on the critical moisture content of a porous masonry wall. This illustration is adapted from a diagram from B.Feilden (1994). The effect of internal air movement is to keep the internal surface critical moisture content of the masonry below the level where the moisture content of timber in contact would exceed 20%. The installation of a French drain can reduce the moisture take-up by the wall due to rising damp. Any excavation adjacent to an historic building should be supervised by an archaeologist.
1. Adapted from diagram by B. Feilden (1994). 2. The effect of internal air movement is to keep the internal surface critical moisture content of the masonry below the level where moisture content of timber in contact would exceed 20%. 3. The installation of a French drain can reduce the moisture take-up by the wall due to rising damp. Any excavation adjacent to a historic building should be supervised by an archaeologist.

The main factors responsible for dry rot in timber at ground level are:

(a) A high external ground level relative to the internal floor level that allows horizontal movement of water through the wall. Adequate ventilation is difficult to achieve in this situation. It is frequently the case that gardening and landscaping operations after construction cause the external ground level to be raised.

(b) Inadequate provision of sub-floor ventilation, both in number and ventilation area. Ventilation rates may also be reduced by later additions to the building which block out existing vents.

(c) A build-up of debris, especially discarded timber, in contact with the soil below floor level. This can reduce or restrict ventilation, and timber in this situation is highly vulnerable to fungal decay. Porous debris in contact with constructional timbers can act as a conduit for the transfer of moisture from the ground.

(d) Water leakage into the sub-floor area from faulty drainage (internal and external) can add to the moisture levels in porous masonry walls so that any existing ventilation may be insufficient to keep surfaces adequately dry.

4.4 Conclusions

Most moisture accumulation in historic buildings comes from inadequate maintenance, often as a result of the complex nature of the historic building and in particular its roof and associated water drainage systems. High quality traditional materials may not be available and the use of modern, often inadequate alternatives may exacerbate situations. Change of use and/or circumstance either by design, (e.g. increased interior insulation) or by neglect or lack of understanding, (e.g. raised external ground levels), may also give rise to conditions which allow the development of dry rot.

Historic buildings, particularly vernacular ones, are not especially prone to dry rot. Normally they are built of permeable materials which allow ample ventilation by the evolution of their construction and the experience of builders. Problems arise on interfaces with new materials which are often impervious (e.g. linoleum, plastic laminate, paint), with the increased use of plumbing and heating equipment and the accompanying introduction of insulation to buildings with reduced ventilation and compromised vapour barriers.

Knowledge of how a building works is of paramount importance in understanding how a) moisture levels in internal timbers can rise and b) dry rot, or other types of fungal decay, can be initiated. Looking for the symptoms of elevated moisture levels is likely to be more rewarding than looking for specific evidence of dry rot. It is certainly a better preventative measure!

5 ENVIRONMENTAL CONTROL STRATEGIES: ASSESSING THE PROBLEM

The overall strategy recommended by this TAN advocates:

- early detection of building defects which may potentially lead to moisture accumulation,
- adequate maintenance to PREVENT the development of conditions which would allow dry rot,
- detailed surveys and monitoring of problem areas of buildings and
- a holistic, knowledge and science-based approach to treatment of dry rot in infected buildings

The holistic knowledge should be used to prevent decay in buildings and to inhibit existing infestations to the point of elimination of the active fungus. The environment required to achieve this is also one which is most conducive the health and safety of the occupants and the overall durability of the building.

5.1 Introduction

Working hypotheses for the environmental control of dry rot are as follows:

There are nearly always indications of potential dry rot problems in buildings – the idea that the fungus is able to hide away and destroy building fabric with NO external signs is normally fallacious.

The sooner a potential dry rot problem is recognised, evaluated and corrected the smaller will be the ultimate repair bill.

There is nothing particularly mysterious about the dry rot fungus, nor its control. Though it is well adapted to the environment within buildings it is adapted only to the ill-designed or badly maintained built environment. The conditions required for growth of S.lacrymans should not normally be present in buildings.

The 'secret', in terms of early identification of dry rot, is not to look for the fungus but to look for the conditions that would facilitate its development and growth. Careful evaluation of the exterior of a building is as important to the surveyor as is evaluation of the interior.

The nature of the potential dry rot problem should be thoroughly investigated BEFORE remedial work is instigated, though it must be borne in mind that the scale of related dry rot incidents may only become fully apparent once work is underway.

5.2 Overall strategy

5.2.1 Inspection

In the past much dry rot remedial work was initiated by the offer of a 'free' survey. More recently larger surveys, at least, tend to be costed. The normal result of a free survey is a brief description of the likely extent of the dry rot outbreak and any other potential problems, a brief survey report showing the proposed area of treatment and an estimate of potential costs plus a warning that further problems may be uncovered during the course of the subsequent remedial work. This warning should be taken seriously by any potential owners subjecting themselves to this approach, as the cost can escalate to multiples of the original quotation. Costed surveys will tend to be more comprehensive however in many cases surveyor and treator will be one and the same, and to ensure an objective view a report by an experienced independent surveyor is recommended. Such a surveyor will not produce a report free but will endeavour to determine the full extent of the outbreak at the outset. If this is not possible, for example due to access difficulties, the report will at least highlight potential problem areas where further investigation may be justified. How this fuller survey fits into the overall strategy for environmental control is detailed in Illustration 9.

Moisture for the dry rot fungus can come from either external sources (rain water and ground water) or internal sources (due to defective plumbing or condensation). Not all potential sources of moisture are identified in this TAN but inspection essentially requires commonsense, an ability to investigate and assess anything that looks like a building defect that could cause elevated moisture levels, plus a good knowledge of building construction. It has to be recognised that not all areas of a building are easily accessible. The methodology in this TAN encourages a full survey before any remedial work is instigated. Such an inspection may require investigation of enclosed areas, preferably using fibre optic instrumentation to minimise damage to the building fabric. A preliminary report should be produced which identifies those areas found to be at risk and those which will require further investigation.

It is possible for the owner/occupier/manager of an historic property to undertake a preliminary survey for himself to assess the likely problem areas within a building. Indeed, developing a knowledge of the at-risk areas of a building is an excellent discipline, one which is very likely to prevent problems in the long term. To help with this, and to give a general guide to the survey of properties for dry rot defects, the following protocols are suggested. The protocols will also allow owners and property managers to evaluate the quality of a surveying service offered. Following these protocols should become part of the 'good housekeeping' associated with the maintenance of an historic property (see also '*Scotland's Listed Buildings – a Guide for Owners and Occupiers*, published by Historic Scotland, Edinburgh)

5.2.1.1 External investigations

A survey of a building should always start on the exterior.

- Where access to the roof can be gained in safety and without risk carry out an inspection of the roof surfaces, parapet walls, valley gutters, flashings, chimneys, flat roof surfaces, gutter outlets and hopper heads to note and record any defects or deterioration. Take note of the adequacy of the existing drainage system and whether improvements need to be made. Specific details to be noted would include a) are certain gutter outlets overloaded, b) do they have adequate protection, c) do they have overflows which can give warning of blockage and prevent water ingress, d) are there any internal gutters/downpipes and e) can any internal gutters/ downpipes be re-routed to the exterior?
- Study the nature of the building from the outside looking for any signs of inadequate rainwater disposal (examples would be algal and plant growth on walls, vegetation growing in gutters, overflowing hopper heads, cracked downpipes, staining to and spalling of masonry, saturation of masonry with moisture), loose or missing pointing or defective mastic around window openings.
- Look for any other potential problem areas (cracked or missing slates, valley gutters (particularly hidden gutters), crow step gable, defective pointing, overflow pipes from internal plumbing systems, defective chimney flashings).
- Identify all sources of under floor ventilation and check whether such sources are operational (changes in surrounding ground levels, dense vegetation, overtly blocked grilles).
- Look for evidence of bridging between external soil and walls and bridging of existing damp proof courses, i.e. damp in walls coming from the soil at levels above the lowest timber elements in the building.
- Look for inappropriate alterations to the property, including hard cement-based mortars and renders bridging damp proof courses and trapping moisture in walls; cracking of original, or new, renders allowing water ingress into the wall fabric, poor construction and detailing of any new work or extensions.
- Use common sense to evaluate any other defects which might allow ingress of water from the outside of the building.

The survey report should recommend that any obvious defects, particularly blocked rainwater pipes and blocked ventilation pathways, should be corrected as quickly as possible. More complex problems should be remedied at the earliest possible time and certainly well before the start of any internal remedial work in the area of timber decay. Illustrations 25-31 show a number of common symptoms and areas of water ingress.

Illustration 25. Faulty downpipes
The downpipe located on the façade of this Dublin office block is faulty at several points. The hopper is blocked and there are a number of breaks in the pipe. The algal growths on the wall, and the fern beneath the hopper, indicate that problems have existed for some time.

Illustration 26. Plant growth on a building façade
This tenement in Glasgow boasts a luxuriant growth of ivy on its façade. Such growths may encourage retention of moisture in a wall and certainly should not be allowed to block rain-water discharge systems. However, uncontrolled removal of ivy can cause damage to stonework. The ivy should be cut at ground level (a section of stem removed) and the plant allowed to die before careful removal by hand from vulnerable stonework or brick wall.

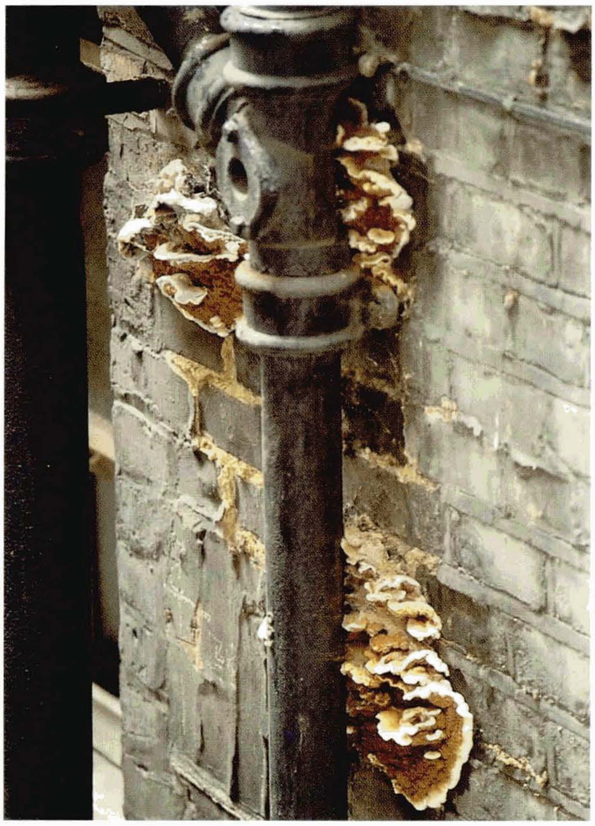

Illustration 27. Faulty rainwater pipe saturating a brick facade resulting in an internal outbreak of dry rot and an external fruiting body. © Hutton+Rostron

Illustration 28. Stained walls
The black staining on the walls indicates a problem with the rain water discharge from the roof of this Tudor-style villa of c. 1828 on the outskirts of Glasgow.

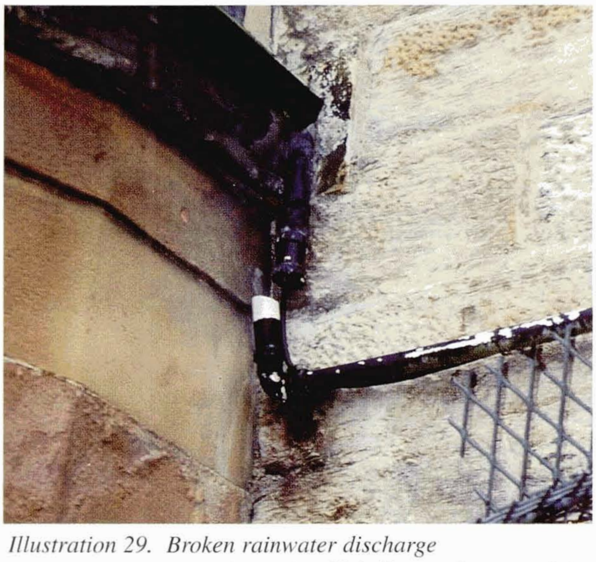

Illustration 29. Broken rainwater discharge
Closer inspection of Illustration 28 indicates that one of the discharge pipes is completely severed.

Illustration 30. Flat roof features
Rainwater discharges from leaded, flat roofs are notoriously prone to blockage due to fallen leaves etc. The feature in this illustration has been kept clear but should be fitted with a wire balloon or other type of grating which should be inspected regularly as they will become blocked with leaves. There is no substitute for ample pipe sizing and numbers, catch pits adequately sized and regular inspection.

Illustration 31. Plant and algal growth
Staining on walls and around downpipes is a sure sign that internal moisture levels are likely to be elevated and timbers at risk. In the situation illustrated dry rot is likely to be present inside. Whilst the rot might still be hidden, the cause of the rot is manifest for all to see.

In some cases rot may not be caused by external problems and rather may be as a result of internal plumbing defects. In such cases no exterior signs may be present and identification of at-risk areas will depend upon a detailed internal investigation. In either case the external survey will be followed by an internal one.

5.2.1.2 Internal investigations

- Start the survey at the top of the building, always keeping in mind the findings of the external survey. Moisture will spread out in a cone shape down the building from the point of entry of the water, such as the roof.
- Take note of any discernible air movement, or lack of it, in roof spaces. If there is air movement, note its source and assess its effectiveness.
- Check loft spaces, paying particular attention to the ends of the rafters, ceiling joists and the wall plates, as defects to the roof usually lead to development of decay in these areas rather than at the ridge. Probing and drilling of plates may be necessary if surface decay or discolouration caused by water staining is observed. Check the ends of purlins built into gable walls and timbers around water tanks. Check that there is adequate ventilation into the roof space and that insulation, if installed, is not blocking ventilation of the eaves. Note any dampness or water staining on the sarking and rafters, be aware that staining may be from long past episodes of water penetration.
- Look for any signs of water penetration on internal walls and ceilings, particularly in relation to known internal pipes, this may be evident as mould growth, damp staining, cracked or loose plaster and damage to wall finishes. Use a moisture meter to test if the surface is damp, but only use such meters in conjunction with other observational methods. If a high reading is obtained further investigation is necessary. Electrical resistance-based moisture meters can give false results (see APPENDIX D) , high readings should be the basis for further investigation and may not be a positive identification of dampness. If high readings are obtained adjacent to a known external defect this can usually be taken as positive proof of dampness. If this is not the case then mortar samples should be taken from the walls to test gravimetrically for moisture content and hygroscopicity.
- Check any under floor spaces which can be investigated – particularly under the lowest floor where the existence, or otherwise, of ventilation should be checked. Note that floorboards and pugging may need to be lifted in areas requiring further investigation
- Investigate the source of any 'mushroom-like' smells. *S.lacrymans* produces an odour very much like that of the common edible mushroom *Agaricus bisporus*.
- Try to access areas adjacent to identified external defects. Where a defect is high up, for example a blocked rain water gutter, the cone shaped area of elevated moisture beneath the defect will indicate the area possibly affected by dry rot. Plot problem areas from floor to floor.
- Built-in timbers such as window safe lintels in areas of dampness should be investigated by exposure, or preferably drilling, to test for decay and moisture content using a deep probe (APPENDIX D). Floor joists built into damp masonry, or other suspected areas, should be inspected preferably by lifting of a floorboard along the ends of the joists to allow for physical inspection using a sharp prodding instrument and a moisture meter. If a floorboard cannot be raised, then fibre optics should be used to investigate the cavity for signs of decay and dampness. It is sometimes possible to drill into joist

ends which are obscured by floor coverings using a small diameter drill bit to test for decay and moisture content (APPENDIX D). The floor joists can be located from the position of the nails in the floorboards.

- Look out for recent changes to the decorations, for instance, new areas of floorboards, skirting boards, uneven surfaces to gloss painted woodwork particularly at window panelling and skirting boards. These may be areas of previous dry rot infestation where an attempt has been made to conceal defects.
- Check under floor spaces at ground level. Typical problems are debris in the floor void, often builders rubbish, timbers etc, which can be an ideal nutrient source for a dry rot outbreak should the ventilation be impaired. Check the wall plates against external walls and adjacent to external drainage gulleys.
- Use a moisture meter to take moisture contents of skirting boards rather than wall surfaces at ground floor level, as this will give more accurate assessment of dampness.
- Check basements for dry linings on the walls that use timber battens directly in contact with the damp walls. Check also for door frames in contact with damp masonry and suspended timber floors with no ventilation.
- Areas that are not accessible, particularly if adjacent to external defects, should be noted. It should be stated in the report that no access was possible and an attempt to assess the situation from other, external and adjacent internal features should be made.
- Large-dimension timbers such as beams and bressummers built into walls should be inspected if dampness is suspected. This can be done by drilling and testing moisture contents with a deep probe.
- Check bottoms of door frames especially adjacent to solid floors, check whether floors are regularly washed
- Lath and plaster walls will often hide dampness in the underlying masonry as the void acts as a barrier. If the void becomes blocked moisture can build up and lead to dry rot decay.
- Look for signs of discolouration in woodwork though be aware that such discolouration may simply be a historical record of past defects or timber treatments.
- Use common sense and record observations carefully, in particular, noting areas where further investigation may be necessary.
- Note all visible evidence and peculiarities even if the cause is not immediately evident.
- Record observations carefully with a camera.

It is also important that the owner's/occupier's/ manager's views and recollections of damp problems within buildings are noted. Such views and recollections are a potentially valuable record and as much information as possible should be extracted from them. However care is required in evaluating such information. It may be that a memory suggests that a problem was totally remedied in the past when in fact underlying causes were not fully investigated and apparently trouble-free areas may still harbour defects.

5.3 The report

The report would be expected to contain the following sections:-

- An overall summary of the condition of the building and an assessment of any dry rot problems identified. This summary should allow the building owner/ manager to gauge if the surveyor has understood the salient features of the building. This summary should be read carefully and any inaccuracies noted. The summary should also detail any shortcomings of the survey, for example areas of the building which could not be surveyed and the reasons given. Finally the survey should make clear the overall approach of the treatment company and the salient defects that it has found with the building.
- The second section of the survey report would be expected to detail the results of the external inspection of the building. The overall structure of the building should be detailed and the defects which may give rise to elevated internal moisture levels identified. Most of these observations will be purely visual and it is recommended that the owner/ manager checks the observations and confirms their veracity
- The internal details of the property should be given. In the case of a whole building survey every room should be mentioned even if only to say that no defects were recorded. In the case where only a portion of a building has been surveyed it should be made clear which regions have been thoroughly surveyed and which have not. Diagrams indicating areas of elevated moisture and of active dry rot would be expected in this part of the survey. Links between the defects observed externally and any internal defects should be identified. Specifications for treatment of all suspect areas would be included in this section. Justification for the methodologies recommended should be included unless overall justification has been given elsewhere, for example in the Summary.
- Finally some overall recommendations for the longer term management of the building might be expected, for example identification of potential at-risk areas (parapets, hoppers, valley gutters, etc. and for future inspections).

After reading this report the owner/ manager should feel comfortable that the whole problem within the building has been identified and that the works that have been recommended will remediate the complete problem. It would not be expected that phrases such as 'further investigation may reveal more extensive occurrence of dry rot' would occur in the report unless it is a preliminary report. If this in the case then this should be made clear to all. It must be appreciated that preparing such a survey and report to the necessary degree of professional skill cannot be cheap but is worthless if not done thoroughly.

5.4 Difficulties with surveying historic buildings

Because of their often complex structure and because of the presence of important artefacts historic buildings present specific difficulties to the surveyor. It may be that areas of the building are very difficult to access, it may be that historic surfaces and fitments (e.g. specific types of wall covering) must not be damaged. To overcome these problems the specialist surveyor will be equipped with a range of different types of equipment, purchase of some of which may be of benefit to the owner/ manager. A list of suitable equipment, together with their and any limitations, is given in Appendix D together with details of suppliers. Advice on purchase can be given by the environmental treatment companies listed in Appendix G. Historic buildings maybe derelict or unsafe structures. Surveyors will certainly require specialist training and would be wise to work in pairs.

5.5 Professional indemnity insurance

At the time of writing it is true to say that, whilst the majority of surveyors and architects will be aware of the environmental approach to dry rot treatment, with the current level of understanding many do not recommend this method of treatment to their clients. Rather, upon discovery of a dry rot outbreak, they will suggest that a specialist timber-treatment firm be asked to conduct a (free) survey and to take control and responsibility for the subsequent treatment. Such firms will normally offer a guarantee covering their work. In this way, the architect or surveyor has abrogated responsibility for an area of work that is related, in a fundamental way, to the survival of the fabric of the building. In addition, when responsibility for the property lies with a local authority there is a requirement to obtain competitive tenders for the work. The simplest solution (although not necessarily the best) is to request tenders from specialist treatment firms to treat the dry rot outbreak. The availability of a guarantee is perceived to be a further benefit to the building owner.

Guarantees should be treated with caution. As Dr Coggins, Director of the BWPDA states 'guarantees deal solely with the responsibility of the issuer to return to correct any deficiencies in his work or materials. It is no 'guarantee' that the work was done correctly in the first place. Guarantees have value if the issuer remains in business for their duration or if the guarantee is protected by insurance or by a third party (usually a larger supplier to the contractor). In the latter case the protection is only good as long as the supplier remains in business. Guarantees, like other legal documents, are limited by their small print. Guarantees will always require appropriate maintenance over their period of validity so it is foolish to see guarantees as a substitute for maintenance'.

Professional valuers (usually general practice surveyors), when surveying a property for valuation in connection with house purchase, frequently recommend timber treatment by specialist timber-treatment firms if they suspect that there is timber decay in the property. The cost of a valuation survey will not include the level of investigation necessary to establish the nature and extent of a timber decay outbreak, and the recommendation in this case simply highlights a potential problem. In the event, the mortgage lender will then insist, as a condition of the loan, that the work is carried out by a timber-treatment company. An environmental treatment approach does not therefore become an option within generally accepted practice.

The reasons for architects and surveyors to adopt such a strategy can be appreciated, especially under the current climate of litigation when things go wrong. Also, a lack of knowledge and understanding of the behaviour of *S. lacrymans*, together with an unreasonable fear of the destructive effects of the fungus, has directed many consultants towards specialist treatment firms. There is, in addition, the question of professional indemnity insurance to be considered. Consultants may be concerned that they may be in breach of the terms of their policy if they take responsibility for this specialist area of work. However, there is a growing number of building professionals who are prepared to forgo the apparent advantages of using specialist firms and are recommending the environmental approach to dry rot treatment. The approach adopted in the Case Study (Appendix A) is a good example of such a strategy. By doing so practitioners look at the problem in a holistic way and focus on the underlying sources and causes of the moisture that is responsible for the decay. Providing that a surveyor or architect can demonstrate to his insurers that he has the necessary knowledge and expertise to deal with dry rot in property, or that he will use the services of a specialist dry rot consultant to carry out the detailed survey, it is unlikely that there will be difficulties with the cover offered by insurers.

6 ENVIRONMENTAL CONTROL STRATEGIES: TREATING THE PROBLEM

Once the survey is completed the causes of any dry rot problems in a building will be apparent. To prevent decay from worsening immediate action should be initiated to prevent further moisture ingress to the structure of the building and to increase ventilation within infected areas. These two actions alone can be used to 'mothball' a building which, for whatever reason, cannot undergo a full repair at the time.

6.1 'Mothballing'

Mothballing essentially entails instigating systems that will minimise further water loading of the vulnerable areas of the building and at the same time improve the rate of drying of damp areas. A range of different techniques can be used for example:

- correcting all defects in rainwater systems (i.e. clearing out gutters, making temporary repairs to valleys and providing suitable overflows, etc.),
- correcting other building defects which allow water penetration, for example defects in leadwork and inadequately pointed stonework, defective windows and their pointing,
- unblocking chimneys and re-capping thus allowing ventilation of flues, unblocking any external ventilation systems, opening up fireplaces,
- increasing under-floor and general building cavity ventilation by opening up airways, removing single floorboards next to walls, making slots in walls at ceiling and floor level, installing hatches into ceiling voids,
- checking ventilation in roof voids and encouraging through (or cross) ventilation where appropriate by the installation of roof vents or adapting eaves construction,
- removing floor coverings and moving clutter away from walls,
- exposing internal downpipes, checking for watertightness and repairing as necessary or diverting water streams away from walls, etc.,
- stripping off salt and water damaged plaster to speed up drying of masonry,
- stripping the plaster from safe lintols over windows and doors, etc., exposing wall plates if possible,
- removing external hard cement-based renders to encourage evaporation from external wall surfaces,
- improving ventilation around beams in wet masonry, if necessary enlarging the beam pocket, isolating bearing surfaces from saturated masonry,
- opening window shutters, wedging windows securely open to an extent which allows draughts but does not allow entry of birds, and without compromising security,
- removing door frames if badly decayed, taking apart window soffits, reveals and base boards to ventilate underlying masonry and
- removing inappropriate wall coverings, e.g. plywood/ hardboard-based materials and removing skirting boards if decayed or if they are likely to prevent drying,

Some of these changes may cause disruption of internal components of buildings, e.g removal of plaster, and the historic importance of such components will need to be evaluated. The efficiency of each of these systems can be checked by using moisture meters, data loggers, visual observations and commonsense. The objective of the systems is to prevent buildup of moisture in enclosed areas where the fungus can continue to attack timber components. Whilst mothballing may not reduce the rate of fungal degradation to zero, it will have a dramatic effect on the rate of decay and in the long term, if carried out and maintained in an effective manner, will kill the dry rot. The most noticeable differences for the property manager are likely to be a reduction of humidity within the building, together with a loss of odour and increased freshness of the internal atmosphere. There will be a dramatic die-back of visible fungal mycelium and, in time, a possible increase in the formation of fruiting bodies as the dry rot fungus responds to the stresses caused by the environmental treatment. During the mothballing the building will slowly dry out and general conditions will become much less favourable for the development of new dry rot outbreaks. The actual drying-out time will be dependent on a number of factors including level of saturation, location, orientation of the affected part of a building (e.g. walls), construction methods, condition and the presence of existing defects. These factors will need to be taken into account when repair of the building finally takes place.

Additional improvements which can be made, and which would reduce risks from dry rot include:

- adoption of a policy on implementing remedial works and preventative strategies,
- development of rigorous inspection regimes,
- installation of inspection hatches, access ladders and roof walkways to increase opportunities for monitoring of the building fabric,
- fitting movable grills on drains to prevent blockage and facilitate cleaning and
- installing snow boards and/or gutter heating systems to prevent ingress of water after snowfall and during subsequent thaws

Internal heating will increase the rate of drying but this is probably not economical during the mothballing process.

6.2 Remedial treatments

Two basic approaches to reducing the risk of reinfection of dry rot after remedial treatment are possible. The first assumes that it is inevitable that conditions which will allow the growth of dry rot will occur, and to reduce this risk anti-fungal chemicals must be incorporated into any repair. The second assumes that dry rot development is not inevitable and can be prevented by good maintenance associated with an understanding of how a building works. Neither system is risk free. The conventional system (first approach), in the absence of regular surveys and good maintenance will not prevent dry rot occurring in untreated areas. The environmental system (second approach) minimises risks by treating the building in a holistic manner and insisting on regular surveys. Again good maintenance is essential. It can be seen that both approaches require regular inspection and maintenance. The main drawback with the conventional approach is that it does not normally recognise the need for survey and maintenance and, inherent in the guarantee that usually comes with the repair, is a suggestion that the dry rot problem has been solved at least for 25 years, or however long the guarantee lasts. With such a piece of paper in his hand there is a great temptation for the owner/ manager to assume that dry rot will not appear again for a generation. Of course nothing could be further from the truth.

Conventional treatments are well described elsewhere and the remainder of this section will detail the main features of an environmental treatment.

6.3 The environmental control strategy

6.3.1 Preliminaries

6.3.1.1 Preventing water ingress and drying masonry

The first objective of any environmental control strategy must be to cut off water supplies to the dry rot fungus. If, for example, a faulty downpipe has been identified as the major cause of elevated moisture levels in an area of a building then this should be corrected as soon as possible. There is no point in spending time reviewing and evaluating various timber repair estimates whilst leaving the cause of the problem unattended to. So the cause of the dry rot problem should be 'cured' as soon as possible after identification. If this is done first, then time taken assessing potential strategies will in fact help matters since the destruction of the decay potential of the dry rot fungus will already have been initiated.

When the causes are corrected, the monitoring of the building should be implemented to ensure that moisture penetration is no longer occurring. Also, ventilation to infected areas should be introduced or improved. Consideration should be given to the removal of salt and water damaged plaster in areas of water penetration to increase the rate of drying. However if such plaster is of historic importance then each case should be assessed individually, and, where appropriate, efforts must be made for its conservation. The use of fans to circulate the air and speed up the rate of drying is recommended. Dehumidifiers may be useful in certain instances, although their use can be considered rather specialized and costly and, if they are to be effective, careful tenting of the damp area is necessary. Calculation of the capacity and type of dehumidifier unit to be used in any circumstance must be carried out and, it is recommended that advice should be sought from a specialist in this area to optimise the benefits.

Following initiation of drying, periodic gravimetric mortar sampling should be employed to monitor the actual rate of drying in masonry, and the results used to modify the drying regime as appropriate. All these processes will actively assist in the elimination of *S.lacrymans*, and can be carried out whilst the overall strategy is being developed. With these types of process in place there is little likelihood of a dry rot situation worsening. Crisis management, as is typically induced by conventional remedial treatment strategies, is therefore both unnecessary and unwise.

Removal of moisture from the internal building fabric may take extended time periods, the massive nature of traditional masonry wall construction is not conducive to rapid drying. Once the core of such a wall and any porous stones within the wall become wet, drying the wall out will be difficult and time consuming. Indeed, in the Scottish climate, complete elimination of all moisture is likely to be impossible, especially in a poorly heated building. Also, as previously identified, the degree of permeability of the external wall surface will influence the drying rate of the wall. Nevertheless, it is important when dealing with a dry rot outbreak to eliminate all sources of moisture that are raising the moisture content of timber. To ensure that timber is not affected adversely by damp masonry the recommendations in Table 4 may provide appropriate solutions.

6.3.1.2 Dealing with dampness in timber

Before any repair or treatment is undertaken it is necessary to decide upon the relative 'purity' of the process. Examples of possible approaches would be:

a) *no replacement* of any timber – retention of all original materials, no chemical treatment, strengthening weakened timber elements by addition of complementary structures,

b) *minimal replacement* of timber, strengthening of decayed timbers with resin-based materials, use of chemical preservatives in very restricted circumstances

or

c) *replacement* of infected and suspect with preservative-treated timbers, relatively widespread use of chemical preservatives.

In addition, before initiating any works, the viability of any *S.lacrymans* in a dry rot outbreak needs to be assessed. Old attacks, typified by dried mycelium and strands and dry wood and with no associated elevated moisture in surrounding materials do not represent a danger to future conservation. In most instances, all that will be required is to assess the structural characteristics of remaining timber and to add additional support if necessary. If structural strength is unaffected (this can be assessed using a drilling system as described in APPENDIX D) timbers can remain in place. Local strengthening by, for example, plating may be required if some loss of strength has occurred.

This TAN is designed to give information allowing the use of the first two approaches outlined above, the third approach is the one normally offered by remedial treatment companies and is not recommended in historic buildings where retention of fabric is important. In addition the reliance that the process has on preservatives is misplaced as, for example, i) non-treated wood is still at risk if moisture sources are still extant and ii) the irrigation of rubble walls with preservative, as may be recommended, is of little value, as the injected preservative will not come into contact with much of the fungal material in a wall. (It

Table 4 Dealing with dampness in masonry
Techniques and processes which can be instigated to overcome the difficulties associated with the slow drying of massive masonry walls as found in many Scottish historic buildings.

1	Where possible, expose the internal surfaces of masonry walls to internal heating to aid the drying process. It should be recognised, however, that this may not be achievable because: (a) removing historic internal fabric would cause unacceptable damage to the materials, (b) large areas of internal finishes may need to be removed for effective drying of the masonry to take place, (c) high levels of heating will be required, usually from industrial type heaters contained within tents and with forced ventilation, (d) sudden and uncontrolled heating of the fabric of the building may cause drastic and irreversible shrinkage of timber, plaster and other porous materials and (e) the wall will need to be exposed for a long period of time to allow the core to dry.
2	Replace any external hard cement renders with suitable lime-based renders, which will encourage a greater evaporation rate from external wall surfaces. However, repeated applications of limewash to the lime-based render will reduce the permeability of the render. The benefits of replacing a less permeable render with one that is more permeable will be evident in the longer term, as immediate drying effects are likely to take place over several years and will be influenced by climate and orientation of the facade.
3	Where timber is built into a masonry wall that is unlikely to dry out for some time, the timber should not come into contact with the masonry, but should be set into a ventilated pocket with the bearing surface set on a suitable damp proof membrane.
4	Replacement timber which, unavoidably, must come into contact with wet masonry, such as fixing plugs, grounds and beam ends should be pretreated with a preservative to BS4702, Part 2. Cut ends of pretreated timber should be given a brush treatment of, or dipped in, an end treatment fluid.
5	Ensure that all timbers within enclosed cavities, in contact with potentially wet masonry walls, are exposed to air movement sufficient to prevent timber moisture content being raised above 20%. However, care should be taken to ensure that fire safety of the building is not compromised. To provide the necessary ventilation behind plaster lath on walls, small-area vents at skirting and ceiling level will normally be adequate. It is worthwhile checking cavities for existing air movement before installing additional vents. Old properties frequently have high air-leakage rates and it is not uncommon for high air velocities to be present behind lath and plaster. Cavities should be checked to ensure that no stagnant air pockets remain, especially behind plasterwork at recesses in external masonry walls.

should be noted that the efficacy of chemicals for use in wall treatment is tested by effects on/ in small plaster blocks – scaling up from this level to that found in historic buildings is likely to be unreliable.) The major operational difference between a) and b) is likely to be the time required for the repair. If there are to be no precautions introduced to protect timber from, for example, wet masonry then additional time may be required for the introduction or improvement of ventilation and to ensure that all potential moisture sources have been thoroughly eliminated. The use of chemically-treated timber may reduce this time, but with risk, if other measures have not been incorporated. Chemical treatments will only delay the onset of decay in damp areas and should not be used as a substitute for good building practice (i.e. isolation of timber from damp masonry and introduction of ventilation).

Illustration 32. Floors opened up to increase ventilation. Opening up floors will improve ventilation, promote drying and prevent further decay by the dry rot fungus.

6.3.2 The repair

Experience from companies involved in environmental control coupled with the research findings on which this TAN is based indicate that dry rot fungus can be fully controlled, in most situations, simply by actively altering the environment where it is growing, i.e. by stopping its access to moisture. As detailed above, in terms of environmental control this means:

a) preventing the ingress of water into the building and drying out those areas of buildings which have become damp due to bad maintenance or inappropriate use,

b) ensuring that high humidity levels do not occur and

c) allowing adequate ventilation – in the building context 'adequate' essentially means 'any' since experimental results indicate that even very low air flows are sufficient to prevent growth of the dry rot fungus; stagnant air in totally enclosed spaces is the real problem, (however it must be noted that low air flow may induce the fungus to seek out 'safe havens' of stagnant air – these safe havens must be eliminated),

New timber should not be built into damp masonry, as it will certainly rot. The timbers should be isolated from the masonry and/or the masonry should be dried out. Treatment with chemicals is often cited as a good support measure as it may buy time whilst the wall is drying out. In many instances walls take years to dry and chemical treatments are likely to become less effective with time. If timbers have to be saved and are of historical importance then permanent ventilation should be provided. This can be backed up by use of a boron formulation, e.g. formulations of boron compounds (e.g. sodium octoborate) in glycol, or glass rods made of a boron-based biocide. Both of these types of formulation will give good penetration of the preservative into timber and each is mobilised by the presence of elevated moisture levels. Such types of treatment normally will only need to be given to the built-in ends of beams.

Boron-based compounds are toxic to fungi but are only detrimental to organisms that feed on wood macromolecules. Their effects on humans and other mammals are minimal as long as they are used us described under the 'Control of Pesticides Regulations (1986)'. They represent a useful weapon in the armory to be used against timber decay in buildings however relying on the effectiveness of such chemicals is a risky strategy and conditions should be fully monitored. Allowance must be made for further repairs if the treatment is unsuccessful. Wherever possible timbers should be isolated as detailed below.

6.3.2.1 Beam repairs

Once the full extent of decay has been determined, decayed beam and truss ends should be cut back to the last signs of structural decay (decay is usually confined to ends of beams and trusses were they make contact with damp masonry) and repaired by one of the methods described below. In cases where original material is sacrosanct cutting back can be avoided by bolting new load-bearing timbers to the sound parts of the old. The advice of an engineer experienced in the repair of traditional buildings will be needed to confirm that sufficient strength is available within the old timber.

Repairs should be made on a like-for-like basis by splicing with timber, particularly if timbers are of historic or aesthetic importance. If not then repairs using steel or partnering with a suitable timber and resin or a combination of these can be used. If the full length of the beam or truss is structurally compromised then it should be renewed on a like-for-like basis. An alternative such as steel may be used for concealed repairs if structural needs are paramount. If timber is used for the repair then the new bearing end should be isolated from the masonry on a damp proof membrane (DPM - a material impermeable to moisture). This should be placed under the bearing end. Completely wrapping the beam end in such a material is not recommended as this could trap moisture at the end of the beam in the case of further water penetration into the building. If the beam is built into the wall then, ideally, it should be in a ventilated pocket i.e. an air gap should exist around the three sides and the end should rest on a DPM. Plastic wedges can be used for lateral support as necessary. Ventilation should be provided wherever possible to allow for dispersal of moisture. The complete wrapping of a beam end may be justified, for example in the case of a beam entering an internal wall that is unlikely to become damp in the future (Illustration 33).

Illustration 33 Use of DPM wrappings to protect beam ends.
Complete wrapping of the end, as shown here, would not be recommended for beams in external walls:- at least one face should be left exposed to prevent water being trapped in the timber

Active dry rot may apparently remain on the surface of the timbers once isolated from the bearing end, however the dry rot fungus will quickly be inactivated when exposed to ventilation. These processes will maximize conservation of the original material and substantially reduce the cost of repair (many practitioners still insist on cutting back one metre beyond the last signs of decay).

6.3.2.2 Floor joists

Floor joists should be repaired by cutting back to the last visible signs of structural decay and partnering or splicing to repair. The repairs described above for beams may be appropriate for larger cross-section joists. The new repaired ends should be supported and can be isolated from the walls by the use metal hangers where possible (Illustration 34). Alternatively, for historical importance or where joists are visible, splicing and isolating joist ends on a damp proof material could be used.

Illustration 34. Use of metal hangers where it is necessary to isolate timbers from masonry
An alternative to wrapping joists is to use metal hangers. These are not suitable for all buildings and an engineer should be consulted to advise on the most appropriate solution.

6.3.2.3 Windows and door frames

Windows and door frames infected with, or decayed by, dry rot should be repaired by piecing-in, or if beyond repair, should be renewed to match the existing. New windows and door frames must be isolated from damp masonry by a vertical DPM. Decayed fixing timbers for the frames should be removed and the voids filled.

6.3.2.4 Timber lintols

Decayed timber lintols with compromised structural strength (consult a structural engineer for advice if necessary) may be renewed with pre-stressed concrete or steel. In certain types of construction timber lintols may be visible and, thus may be of aesthetic and historic importance. In this case decayed lintols should be replaced with new, and if required, pre-treated timber however the faces of the timber in contact with any masonry should be protected using a damp proof material. Timber lintols may be left in place once the building and masonry are dry as long as sufficient structural strength remains.

6.3.2.5 Skirting boards

Decayed skirting boards should be renewed to match and isolated from the walls by use of a damp proof material.

6.3.2.6 Bonding timbers/wall plates

Decayed bonding timbers and wall plates built into damp masonry should be removed and the voids bricked in. If the plates are supporting joists then the new plate should be isolated from the masonry on a damp proof material. Alternatively replacement with brickwork is possible if acceptable from a conservation viewpoint.

6.3.2.7 Traditional lath and plaster

Dry rot-infected lath and plaster may be saved provided the source of moisture is eliminated and ventilation can be introduced. Lath and plaster is relatively thin and it will dry out quickly. Repairs may be needed to the plaster if the laths have swelled (due to moisture uptake) resulting in damage to the plaster keys.

6.3.2.8 Pugging/deafening

If pugging and deafening has become infected with dry rot this should be removed - particularly around the perimeter of rooms adjacent to damp masonry - so that ventilation can be maximised. Modern substitutes can be used to reinstate acoustic insulation between floors in buildings, however their effectiveness, compared to traditional materials, is questionable.

6.3.2.9 Modern dry linings

Plasterboard dry linings infected with dry rot may be saved provided ventilation can be introduced into the void behind by removal of skirting boards and cutting of ventilation slots at the top and bottom. If badly decayed, the battens supporting dry linings will be structurally damaged and these may have to be renewed. If this is the case, then ventilated dry linings using metal battens (firrings) are recommended. Timber battens may also be used as long as they are isolated from masonry on a damp proof material and fixed with non-ferrous screws and plugs; however metal firring systems are readily available, are cost-effective and do not provide a food source for dry rot.

6.3.2.10 Timber panelling

As with plaster-based dry linings, timber panelling can be dried *in situ* in many instances, by encouragement of ventilation behind the panelling. Dismantling of timber panelling can often cause more damage than the dry rot itself.

6.3.2.11 Masonry

Damp masonry can in most instances, given time and necessary repairs, be dried out using heating, ventilation and dehumidification. Whether this is appropriate and practicable generally depends on the location of the masonry, the mass of the masonry and whether the masonry is accessible (it may for instance be covered with ornate historic finishes). If the masonry is in a basement then it may not be possible to dry, and remedial work to timber would need to take this into account. If the wall material is saturated and of large mass then drying may be ineffective. For an internal wall drying may be carried out by dehumidification by tenting preferably from both sides. Mortar sampling should be used to determine when it is dry (i.e. moisture content of <20%). External walls are always likely to dry more slowly than internal walls.

Damp and dry rot-infected masonry which cannot be dried in the short term can delay refurbishment of the building and lead to further dry rot outbreaks. In this situation, permanent ventilation should be provided to allow drying of the masonry; for instance ventilated dry linings can be used as detailed above. The drilling of infected masonry and injection with chemicals is not necessary, such procedures introduce more moisture into the masonry and there may be a potential health hazard. From a conservation viewpoint such procedures are unnecessarily introducing non-original materials into the building under repair, and will cause damage to original fabric.

The crucial factor in all this is to prevent a bridge developing between the damp wall and any untreated wood coupled with the introduction of ventilation where possible.

Table 5. Comparison of conventional (BRE) repair and recommendations from this TAN

Problem	Recommendation by BRE	Recommendation from this TAN
If timber is structurally weakened?	Timber should be replaced by preservative treated timber or concrete or steel	Since timbers can remain intact in buildings for centuries this recommendation, based on an acceptance of inadequate maintenance, seems unnecessary. Weakened timbers must be strengthened but untreated wood can be retained as long as the appropriate precautions are taken
Timber in affected area will take up to 6 months to dry	Apply preservative, treat masonry with fluid	Timber must not be put into damp masonry. Methods, as described in the text, for preventing bridge formation between masonry and timber are necessary. In situ timber can be treated with a diffusible biocide, masonry treatment is not justified
Timber in infected area will take more than 6 months to dry	Isolate timbers from damp masonry, replace with treated timber or concrete or steel	Consider if more rapid drying methods can be instigated, use metal hangers to prevent bridging between timbers and damp masonry, build ventilation pockets around the ends of beams. The use of concrete or steel components depends upon the 'purity' of the conservation process

A number of historic and domestic properties have been treated successfully by these methods over the past twenty years by specialist environmental control practitioners. The holistic nature of the approach must always be appreciated and a typical set of solutions, in this case for a set of domestic properties in Perth, Scotland, is shown in Illustration 35. A detailed example of a treatment schedule used for part of Keith Hall, Aberdeenshire, is given in APPENDIX A.

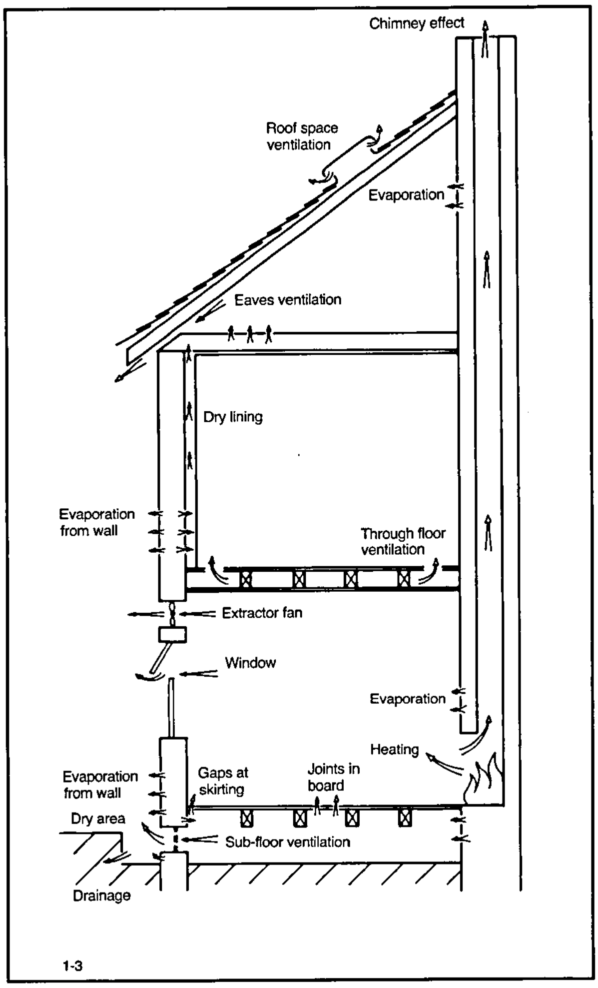

Illustration 35. Environmental control applied in a domestic housing situation.
This diagrammatic representation shows the principles of environmental control applied successfully to a number of projects in Perth, Scotland. © Hutton+Rostron

6.4 Old versus new methods

A comparison of the recommendations here can be made with those detailed in 'Remedial treatment of wood rot and insect attack in buildings' by R.W.Berry of the Building Research Establishment (1994). This book, which forms the basis of many conventional treatments makes the recommendations shown in Table 5. The equivalent recommendations from this TAN are also shown.

6.5 Monitoring

Dry rot will return to any building in which the appropriate conditions are allowed to develop. The presence of preservative-treated wood or masonry may help to prevent decay in the treated areas, but outwith these timber is still at risk. Monitoring, and an understanding of the dry rot fungus and how dry rot develops, are therefore required in order to prevent problems recurring. Adequate ventilation needs to be maintained throughout living areas, moisture ingress due to poor maintenance needs to be avoided. The instigation of a regular building inspection regime is essential to prevent new problems from developing.

There can be no long-term guarantee that dry rot will not reappear in a particular building. However regular inspections will reduce the likelihood of long-term damp problems recurring. If damp problems are rectified at an early stage then dry rot will not have time to become established. The reader is referred back to the 'checklist' of ideal conditions for the development of dry rot in Table 2.

An adjunct to regular inspection regimes is the installation of a remote monitoring system (for suppliers see Appendix G). These systems are based on the installation of moisture sensors, particularly in remote or inaccessible regions of buildings. The sensors can be linked to telephone lines and will indicate moisture build-up either to the local building manager or to a remote, off-site, specialist surveying company. The advantage of these sensor systems is that they do not rely on an individual to identify, and then do something about, a problem. Once moisture levels in an area increase, an alarm will be sounded and remedial action needs to be undertaken immediately.

There are two disadvantages to remote monitoring systems. First, they are relatively expensive to install, though once installed running costs are low. Second, they cannot be installed in all sites within a building and an expert is required to identify the at-risk areas.

Whether or not installation of a remote monitoring system is likely to be cost effective depends on a number of factors. For example, a well-used building is less likely to be at risk than a building which contains areas that are infrequently visited. A building of high historical value with important, and intact, interiors would be more appropriate for a remote monitoring system than one of lesser significance. A complex building with many high risk features (parapet gutters, internal rain water pipes, etc.) would benefit more from a remote monitoring system than one of simple design. Expert companies such as those listed in Appendix G can give further advice on this matter.

Remote monitoring systems are very good value compared with normal physical inspection when time and travelling costs are considered. The early warning offered by such systems more than covers their capital cost by the prevention of dry rot and collateral damage from other defects.

6.6 Risk assessment strategies

Dry rot should not occur in buildings, and can be viewed as a disease of badly maintained buildings, inappropriately used buildings or badly designed buildings. There is little that the conservator of an historic building can do about bad design, apart from trying to make modifications which reduce risk. However, inappropriate use can be avoided if the essential risks associated with dry rot development are understood, and poor maintenance can be mitigated by the development of appropriate monitoring regimes.

Currently at-risk areas of buildings can only be identified by experience and by reference to specific texts. The development of a full risk assessment strategy for the avoidance of dry rot, whilst desirable, has not as yet been undertaken. However by reference to this text the conservator of a building should be able to produce a checklist of potential defects, and a monitoring schedule for their inspection.

An alternative method for ensuring adequate monitoring involves the use of remote moisture sensors as detailed in 6.5. For high value, large buildings, notably Category A-listed buildings, these systems have particular value. Other features which should be considered when evaluating the relevance of sensor systems include: a) the degree of occupancy of the building (problems in well occupied buildings are much more likely to be reported than in unoccupied buildings), b) the complexity of the building and the number of hidden features (e.g. parapets, valley gutters), c) the climatic conditions (wet west coast climate or drier east coast), d) the management and ownership of the building and e) the 'value' of the building (whether financial, historic or emotional). However the total reliance on such systems is probably best avoided as it is always possible that they are missing some obvious defect. A regular inspection of potentially at-risk areas of buildings is therefore recommended.

Record keeping is an important factor to prevent incidents of dry rot. Many dry rot problems seem to recur at cyclical intervals, often because lessons learnt at one time have been forgotten, or ignored, at some time later. A record of observations, repairs, problem areas, treatment and maintenance schedules, would overcome this. Whilst such a Building Record or Log Book is probably unrealistic for small properties which may change hands at regular intervals, for larger buildings of historic significance the production of a maintenance and repair record should not just be feasible, but is strongly recommended.

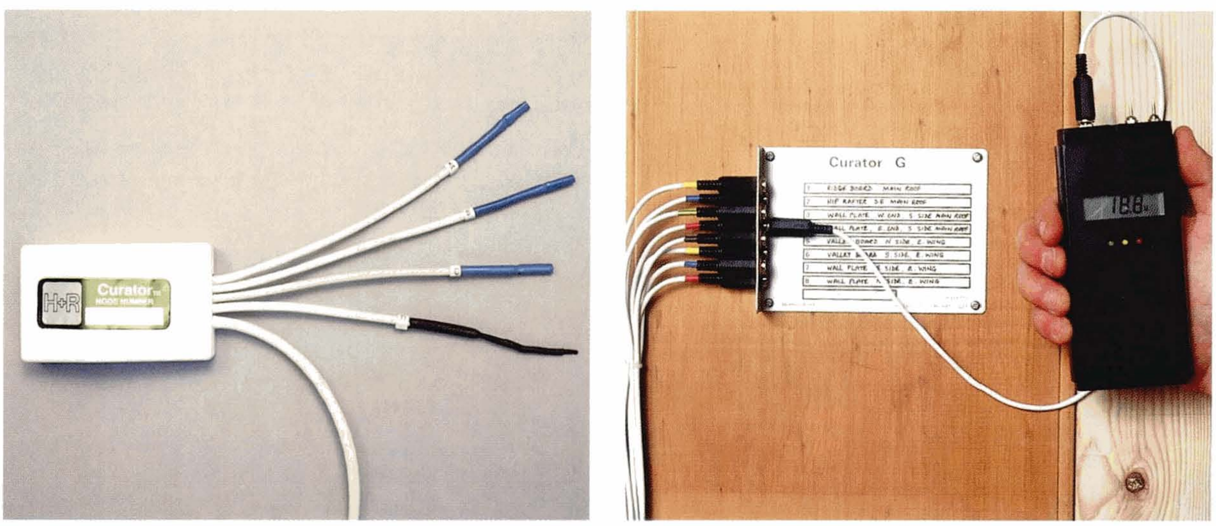

Illustration 36 A remote monitoring system. a) Node with single cable serving four different sensors such as remote humidity or timber moisture content sensors. b) An eight channel Curator® system for manual reading used in small domestic installations. Network can connect to a local control unit and to central station computer. © Hutton+Rostron

7 SELECTING AND APPOINTING SPECIALISTS

More widespread use of environmental control requires the development of a more extensive knowledge base amongst those having an involvement with a building, from owner/ manager to tradesmen and treatment specialists. How to establish how much a 'specialist' knows can form an important part of evaluating any proposed treatment systems.

7.1 Evaluating the 'specialist'

It should be apparent at this point that the full evaluation of a dry rot problem within a building requires a variety of skills and levels of understanding. To evaluate how a building is constructed requires architectural awareness, to understand how *S.lacrymans* colonises a building requires some knowledge of microbiology, to appreciate the features of dew points and how condensation can cause moisture build-up requires some knowledge of physics. Assessing a building for dry rot requires multidisciplinary skills. Perhaps it is not surprising, therefore, that the conventional treatment methods have been designed to overcome these complexities in a simple fashion which does not always analyse the roles of the various contributory factors.

However, many specialists in this field are unaware of the complexities of the issues and of the complexities of historic buildings and also of the underlying simplicity of the solution – *remove sources of moisture ingress and encourage drying and low humidity by ventilation*. The BWPDA runs a certification scheme (Certificated Surveyor in Remedial Treatment – CSRT) which ensures that their members are familiar with the issues, if not necessarily the construction of historic buildings. As would be expected much of the certification scheme is associated with the safe use of chemical preservatives.

In a recent survey of conservation practitioners' views the significant factors associated with the emergence of dry rot were considered to be as follows, listed in order of increasing significance (most significant first):

- moisture content in materials,
- presence of softwood,
- restricted air movements,
- availability of nutrients,
- high humidity,
- lath and plaster,
- temperature,
- adequacy of maintenance and
- general state of repair of building

Other factors such as:

- presence of concrete,
- low humidity and
- aesthetic use of material

were not considered, by the specialists, to be at all important.

Whilst many of the parameters were correctly assessed some perceptions were misguided. For example, it was thought that dry rot affected only softwoods; that pH of materials had no effect on decay; and that the need for good maintenance and monitoring was not the highest priority. Perhaps it is not surprising that the immediate reasons for the development of dry rot came highest on the list whereas underlying causes, such as maintenance and repair, were considered of less importance. However to the property owner, or conservator, these underlying causes of dry rot are crucial. Respondents were also asked for their views on different types of treatment method including 'environmental control', 'remedial chemical treatment', 'physical protection systems', 'heat treatment' and 'biological control'. In all cases respondents were informed of the meaning of these terms. Physical protection systems and remedial chemical treatments were considered to be the most effective.

Respondents were also offered the chance to assess a specific case and to suggest an appropriate remedy. Few offered comments which indicated a full awareness of the crucial role of water/ moisture in the development of dry rot. **Most remedies started with treatment of the decayed area, not a review of problems associated with water 'mismanagement' in the scenario under consideration.** It must be emphasised that evaluation of a dry rot problem starts with an analysis of moisture problems. Those commissioning remedial work should also be prepared to critically evaluate the knowledge base of 'specialists' (see also APPENDIX C).

7.2 Interacting with the professional

Normal procedure for dealing with a suspected dry rot outbreak starts with the survey (possibly free) undertaken by one, or more, remedial treatment companies. A better starting point would be a specialist surveyor who is not tied to a specific treatment company, or strategy. The remedial treatment company may be acceptable as long as the following guidelines are followed:-

- First ask for a detailed evaluation of the causes of any dry rot outbreak and the repair work that is necessary to prevent any further damage.
- Insist that the extent of decay is evaluated as fully as possible in order to assess the extent of repair before works are undertaken; this may well require a second, more invasive, survey. However be prepared for further discoveries and try to make sure that the company takes the opportunity to look for any related rot during the work.
- Question any decisions regarding a) removal of sound timber simply because of its location near to defective wood – ask for an analysis of any such timber using a decay detection drill (see Appendix D) – and b) the use of timber preservatives – specifically ask for the nature of the active ingredients in any preservatives and the nature of carrier molecules as this will help to evaluate the level of understanding of the company. Ensure that the chemicals are not being used because 'that's the way it's always been done'.
- Check the credentials of any treatment company asked to give a quote for a particular repair. Three types of company exist. First there are companies which specialise in environmental control methodologies. Second there are companies which are members of the remedial treatment trade organisation, the British Wood Preservors and Damp Proofers Association (BWPDA). BWPDA-attached companies will normally utilise chemical preservatives in their treatment methodologies as described by their trade organisation. Their operatives will be well trained, but are likely to insist on applying conventional remedial treatment systems. Thirdly, there are remedial treatment companies who are not members of BWPDA and these should normally be avoided. The exception would be the company that uses the types of environmental technique described in this TAN:- such companies may well not belong to BWPDA. The client should question such companies closely in terms of other projects with which they have been associated to ensure that they belong to the first group.
- Ask for information on long term preventative systems for ensuring that dry rot does not appear. If the company suggests that you rely solely on the 25 year guarantee that they will probably offer – beware, guarantees do not stop dry rot.
- Always get advice from more than one company, and call in a specialist surveyor if you are in any doubt of the veracity of the companies' findings.
- Keep your perspective correct – the dry rot fungus is not a super-normal organism, its strengths and weaknesses are very much like any other organism.
- Do not be panicked into making decisions about treatments. Most dry rot outbreaks can be halted using the methodologies described in section 6.1 (Mothballing). If you are in doubt about what to do then instigate some mothballing procedures to prevent matters getting worse, and seek specialist help.

To assist further in this evaluation Appendix C gives a more detailed list of questions which practitioners could use to evaluate the knowledge and philosophy of contractors, together with information on potential answers (see also Table 6). Lists of companies with a special interest in environmental treatment are given in Appendix G.

Finally, and to repeat, be wary of the 25 year guarantee. Such a guarantee may well produce a sense of security but will not, itself, keep dry rot at bay. The guarantee will only apply to those areas of a building that were the subject of the contract, all other areas of the building will remain at risk unless careful maintenance and monitoring regimes are implemented. So the guarantee, which of course may never be honoured, is very likely to lead to a false sense of security. Much better is to discuss, with a specialist company, ways of avoiding dry rot based on the guidance given in this TAN.

7.3 Appointing specialists and contractors

The following questions may also help to assess the 'credentials of potential contractors (see Table 6). These questions concentrate on conservation issues; a more complete set of questions is offered in Appendix C 'Checklist for Practitioners. If the questions listed in Table 6 are not answered satisfactorily then the commissioner of the work should beware.

7.4 Factors related to costs

The overall expense of using the environmental approach to treatment of dry rot is likely to be less than that for a traditional repair. However a number of factors will impact upon the costs, some of these are related simply to the nature of the building in question, some to the repair itself. Table 7 lists the most important of these factors.

Table 6. Assessing the credentials of contractors from a conservation standpoint.

Question	Appropriate response
Are you familiar with the special requirements of working in an historic /listed building?	I am familiar with the Historic Scotland publications *Scotland's Listed Buildings. A Guide for Owners and Occupiers,* and the *Memorandum of Guidance on Listed Buildings and Conservation Areas.*
Have you previous experience of working on an historic building?	I can provide a list of historic properties on which I/we have successful worked. You may contact the owners for references.
What action would you take should alteration be required to the fabric of the building?	I would check with the local planning authority to clarify the position with regard to the need for listed building consent.[1] I would identify and record all parts of the fabric that contribute to the 'importance' of the building and which is likely to be affected by the work.
Would you alter your procedures to take account of the historic fabric of the building?	The response should recognise that minimum disturbance of historic fabric will be required, which may influence the extent of opening up. But judicious use of small-diameter borescope inspection of cavities will ensure the full extent of the dry rot is identified.
If historic fabric has to be removed for access, what precautions should be observed?	Only experienced and skilled tradespeople, familiar with working on historic buildings, should be used. Any fabric removed temporarily should be carefully stored in a safe place and maintained at a suitable temperature and humidity, e.g. flooring, panelling, windows, shutters, fitments, etc.

1 Changes which may seem minor, such as cleaning or painting part of the property or alteration/replacement of timber windows with windows of different style or material, may have a major impact on the building's character and may be subject to listed building consent.

Table 7 Factors affecting the cost of an environmental treatment of dry rot

Factors related to historic building status	Factors related to environmental control
Need for skilled and experienced tradesmen/ craftsmen to work on historic fabric and for high level of supervision	Appointment of a specialist company which understands both the principles of environmental control and the philosophies of historic building conservation
Protection of historic fabric during the work	Production of a detailed report, the report to note precautions needed to avoid damage to the historical features of the building
Production of a detailed specification of works	Production of a detailed specification of works
No use of inferior materials to reduce costs or to ease supply difficulties	Use of well seasoned, and appropriate, timbers
Need to investigate and record any historic surfaces that will be disturbed and to reinstate with similar materials and finishes	Need to evaluate all areas of moisture ingress and correct both timber failures and, crucially, building defects associated with elevated moisture levels
	Need for complete removal and safe disposal of such infected timber as is structurally unsound and cannot be re-used
	Need to implement long term monitoring systems to check moisture levels in the building Need to ensure high quality maintenance and repair

8 SPECIFYING DRY ROT TREATMENT

8.1 Key points to be included in the specification

In a typical environmental treatment the specialist company will produce a report which itself allows the production of a specification, or schedule, of works. Each property will be different but certain key points would be expected in the specification of any dry rot repair or treatment. Amongst the salient points would be the following.

- Brief description of the works.
- Notes on any historical features and how they will be protected.
- Description of all specific types of work to be undertaken, e.g. general building work, slating, carpenter and joinery work, plumber and electrical work.
- Each type of work should be preceded by a detailed description of all the relevant materials to be used and quality of workmanship required (both would be expected to be of the best quality). BS references to be included where appropriate.
- Section on the actual works to be undertaken including, in the case of multi-owned properties, distinction between 'mutual works' and those related to specific property owners.
- Alternative approaches where possible.
- List of general items including any points that the potential contractor feels is missing from the specification, allowances for insurance, cartage, travelling and clearance of rubbish.
- Summary.

This list is not exhaustive but any specification and tender which lacks elements of the above should be questioned and any omissions rectified.

8.2 Standards required, particularly for repairs to historic buildings

In the treatment of dry rot using the environmental approach most of the work involved is of the type normally associated with building repair and maintenance. In this case the minimum standards required will be those set out in the relevant British Standard Specifications and Codes of Practice and European Standards, especially BS7913, 1998 *Guide to the Principles of the Conservation of Historic Buildings*. Repair to historic buildings poses particular problems for the designer and specifier because of the need to respect the authenticity of historic fabric and to arrest the decay without alteration or damage to the historic fabric. It is recommended that, before a specification for repair is prepared, the Historic Scotland publication *The Repair of Historic Buildings in Scotland (1995)* is consulted.

In preparing a specification for dry rot treatment in an historic property, the following guiding principles should be observed.

(a) As far as possible, the full extent of the work should be determined at the outset to avoid unnecessary damage to the fabric of the building through over-enthusiastic dismantling of finishes and the like.

(b) Look at the building in a holistic way as the work proceeds. Whilst every attempt should be made to determine the full extent of a dry rot attack, the way in which the attack spreads in timber hidden from view often means that, when building elements are exposed during work, it may become clear that the initial assumptions were not entirely correct. It may be necessary therefore to change the planned approach, methods or materials to address best the changed situation. However, the specification should be written in a way that ensures that any changes required during the course of the work are subjected to the same need to respect the authenticity of the building as envisaged in the original specification.

(c) Respect the character of the historic fabric so that the authenticity of the building is not compromised. Recognise that earlier repairs form part of the history of the building and, if they are still effective in performing their required function, they should be retained.

(d) Avoid replacement of historic fabric where this is not a necessary part of the dry rot repair. Any unnecessary replacement will have a serious effect on the authenticity of the building and reduce its value as a historic resource.

(e) Where possible the opportunity should be taken to reinstate lost features and elements, which were part of the original fabric, and are important to its original design. For example, members of a timber roof truss may have been replaced in the past with inappropriate materials which compromise the original design. In such a case, where structural integrity has been compromised, timbers, connections and other features should be replaced with more sympathetic materials and elements. However, replacement should only take place where there is sufficient evidence available to ensure the authenticity of the repair or replacement.

(f) Before any replacement of missing elements and the like, or other works of alteration (other than repair), there is a need to ensure that listed building consent has been obtained, where this is appropriate. (See Section 9)

9 LEGISLATION AND HEALTH AND SAFETY

9.1 Statutory consent

Before carrying out any work on a listed building it is necessary to identify precisely the nature of the work to be undertaken as this will determine whether listed building consent is required. Work that is clearly confined to repair of the fabric, as would be the case for the treatment of dry rot, does not normally require listed building consent. However, if the proposed works would affect the building's character, as a building of special architectural or historic interest, listed building consent is required. Whether the proposed works fall into this category is the decision of the local planning authority and the advice of its conservation officer should be sought. The requirement to obtain listed building consent is extended to objects or structures which are fixed to a listed building or which come within its curtilage and have done so since before 1 July 1948. Any work on a listed building which is also a scheduled ancient monument does not require listed building consent but will require scheduled monument consent, obtained direct from the Scottish Ministers.

Water leaking from gutters and downpipes can lead to excessive biological growths on the stonework of a building façade and, in the course of repairs to the fabric, it may be thought necessary to clean such growths from the stonework. In the case of scheduled monuments, scheduled monument consent must be sought in advance. In the case of a listed building, it will be for the local planning authority to decide whether listed building consent is required. For further advice on cleaning biological growths from buildings reference should be made to Technical Advice Note 10, *Biological Growths on Sandstone Buildings: Control and Treatment* published by Historic Scotland (1997).

9.2 Protection of bats

Because of the decline in their number, bats and their roosts are protected in Britain by the Wildlife and Countryside Act 1981. There are three main areas of protection applied to bats which means that it is illegal to intentionally kill or injure any bat, disturb a bat at roost or damage a roost site or obstruct the entrance. However, it is not illegal to remove bats from the living area of a house. This has particular relevance to works for the treatment of dry rot as bats regularly colonise roof spaces of old buildings and treatment of timber in such spaces will cause disturbance to the bats. Should any work be planned that may disturb bats or their roost, or planned in a building suspected of housing bats at any time, Scottish Natural Heritage (SNH) or English Nature must be consulted and allowed to advise. Work will not be prevented, but advice will be given on the least disturbing way of doing it, both for the building occupants and the bats.

When inspecting a property it is important therefore that the surveyor looks for evidence of bats. A colony of bats in residence may indicate their presence by chattering at certain times of the day or through their droppings. The absence of bats from a roosting site does not mean that the roost has been abandoned, and SNH must still be notified.

9.3 Contractual arrangements and legislation

It is not the purpose of this TAN to provide definitive advice on the detailed operation of relevant legislation. Rather, the intention is to raise awareness of building owners, their consultants, specialists and contractors to legislation and regulations that may influence the dry rot treatment processes. All persons involved should therefore ensure that they are familiar with the requirements of all legislation and regulations that will be invoked during the treatment of dry rot and repair of the fabric, and should establish the requirements which will apply to any specific work.

Contractual arrangements will have an important bearing on how statutory health and safety responsibilities are managed and discharged. They should define how the parties involved should fulfil their requirements, and fill out the particulars of the general statutory arrangements for the provision of accommodation, welfare facilities, first aid, fire prevention, protective clothing, reporting and recording of accidents etc. Proper planning for health and safety should be an integral part of the overall preparation for the efficient running of the project.

9.3.1 Construction (Design and Management) Regulations 1994

It is important that consideration for such work should involve only contractors who are able to demonstrate their competence in management of health and safety matters. This competence in management is a requirement of the Construction (Design and

Management) Regulations (CDM) 1994. CDM may be applicable to repair work associated with dry rot treatment, but not to the prior investigation work. These regulations impose duties upon clients, designers and contractors that require them to plan, manage and co-ordinate health, safety and welfare throughout the project. They do this by assuming the existence of a client and a planning supervisor for each project.

The Regulations require the planning supervisor to co-ordinate and manage health and safety during the design and early stages of preparation, and to prepare a pre-tender safety plan. The principal contractor is required to develop a health and safety plan prior to the project commencing. Everyone involved in the construction process is required to take into account the general principles of prevention and protection that are set out in the Regulations. On completion of the project, the Regulations require the preparation of a health and safety file about the project itself, which is to be passed to the client.

CDM will apply to large contracts that involve continuous work for more than 30 working days or more than 500 person days of work. Such contracts are 'notifiable' and the Health and Safety Executive (HSE) must be informed before work commences. However, many works of repair and treatment associated with dry rot will not be classified as large contracts but may still fall within the scope of CDM. This will be the case when the following situations exist:-

(a) Non-notifiable work where five or more people are working on the site at any one time. However, if four or fewer people are working on the site and the construction phase is less than 30 working days and involves less than 500 person days of work, then most of CDM does not apply.

(b) The work involves dismantling/demolition of any scale.

(c) CDM will apply to design work of any size no matter how long the work lasts or how many workers are involved on the site, unless the local authority is the enforcing authority for the work. In this case, CDM Regulations do not apply.

9.3.2 Health and Safety at Work Act 1974

All parties involved in the project, whether as owner, client, professional advisor, principal contractor, contractor or operative have certain responsibilities and duties placed on them by the Health and Safety at Work Act 1974, and other relevant legislation.

Under the Act employers have a general duty to ensure, so far as is reasonably practicable, the health, safety and welfare at work of their employees and, where appropriate, the general public. This duty includes the provision of safe plant and equipment, a safe work place, and all necessary information, instruction, training and supervision. In addition, employers should consult safety representatives appointed by recognised trade unions.

When employing five or more persons the employer is also required to prepare and issue a statement of safety policy, outlining the arrangements they are making to satisfy these duties, including how they intend to ensure that the necessary safeguards are adopted. The contractor should be asked by those managing the project to provide a copy of their safety policy, with evidence of ability to put it into practice.

In addition to those directly employed the employer must ensure, so far as is reasonably practicable, that persons not in his employment are safe and without risk to health, and to provide such information as is necessary to avoid risks. Such persons would include occupiers of the premises, visitors to sites and premises and any member of the public who might be affected by the work activities.

Employees have a duty under the Act to take reasonable care of their own safety and the safety of others who may be affected by their actions. They should co-operate with their employers so far as it is necessary to enable their employer to comply with the Act. Every self-employed person is required to conduct their undertaking so as to ensure that they and other people who might be affected are not exposed to risks to their health and safety.

Duties are also imposed on those who have to any extent control over non-domestic premises which are used by people (not their employees) as a place of work or as a place where they may use machinery, equipment etc., or substances which have been provided for their use. The person having control over the premises, the means of access, or of any plant or substance in the premises, has a duty to ensure that, so far as is reasonably practicable, they are safe and without risks to health.

Any person who has, through a contract or tenancy, an obligation of any extent in relation to maintenance and repair of the premises, or to the means of access, or for guarding against hazards from plant or substances therein, will be regarded as the person who has control of the premises, and who has the above duty to the extent of their obligations.

Manufactures, which means any person or company who designs, makes or supplies (including hiring) anything for use at work, are required to ensure that the product is safe and without risk to health when properly used. This requires paying attention to design and arranging for any necessary testing. Importantly, it also means that users are entitled to necessary information concerning the proper use and other conditions required to ensure safety and absence of risk to health in connection with the use of the product at work.

The requirements of the Act and related legislation are in their respective spheres enforced by the Health and Safety Executive, certain local authorities and other agents acting on behalf of HSE. The methods of enforcement available to the authorities include prohibition and improvement notices and prosecution. As enforcing authorities, they provide advice and information, as well as taking enforcement action when necessary.

9.4 Hazard information

The environmental approach to the treatment of dry rot, as would also be the case in any competent treatment strategy, does not employ chemical treatment as the primary method. Nevertheless, there may be occasions when treatment of timber, either pre-treated or insitu, using organic solvent-based preservatives or aqueous solutions will be appropriate.

Wood preservatives, and other biocidal products, are now subjected to a European harmonised authorisation system based on the assessment of risks to people and the environment, together with consideration of efficacy. This is the Biocidal Products Directive - 98/8/EC and came into effect in May 1998. The aim is to ensure that all biocidal products on sale are safe when used properly and can be freely traded within the European Union. The implementation of this Directive in Great Britain is enforced through the Biocidal Products Regulations 2001. From May 2000, all new substances will be assessed under the Biocides Review Regulations. However, since 1998 some biocidal products, including wood preservatives, have been subject to an existing national approval scheme, the Control of Pesticides Regulations 1986 (COPR). Products approved under COPR will continue to carry approval until their active ingredients have been approved under the new biocides regime.

In any dry rot treatment process where the use of timber preservatives is proposed, it is recommended that practitioners supervising the work and building owners or managers are fully familiar with the Biocidal Products Regulations. For further guidance the Health and Safety Executive has published a guidance note for users of biocidal products, A guide to Biocidal Products Regulations for users of biocidal products. Supervisors and owners should therefore ensure that all products used in the treatment process have been approved under the Biocidal Products Regulations or are approved under COPR and that their use conforms to the guidance contained within these regulations.

Care must be taken in the disposal of waste timber that has been treated with preservatives. Treated timber waste must be regarded as contaminated waste and disposed of by incineration through a licensed waste disposal site.

9.5 Work at heights

In dealing with dry rot, the nature of the treatment will almost certainly require work to be carried out on the internal and external fabric of the building. It may also mean working at heights above ground outside the building or above floor level within the building with access provided by scaffolding or mobile work platforms. The use of such equipment on and within historic buildings demands special care and attention to ensure that historic fabric is not damaged during the processes of erection and dismantling. It is important, therefore, that persons employed to do this work are made aware of the vulnerable nature of the fabric and have received appropriate training in measures to protect this fabric.

Having selected the systems to be used, the design stage will be influenced by the site location, public access, methods selected for treatment and repair, containment sheeting, lifting operations, loading of the scaffold and site security. In certain chemical applications, the ends of scaffold poles must be plugged to prevent ingress of chemicals.

The construction of all scaffolds must be carried out within the requirements of the Construction (Health, safety and Welfare) Regulations 1966 and any local authority requirements. All scaffolds, including mobile towers, require to be of sound construction and erected, maintained and inspected by a competent person. Where scaffolds are provided by the main contractor for common use, the onus is on the user to ensure that it is fit for its intended use by their employees. Scaffolds should be inspected weekly to see that they remain in a safe condition and in compliance with the regulations, with details of inspections recorded in a scaffold register.

Scaffolding must be erected on a safe foundation (sole and base plates) and it should be perpendicular without the uprights leaning away from the building. It must be suitably braced and tied with all components properly spaced. The working platforms must be fully boarded out (600mm minimum width) and must always include toeboards, intermediate rails and guard rails, with brickguards and containment sheeting where necessary. The access ladders must project one metre above landing platforms, should be angled 4:1 to the vertical and be securely tied.

In certain circumstances, the need for mobile scaffolds may arise. They must be of sound construction, never less than 1200 mm minimum base dimension, and the height limitations are 3.5 times the shorter base dimension for internal work and 3 times the same dimension for external work (these dimensions are inclusive of outriggers). Mobile scaffolds should, where possible, be tied into the building. In the case of historic buildings, the positioning of tying-in points needs to be selected with great care to avoid damage to historic fabric. The type and location of fixings must be agreed with the project manager and any necessary consents obtained before installation. The working platform must be fully boarded and equipped with toeboards, guardboards and an internal secured ladder. The wheels should be no less than 125 mm in diameter; they must be secured to the standards and fitted with brakes. Mobile scaffolds should be used only on level, firm ground and must never be moved until all persons have returned to ground level.

Mobile platforms are sometimes used to provide temporary working places for minor repairs, giving access to localised areas above and below ground level. They provide an alternative to scaffolding and must be used in accordance with the manufacturer's instructions and other guidance. The use of cradles is not recommended for normal repair work.

When scaffolds are used inside historic buildings the loadbearing capacity of floors and other bearing surfaces must be investigated by a competent person to ensure that the additional loads, particularly point loads, do not exceed the safe bearing capacity of the bearing surface. Any temporary loads that may placed on the scaffold during the repair work, for example stones from the structure, should be taken into account.

Internal scaffolding or towers must not be located or fixed in position in such a way as to damage wall, ceiling or floor finishes, fitting or fixtures. Wherever possible loose items should be removed from the immediate area before scaffolding is erected, and any necessary temporary protection should be put in place.

10 ENVIRONMENTAL CONTROL: KEY ISSUES

The following points identify the key issues that need to be considered when using the environmental approach to the treatment of dry rot in historic properties.

- Dry rot can be avoided by regular monitoring and good management of the building.
- If an outbreak of dry rot is discovered, do not initiate panic measures. The situation, whilst unwelcome, can be controlled and managed with appropriate action.
- Early detection of building defects is vital. This requires regular, rigorous and competent inspection of the property, especially at vulnerable locations.
- It is essential to treat the sources of high moisture levels in buildings rather than simply to focus on the symptoms. Repairs to eliminate sources of moisture must be carried out as soon as possible
- Assess the building in a holistic manner and be aware of all possible moisture sources and paths within the building.
- Apply 'mothballing' techniques wherever possible (i.e. encourage drying of the building and its fabric), but avoid the introduction of fire paths through a structure.
- Ensure adequate levels of ventilation to all enclosed timber. Even low levels of air movement will inhibit active growth of the dry rot fungus. Eliminate all stagnant air pockets within the construction but do not create fire paths.
- Check for evidence of interstitial condensation in vulnerable locations, e.g. flat roof voids, behind dry lining to basement walls, behind panelling and shutters, but without disruptive investigation.
- Always try to identify the extent of the dry rot attack before commencing remedial work. However, be aware that further work may become necessary when the construction is opened up.
- Identify and record all vulnerable historic surfaces, elements and materials before work starts and prepare a repair methodology that affords them maximum protection so that the authenticity of the building is maintained.
- Employ only suitably qualified and experienced consultants, contractors and tradespeople who have the necessary skills to advise and work on historic property.
- Repair work should be kept to the minimum necessary to eliminate sources of moisture and the removal and replacement of decayed timber, avoiding unnecessary damage.
- In the treatment of dry rot, avoid the unjustified use of chemical preservatives and removal of original timbers.
- Timber must not come into direct contact with unavoidably wet masonry. Steps must be taken to dry the wall (ventilation and heat) but recognise that traditional masonry walls can take a long time to dry out. Isolate the timber from wet masonry by the use of a DPC under the bearing surface and allow air to circulate around all timber embedded in walls.
- Where non-volatile, diffusible biocides are used for the treatment of timbers *in situ* their use must be accompanied by careful monitoring.
- To prevent a re-emergence of the fungus, rely on rigorous identification of defects at the outset, good workmanship, suitable materials compatible with the historic fabric, the implementation of preventive maintenance and regular monitoring. Do not rely on 'guarantees'.
- Keep detailed records of all defects and remedial work carried out; including materials used, treatments, modifications, repairs and replacements. By doing so a sensitivity to the way in which the building performs is built up and a historical record established.

APPENDIX A
CASE STUDY

Keith Hall, Aberdeenshire – the Use of Environmental Control

1 Background

Keith Hall in Aberdeenshire, Scotland, is a complex building constructed over many centuries. The building features a 16th century tower house with 18th and 19th century additions. The frontage of the building dates from the 1850s. Currently various parts of the building are used and owned separately, this study relates to just one part of the Hall, its southern portion.

Illustration 36. West front of Keith Hall, Aberdeenshire

In 1985 this area of the Hall was purchased by a developer with the intention of rebuilding it internally and dividing it into eight apartments. During the course of the development, dry rot was discovered at a number of sites and both dry rot and woodworm treatments were carried out using traditional methods. It would appear that the main priority at this time was treatment of the rot and a full analysis of the causes of the rot was not undertaken. By 1986 treatment was complete and soon after this the apartments were offered for sale.

Over the next few years new outbreaks of dry rot appeared in the property. As might be expected, the new owners of the property were concerned both by the appearance of the rot and by the quality of the work which had been undertaken during the first remedial treatment. Estimates of the cost of rectifying the new situation were obtained from two well respected BWPDA-certified remedial treatment companies. The costs seemed high. The original architects on the project, Douglas Forrest Partners suggested to the Consultant Building Surveyors, Squire Associates, that they might like to contact Hutton and Rostron Environmental Investigations Ltd. (H&REI) who offered some new perspectives on dry rot treatment. In particular the company offered an 'environmental approach' to treating dry rot in the building, and was subsequently instructed to carry out a new survey.

Illustration 37. Detail of part of the west elevation of Keith Hall showing granite lintols, crow's step gable end and new rainwater discharge systems

Before considering the details of the recommendations of this survey it should be noted that the first treatments were carried out in a way which would not have been approved of by the BWPDA. The reappearance of dry rot was not because of any underlying flaw in the traditional method of remedial treatment, but rather that in this case basic rules of treatment, such as removing causes of moisture build-up, had not been followed. However, it should also be noted that the proposal for environmental control treatment was costed at considerably less than the proposals of the two remedial treatment companies and involved far less radical surgery to the timber components of the building. Finally, it cannot be ignored that traditional dry rot repairs do tend to concentrate on remedial treatment to timber, whereas the crucial element in the repair must be reviewing the reasons for the attack, and correcting the underlying defects. This is the basis of the environmental method.

2 The analysis of the problem

2.1 The conventional approach

Two respected dry rot companies (both BWPDA members) produced free reports on Keith Hall in 1989. Report from Company A ran to 7 pages and included information on fungal attacks in all of the apartments. There was an acknowledgement in the report that further outbreaks of dry rot might become apparent during treatment. There was little or no information on the repairs necessary to prevent a recurrence of dry rot.

Report from Company B ran to about 15 pages and treated the individual apartments separately rather than looking at the building as a whole. Much of the work detailed was to be sub-contracted and again there was little information on the building works necessary to prevent re-emergence of dry rot at some time in the future.

On the face of it, these surveys seemed to offer a solution to the immediate problems of Keith Hall but they did not inspire confidence for the future. Both companies made it clear that the extent of the problem could not be fully determined at the time of their survey and that more problems might well be unearthed.

The residents' view was that they wanted a more definitive analysis of the problems with their properties. They were also aware now that guarantees, against the reappearance of dry rot were limited to treated areas and gave no protection against other outbreaks of the fungus.

Illustration 38. Methods to increase sub-floor ventilation were introduced throughout Keith Hall

2.2 The 'environmental control' approach

2.2.1 Overview

The proprietors were advised at an early date that the environmental approach required a very detailed survey, and that this survey would not be free. After a brief preliminary report the full survey was commissioned. This survey, which included detailed diagrams of all areas of active decay, ran to some 66 pages. Within it were detailed instructions on procedures necessary for the eradication of active dry rot in all areas of the house. Also in the survey were details of the faults that caused the timber problems in the building and recommendations for their rectification. It was noted that at the time of the earlier treatment many of these faults appeared to have been left uncorrected.

Many of the problems at Keith Hall were due to modifications important to the occupants life styles, e.g. internal bathrooms, rarely opened windows, high temperatures, fitted carpets, high levels of domestic humidity in the kitchens from laundry and dishwashers and, in some cases, intermittent occupancy. These matters were all discussed with the occupants. Keith Hall illustrates the way in which change of the layout of an historic building changes an established environmental pattern based on a draughty single domestic occupancy. Highly compartmentalised multiple occupancy with a 'tight' structure using modern materials such as glazed tiles, chipboard, fitted carpets and acrylic paints is likely to result in problems if introduced without a full understanding of the issues.

2.2.2 Main findings of the survey

During the course of the conversion of the southern part of Keith Hall into apartments a number of dry rot outbreaks had been detected. These had been rectified but there appeared to have been little attempt to rectify the faults that had caused the dry rot. The main problems were caused by lack of attention to detail of rainwater systems, the production of tightly sealed living areas within the overall building envelope and an internal downpipe in the centre of the property which was discharging its contents on to the solum of the building. Not surprisingly many areas of the property showed elevated moisture levels and a number of dry rot outbreaks were found.

2.2.3 Details of the survey

The main element of the survey was a detailed description of the findings within each of the rooms of the converted apartments. This was followed by recommendations for treatment. For example, relevant information from the 'Utility Room' of one of the apartments was as follows:

Utility Room

THE INSPECTION

Borescope inspection numbers 19 to 22 *(this refers to the relevant plan of the area)*

Ceiling: good condition

Walls: dry, at less than 1 per cent surface moisture content. Fibre optic inspection into wall void (inspection hole nos 21,22) in the south west corner of the room at skirting board level and at ceiling level revealed no visible signs of decay

Floor: floor void inspected through hatch in south east corner of the room (inspection hole no 19) revealing no visible signs of decay

Borescope inspection in south west corner of room (inspection hole no 20) revealed active dry rot growth on the external wall in the floor void. See diagram 6 *(this refers to the plan of the area)*. This outbreak is probably due to dampness as a result of overflowing guttering in the light well at this level.

Timber moisture contents in the floor void in the south east corner of the room ranged from 10 to 14 per cent.

Environmental conditions: Relative humidity of 55 per cent at 16 degrees centigrade

Relative humidity of 62 per cent at 15 degrees centigrade in floor void (inspection hole no 20)

CONCLUSIONS

The dry rot outbreak in this room is due to overflowing guttering in the light well on the south side of the room. This has wetted up the wall and attacked timber, which were unable to dry out due to the unventilated floor void

RECOMMENDATIONS

Lift floor boards along south wall and remove decayed timbers in the floor void, vacuum out any debris in the floor void

Fit permanent ventilation into the floor along the wall and isolate all timbers from the wall on a DPC material

Ensure the guttering in the light well is watertight and increase the size of the outlet to 125mm in diameter.

Illustration 39. Careful attention was paid to external ground levels and new air vents fitted where appropriate

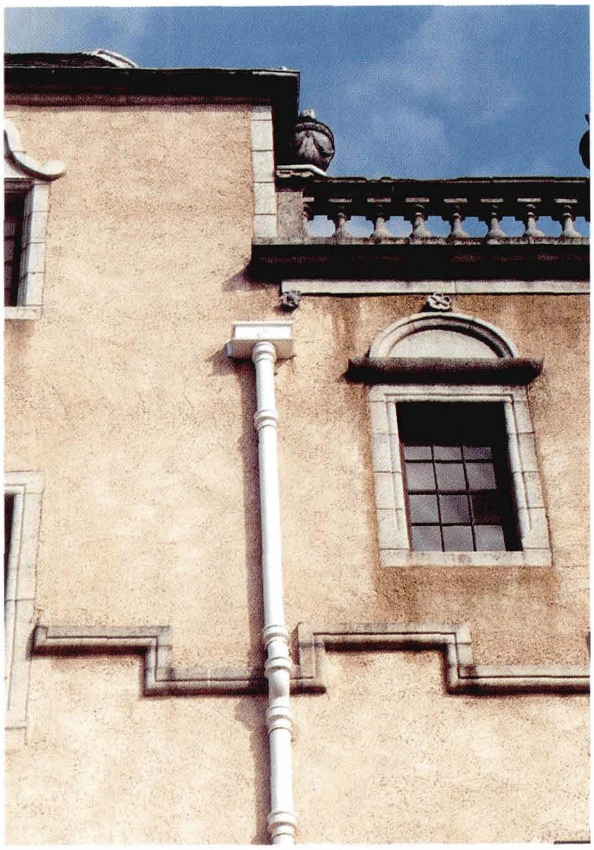

Illustration 40. New, external, downpipes fitted to replace potentially troublesome internal pipes draining from a parapet gutter

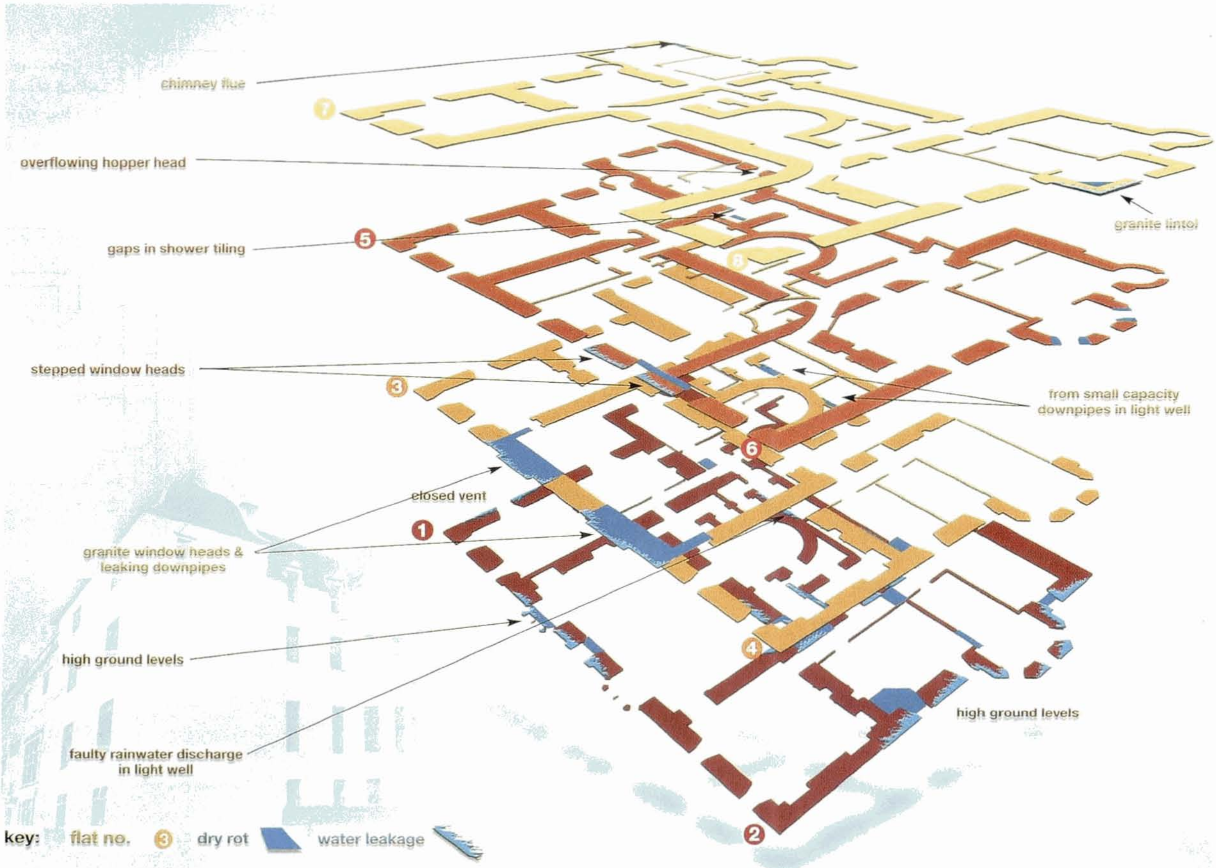

Illustration 41. 3D image of the moisture and timber problems in Keith Hall

2.2.4 Salient features of the survey

- All rooms of the property surveyed were described in this level of detail in the report.
- All areas of water ingress were identified
- Recommendations included necessary alterations to timbers and methods for improving the environmental conditions within the building envelope
- Recommendations for remedial treatment to prevent further water ingress were detailed
- Despite taking a holistic view of the building and attempting to identify and find remedies for all problem areas of the building, the total cost of the repair was less than that quoted by the specialist remedial treatment companies
- The use of chemical preservatives in the building was minimised and only recommended in a limited number of sites where timber had necessarily to be placed in contact with damp masonry

3 The 'repair'

The underlying philosophy of the environmental treatment of Keith Hall depended upon the following:

- the first stage of 'treatment' would be identification and repair of features of the building which were allowing rain water penetration
- to prevent current outbreaks of dry rot from worsening ventilation should be introduced into subfloor areas of the apartments and between inner walls and the outer building envelope
- direct connections between damp masonry and timber should be broken
- only structurally defective timbers would be replaced.

A draft 'Schedule of Works' was then drawn up by Squire Associates in discussion with the building owners. In some instances alternative methods of treatment were proposed and the owners made their choice. The final schedule, which runs to some 38 pages, was then put out to tender.

Note the huge difference in preliminary work between this approach and the more conventional approach. It is, perhaps, not surprising that the owners had more confidence in the 'environmental' contractor than in the traditional remedial treatment companies.

Specific features of the repair included:-

- lowering of external ground levels around the building coupled with the development of hardcore access paths surfaced with granite chippings (improves the ability of lower parts of the building to dry out and reduces moisture penetration)
- assessing the performance of all rainwater discharge systems
- introduction of ventilation into all roof voids and removal of debris
- break-up of bitmac front forecourt where it abutted directly on to the building
- introduction of sub-floor vents to the external walls just above ground level
- introducing, or increasing, the number of permanent skirting level ventilators along the external rooms of all the apartments
- removal of detritus and vegetable material from the solum
- removing decayed joists and their replacement with joists isolated from damp masonry with DPC's (specified as hessian based bituminous sheeting)
- introducing extractor fans into bathrooms together with vents in doors to ensure cross ventilation
- capping, and ventilation, of selected chimneys
- ventilation of dry lined walls
- repair external pointing where it is damaged and allowing moisture ingress
- repairing faulty guttering and unblock where appropriate
- isolating internal decorative timbers from damp external masonry and
- installation of plastic skirting boards and other floor contact fittings on the ground floor where a solid floor was to be installed.

The report did not specify any major roof repairs as these had been done at the time of the original conversion.

A feature of the repair was that owner/occupiers did not have to vacate the building for extended time periods whilst the building dried out. It was the belief of the contractors, and this belief has been confirmed with the passage of time, that the building did not have to be dry before reinstatement could be initiated. However, it was essential that no untreated wood came in contact with damp masonry and that ventilation channels were opened up in the building to allow drying to progress.

4 Other recommendations

The works outlined above solved the immediate problems at Keith Hall. However no remedial treatment for dry rot can ever be permanent. The traditional remedial treatment company buys time by inserting treated timbers into repairs and irrigating walls with preservatives. The equivalent for the environmental company is monitoring.

Amongst the recommendations for the long-term well being of Keith Hall were:

- regular clearing of guttering and other rain water systems
- borescope inspection holes should be left open for future inspections

In addition a biannual inspection of Keith Hall was instigated which at the time of writing (September 2000) is still extant.

5 The outcome

Over ten years later Keith Hall is functioning well as a converted building. The airways in the building remain open and the building is free of any sign of dry rot caused by external rainwater. (A small recent attack, resulting from an internal plumbing leak, was quickly identified and rectified.) The management programme for the building is still operational and there is no reason to believe that the repairs instigated in 1990 have been anything other than highly successful.

APPENDIX B
THE ENVIRONMENTAL APPROACH: A SPECIALIST'S VIEW

Geoffrey Hutton, a leading UK proponent of the environmental control of dry rot and a long-time consultant in this area, has contributed the following observations which are highly relevant to the environmental approach.

- There is no such thing as a permanent, foolproof **treatment** for dry rot. Even if all of the timbers in a building were treated with a toxic biocide, decay would occur eventually. However, timber integrity can be guaranteed if moisture levels are kept low and if adequate ventilation is provided.
- All dry rot treatments must necessarily include an element of risk. The conventional way of minimising this risk is to use biocidal chemicals – however this just confines the risk to the treated area, other areas of a building remain at risk. The environmental approach minimises this risk by **inspection** associated with a detailed knowledge of building construction.
- Conditions which favour decay are not the ones that people normally want within their buildings but, as the occupants become used to dampness/smells external agencies are often better at finding problems than owners/occupiers. Water ingress can be detected either by surveyors or by remote monitoring systems. Absolute measurements are not required, but recognition of changes in levels and moisture patterns are crucial
- Successful, long-term treatment of dry rot requires an understanding of buildings as a whole and needs an interdisciplinary approach. Architects, biologists, structural and service engineers will all have relevant information to provide. Owners and occupiers also have a role and indeed occupiers may themselves be part of the problem. Modern living, which generates large amounts of moisture and often shuns ventilation (draughts), is not necessarily compatible with old buildings. Modifications to such buildings will be required to allow for these aspects of modern life – tight boxes within an old frame will not do.
- Buildings need consistency. Cyclical changes in temperature and moisture levels are very well handled by buildings. Fast changes can be disastrous. A building which is occupied intermittently over the year is often at more risk than one with continuous occupation.
- Heating systems can exacerbate problems – we are all keen on space heating but this allows high internal humidity which, in conjunction with other aspects of modern life, may eventually cause elevated moisture levels in structural components. Ventilation and draughts, which would solve this difficulty, are shunned.
- The relationship between the 'dry rot treatment' company and the building should be similar to the relationship between a GP and his/her patient.
- The 'dry rot expert' needs to understand thoroughly the dry rot organism, the way in which it establishes itself and the factors which encourage, and inhibit, growth.

APPENDIX C
CHECKLIST FOR PRACTITIONERS

There are three phases involved in the solution of any dry rot problem – inspection and evaluation of the problem, instigation of works to overcome the problem and monitoring to prevent the problem from recurring. Traditionally, phases one and two are undertaken by the same company, phase three is often largely ignored. The environmental treatment companies will concentrate on phases 1 and 3 and will normally sub-contract phase 2 to a builder working to their *specification*. The benefits of this alternative strategy are clear. It is in the interests of the environmental treatment company to do a thorough survey at the outset and define the complete scale of the problem from day one. This may not be the case for the more traditional company which is inevitably, in the first instance, trying to produce a low estimate of total cost. It is hardly surprising, therefore, that in a traditional repair 'further out-breaks of dry rot' are often discovered, with associated increased costs.

To try to avoid costs escalating, and to get a clear picture of the works that are recommended by any company, the client (practitioner) is advised to get answers to the following questions (appropriate answers are provided). Most questioning needs to be undertaken during the Inspection and Evaluation phase as it is at this time that crucial decisions will be made about the strategy to be adopted by the treatment company.

Phase 1 – Inspection and evaluation

Question	Appropriate Answer
What will be the main objectives of the initial survey?	First – to identify any water sources resulting in elevated moisture levels in the building Second – to identify areas of timber decay
What equipment will you be using to undertake this survey?	Of interest should be whether or not the company use equipment such as moisture meters and the borescope. Use of the latter suggests that a detailed survey will be undertaken
Will your company also be doing the repair?	Yes: suggests a traditional remedial treatment company No: suggests an environmental treatment company
Have you heard of the method of 'environmental control', and what do you think of it?	The practitioner will need to evaluate the answer to this in the light of information provided in the TAN. Beware of companies that are completely opposed to environmental control methods
Is your company 'tied' to a company producing timber preservatives?	The answer may be yes for a traditional remedial treatment company
Does the remedial system that you propose depend upon the use of chemicals?	This depends upon the views of the client. The environmental control advocated in this TAN suggest much less reliance on preservative chemicals than is normal. Whatever the case, preservative chemicals must only be used in accordance with HSE regulations and preferably using guidance from BWPDA Code of Practice.
Will you be undertaking any 'opening up' to access enclosed spaces?	The answer to this should be 'Yes, if necessary'. If the company says it will only start 'opening up' when it does the repair then expect the costs to rise
Will you attempt to identify all incidents of dry rot during the survey and estimate their scale?	An environmental treatment company will try to do this, though even they may not be 100% successful. Any competent company will also try to do this.
Will the survey be free?	There is no such thing, in reality, as a free survey. The traditional remedial treatment company will incorporate the price into the price of the repair
Are you prepared to leave partially decayed wood *in situ*. If so what precautions will you take to prevent any further decay?	Yes – as long as structure is not compromised. If the wood cannot be isolated physically from surrounding, damp, masonry then diffusible biocides will be used to prevent further decay
What type of report will you produce?	The practitioner needs a detailed report, together with diagrams, of all outbreaks of dry rot together with information on moisture sources. The repair methods for both timber failures and the elimination of moisture ingress should be detailed.
Does your company offer a guarantee?	Most companies will say yes
Are you a member of the Guarantee Protection Trust (GPT)?	If not then the usefulness of the guarantee, in the longer term, must be doubted The GPT will 'guarantee' the Guarantee in case of company insolvency or whatever

Before moving on to the next phase the survey report needs to be evaluated. Pertinent questions would include the following.

Question	Appropriate Answer
Have all timbers in the vicinity of a moisture source been inspected (i.e. has the cone shaped area beneath a source been fully reviewed?	If the answer is no then further dry rot may well be found subsequently. This often occurs when a moisture source is high up in a tall building. The potential moisture path right through the building needs to be checked
Are chemicals being used in an unjustified way?	Any use of preservatives should be specifically justified otherwise the company will be acting illegally
Does the repair include cognisance of any future problems?	Blocked airways should be opened up and ventilation systems improved if necessary
Do the proposed causes of the dry rot fit with the practioner's own knowledge of the building?	Often a region of a building will have been known to have been damp for some time. The owner may be able to confirm that this is the case.
Are there any other tell tale signs of moisture ingress on the outside/ inside of the building which the surveyor seems to have missed?	Always question the surveyor if it looks as if some signs of problems have been overlooked.
Does the proposed repair include repair to the defect resulting in moisture ingress?	If not then be very suspicious of the report and remove the company from your list of potential contractors

Phase 2 – Instigation of Works

Assuming that the questions from Phase 1 have all been answered and the responses are adequate then work should proceed smoothly. If the repair is being done by an environmental treatment company then the practitioner/ client will have an advocate to ensure that the work is done correctly.

Phase 3 – Monitoring

Questions	Typical answers with comments
What monitoring systems would you recommend to prevent reoccurrence?	1. Don't worry the guarantee will cover any future problems – *don't rely on the guarantee* 2. Instigate a regular inspection routine – *this is a crucial element of the Historic Scotland 'Good Housekeeping' strategy for the protection of Scotland's listed buildings.* 3. Install a moisture monitoring system – *the practioner will need to evaluate if this is appropriate for the building in question*
How frequently should I monitor the property?	Take a careful look at all external areas of the property on a yearly basis, instigate investigation if any signs of water penetration are apparent – *this is a sensible approach to the 'Good Housekeeping' strategy*

APPENDIX D
USEFUL EQUIPMENT

Introduction

With the knowledge base provided in this Technical Advice Note it should be possible for any property owner, or conservator, to make an initial assessment as to the nature of a dry rot outbreak. Some basic equipment will help in this, individuals/ organisations responsible for large collections of buildings may wish to purchase specialist equipment. The following is a list of equipment, those marked * are really for the specialist surveyor. The client might well ask his surveyor/ remedial treatment company, if they have access to such equipment.

Note: the inclusion of manufacturers' trade names does not imply endorsement of their particular products over any other, they are merely representative of suppliers of equipment available for a specific purpose.

Illustration 42. The tools of the trade
A wide variety of equipment is now available to assist in the detection of rot within buildings. The illustration shows a well equipped operative. However the building manager can do a great deal with a sharp prodding instrument, a moisture meter and a reasonable level of common sense.

Notebooks, writing materials

Binoculars

Small mirror and/or Surveyor mirror *

Equipment for lifting floorboards, etc

Hammer, screw driver, ladder

Torch, compass, camera

Moisture meter * (normally a conductivity meter for example the "Protimeter", preferably with a probe that can measure moisture at depths up to at least 250mm – or a capacitance meter)

Electric drill and small diameter (6 mm) drill bit (to make holes for Borescope inspection, to drill for gravimetric moisture samples and to probe larger section timbers for decay)

Borescope * (Olympus or Top Optic) allowing visual inspection of voids through holes of minimal size.

Decay detection drill * (e.g. Siebert drill or Resistograph drill) for assessing the soundness of wood.

Data loggers * with sensors for measuring temperature and humidity and material moisture content.

Personal safety equipment, such as face masks and safety helmets, may also be necessary

In planning any building inspection, the safety of the individual is paramount, and provision must be made for safe access and methods of working.

Further information on some of the more specialised items on this list follows.

Essential and specialist equipment

The basic but essential tool for assessing timber decay is a sharp prodding instrument such as a screwdriver. This will provide most people with the ability to assess timbers for surface decay and /or highlight areas that need further investigation using more specialist tools.

Moisture meters

Most moisture meters are calibrated for wood and give accurate results in timber (unless the timber is treated in which case false high readings are given). They can also be used on masonry were they are of most use in spotting trends rather than giving absolute information on moisture levels. They can often give misleading results, the most notorious being when used in areas with foil backed wall coverings and in areas of previous water penetration were salts are present. If salts are suspected (for instance, high readings but no obvious external defects) then mortar samples should be taken for gravimetric analysis. Used with common sense they can be most informative, particularly when assessing timber for moisture levels above 20%, the level at which decay is likely. When used with a drill and deep probe, the moisture content of timber at depth can be assessed (for instance, the built in end of a beam) giving invaluable data on decay potential.

The client should always ask an operative, who is insisting that moisture meter readings indicate dampness, what other evidence is available to support this conclusion. It is easy to be overly, and inaccurately, impressed by meter readings.

Borescope

A rigid Borescope enables a surveyor to inspect hidden voids with minimal damage to the fabric. A 10mm diameter hole is drilled if an existing hole is not available to provide access for the borescope (Illustration 43).

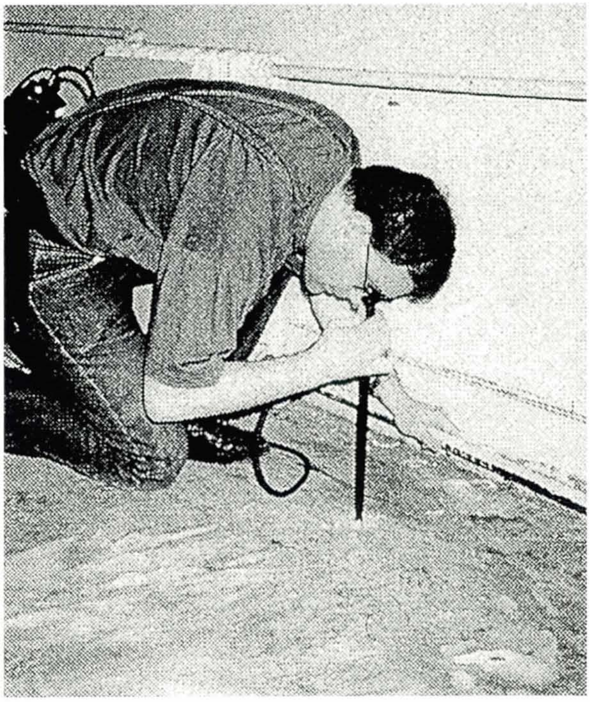

Illustration 43. Use of the borescope

A wide variety of equipment is now available to assist in the detection of rot within buildings. The illustration shows a well equipped operative. However the building manager can do a great deal with a sharp prodding instrument, a moisture meter and a reasonable level of common sense.

A high-intensity light illuminates the viewing area allowing hidden voids and cavities to be viewed. However interpreting information from a borescope requires practice and it can be easy, for example, to confuse spiders' webs with fungal mycelium (Illustration 44). Borescopes are excellent at allowing an assessment of the distance that a dry rot outbreak has grown from its origin. They can avoid damage to precious wall coverings and avoid the necessity for whole scale lifting of timber to allow access to hidden areas. However if decay is detected, then opening up may be necessary to test the fabric for physical damage. With the information provided by the borescope it is possible to minimise any associated damage.

Illustration 44. The borescope view of the world
Interpreting the image from a borescope can be difficult. In this view a mass of white mycelium can be clearly seen on the surface of the wood. However other materials such as spiders' webs and old insulation material can be confused with the mycelium of the dry rot fungus.

Electric Drill

The electric mains or battery-operated drill is not, as such, a specialist tool although the techniques for its use in this context are. Drills are used for making access holes for borescopes, taking mortar samples for gravimetric analysis and for probing larger section timbers for decay. The latter is a specialist technique, which requires experience to interpret the results. Larger section timbers are drilled into with a small diameter drill bit at regular centres. The resistance to drilling changes if decayed or soft timber is encountered this is interpreted by feel, so that an experienced operative can give accurate assessments of decay. The main advantage of this technique is that it is easily carried out, gives accurate results, allows deep moisture contents to be taken by means of a deep probe (by inserting through the drill hole) and is cost effective because the drill bits are cheap and robust. The disadvantage is that relatively large holes are needed, these may well be unacceptable in some situations. This is where a specialist drill is most useful.

Illustration 45. Decay detection drill the 'Seibert Drill'
In the illustration the Seibert Drill is being used. The alternative, more expensive, Resistograph performs the same service. Both pieces of equipment can give information on the integrity of large dimension timbers, and access is only required from one side.

The decay detection drill is an expensive piece of equipment, which only a limited number of operatives will possess. The drill is used to detect the presence of decay cavities in wood and is most useful in assessing potential damage to timbers close to, but not directly involved in, dry rot outbreaks and where surface damage is unacceptable (Illustration 45, see also Illustration 46). The drill will identify changes in the density of wood and hence regions which may have been infected by the fungus. The main difficulty associated with the use of these drills (because of the small diameter of the drill bit) is to ensure that the drill bit goes through, rather than around, growth rings or else false readings will result. The drill bits are also fragile and expensive.

What the drill cannot do, and there is no equipment available at present which can do this, is give direct information on the residual strength of partially decayed wood *in situ*. The presence of any sort of decay pocket must therefore be used as evidence for strength loss and treated accordingly. If structural integrity is suspected then splicing in new wood, bolting on sound wood, use of resin formulations or replacement will be necessary.

Illustration 46. The Mattson auger
A more traditional method for obtaining information on the integrity of large dimension timbers. The hole left by the auger can be used to determine internal moisture levels within the wooden feature.

Data loggers and sensors

Data loggers recording temperature, relative humidity and moisture contents of materials with the appropriate sensors are useful in areas where drying of the structure is being carried out. They enable a constant assessment to be made and, based on analysis of the data, allow changes to be made to the drying regime accordingly.

There is no doubt that long term monitoring of buildings, using the various methodologies associated with equipment of the general type described in this Appendix, will be a sound investment.

APPENDIX E
GLOSSARY OF TERMS IN COMMON USAGE

Basidiomycete
a fungus from the subdivision Basidiomycotina of the fungal kingdom; this group contains the principal wood decay fungi including *S.lacrymans*.

Brown rot
a fungal decay of wood that results in the degradation of cellulose, the predominant structural constituent of wood, with little effect, other than modification, on lignin. *S.lacrymans* is an example of a fungus which causes brown rot.

Cellulose
glucose-based polymer, structural element of wood, susceptible to digestion by brown and white rot fungi.

Diffusible preservative
a preservative that can be applied at one point but have its effects at a distant. In order for such a biocide to diffuse through timber, free moisture must be present in the treatment area. Boron-based compounds are the most commonly used diffusible preservative for timber.

Dry rot
wood decay predominantly caused by *S. lacrymans*, the 'true' dry rot fungus (or by a few related fungi, all of which are rare in, or absent from, the UK).

Environmental control
holistic treatment of dry rot which concentrates on the conditions which allow the development of decay and, by correcting these conditions and introducing regular inspections, prevents the reappearance of dry rot.

Fibre saturation point
if previously dry timber is progressively moistened by atmospheric and allowed to equilibrate with a saturated atmosphere (100% RH), a state known as the fibre saturation point is reached. This state is characterised by the fibres of the woody cells completely imbibing moisture without there being any filling of the microtubular structure, such as absorption of liquid water would cause.

Fruit body
reproductive structure produced by a fungus for the distribution of spores, for organisms such as *S. lacrymans* also termed a basidiocarp.

Heartwood
wood from central region of the tree, often darker than the sapwood, may contain natural preservatives rendering the wood relatively durable.

Hyphae
fungal filaments collectively forming the mycelium (singular hypha) – see Illustration 1.

Lignin
complex polymeric structure in wood, contributes to strength and durability and protects the cellulose to some extent. Modified, but not degraded by brown rot fungi such as *S. lacrymans.*

Moisture content
is the percentage of water in a material. Normally it is defined as the wet weight of a material minus the dry weight, all divided by the dry weight and multiplied by 100. As timber decays its maximum moisture content increases as woody material can be replaced by water.

Mycelium
the vegetative (non-sexual) growth of a fungus that is made up of a mass of individual hyphae (plural mycelia) – see Illustration 1.

Relative humidity
(RH) an index of the moisture content of an atmosphere in relation to the maximum water-holding capacity at a particular temperature (expressed as a percentage).

Sapwood
outer zone of the tree which contain(ed) living cells. Lighter in colour than heartwood and with no specific durability characteristics.

Serpula lacrymans
the causative organism of dry not. Name derived from 'serpula' the Latin for 'to creep' and 'lacrimans' (sic), the Latin for 'tears' – water droplets often appear on the surface of the *S.lacrymans* mycelium during the decay process.

Strand
a mycelial formation composed of an aggregation of hyphae and which is used by the fungus to transport water and nutrients around the mycelium; sometimes referred to as a rhizomorph or a cord.

Wet rot
rot caused by fungi other than those defined by the term dry rot fungus.

White rot
a fungal decay of wood that results in the degradation of both lignin and cellulose as well as associated hemicelluloses.

APPENDIX F
BIBLIOGRAPHY

Useful texts

General texts on building conservation

- British Standards Institute 1998 BS 7913 *Guide to the Principles of Conservation of Historic Buildings.*
- Feilden, B 1994 *Conservation of Historic Buildings*, Butterworth-Heinemann, Oxford.
- Historic Scotland 1999 *Scotland's Listed Buildings: A Guide for Owners and Occupiers*, Historic Scotland, Edinburgh.
- Historic Scotland 1998 *Memorandum of Guidance on Listed Buildings and Conservation Areas*, Historic Scotland, Edinburgh.
- Knight, J (Ed) 1995 *The Repair of Historic Buildings in Scotland*, Historic Scotland, Edinburgh.

For an extensive review of many aspects of the biology of the dry rot fungus including an early exposition on environmental control see:

- Jennings, D.H. and Bravery, A.F. (1991) *Serpula lacrymans*: fundamental biology and control strategies. Wiley, Chichester, UK.

For a detailed analysis of the effects of fungi (notably *S.lacrymans*) in buildings see:

- Singh, J. (1994). Building Pathology: management of decay and health in buildings. E&FN Spon, London, UK.

For an extensive and fully illustrated review of many aspects of *S.lacrymans* see:

- Bech-Andersen, J. (1995). The Dry Rot Fungus and other fungi in houses. Hussvamp Laboratoriet ApS, DK-2840 Holte, Denmark.

For a review of the generally accepted UK systems for the treatment of dry rot and, interestingly given the industry concentration on preservative chemicals as the basis for treatment, information on environmental control strategies see:

- Berry, R.W. (1994). Remedial treatment of wood rot and insect attack in buildings. Building Research Establishment, Watford, UK
- Health and Safety Executive 2001. *A Guide to the Biocidal Products Regulations for users of biocidal products* ISBN 0 7176 1882 6

For a simple guide to the identification of wood decay fungi in buildings see:

- Bravery, A.F., Berry, R.W., Carey, J.K. and Cooper, D.E. (1992). Recognising wood rot and insect damage in buildings. Building Research Establishment, Watford, UK.

and for information on normal UK practice as recommended currently for the BWPDA see:

- British Wood Preserving and Damp-Proofing Association (1995). Remedial Timber Treatment. BWPDA, Stratford, London, UK.

For the traditional perception of dry rot see:

- Barber, P. (1993) Dry Rot: the beast in the basement. Lennard Publishing, Harpenden, UK.

Papers of historical interest on dry rot/ Serpula lacrymans

There is a very long and varied history of publications on the dry rot fungus. The classical studies on the organism were undertaken by Richard Falck early in the 20th century. Some of the most important and relevant papers published since then are as follows:-

- Die Merulius faule des Bauholzes Hauschwammforschugen, Vol. 6 pp1-422. Falck, R. (1912). Dry rot in timber. Translated as an extended abstract by Hornung, U. and Jennings, D.H. Bull. Br. Mycol. Soc. 14, 119-130 (1980). *This is the classical study of dry rot fungus and demonstrates again how 'old' knowledge of the fungus has tended to be forgotten in the modern age.*
- Dry rot investigations in an experimental house. Findlay, W.P.K. Forest Products Research Record No 16. DSIR, HMSO, London, UK. (1937). *A first attempt to develop large scale models to study the effects of S.lacrymans and its control.*
- The decay of timber and its prevention. Cartwright, K.St.G. and Findlay, W.P.K. HMSO, London (1958). *A classic text from the Forest Products Research Laboratory in the UK*
- A bibliography of the dry rot fungus Serpula lacrymans. Seehan, G. and Hegarty, B. International Research Group on Wood Preservation, Doc No. IRG/WP/1337, (1988). *A list of ALL the papers on dry rot published up until 1988. For papers after this see Palfreyman et al (1995) from the research paper list and the thesis of G.A Low.*

Selected recent research papers on *Serpula lacrymans*

- The management and control of dry rot: a survey of practitioners views and experiences.Krzyzanowski, N., Oduyemi, K., Jack, N., Ross, N.M. and Palfreyman, J.W. Journal of Environmental Management **57**, 143-154 (1999). *An analysis of practitioner knowledge about dry rot and the dry rot fungus. The information in the paper was collected from the questionnaire in Appendix E*
- The impact of current research on the treatment of infestations by the dry rot fungus *Serpula lacrymans*. Palfreyman, J.W., White, N.A., Buultjens, T.E.J., and Glancy, H. International Biodeterioration & Biodegradation 35, 369-395 (1995). *A review of the field in 1995*
- Palfreyman, J.W., Phillips, W. and Staines, H.J. (1996). The effect of calcium ion concentration on the growth and decay capacity of *Serpula lacrymans* and *Coniophora puteana*. Holzforschung 50, 3-8. *One the dependence of the dry rot fungus on calcium from masonry*

Some useful WWW addresses on *Serpula lacrymans* and mycology in general

http://scieng.tay.ac.uk/drrg/index.htm
Web site of the Dry Rot Research Group at the University of Abertay Dundee

http://www.hussvamp-lab.dk/nyhedsuk.html
Site for the company run by Prof Jorgen Bech Anderson in Denmark

http://www.ridoutassociates.co.uk/pr01.htm
The Ridout Associates web site

http://pacificcoast.net/~mycolog/chapter5b.htm
General information on mycological aspects of wood decay

http://muse.bio.cornell.edu/~fungi/welcome.html
A general mycology resource

http://www.rbgkew.org.uk/mycology/index.html
Information on the mycological resource at the Royal Botanic Gardens, Kew, London, UK

In addition

http://www.historic-scotland.gov.uk/
The website of Historic Scotland for more information on Historic Scotland publications, policies and buildings.

Many of the companies involved in dry rot treatment also have Web sites. Relevant ones are listed in Appendix G

APPENDIX G
USEFUL ADDRESSES
(AS AT SEPTEMBER 2002)

Specialist services and equipment are currently available as listed below. This information is provided in good faith but the inclusion of any particular firm, individual or product does not imply endorsement by Historic Scotland. Other companies and individuals may offer similar services.

Conventional Remedial Treatment Companies

Contractors assessed for technical competence and compliance with the BWPDA Code of Practice and compliance with health, safety and environmental protection legislation can be contacted via:

Evironmental Treatment Companies

Environmental Building Solutions Ltd.
Dr Jagjit Singh
EBS Ltd., 30 Kirby Road,
Dunstable, Bedfordshire,
LU6 3JH United Kingdom
Tel: 44-(0)1582-690187
Fax: 44-(0)1582-690188
http://www.ebssurvey.co.uk

Hutton and Rostron Environmental Investigations Ltd (H&REI Ltd)
Tim Hutton
H&REI,
Netley House,
Gomshall, Guildford, Surrey,
GU5 9QA United Kingdom
Tel: 44-(0)1483-203221
Fax: 44-(0)1483-202911
http://www.handr.co.uk

Ridout Associates
Dr Brian Ridout
Ridout Associates
147a Worcester Road, Hagley,
West Midlands, DY9 0NW, U.K.
Tel: 44 - (0)1562 885135
Fax: 44 - (0)1562 885312
http://www.ridoutassociates.co.uk/pr01.htm

The British Wood Preserving and Damp-proofing Association
1 Gleneagles House
Vernon Gate
South Street
Derby
Tel: 44 - (0)1332 225100
Fax: 44 - (0)1332 225101
http://www.bwpda.co.uk

For independent information on the dry rot fungus

Dry Rot Research Group
Professor John W Palfreyman,
DRRG,
University of Abertay Dundee,
Bell Street,
Dundee, DD1 1IH
Tel: 44 - (0)1382-308640
Fax: 44 - (0)13282-308663
e-mail: J.Palfreyman@abertay.ac.uk

and for advice on timber problems in general

SIWT Projects Ltd.
Dr Derek Sinclair
SIWT Projects Ltd.,
University of Abertay Dundee,
Bell Street,
Dundee DD1 1HG
Tel: 44 - (0)1382-308930
Fax: 44 - (0)1382-308930
e-mail: mltdcrs@tay.ac.uk

Suppliers

Moisture Meters

Protimeter
Protimeter plc
Meter House
Fieldhouse Lane
Marlow
SL7 1LW
Tel: 44 - (0)1628 472722
Fax: 44 - (0)1628 474312
http://www.protimeter.com

Sovereign
Sovereign Chemical Industries
Barrow in Furnace,
Cumbria, LA14 4QU
Tel: 44 - (0)1229 870800
Fax: 44 - (0)1229 870850
http://www.sovchem.co.uk

Borescopes

Endoscan
Endoscan Marketing Ltd.
58 Acacia Road
St John's Wood, London, NW8 6AG
Tel: 44 - (0)207 483 2300
Fax: 44 - (0)207 586 8717
http://www.endoscan.co.uk

Davin Optronics
Davin Optronics Ltd.
Chester Road,
Borehamwood, Herts, WD6 1LT
Tel: 44 - (0)208 905 1414
Fax: 44 - (0)208 207 6581
http://www.davinoptronics.com

Olympus
Olympus Optical Company (U.K.) Limited
2-8 Honduras Street
London
EC1Y 0TX
United Kingdom
Tel 44 (0)20 7253 2772
Fax 44 (0)20 7251 6330
http://www.olympus.co.uk

Micro drills

Sibert Drill
Sibert Technology Ltd.
2a Merrow Business Centre
Merrow Lane, Guildford
Surrey GU4 7WA England
Tel: 44 (0)1483 440 724
Fax: 44 (0)1483 440 727
http://www.sibtec.com

Resistograph
Frank Rinn
Kuehler Grund 48,
D-69126 Heidleberg, Germany
Tel: 00 49 6221 314 387
Fax: 00 49 6221 315 406
e-mail: 100526.2713@compuserve.com

Remote Monitoring Systems

Curator System
H&REI Ltd.
(see under Treatment Companies)