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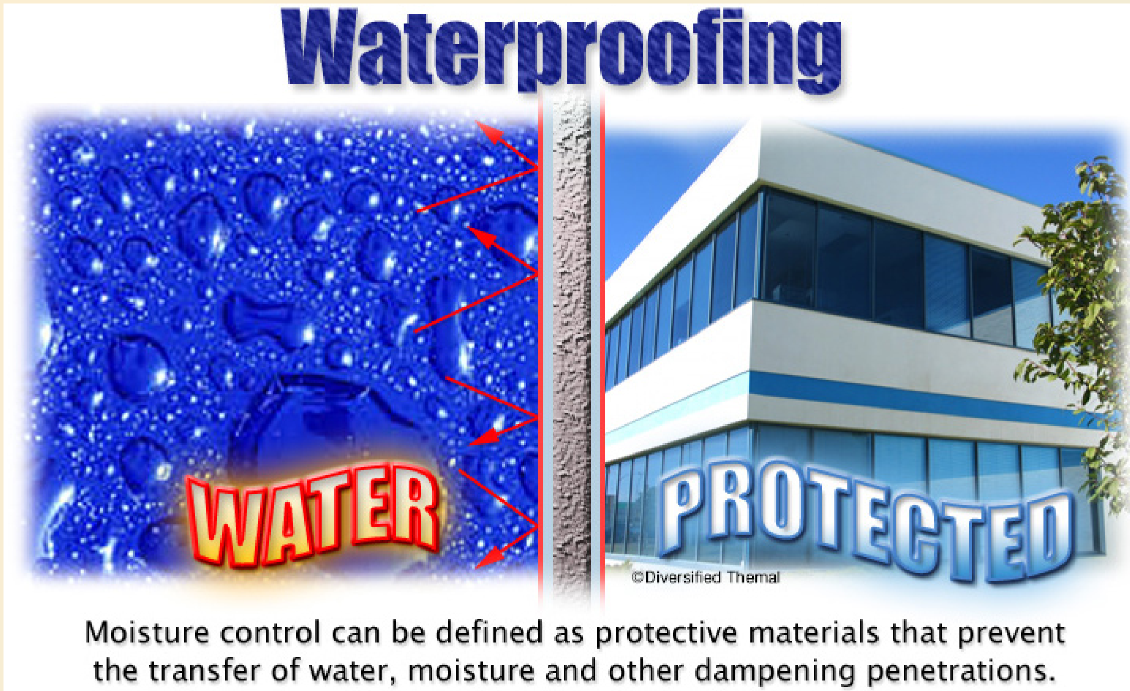

Prokem SPECIALITY CHEMICALS

محتويات الملف

- البرنامج الزمنى
- اهداف البرنامج
- مقدمة وتعريف بالموضوع .
- الرطوبة والنشع ورشح المياه فى المبانى (الاسباب وطرق القياس والعلاج) .
- عزل البدرومات (الاسباب وطرق العلاج والمواد المستخدمة) .
- عزل الاسطح وخزانات المياه وحمامات السباحة (المعاينة والتطبيقات والمواد) .
- رسومات كروكية توضيحية .
- النشرات الفنية للمواد العازلة انتاج شركة بروكيم وتطبيقها .
- مقالات عملية وعلمية حول موضوع العزل المائى للاسطح وحمامات السباحة وخزانات المياه .

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فهرست الملــف

اهداف البرنامج

بعد الانتهاء من هذا البرنامج التدريبي ينبغي ان يكون المتدرب قادرا على :-

1) التعرف على الرشح والنشع فى المنشآت واسبابه وطرق القياس .
2) كيفية معاينة المنشآت التى تحتاج لاعمال العزل او التى تعانى من مشكلات النشع والرشح وتسرب المياه وكيفية تقييم المشاكل وتحديد اساليب العلاج .
3) معرفة اساليب وطرق العزل على اختلاف انواعها .
4) معرفة نوعيات المواد المستخدمة فى اعمال العزل وكيفية اختيار النوعية المناسبة للمكان المناسب .
5) التعارف على منتجات شركة بروكيم وتطبيقاتها العلمية .

Dampness in Buildings

Diagnosis, Treatment, Instruments

Introduction

A word for the professional

The purpose of this book is to provide a better understanding of dampness problems in buildings and to offer advice on diagnosis and cures; it is not to provide any data for the design of buildings.

In writing it we initially thought of addressing it only to you, the professional surveyor, architect, environmental health officer and builder. We well remember the enthusiasm with which the first Protimeter moisture meter was received by you in 1956. Many of you have since gone on record as saying that you do not know how you were able to carry out an efficient survey of a house without using a Protimeter; and many more of you are proving it daily by your continued use of this type of meter. The collaboration between you, the professional and Protimeter plc has been a fruitful and happy one lasting over more than a quarter of a century, and is still continuing.

Moisture problems have always been the bane of your lives. And if anything, they are even worse today than they were 25 years ago. Condensation has become a much more common problem particularly as it can so often be confused with rising damp.

Indeed, we have good reason to believe that only about one third of all dampness problems are due to rising damp. The other two thirds are condensation and other forms of moisture ingress:

> First there is the survey carried out by the Building Research Establishment Scottish Laboratory between November 1979 and March 1980, the results of which were published by HMSO in 1982 under the title 'Dampness: one week's complaints in five local authorities in England and Wales'. One of the significant conclusions of the survey is that 66 per cent of the identified dampness complaints were caused by condensation.
>
> Secondly, in the Protimeter Laboratories specimens of wallpaper and plaster are received almost daily from surveyors and local authorities for chemical analysis for the presence or absence of certain nitrate and chloride salts, which are the typical by-products of rising dampness (*see* Chapter 4).
>
> Although the specimens obviously come from walls where the surveyor or environmental health officer suspects the possibility of rising damp, yet salts are consistently found from year to year to be present in only about one third of all specimens tested.

This is proof, if proof is needed, of how very difficult it often is to diagnose the true cause of dampness; and whilst there are, of course, many conscientious remedial treatment firms, there are inevitably some which are keen to carry out a profitable cure for rising damp irrespective of the true fault; and if you happen not to agree with their prognosis, they produce ingenious gadgets and arguments in support of their case.

This book will help you where appropriate to prove them wrong.

Having said this we hope you will not mind if we address this book also better to call in a specialist and tell him what needs doing, than to invite a 'free' survey which must be paid for eventually out of the profit on the job; in the long run, no survey can be truly free.

We urge you to help yourself in matters of dampness in the home. Know and understand what is the true condition of your house; diagnose and cure any dampness before it can cause you any trouble. Avoid being 'sold a pup' in the house you are buying. Above all, avoid putting yourself in the hands of firms which have a vested interest. Use specialists only to do what really needs to be done.

You can't do this without a moisture meter. All professional surveyors use them; by far the greatest number use Protimeter instruments, sophisticated and highly sensitive tools appropriate to their professional skills. But for detection and diagnosis of dampness before you can feel it or see it, and for finding the source of any obvious dampness which you can see, there are one or two small meters available to you which are comparatively easy to use. They are sufficiently sensitive and extremely portable. You can use them on top of a ladder, in the loft, or in the space under the floor.

When to call in a surveyor

In one respect you, the householder, have an advantage over the professional, because you can inspect regularly. You can keep odd damp patches under observation to see whether they are growing or declining and so have the benefit of monitoring changes which the professional surveyor on a single visit cannot do. You need not call in a professional surveyor for simple problems, but you should do so, as one calls in a doctor, if a problem gets beyond you. But, even if you find you need outside help, at least by carrying out regular instrumental inspections you may be able to prevent a small problem becoming a large and expensive one.

For the house owner, detailed guidance on how to conduct a survey for dampness in your own home is given in the Appendix of this book.

Remember that your home is a big and worthwhile investment. Do look after it.

The dampness problem

Those who have responsibility for buildings, and those who use them, are more conscious of dampness now than in the past. If they are surveyors, they have onerous responsibilities which demand that they overlook no sign of dampness, and they are expected to advise their clients on the extent, severity, and future implications of what they find. If they are building or housing managers, or enviromental managers, they will be left in no doubt by the occupants if dampness is among the defects that they suffer, and they will also be expected to prescribe the cure. But a cure is only possible on the basis of a correct diagnosis. This book, therefore, is to help the reader towards a correct diagnosis.

The great majority of surveyors use electrical meters based on the measurement of conductance for detection and evaluation of dampness; their job, insofar as it concerns building dampness, would be impossible without them. Many building, housing management, and environmental health departments also find these instruments essential. But dampness is usually not a simple problem and hence correct diagnosis is sometimes very difficult. Electrical instruments will not, themselves, diagnose the cause of dampness. They do, however, provide indications of great value, including the quantification of dampness which might otherwise not yet be detectable.

An electrical moisture meter for buildings is therefore part of a system for diagnosis, of which the other part is the knowledge and experience of the operator. It is the aim of this book to provide the knowledge and to show how a range of conductance type moisture meters, together with their accessories, and an analytical service, can provide the evidence. The remaining factor, the experience, we cannot supply. But experience will be gained more quickly if interpretations are based on understanding, which we hope this book will provide.

All dampness is water out of place, but it is convenient to classify its different manifestations by their source, and the routes by which the unwanted water enters the inhabited areas. A primary distinction is between water which enters as a liquid, and water which is condensed from the atmosphere. Until the 1960s the latter was almost unknown within buildings, but with changes in building design and in living styles, condensation has become a major problem, causing about two thirds of the complaints of dampness in houses received by housing authorities. It is this huge increase, and the difficulty of diagnosis which it often presents, which is partly responsible for the greater awareness of dampness among both professionals and laymen. Another factor is the great amount of rehabilitation of older buildings, large and small, which is now undertaken. This has often revealed dampness which was tolerated, or regarded as inevitable, by our forebears; in addition 'modernization' does much to increase condensation by total elimination of draughts and modern decoration makes it more obvious.

Awareness of dampness has also been stimulated by the rise of a service industry of 'specialist' firms devoted to curing it. This is an industry largely directed towards curing rising damp. It is generally based on the valuable and relatively cheap process of injecting water repellent materials into the lower parts of walls, thereby exploiting a principle explained later in this book for preventing the rise of water by capillarity. This is a competitive industry which uses a lot of publicity; it has spread quite widely the impression that rising damp is the main cause, or at least a very frequent cause, of dampness in buildings. In fact rising damp is relatively uncommon cause of dampness in buildings.

The specialist damp-proofing industry includes a majority of responsible firms. Many of them are members of the British Chemical Dampcourse Association and similar organizations in other countries. These firms work to the excellent codes of practice published by their Associations. However, the standard of others is not universally high. It is necessary, especially, to look critically at the survey reports produced by some who are surveyors in name only. It is one function of this book to aid such critical evaluation. It is hoped that critical customer appraisal will bring to an end the practice of attempting to cure condensation, penetrating damp, or even plumbing leaks, by irrelevant treatments for 'rising damp'.

Decay of wood is one of the most serious consequences of dampness. It is therefore a considerable advantage of the conductance type of electrical moisture meters that they give direct measurements of water in wood. With the aid of a deep penetrating hammer electrode, the instruments especially designed for timber can show whether or not there is serious dampness within thicker pieces which is not apparent at the surface. This is important when structures are drying out after flooding or saturation during fire fighting.

If, as sometimes happens, it is impossible or uneconomic to cure a source of dampness completely, it is important to treat wood with preservative, or to use wood which has already been so treated, for replacement. Wood preservative treatments, or methods of application, are not all equally effective;

some may be little better than cosmetic. Some other products are designed to be diluted on site, and if this is poorly controlled the results may be correspondingly poor. The best safeguard is to use firms who are members of the British Wood Preserving Association, the American Wood Preservers Association, or similar responsible organizations, and to use products made by such firms. The Associations' codes of practice and lists of approved products for use in remedial or pretreatment preservation are a valuable guide.

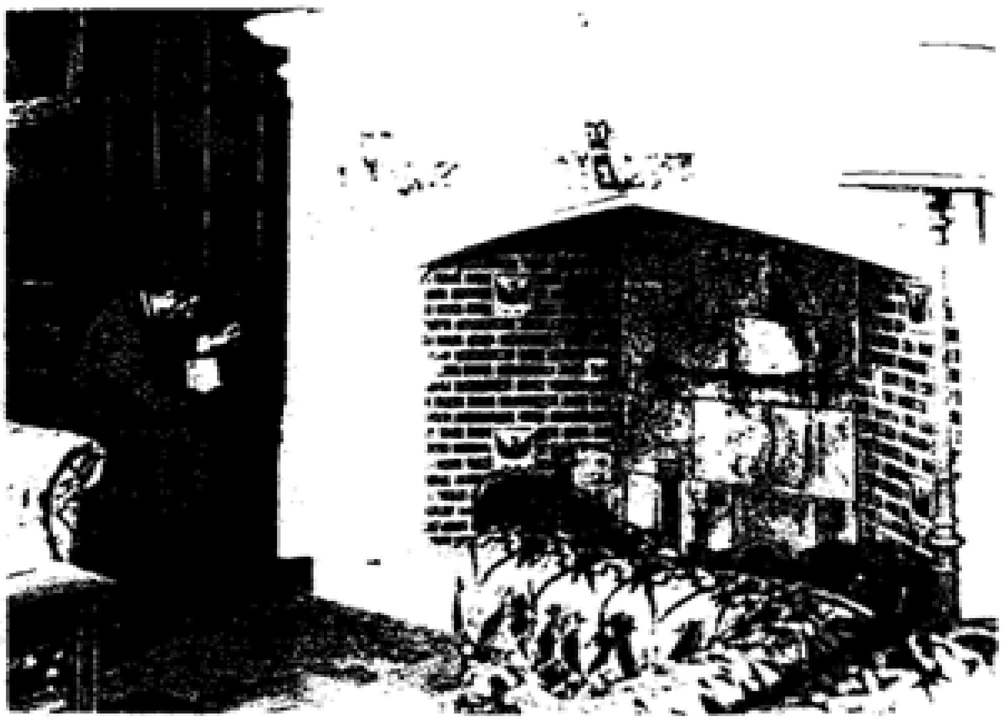

Figure 1.1 Surveying for dampness in the house

Although this book is primarily concerned with diagnosis, we believe that it is useful to give some guidance on techniques for cure of dampness. Therefore, each of the sections of this book on the various types of dampness problem either contains, or is followed by, an 'answer' outlining the principles and methods appropriate to each. These are not intended to be comprehensive, but we hope they will guard against the use of irrelevant or inappropriate measures.

Beware of the man who does not use a moisture meter because he claims it is 'misleading'. It is more correct to say that the meter is 'revealing', because without it, much significant dampness would pass unnoticed. Without the graduations in dampness which a meter gives, the further information given by its accessories and the associated laboratory service, it would often be impossible to diagnose the true cause, especially in the early stages.

Box 1

How moisture is measured in a laboratory

The basic measure of moisture content is made by oven drying. A sample is weighed, dried, and weighed again. The loss in weight is assumed to be water and this is expressed as a percentage of the final oven dry weight.

Suppose a piece of brick is to be tested for its moisture content. It must, of course, have been wrapped in foil or several layers of polythene, otherwise it will have lost or gained moisture since it was removed from the structure. If large enough, it should be broken into two or three so that the determination can be carried out in duplicate or triplicate. Assume that it is broken into three pieces, dust is rejected, and the pieces are weighed.

It is specified that the sample must be dried to 'constant weight' at a temperature of 105 °C. It is therefore dried in a thermostatically controlled oven, probably for two hours in the first instance, then for a further four hours, and then a further 16 hours:

	Sample 1	*Sample 2*	*Sample 3*
Original weight/g	3.721	10.086	2.820
Weight after 1st drying/g	3.629	9.788	2.735
Weight after 2nd drying/g	3.582	9.710	2.719
Weight after 3rd drying/g	3.580	9.705	2.712
Calculated moisture content/%	3.94	3.93	3.98

Average = 3.95 per cent reported as 4.0 per cent

In future the laboratory would always dry material of this type for about 18 hours having found that 6 hours is not sufficient. The laboratory would be careful to use a lower temperature for samples containing gypsum plaster because this material decomposes at high temperatures and will lose 16 or 17 per cent of its weight. This is chemically combined water (see Chapter 2) and not dampness. If a moisture as high as 16 per cent is reported by a laboratory you will know that it has been overheated. Even saturated gypsum plasters will not hold more than a few per cent by weight of water.

between hardwoods and softwoods, there is not nearly as great a difference as there is between other building materials. This is why moisture meters usually give a moisture content scale for wood, but do not attempt it for other materials. The accompanying graph (*Figure 2.1*) shows the average humidity/moisture content relationship for typical softwoods used in buildings.

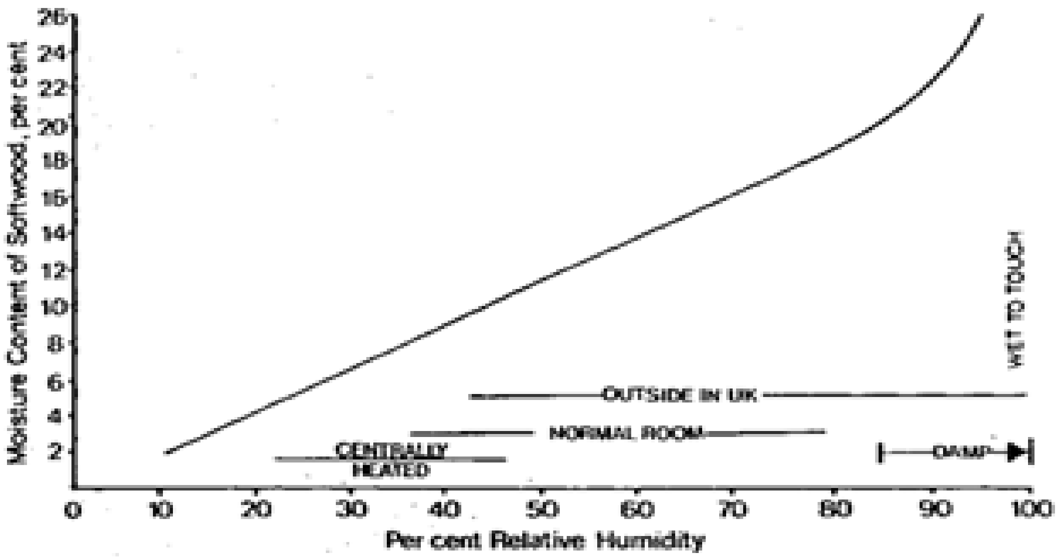

Figure 2.1 Wood moisture content and air relative humidity

The graph shows the approximate relationship between the relative humidity of air and the moisture content of wood. This applies to typical softwoods used in building; the curve for some of the heavier hardwoods would be different. The horizontal lines show the typical range of humidities met in various circumstances. Wood kept in these environments will gradually come into equilibrium at the moisture content levels indicated on the vertical scale. This shows why wood becomes very dry (water content 4–8 per cent) and often shrinks and cracks in centrally heated rooms, but will become much damper, though not dangerously damp (up to 16–18 per cent) in a normal room. Wood exposed to outside air continuously changes in water content over a very wide range. Although it becomes very wet in wet weather it does not decay so long as it has the opportunity to dry out in dry weather

The percentage moisture figures are derived from oven drying tests and are based on this universally accepted formula:

$$\frac{\text{Wet weight of the material} - \text{dry weight of the material}}{\text{Dry weight of the material}} \times 100$$

In the test the sample is very accurately weighed (wet weight), and it is dried in a ventilated hot air oven especially designed for the purpose at an accurately controlled temperature until it reaches a constant weight, that is, until it loses no more moisture. It is then allowed to cool in specially dried air. When cool it is again accurately weighted (dry weight). The loss in weight due to evaporation of water is expressed as a percentage of the final weight as shown above.

It follows that a heavy material has a much lower percentage moisture content than a light material which has the same amount of water in it!

Graphs could also be drawn for every other building material, but the materials are so immensely variable that such graphs would probably be different for every brick, every sample of mortar, plaster, concrete or wallboard, and all would be very different from wood. If several different materials are built into the same wall the effect of this will become obvious. For example: Wood battens are set into brickwork covered with wallboard on one side, and plaster on the other; they will exchange moisture with each other, and with the air, until all have come into equilibrium. Suppose the atmosphere is at a relative humidity averaging 50 per cent; it will be seen that the moisture content of the wood is just under 11 per cent. But the bricks may vary between, perhaps, 1½ and 2½ per cent, the plaster probably less than 1 per cent and the wallboard perhaps 9 or 10 per cent. This is the normal condition of a perfectly normal wall.

Now if this wall becomes damp, all the materials will share in the dampness until they are again in equilibrium; their moisture contents will be higher, but will continue to be widely different. If the air has not changed they will begin to lose moisture to it as they dry out. But if, when the wall became damp the air also became damper and happened to remain in equilibrium with the wall, its various components would not dry out, and they would remain at their widely different moisture contents.

Obviously it is meaningless to quote a moisture content for such a diverse structure and to say that such and such a moisture is 'dry' or 'wet' unless you know the characteristics of each of the components, which in practice you never will (see Chapter 7). The single common component is the relative humidity of the air. If you can say that a particular structure is in equilibrium with a particular relatively humidity you have made a very useful statement about the dampness of the structure, because *it is the relative humidity which determines whether or not moulds will grow, decay fungi develop in wood, or decorations be damaged*. It is useless, from this point of view, simply to quote the moisture content (unless you are talking about wood).

Now it is possible to answer the question, 'what dampness is'. It is usual to say that a material is damp if it is wetter than 'air-dry' as defined below.

We said earlier that at the relative humidity of 50 per cent, wood will contain about 11 per cent moisture, that is about one tenth of its weight is water. Yet it is regarded as 'dry' although 'air-dry' is a more accurate description. It follows that 'air-dry' means 'in equilibrium with a "normal" atmosphere'; although 'normal' atmospheres do vary considerably, from as low as 30 per cent relative humidity in a well-ventilated centrally heated office to 70 per cent relative humidity in a busy classroom. Air-dry wood defined in this way (as can be seen from the graph) has a moisture content of between about 6 and 16 per cent.

In this book we take 'air-dry' to mean the condition of a material in an ordinary indoor, inhabited environment with a relative humidity not exceeding about 70 per cent.

A definition of 'damp'

From the above discussion follows the definition of 'damp'. The serious complaints about dampness relate to development of moulds, spoilage of decorations, decay of wood and wood-based materials, appearance of mites (minute eight-legged creatures related to spiders) and possible adverse effects on health. All these have a biological origin. Each of these requires dampness to develop and they all have a similar limit of dryness below which they cannot live or multiply. It is reasonable to take this limit as the line between dry and damp in buildings. It is not a precise line because there is a range, between about 75 and 85 per cent relative humidity, in which the offending organisms can develop, but very slowly and without causing much trouble. For wood (*see Figure 2.1*) this is between 18 and 20 per cent moisture content. Above 85 per cent relative humidity, moulds, decay fungi, and mites can develop quite quickly, the rate becoming faster and more troublesome at higher levels.

We can therefore say that 'damp' is an atmosphere wetter than 85 per cent relative humidity; and a material is 'damp' if it is in equilibrium with this humidity.

Wet wall, dry air

The air will not necessarily be at this high humidity if the dampness is caused by water from a source other than high air humidity such as rising or penetrating damp or a plumbing leak. If the wall is damp (wetter than air-dry) it will be losing water to the air all the time. But while it is still wet, the air in a layer close to its surface, and in any cracks, will be in equilibrium with it regardless of the dryness of the general air of the room. So the moulds, fungi and mites which are the adverse consequences of 'dampness', being very small, are affected by the equilibrium humidity of the wall, not by the actual humidity around it. In due course, when the wall dries, as it will if the air continues to be dry and there is no continuing source of water, the offending organisms will die, being dried up. But if there is a continuing source of water, such as a plumbing leak, water penetration from the outside, or rising damp, the wall will not dry even though the air in the room is dry. So moulds, fungi and mites will be able to grow on and within a wet wall even in a dry room.

Measuring dampness

Since moisture content is such a poor measure of the dampness of a wall which is wetter than air-dry, what alternative is there? The theoretical ideal is to cover the suspect damp area with a waterproof tent of polythene, or foil, or with a box, and have a humidity measuring device under it. Water evaporating from the wall, into the small amount of air trapped in the tent or box, will raise its relative humidity until it is in equilibrium. Then, by measuring the relative humidity it is possible to say exactly how damp the wall is, regardless of the humidity in the room as a whole.

Obviously this is an impossibly laborious process for surveying a building, for it would take several hours at each point. However it is the recommended method (British Standard Code of Practice No. 203) for determining whether or not a concrete slab is dry enough for a moisture-sensitive floor to be laid.

Fortunately this is not the only method. The relative readings of an electrical moisture meter (especially of the conductance type) measure only the free water in a material; therefore they closely indicate the relative dampness of different materials. Although they do not measure relative humidity, their indications are a fairly close representation of it. Thus a high reading on such a meter (in the absence of contaminating salts or carbonaceous materials) indicates a damp condition of

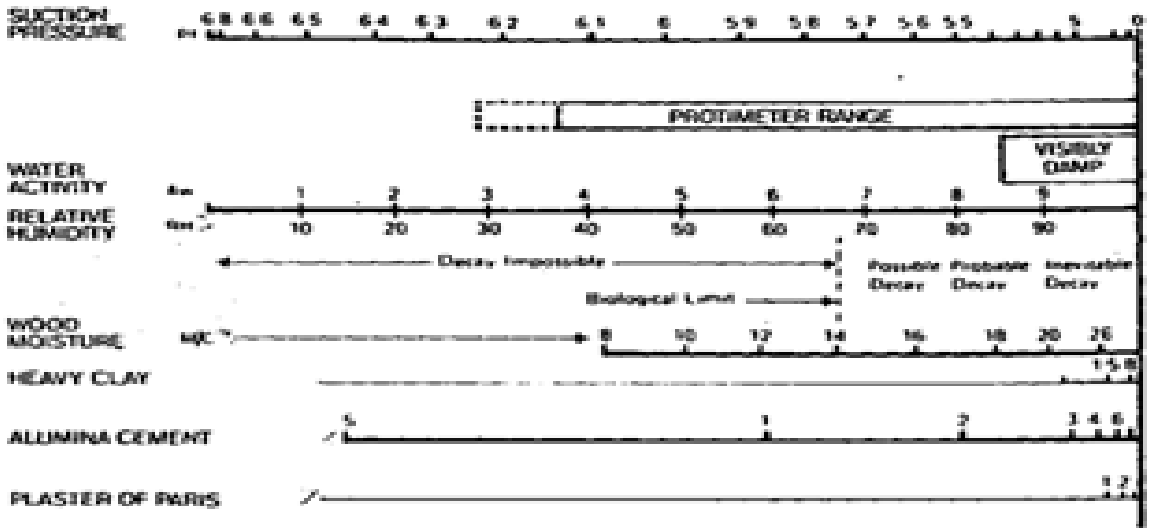

Figure 2.2 A 'dampness spectrum'. The relations between several different ways of expressing the significance of water in material are illustrated in the diagram which can be called a 'dampness spectrum'. It is drawn on a regular scale of relative humidity (RH) from zero to 100 per cent and exactly corresponding to this is a scale of 'water activity' (Aw) from zero to unity which is a very useful measure of wetness and dryness much used in industry, but not referred to elsewhere in this book.

Along the top is 'suction pressure', much used for soil and sometimes for building materials. It is useful for dealing with very wet conditions because, as can be seen, most of the scale [from 0 (i.e. saturated) to 5] is *above* 95 per cent relative humidity.

Wood moisture content (average soft wood) is shown and the correspondence between moisture content and relative humidity is easily seen.

The moisture content of three mineral materials, comparable with building materials, is also shown. It is clear at once that in plaster of paris (gypsum) and heavy clay, measurable moisture contents have no significance over most of the range and can only be used in very wet circumstances. Only for alumina cement (of these three examples) could moisture content be interpreted over a reasonable range.

The 'visibly damp' indication is very approximate. Wood does not appear damp over all this range, but some wallpaper may be just detectably damp down to the level shown. The inference is that significant dampness cannot be detected by the senses alone.

'Possible', 'probable', and 'inevitable' decay indicate the effects of dampness at different levels and the 'Protimeter range' indicates the range over which the various conductance type instruments can give significant readings approximately equal significance in wood, brick, plaster or wallboard, regardless of their very different moisture contents. Therefore it is possible to mark on the scale of an electrical meter indications of 'safe', 'intermediate' and 'danger' which correspond reasonably well with the humidity equilibria of most non-metallic or non-carbonaceous materials on which they may be used. Some well-known instruments do this by a colour code: green indicates the 'safe' condition, corresponding to an 'air-dry' condition in an ordinary indoor, inhabited environment. Red indicates a humidity equilibrium in excess of about 85 per cent and a hatched or amber area indicates the region between.

Yet it is important to note that materials do not become visibly damp, and do not feel damp to the touch, at 85 per cent humidity equilibrium. Wood, for example, does not feel damp below 30 per cent moisture content (i.e. around 97 or 98 per cent relative humidity). Thus dampness is hazardous long before it can be detected by the unaided senses. This is why it is so essential to use a moisture meter when surveying for damp, and making judgements about its severity (*see also* Chapter 7; measurement of moisture on site is described in Chapter 3)

How water is held in building materials

There are three ways in which moisture is held in building materials:

(1) *Chemically combined (or 'bound') water*
This is part of the water mixed with materials such as concrete and plaster during building construction. The amount of water used in construction of an average sized house can be as much as 4000 kg (4 tonnes) and the drying period may be as long as a year. During this period much of the moisture

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evaporates into the internal air of the building and may cause condensation, particularly where ventilation is poor and the heating intermittent. Once the drying out period is over, a quantity of water remains chemically combined in the material, which does *not* contribute to dampness problems. Water, when it is chemically combined in cement, gypsum, or other setting material is not water at all, it is permanently part of the set material.

(2) *Sorbed water*
As explained in previous pages most materials can take up water directly from the air, the amount of water absorbed depending upon the ambient humidity. Over a fairly narrow range most materials are changing in moisture content all the time in response to changes in the air humidity, but direct sorption of water from the air by uncontaminated materials does not give a dampness problem in buildings unless the ambient air humidity is persistently very high (*see Figure 2.2*). This is most common when condensation has become a problem. However, when materials have been contaminated with hygroscopic inorganic salts, an excessive amount of water may be absorbed directly from relatively dry air, and the material (usually plaster or paper) becomes visibly damp.

(3) *Capillary water*
Nearly all building materials have a porous (or capillary) structure, and if these pores (or capillaries) are filled with water, a serious dampness problem can result. It is when water is in capillary form that it can move through a material, rising from the foundations (rising damp) coming through walls (penetrating damp) or soaking into a wall subject to persistent condensation.

To sum up

Because significant dampness cannot be detected by the unaided senses, buildings ought to be regularly surveyed for damp by use of a meter. Following the instructions (see Chapter 7) it is possible to detect and pinpoint accurately damp spots or areas or, alternatively, to give a house a clean bill of health. But it is necessary to exercise judgement. When dampness is found it is necessary, first to satisfy yourself that you know the reason why the material is damp, secondly to decide whether it is transient, or likely to be persistent, and thirdly to take appropriate curative action if it is likely to persist. Over-hasty reaction to a single high moisture reading is not justified. Diagnosis of the cause of dampness is often not straightforward. It requires a professional, or well-instructed, approach and it requires tools.

The moisture meter is to the engineer, the architect and the surveyor what the stethoscope is to the doctor; it is a tool giving indications which cannot be gained from the unaided senses, but it requires understanding for correct diagnosis.

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Is there a dampness problem?

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Measuring dampness on site

We have shown that most dampness problems ir buildings exist before they can be recognized by the human senses. It follows that the professional surveyo or the house owner carrying out his annual inspectio must use one of the techniques available to make sur he finds all the areas where excess of moisture i present. Even if dampness is obvious, measuremen will be needed (*a*) to see how damp it is and to asses future hazards and (*b*) outside the limits of obviou dampness to see how far the hazard extends and t pinpoint its source (*see* Chapter 7).

There are three basic techniques for measurin dampness in building materials:

(1) Sampling
  (a) Measurement of moisture content
  (b) Measurement of equilibrium relativ humidity
(2) Use of a humidity transfer technique
(3) The use of moisture meters
  (a) Conductance type moisture meters (e.g Protimeter)
  (b) Capacitance (dielectric) type moisture mete

Sampling

To obtain moisture content

If a moisture meter is not available, the usual alternative procedure is to take samples, a process which is somewhat destructive. It is carried out either by drilling and collecting the spoil removed by the drill, or by removing whole bricks, or large parts of them, with hammer and chisel. Obviously brick removal is a very drastic process taking much time and effort and causing immense disturbance and mess. It is only possible to do this at a few points so that it is impossible to map out dampness areas. Such a procedure is obviously not practicable for survey purposes.

Less disturbance is caused by drilling, and in principle it is possible to obtain quite a large number of samples and make some attempt to map out damp areas, with the advantage that dampness at various depths can also be determined. It is necessary to drill at a regular speed with a freshly sharpened bit to minimize heating, which would cause rapid loss of water from the small sample of brick dust, and to collect the sample immediately into an airtight container. Measurement of the moisture content in the sample thus obtained requires either full laboratory equipment (thermostatically controlled oven, balance sensitive to one milligram, drying tins and desiccator; see Chapter 2) or the use of an acetylene pressure type instrument. For the latter, at least three grams of brick dust is needed so that it is necessary to drill with quite a large bit. A standard amount of the sample is accurately weighed and immediately placed in a small pressure cylinder. A measured amount of calcium carbide powder is added. The lid is replaced and screwed down and the container is shaken to mix the carbide with the sample; the water in the sample reacts with the carbide producing acetylene gas. The pressure which builds up in the cylinder is therefore a measure of the amount of moisture in the sample. A pressure gauge calibrated in percentage moisture will give the moisture content of the sample based on the standard weight taken at the beginning. It is absolutely essential to keep the instrument in perfect condition, the washers regularly renewed and only fresh carbide powder used, or low readings will be obtained as a result of leaks. As acetylene gas is highly inflammable, smoking or the use of naked lights whilst using this instrument must be forbidden.

Although drilling is less destructive than removal of bricks, it causes damage to walls and decorations which would be unacceptable for survey purposes in most situations. In addition it is relatively slow; half a dozen readings obtained in an hour would be quick work. Obviously this is not a suitable method for survey work, and although it can be used to determine the moisture content of drilled samples taken from deep inside a wall irrespective of the presence or absence of hygroscopic salts, it cannot be used to obtain surface readings in walls nor can it be used to obtain moisture readings in wood. But, as has been shown in Chapter 2, moisture content is not a useful measure of the significance of moisture in a building material other than wood.

To obtain percentage relative humidity

The alternative of measuring the equilibrium relative humidity of a sample has the advantage of giving a result of direct significance independently of the nature of the material. But it requires a rather larger sample than can conveniently be obtained by drilling and it requires an accurate instrument for measurement of relative humidity of a kind which does not itself affect the atmosphere it is measuring. A direct reading Dew-Point Meter is ideal. Obviously this is not a method which can be used for survey work, but it has advantages for diagnosis which may, in difficult cases, justify its use. It is a useful measure of the significance of moisture in building materials.

The 'humidity transfer' or 'isopiestic' method

An alternative system makes use of 'humidity transfer' devices in which small pieces of wood are used as the transfer medium. These take either of two forms: 'transfer patches' or 'profile probes'.

The transfer patch consists of a band of small pieces of wood veneer, only about 10 mm long and 2 mm wide, stuck side by side to a piece of foil. This makes a flexible band which can be wrapped round the sensor of a sensitive electronic hygrometer (for example, a Protimeter Digital Diagnostic Hygrometer or a Protimeter Dew Point Meter) and the equilibrium relative humidity of the wood obtained. The patch is held in a light aluminium frame from which it can be quickly removed. In use the patch, in its frame, is secured against a surface to be tested by adhesive tape and left for at least 24 hours. The veneers come into equilibrium with the surface and thus the reading obtained when this is tested with the hygrometer is equal to the surface humidity (and hence indicates its water activity; *see Figure 2.2*). This method is obviously very slow and is not a survey technique. However, it is non-destructive and gives an unequivocal result even in the presence of contaminating salts or electrically conducting materials. This method is also used for establishing whether or not a concrete slab is sufficiently dry for a moisture-sensitive floor to be laid.

The profile probe consists of a succession of numbered and weighed cylindrical wooden beads about 6 mm in diameter and 15 mm long threaded on a 3 mm metal rod. They alternate with metal separators. In use, a hole (7 mm diameter) is drilled in the wall to any desired depth and the probe inserted. It is left in position for at least 24 hours. It is then quickly removed, wrapped in foil, and taken to a laboratory water is added to the dry material, at first there is very little effect, but the addition of more water gradually increases its conductivity (i.e. its ability to pass a small current of electricity) in a regular way, so that by measuring conductivity to electricity it is possible to tell how much water has been added, up to a point beyond which further additions have little effect. This relation between the amount of water and the electrical conductivity of materials which are insulators when dry depends not on the conductivity of water itself, but on the conductivity of solutions which form, due to the water dissolving minute amounts of soluble materials. Many of these dissolved substances are ionizable, that is, when they dissolve each molecule splits into two parts, one with a positive charge and the other with a negative charge. When an electrical connection is made with the damp substance by means of metal electrodes, these charged particles (called ions) move through the water to the electrodes, the negative ions going to the positive electrode and the positive ions to the negative electrode. Here they give up their charges which results in a flow of electricity. Note that when a very small amount of water is added to a completely dry material, each water molecule is tightly adsorbed on to the dry surfaces. The molecules of water are held very firmly in this position. They are not free to move or behave like water in any way; in particular they cannot dissolve any materials, hence there is no formation of ions and no conduction of electricity. For this reason very low levels of moisture content cannot be measured. But these low levels of moisture content are of no significance, for such tightly absorbed water (sometimes called 'bound' water; *see* Chapter 2) makes no contribution to the physical or biological properties of the material. Bound water does *not* promote decay. Thus conductance measures 'free' water, that is, water which is free to produce the effects on the material usually associated with dampness.

In practice, to measure conductance it is necessary to make electrical contact with the material under test. The conductance type moisture meter does this by means of two sharpened steel pins which are pushed into wood, or pressed firmly into or in contact with harder materials such as brick or concrete.

Capacitance

Capacitance is commonly measured between two metal plates arranged parallel and facing each other, but not touching, so that no electricity can pass from one to the other. Such a system is called a capacitor. If one plate is now charged positively and the other negatively, it requires a certain small electric charge to do so. The ratio of the electric charge to the potential difference is called the capacitance of the system, and its value depends on the area and separation of the plates, but more especially on what is between them. If it is air, the capacitance remains very small. Some substances greatly increase the capacitance; this happens although the substance between the plates does not touch either of them. Indeed, if a conductive substance were to touch both plates, they would short-circuit the capacitor and the capacitance would be effectively zero.

Water has an exceptionally high ability to increase the electrical capacitance of a pair of metal plates, about 80 times that of air. The dry matter of a brick wall, however, is only about four or five times as effective as air. Thus, if the capacitance of a pair of plates is measured, first with air between them, and then with a damp wall between them, a large part of the consequent increase in their capacitance is due to the water it contains. This is the basis of moisture measurement by capacitance. As in the case of conductance, the most tightly adsorbed water ('bound' water) is not measured.

However, in practice it is seldom, if ever, possible in buildings to reach both sides of the material under test while continuing to connect the electrodes to the measuring apparatus by the very short wires which are necessary in order to avoid electrical losses.

Therefore practical capacitance type (or 'dielectric') field instruments depend on the very small spread of the electrical field which occurs from a plate placed on one side of the material only. This is sometimes called the 'edge', or 'fringe-field' effect.

To use a capacitance meter, the sensing head is placed against the surface; it must be very close to the surface at an even distance over the whole sensing area.

How do the two types of meters compare?

Figures 3.1A, B and *C* show how the two types of instrument work in practice.

The solid and dotted lines show the range of effect and sensitivity of the instruments; they respond in greatest degree where the solid lines are passing through the material and in less degree where dotted lines are shown. Measurements below the surface can be made, as indicated in *Figure 3.1C*, by using electrodes (pins) which are insulated on their sides and make contact only at their points. For use in wood this type of electrode is supplied with a movable weight or hammer with which it can be driven in to the desired depth. For survey work in walls, floors and ceilings, somewhat longer, 'deep wall probes' are available for which holes must be drilled. The depth at which these can, in practice, be used, is limited only by the depth to which holes can be drilled.

It will be seen that a conductance type meter responds most strongly to current passing directly between the pins but in lesser degree to current passing by longer routes deeper into the material.

The 'edge effect' of the dielectric instrument falls off very rapidly indeed away from the energized plate; therefore the solid line representing the zone of greatest sensitivity is shown only a millimetre or two

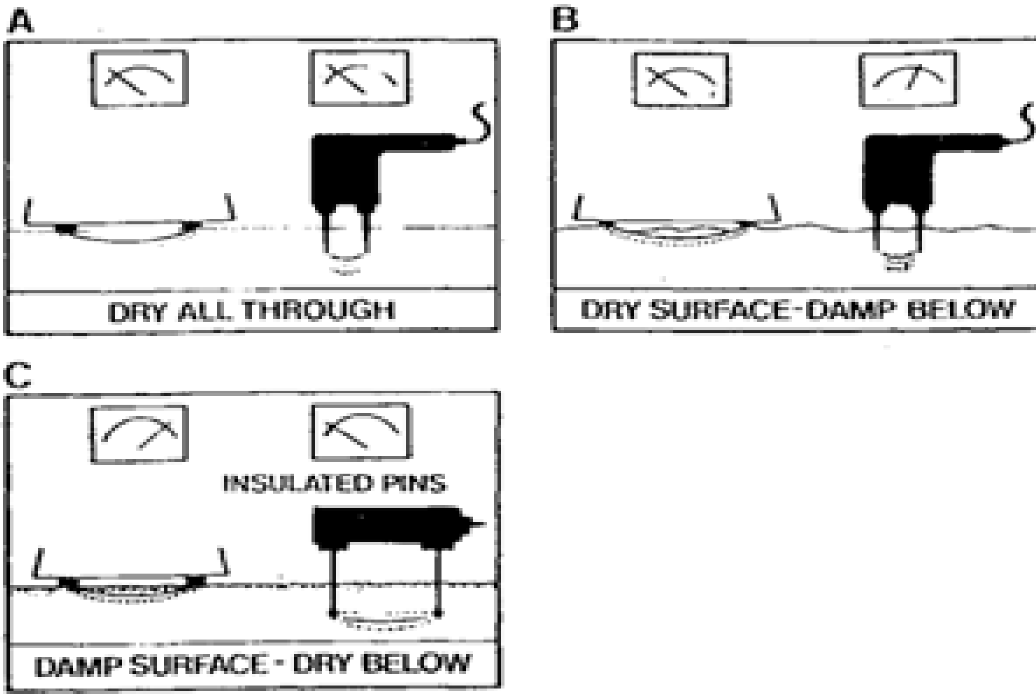

Figure 3.1 Conductance and capacitance meters

The diagrams show the range of response of the two types of electrical moisture meter. The capacitance meter, which has a flat plate electrode, is shown on the left of each diagram, and the conductance meter, which has a two-pin electrode, is on the right. Lines indicate the zones of response to water, and the little inset dials symbolize the readings given by each type of meter. Diagram C symbolizes pins with insulated shanks which can be inserted to a considerable depth in wood or, by drilling, into other building materials

away from the measuring plate, zones of lesser effec extending a short way further in.

Thus the sensitivity of the dielectric instrumen depends directly on the closeness of the measurin plate to the wall.

Any inert material which prevents the measurin plate from coming very close to the wall, e.g. plastic o glass, will seriously affect the readings. Even norma surface roughness of most building materials, e.g brickwork, prevents close contact and lowers th response of the meter to the moisture present in th material. Thus a falsely low reading can be obtained o a dielectric type meter simply owing to the unevennes of the surface or the fact of its being covered with an inert material. Another difficulty arises with the dielectric meter where it is not possible to place the plate flat against the surface, as in a corner or on an edge, or to take readings in limited zones such as the mortar line in brickwork.

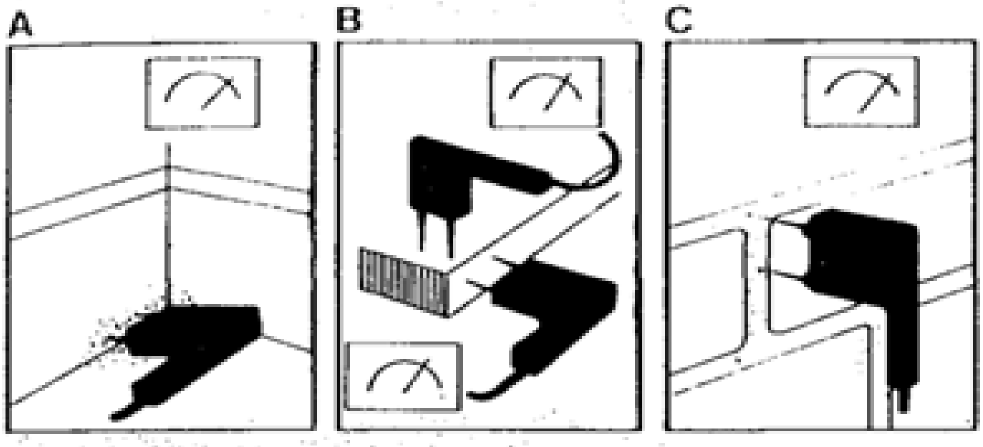

Figure 3.2 Conductance meter used in awkward places

The diagrams symbolize the usefulness of the two-pin conductance type moisture meter. Readings are being taken in important areas where a flat plate type electrode could not be used to obtain selective readings

In such situations, illustrated in *Figure 3.2, A, B* and C, the pins of the conductance type meter can be used without any difficulty. However, an inert material, unless it can be penetrated by the pins, will prevent a reading from being obtained in the same way as with a dielectric meter.

Conclusion

From the foregoing it can be concluded that both types of instrument respond generally to surface moisture, but the conductance type responds to the moisture at the point of contact and the measurement is unaffected by surface roughness. In addition, with the conductance type instrument it is possible, if required, to ignore surface moisture and obtain readings at any depth by using special electrodes inserted into drilled holes (*Figure 3.1C*). These electrodes are insulated except at the tip and thus make contact at any required depth.

When interpreting results it should be borne in mind that the presence of certain salts on the surface of a wall can affect meter readings. How to deal with this problem is explained in Chapter 4. Also carbon, which is present in some breeze blocks in the forms of cinders or coke, and the black colouring in some wallpapers will conduct electricity in similar fashion to a metal; so, obviously, will metal foil used as a facing on some insulating materials and sometimes as a moisture barrier. The very absurdity of maximum readings being obtained all over such a wall will at once show that the instrument is not measuring moisture.

These rather rare exceptions being borne in mind, it is a good general rule that a high reading on a conductance type electrical moisture meter indicates trouble and the need to take action.

Salts contamination in wall surfaces caused by rising damp

The source of rising damp is the soil or subsoil. These are always wet; without moisture in them plants could not grow. But soil consists, in the main, of decaying plant material and bacteria, moulds and soil-living animals. So soil water is not pure water, it is a dilute solution of the soluble materials to be expected from the nature of its source. Of these, nitrogen-containing salts (which eventually become nitrates), are the most characteristic, and chlorides are also generally universal. Rising damp is therefore a rising, dilute solution of various materials including nitrates and chlorides. When the water evaporates these are left behind, because they cannot evaporate. Although rising damp is a slow process, and the solution is dilute, continuance for a number of years results in quite high concentrations of certain nitrates and chlorides at the surfaces from which evaporation occurs. This is the basis for diagnosis of rising damp by analysis of wallpaper, or surface scrapings of plaster, for the presence of nitrates and chlorides. *Figure 4.1* shows a section of a wall in which rising damp had continued for 80 years. The concentrations of salts found by Building Research in the wallpaper, plaster and brickwork are given. It will be seen that the highest concentration is in the wallpaper, at the highest point to which the dampness has been rising (*see also* Chapter 5). However this is not always so as the paper may not have been in position for many years. Note

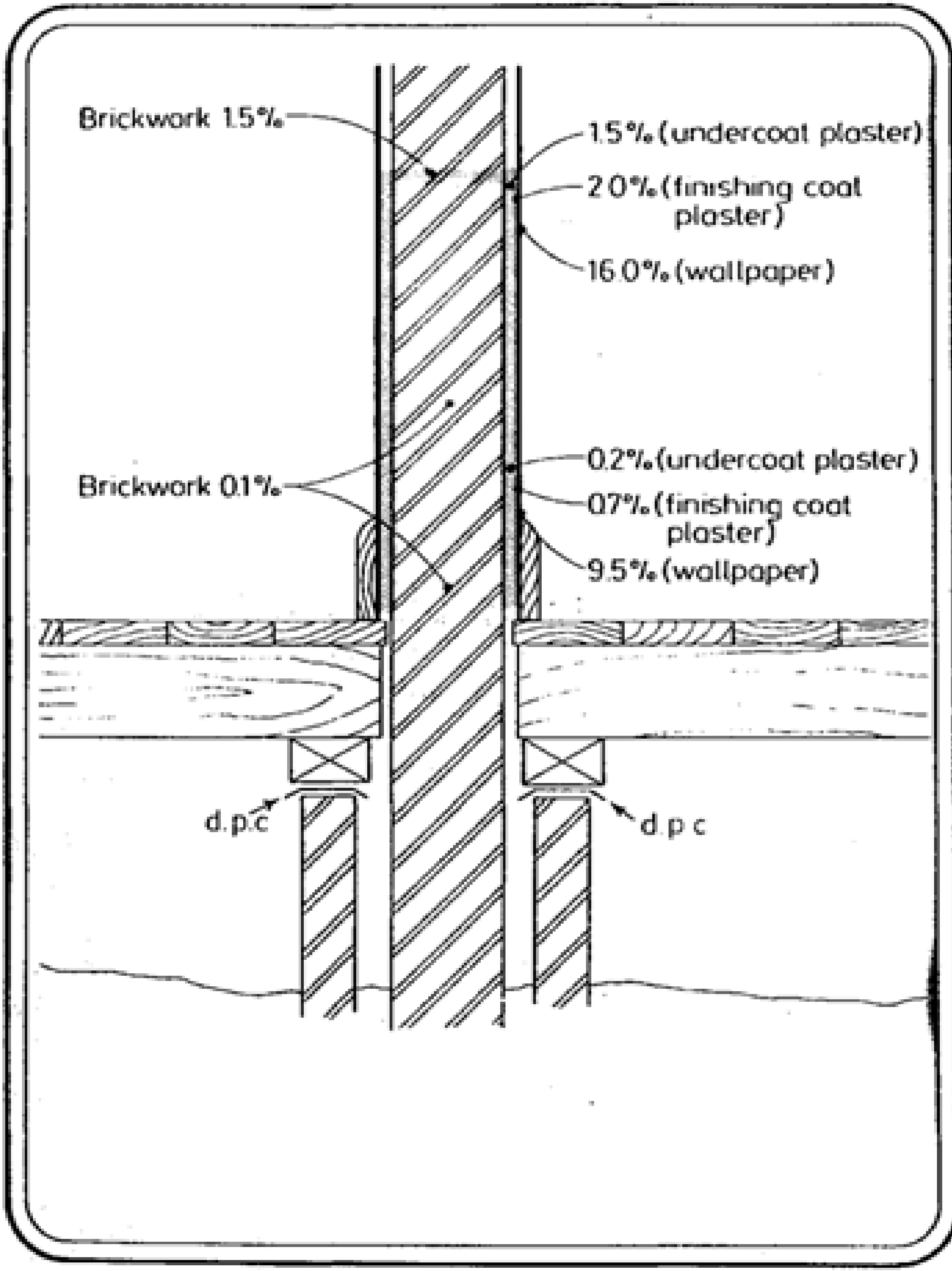

Figure 4.1 Concentration of salts in a party wall in which rising damp has persisted for 80 years. The figures show the percentage by weight of chloride plus nitrate. The shaded area is heavily contaminated

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Measurement of salts deposited on a wall

The analytical data given in *Figure 4.1* show that the mixture of salts deposited by evaporation from a wall affected by rising damp is strongly concentrated at the surface. Note that the wallpaper has about 13 times the concentration (by weight) found in the finishing coat of plaster. And the finishing coat has 3½ times the concentration in the base coat. Even at the upper margin of the salt contamination zone where, as usual in long-established rising damp, the salts extend more deeply into the wall, the wallpaper has eight times the concentration found in the finishing coat of plaster.

Obviously the concentration found in a sample will depend on how deeply into the wall the sample is taken. It is usually specified that the sample should be taken by 'scraping' the surface, which implies removing material to a depth certainly no greater than 1–2 millimetres. It should include the plaster finishing coat (if any), perhaps the whole of it if it is only a millimetre or so in thickness, but nothing below this. It should also include the wall covering (paper or paint) unless this is very new. If the plaster itself is also new (less than one year, say) there will be no point in taking samples anyway, because evaporation will not have had time to concentrate salts in it.

However, the sample is often not taken strictly to this specification. Therefore a quantitative (weight/weight) measure of salts concentration in a wall sample is impossible to interpret. However, *any* measurable quantity of nitrates and chlorides in a wall sample is some evidence of contamination by soil salts. A high concentration of nitrates (certainly) and chlorides (probably) shows that evaporation of soil water has continued for a long time. The depth of sampling cannot exaggerate the concentration of salts, but it can underestimate it. Therefore a semi-quantitative analysis, distinguishing between low, medium and high, on a sample volume basis, is all that is required. More precision is misleading and impossible to interpret, since the analyst has no control over the sampling.

also the relatively low concentration in the thickness of the brickwork.

Soil salts are hygroscopic, that is, they absorb water from the atmosphere (unless this is very dry) and form a solution. Hence they may keep the wall surface damp even though the rising damp which deposited them may have been cured. Characteristically, such dampness is seen by occupants of a building to vary with the weather, becoming more obvious when the atmosphere is humid.

These salts are also electrically conductive, and will give unduly high readings on an electrical type moisture meter. However, their presence is a sign of continuing trouble if the source is not cured and the contaminated plaster removed and replaced. It follows that if a meter gives a high reading, there is a condition which requires investigation even in a wall that seems to be dry.

The inner surfaces of walls in ancient buildings sometimes develop a concentration of salts not necessarily related to rising damp. These can cause high readings on the conductance type meter. This is presumably due to occasional rain penetration under exceptional circumstances over the years, which has leached these salts from the fabric of the building. Such salts are usually not hygroscopic.

Salts Detector

The Salts Detector is an attachment used with certain Protimeter moisture meters in order to determine the presence of electrically conductive salt contamination on a surface. The attachment consists of a resistance measuring circuit and a timing device powered by the instrument battery and using the instrument to display its results. This circuit is connected to stainless steel contact studs on the attachment. A supply of small round circles of absorbent paper is provided together with a soft-surfaced pad on which the papers are laid.

PROTIMETER LABORATORY SERVICE

A guide to interpretation of results of plaster, brick or wallpaper analysis

Salts not attributable to damp rising from the ground

(1) Efflorescent salts (containing carbonate and sulphate ions, which are always present in building materials), merely indicate that moisture is evaporating from the structure. They are seldom hygroscopic and are *not* reported by the Laboratory Service.

(2) Other sources of salts such as storage of fertilizer, recharging of water softeners or urine may be responsible for the contamination of building materials. In areas close to the sea, chlorides may be present owing to sea spray or the use of unwashed sand in the construction of the building. Many of these salts are hygroscopic [see below].

(3) In the vicinity of flue stacks damp patches due to hygroscopic salts may be found. Traces of ammonia and sulphur dioxide contained in the combustion gases from solid, liquid or gas fuel burners can form salt deposits (ammonium sulphate) within the flue wall. These salt deposits are often accompanied by brown stains. Ammonium salts are not reported by the Laboratory Service.

(cont.)

Salts usually attributable to rising damp

(4) The presence of certain salts on the internal surface of a wall provides evidence that the wall is, or has been, affected by rising dampness for some time. Conversely, the absence of these salts suggests dampness due to some other source or cause such as rain penetration or condensation:

4.1 *Chloride ions* may be present in traces (*) in some building materials, but heavier concentrations indicated by (**) or (***) suggest contamination usually derived from water rising from the ground. Where the result is (*) a further analysis should be carried out at six months hence. Most chlorides are hygroscopic.

4.2 *Nitrate ions* are derived from organic matter such as decaying compost and sewage. Their presence indicates contamination of the wall by water containing sewage or water from soil, which normally contains some decaying organic matter. Most nitrates are hygroscopic.

4.3 Therefore the presence of nitrate and chloride ions in significant quantities (** or ***) indicates with reasonable certainty the presence of a dampness problem due to damp rising from the ground. The exceptions noted in (2) above must be evaluated from local knowledge.

Hygroscopic salts

Hygroscopic salts absorb water from the atmosphere and will thus keep a wall damp even after the source of moisture has been removed, If (as with the case of rising dampness) hygroscopic salts are present in heavy concentrations (** or ***) it will be necessary to

(cont.)

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(cont.)

remove them by replacing the plaster, otherwise a dampness problem will persist.

IMPORTANT NOTICE
Analyses are based on the small specimen submitted. If, as a result of the laboratory findings it is intended to carry out structural works, or if the findings are to be used as evidence in a court of law, then additional analyses must be carried out of further, larger samples of not less than 10 g each, taken from several separate places of the wall-area under investigation. It is important that all samples should be from the *surfaces* (not more than 2–3 mm deep) of the areas being investigated. The largest concentration of salts is at the highest point that water has risen from the ground. It normally requires several years of evaporation of soil water for a typical salts deposit to be produced. Therefore it is seldom useful to submit scrapings from new plaster.

In use a paper is wetted, laid on the pressure pad, and then pressed against the electrodes. A low reading is given on the meter and this is noted. The wet paper is then pressed against the suspect wall surface by means of the pressure pad whose soft surface ensures close contact with a wall even if it is rough textured. Contact is maintained for a fixed time by use of a timer built into the attachment which gives an audible and visible signal.

The wet paper is then pressed again on to the electrodes. Any soluble salts on the wall surface will have been absorbed by the wet paper and hence the meter will now give a higher reading than when tested with the freshly wetted paper. Such an increased reading indicates that moisture readings taken with the survey instrument on that wall are higher than the actual dampness justifies. On the other hand, if th reading given by the test paper after contact with th wall is no higher than the original, freshly wette result, all readings given by the survey meter may b taken at their face value. This attachment thu demonstrates the presence of any salts, hygroscopic o non-hygroscopic, or their absence, and enables judgement to be made on the significance of mete readings and the need for stripping the plaster.

Further information on salts found in walls, and the significance, is contained in the example of a guidanc leaflet provided by a British laboratory (the Protimete Laboratory) to aid in the interpretation of the results a an analysis of wall scrapings for the presence of salt and reproduced in *Box 3*.

5

The sources of water causing dampness: liquid water

As stated in Chapter 1 it is convenient to classify the various forms of dampness by the source of the water which is responsible, and it was noted that a primary distinction is that between water which enters building as a liquid and water which is derived from the atmosphere. In this chapter we deal with the liquid sources; the atmosphere as a source is the subject of Chapter 6.

The sources of dampness which involve movement of water in liquid form can be classified as follows:

(1) Direct rain penetration through the structure
(2) Faulty rainwater disposal (gutters and downpipes)
(3) Faulty plumbing (water supply or disposal)
(4) Rising damp
(5) Dampness in solid floors

Rain penetration *(see Figure 5.1)*

The problem

Lateral penetration of rain into brickwork may be due to high porosity of the brick or to failure of the pointing, the formation of hairline cracks in rendering, or lack of adequate protection or weathering on projections outside the building. Dampness due to rain penetration is most frequently found on the south or southwesterly elevation in the UK (and on elevations facing prevailing moisture-laden winds elsewhere) and in solid, non-cavity walls. Moisture meter readings taken on the internal surface of the wall will often show local moisture zones which are adjacent to projections on the outside, or to local breakdown of the brickwork, pointing or rendering. Usually there is evidence of several high moisture zones but more general rain penetration may occur if failure of brickwork or pointing is to blame.

The main function of a cavity wall is to prevent this form of dampness. The comparatively thin outer 'leaf' of the wall, commonly only one brick width thick (4½ inches, 114 mm) is unlikely to be fully resistant to penetration. Probably it is normal for driving rain to penetrate the outer leaf to some extent. But the cavity isolates the inner leaf from this so that penetrating water runs down to damp-course level where it is usually harmless. Window frames which bridge the cavity should be protected by a tray or waterproof layer so that water is diverted harmlessly to either side, or outwards through weepholes. If mortar is spilled on to the ties which connect the inner and outer leaves of a cavity wall this may form a series of bridges conveying water to the inner leaf and this may be picked up as a series of damp spots on the wall inside (see p. 93). Also, mortar spilled to the bottom of the cavity may be responsible for a damp patch at skirting level inside giving some of the appearance of rising damp.

The following is quoted from British Standard 5250: 1975:

> Although a simple cavity adds appreciably to the insulation of a heavyweight wall, thermal resistance can be significantly improved by placing lightweight insulating material in the cavity. This may be done either by placing material such as lightweight slabs in the cavity as the wall is built or by filling the cavity subsequently, either by pumping in foamed plastic or by blowing in mineral fibres. Cavity fill material

common failure is due to blockage of downpipes at low level with the rainwater backing up to a higher point. In many properties, gutters are often hung too low with insufficient or no slope and there may be insufficient downpipes, or some may be blocked by leaves and moss.

On shallow roofs, tiles should overlap the gutter by about 50 mm (2 inches) to prevent water running behind it. Steep roofs overlap much less to prevent water being thrown out of the gutter. When houses are built with minimal eaves, so that the guttering is close to, perhaps even in contact with, the wall, the slightest error in gutter hanging will result in roof water spilling down the wall and perhaps getting behind a loose rendering.

Another source of trouble occurs when a gutter is placed actually along the top of the wall, so that there is no eaves overhang at all. While this method of construction is probably no longer used, it is not uncommon in houses 80–100 years old. When constructed, no doubt the system was effective, but the slightest leak will quickly saturate a wall. The solution is to place a flashing under the gutter and over the top of the wall.

Box gutters are often found between two lean-to roofs, behind parapet walls, on flat roofs or on boundary walls. They are usually not strong enough to support the weight of a person and are therefore frequently damaged not only because of old age but simply by someone standing in them (perhaps to carry out maintenance work, or to inspect them!). Damage cannot usually be made good in patches. To do a satisfactory repair it will be necessary to lay lining on fresh asphalt over the whole guttering (drying it thoroughly first). Box gutters, like flat roofs, are often constructed with insufficient slope. If they are supported by wood members it must be remembered that wood may bend gradually under load, and it may warp slightly as it dries out, if it was very wet when installed.

Such movements have no structural significance but they can result in the proper slope being lost so that permanent pools develop. In this event, even the most minute leak, which would not be significant in a well-drained surface, can result in a considerable amount of water entering the building.

Gutters are best examined (at some discomfort) during a period of heavy rain.

Faulty plumbing

This has to be examined carefully, including those places not easily accessible, such as in ducts and under baths. Pinpointing the damp area with a moisture meter will give a clue to a leak in an embedded pipe (*see* Chapter 7).

In hot water central heating systems joints between pipes and radiators may leak because of expansion and contraction.

Where a galvanized iron tank is used for the storage of water and distributed to fittings through copper pipework, galvanic (or electrolytic) corrosion of the zinc coating will occur where the two metals are in contact. This corrosion can be avoided by suspending a sacrificial magnesium anode in the tank thereby transposing the corrosion from the zinc to the magnesium. Sacrificial anodes last about four years.

Corrosion can also be caused by the excessive use of chemical bleaches when cleaning sinks, particularly if allowed to remain in traps for any length of time. Therefore always use plenty of clean water after using bleach.

A different, but related, problem frequently arises because, as a washbasin, bath or sink is used, a gap often develops between the fitting and the wall. This allows water to run behind the fitting possibly wetting a wooden floor so as to cause rot. To repair use a rubber based sealer which remains elastic (not cement or putty which become brittle).

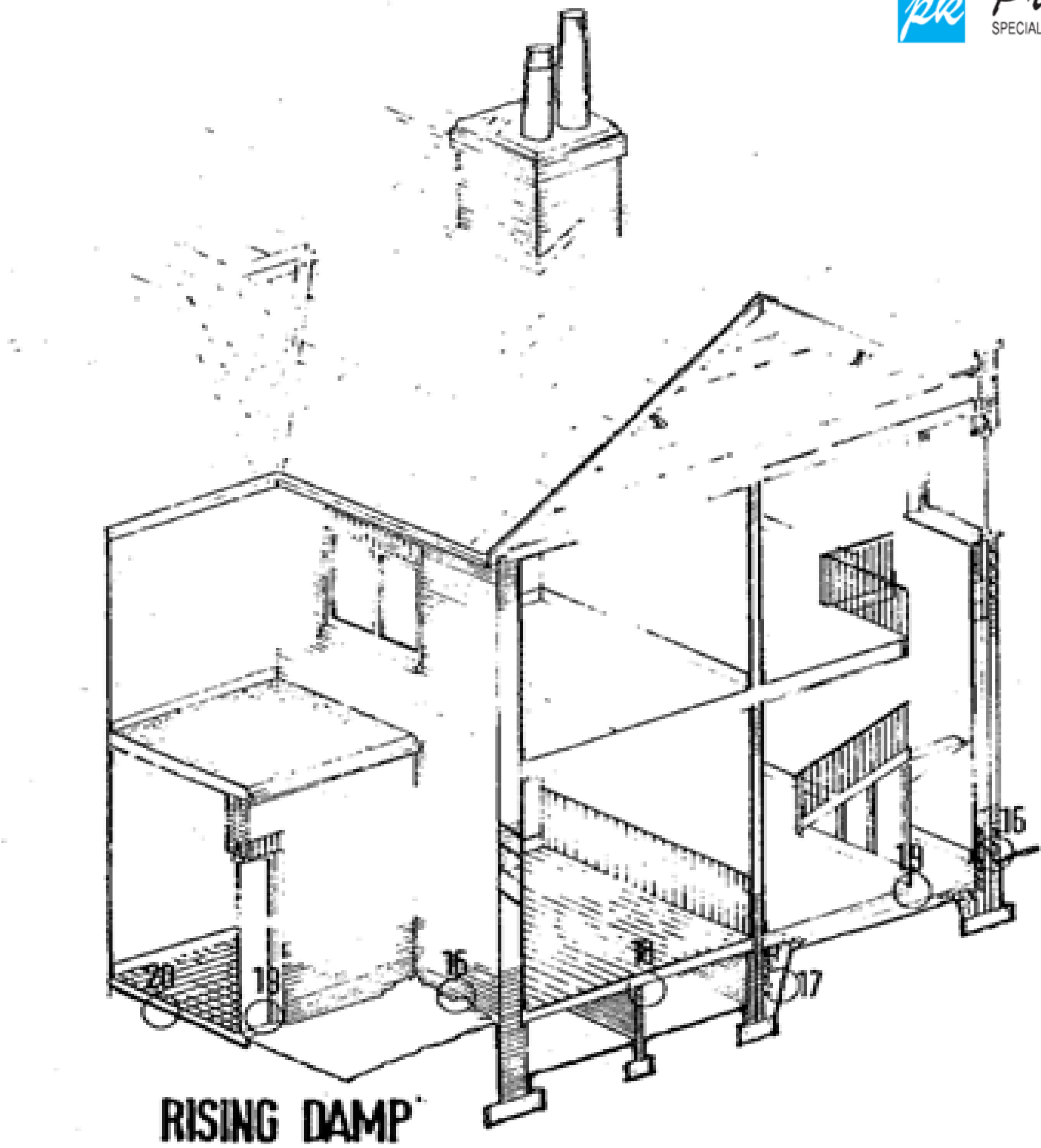

Figure 5.2 16, Earth or path bridging damp-proof course; 17, earth retaining wall not tanked (i.e. no vertical damp-proof membrane) leading to a wet wall and a very high humidity in the cellar. No air brick or other ventilation to the cellar; 18, missing damp-proof course under joists resting on sleeper wall; 19, missing damp-proof course under floor and door frame; 20, when a solid floor is persistently very wet, this may be due to a faulty or missing damp-proof course

Rising damp *(see Figure 5.2)*

The problem

Rising dampness results from capillary flow of water from the ground. In the absence of an adequate

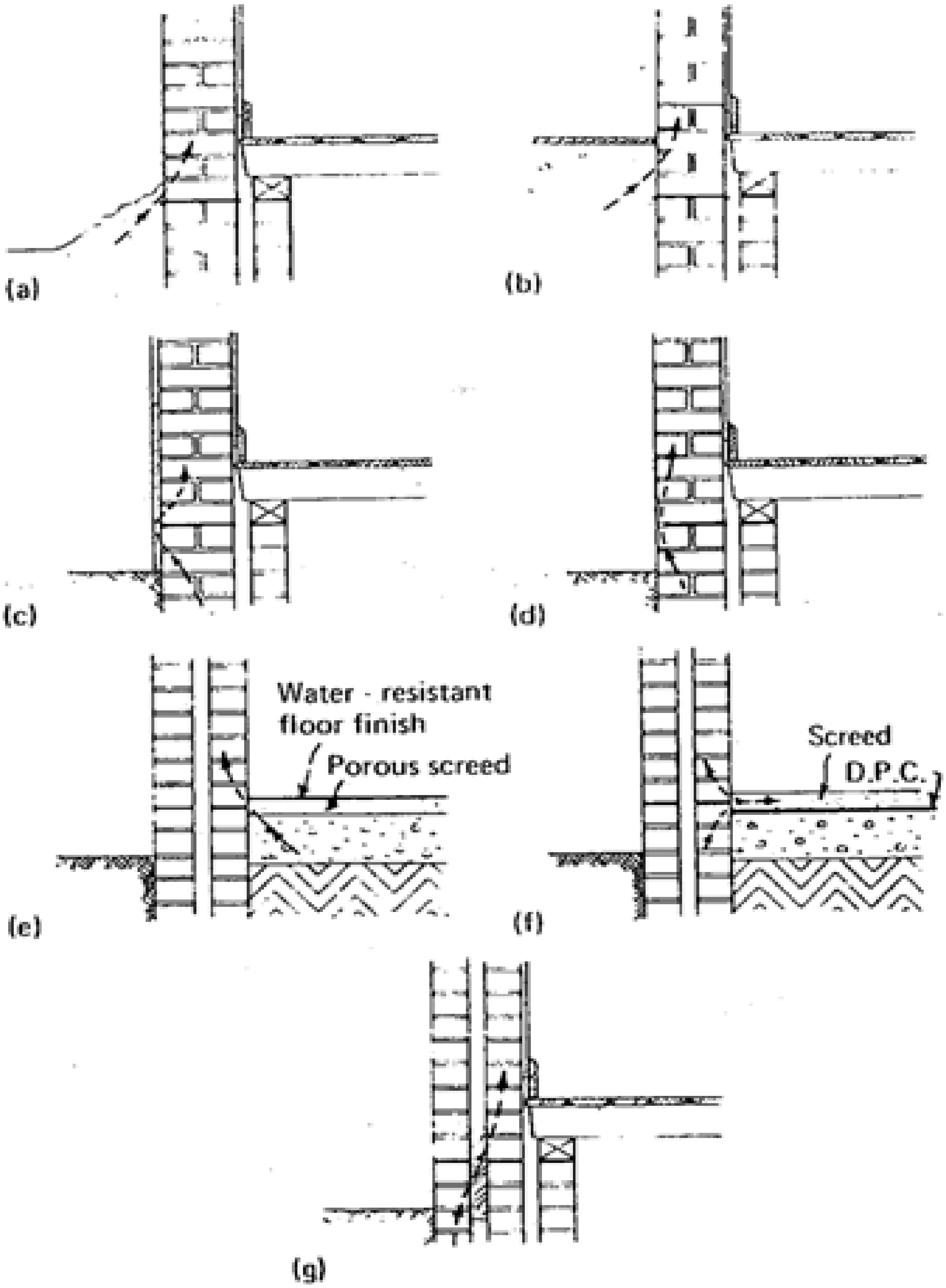

Figure 5.3 Seven ways in which a damp-proof course may be bridged, resulting in rising damp. (a) Bridging by earth; (b) bridging by path; (c) bridging by rendering; (d) bridging by mortar pointing; (e) and (f) bridging by floor screed; (g) bridging by mortar dropping in cavity

[Reproduced by permission of the Controller of HM Stationery Office from Building Research Establishment Digest 245. Crown Copyright] damp-proof course a damp zone extending from skirting level to about 50 cm (20 inches) or more above the skirting along the whole length of a wall may result. Where a damp-proof course (d.p.c.) exists local patches of rising dampness may result if it is broken or if it is bridged by soil in flower beds, or a stone or concrete patio is built up above it (*Figure 5.3*). After a building has been erected there may be changes in water table, perhaps due to removal of trees or new buildings interfering with normal drainage. A persistent rise in the water table up to, or even above, the d.p.c. will inevitably cause rising damp.

The rise of water in capillaries is caused by the affinity of building materials for water. All building materials are wettable; most of them are wet when the building is constructed. Therefore liquid water, when it comes into contact with a dry building material,

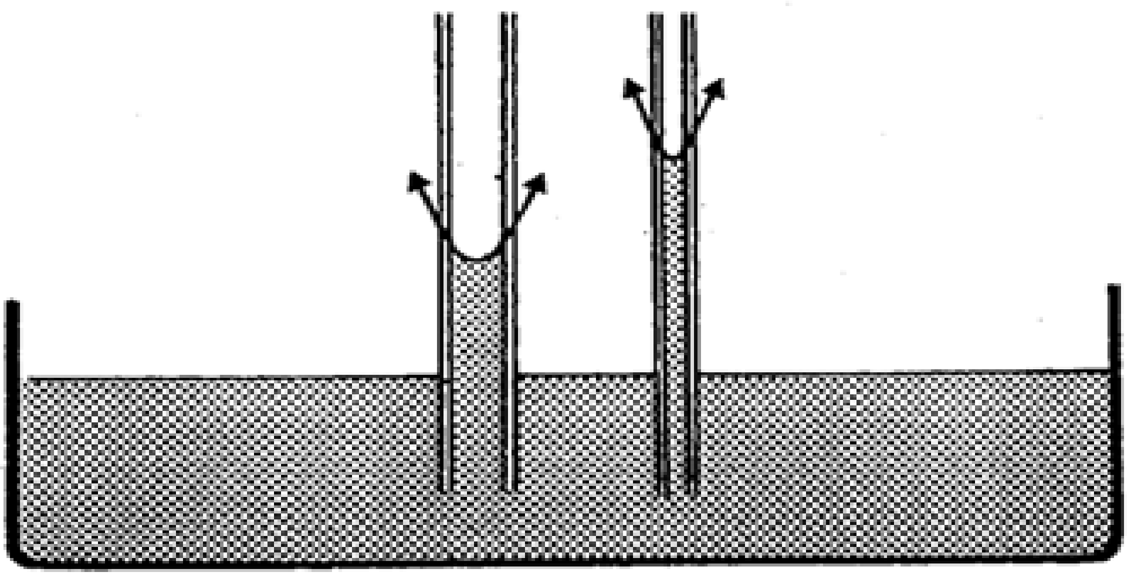

Figure 5.4 Water rising in tubes with wettable surfaces. The inner surface of a fine tube, or 'capillary', is here made of wettable material. Water tries actively to spread over a wettable surface and this produces a lifting force, indicated by the arrows. Gravity pulls the water downwards and so the surface forms a curve, supported only by the edges in contact with the wettable surface. The finer the tube, the higher the water rises. Building materials have fine pores or capillaries and are wettable. Therefore water rises in them, potentially to a great height because the pores are very fine

actively spreads over all the surfaces of the fine cracks and pores and is thus absorbed into the material, just as it is absorbed by blotting paper. This urge of water to wet any surface for which it has an affinity can be seen in a fine bore glass capillary tube when it is dipped in water. In *Figure 5.4* the arrows indicate the lifting force produced by the water trying to wet the surface. The weight of water pulling downwards pulls the surface into a curve called a meniscus – convex downwards, as shown in the figure. If tubes of different diameter are used, it will be seen that the finer the tube the higher the water will rise. The cracks and pores in brick, mortar, concrete, plaster and wood are very fine indeed, so that water could rise as a result of 'capillary attraction' to a great height. But because the cracks and pores in a wall are not continuous, the process is very slow indeed and in practice evaporation sets a limit; that is why rising damp is usually limited to ½ to 1 metre unless evaporation is prevented. If evaporation is prevented by, for example, painting the walls inside and out with an oil-based paint, or lining the walls with foil, rising damp may reach well up to first-floor level.

The answers

More persistent rising damp

Rising dampness which is persistent and not curable by simple means can be stopped by the insertion of a physical damp-proof course or by injection of water repellent chemicals into the brickwork.

(1) A physical d.p.c. consists of a metallic sheet or bitumen-type membrane which is inserted by cutting the wall. This is an effective but very expensive treatment.

(2) It is possible to make materials actually repellent to water, instead of attractive, by coating their surfaces with a suitable 'non-wettable' layer. The effect of this in a glass capillary tube is shown in *Figure 5.5*. The meniscus is now inverted (convex upwards) and the force which originally pulled the water up the capillary now acts in the opposite direction and pushes the water down the capillary. This is the principle of injection damp-proof courses.

In practice this method is comparatively simple: Holes are drilled with a 10 to 15 mm diameter (½ to ¾ inch) drill around the outside of the house about 150 mm (6 inches) above the level of the ground at about 100 mm (4 inch) intervals and a solution in water of a water-repellent material is

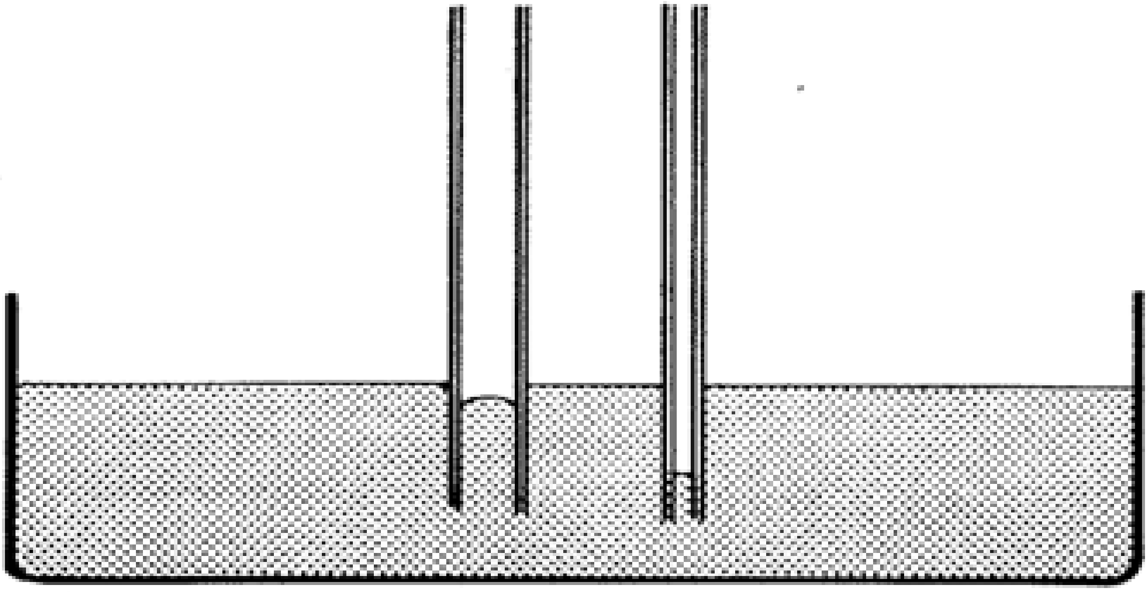

Figure 5.5 Water depressed in tubes with non-wettable surfaces. Water seeks to avoid contact with a non-wettable surface, so that the margin of the water column is pushed downwards. This is the principle of the chemical injection damp-proof courses. The solution injected lines the pores in the building material with a non-wettable (hydrophobic) substance so that water is forced out of the material instead of being drawn in

introduced using gravity bottles, or by a pressure injection process, or in the form of frozen rods. Care should be taken to ensure that the damp-proofing solution diffuses through the wall as fully as possible. Unless the whole of the wall thickness is impregnated, the result will be unsatisfactory. On completion it is usual to fill the holes using a dense 1 part cement – 3 parts sand (1:3) mix incorporating an integral waterproofing agent.

In the case of 'suspended' floors, i.e. wooden floors not in contact with the ground, underfloor ventilation should be increased as this helps to reduce rising damp by reducing the moisture content of the walls below the damp-proof course (if any).

The aim of all damp-proofing work must be to create a dry wall as soon as possible. But a wall which has been saturated by rising damp can take a year or more to dry out. Therefore the following quicker method for producing a reasonably dry surface are suggested

Method 1. Hiding the damp

There are various ways of concealing damp. Here are two of them:

(1) Cover the damp wall with plaster board on timber battens (the battens must be preservative-treated to prevent rotting). This method is cheap but may present difficulties around doors and windows. If the wall behind remains wet the plaster board itself may gradually become wet because of the damp air trapped behind it. The result will be development of mouldy areas, probably after some years. To prevent this the air space behind the board may be vented to the room by holes or grills at the top and bottom of the covering board.

(2) As an alternative, cover the damp wall with corrugated pitch- or bitumen-impregnated lathing. The lathing, being corrugated, forms insulating cavities on the side nearest the wall and a key for re-plastering on the other side. Before fitting the lathing, the old plaster must be removed. Because this will prevent inward evaporation from the wall, the damp will gradually rise higher until evaporation to the exterior equals the rate of rise. Therefore the outside of the treated wall should not be painted or otherwise treated to restrict evaporation.

Method 2. Replastering

Replastering will be very desirable in any event and is normally recommended as part of any curative treatment for rising damp. The skirting must be removed and inspected to see whether it has been affected by rot.

Ideally, a wall which is to be replastered should be allowed to dry out completely before the plaster is removed. During drying out, all the hygroscopic soil salts left in the wall will come to the surface and so be removed with the plaster. But usually immediate replastering is required.

permits meets further resistance at the floor covering so that a water potential develops across it. That is to say, the material below the floor covering must be wetter than the air above. A frequent contributory factor is that the impervious floor covering is laid before a new screed has had time to dry sufficiently. Moisture thus sealed in will dry out only very slowly indeed.

If, instead of a waterproof floor-covering the floor was left bare or even covered with a carpet and underlay (provided these allow the passage of water vapour) or with wood boards, the resistance to water movement which these provide is negligible and the floor surface will remain perfectly 'air-dry' because of the action of the built-in damp-proof membrane. This is its function; it is neither expected nor practicable that it should do more.

Normally no action is required when dampness is detected in the screed below a waterproof floor covering. Concrete, flagstones or bricks can remain wet indefinitely without deterioration, as they do in the foundations of a building below the damp-proof course. If the moisture becomes exceptionally high, however (showing a practically saturated condition), this would indicate either residual moisture of construction or a built-in damp-proof membrane which is very inadequate and could lead to lifting and curling of linoleum or to lifting of tiles and efflorescence through joints between tiles. Worse is the case where the skirting board is in contact with the screed and may become damp enough to decay. Such a condition will be detected at once with a conductance type meter used directly on the skirting.

The instructions given with these instruments warn that as a rule any reading which indicates an above 'air-dry' condition is a cause for concern. Solid ground floors and screeds are an exception to this; in their case the warning can be disregarded, and a degree of moisture tolerated provided four conditions are met:

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(1) The floors are in contact with the ground and covered with an impervious covering.
(2) No decayable material (such as wood) is in contact with the damp floor.
(3) No visible deterioration (such as tiles lifting) has been experienced over a period of several years.
(4) There is no route by which water in the concrete slab can reach the walls. This can happen if damp-proof membranes are omitted or wrongly placed, or if plaster is carried down to the base concrete.

Finally, it must be repeated that for all decayable materials such as wood (or building materials in contact with decayable materials) any moisture meter reading above the 'air-dry' level must give rise to apprehension. Its cause must be investigated and clearly understood. Unless this investigation shows that the cause is transient, any decayable materials must be isolated, preserved or otherwise removed from risk.

The sources of water causing dampness: water from the air

The forms of dampness which are caused by water in the atmosphere are:

(1) Condensation.
(2) Condensation in flues.
(3) Dampness under suspended ground floors.

The first two of these involve deposition of liquid water from the air, but the third is the result of sustained very high relative humidity levels (*see Figure 6.1*).

Condensation

The problem (including some answers)

Water is deposited on the cooler surfaces in a building especially in winter and its presence is often first indicated by the development of moulds in the most affected areas. This is characteristic of condensation, because moulds need pure water for their growth and condensed water is pure. Unlike rising or penetrating damp it is not contaminated with soil salts or material extracted from the building itself. In severe cases the amount of water deposited may be very great, causing actual pools of water on the floor, saturated clothes in wall cupboards and decay of window and door joinery.

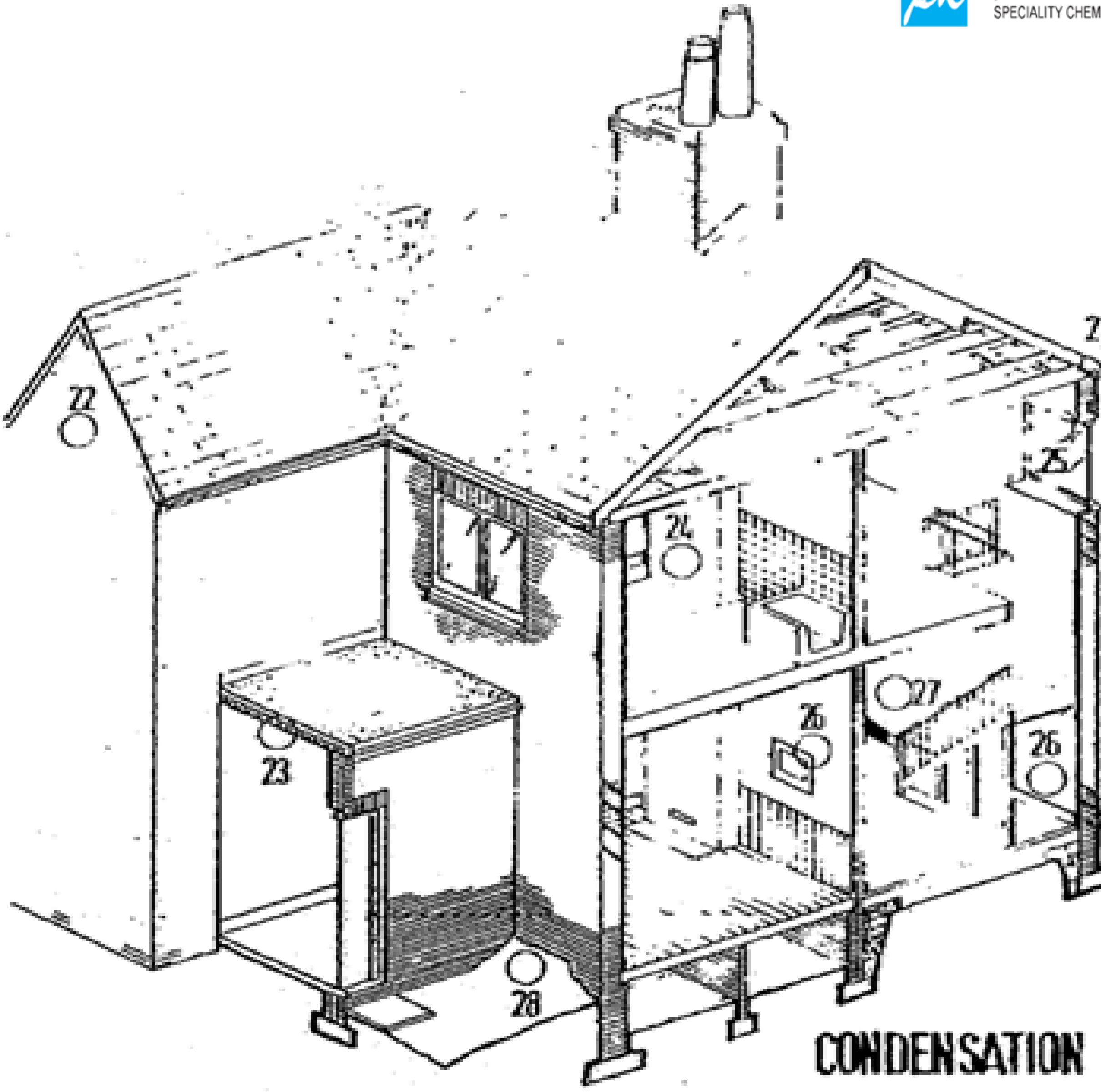

Figure 6.1 21, Blocked ventilation gaps to roof; 22, no air brick to gable wall; 23, interstitial condensation in flat roof owing to absence of vapour barrier 24, no flue vent in blocked-up chimney breast; 25, cold-spot condensation on solid concrete lintel; 26, condensation behind pictures and in cupboards, due to lack of ventilation; 27, condensation at the bottom of an external wall (looking like rising damp; see Chapter 7)

Occupants of affected premises often find it difficult to believe that such severe dampness can be caused by condensation alone; they frequently believe that there is a constructional defect in the building which is usually not the case. But large areas of rising or penetrating damp, or walls or floors not properly dried out after construction, can increase the amount of water in the atmosphere and may be responsible for condensation in other parts of the same premises.

Quite frequently condensation occurs predominantly at low levels where the surface of a wall is cooler, starting in the corners and eventually extending along the length of the wall. When this happens the dampness pattern may look very much like rising damp and can easily be confused with it. Two key numbers which relate to the wetness of air are concerned in condensation. These are: relative humidity (RH) and dew-point. The former is a percentage and the latter is a temperature.

Water in the air

Air, like timber and building materials, always contains some water. This is in the form of water vapour, but unlike the clouds of 'steam' from a boiling kettle, it cannot be seen or felt or otherwise detected by the senses. The amount of water vapour which the air can hold is limited, but depends on temperature. The hotter the air the more water vapour it can hold; very cold air holds very little water vapour.

Saturation

When air holds the maximum water vapour possible (at its temperature) it is said to be saturated. Although this cannot be detected directly by the senses, air which is saturated, or nearly so, feels 'stuffy' whereas air which contains only a small amount of water vapour generally feels crisp and invigorating if it is cool. Warm dry air dries the nose and throat and often leads to a hard dry cough.

Relative humidity

Relative humidity (RH) is the degree of saturation, i.e. the amount of water vapour which the air contains 'relative' to the amount if would contain if saturated. This is often expressed as a percentage; saturated air is

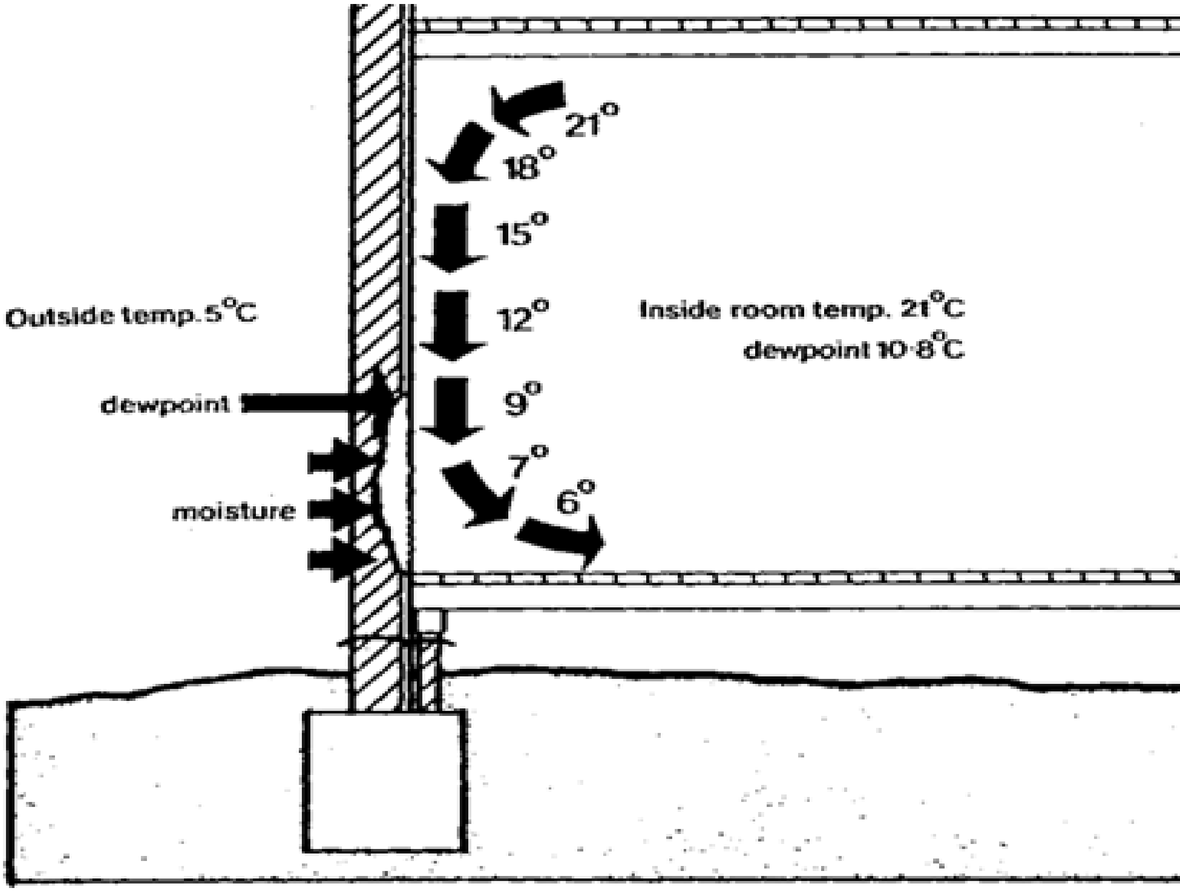

Figure 6.2 Condensation against an outside wall giving an appearance of rising damp

In a room with a cold outside wall the temperature of which falls below the dew-point temperature, it is quite normal for condensation to occur predominantly on the lower parts of the walls and may be confused with rising damp. The diagram shows why this occurs. Warm air is cooled as it comes into contact with the wall and, becoming heavier as it cools, it moves downwards cooling as it does so. Eventually it reaches dew-point as the temperatures on the arrows indicate, and deposits its excess of moisture. This process happens continuously so that gradually all the air in the room is involved. In practice this process is much interfered with by pictures or furniture against the walls, and 'cold bridges' may make the upper parts of the wall cooler than the rest. Nevertheless, this general tendency for condensation to predominate at lower levels, or even on the floor by the wall, can very often be observed at 100 per cent relative humidity, whereas air containing only half what it could contain at that temperature is at 50 per cent relative humidity. But if air is warmed, the amount of water vapour it could hold at saturation is increased, so that the relative humidity becomes lower although no water has been removed from it (*see* example on p. 65).

Similarly, if air is cooled, the amount of water vapour which it can hold is reduced, so that its relative humidity is increased. If it was already saturated, the excess of water vapour which it cannot now hold must condense, either forming mist or fog (tiny drops of water in the air) or forming drops of water on walls, windows or furniture.

Dew and dew-point

It is always possible to cool air sufficiently to reach the point at which water condenses to form dew, mist or frost. This temperature, that is the temperature at which a sample of air becomes saturated and produces dew or mist, is called *dew-point*.

Dew-point is thus the significant temperature to know whenever condensation is concerned; it depends on the amount of moisture in the air (*see* Box 4). Dew-point temperature increases as the amount of moisture in the air increases. Therefore the more moisture that is produced in a room by human activity, the more likely the situation where the dew-point temperature of the air will be increased to become equal to or higher than a wall surface temperature. And if, at any time, the temperature of a surface falls below the dew-point temperature of the air, the air coming into contact with the surface will be cooled to its dew-point temperature and will deposit the water which it can no longer hold. The cold air against the surface will sink to the floor, while fresh warm air takes its place and is in turn reduced to dew-point adding more water to a cold wall (*see Figure 6.2*). A continual

The amount of water vapour in the air

Although in the text we speak of the 'amount' of water in the air, we do not say how this is measured. The 'amount' is normally expressed as the weight of water contained in a given weight of dry air: grams of water per kilogram of dry air, for example. The ratio of the amount of water in the air to the amount of water needed to saturate that air is correctly known as the 'percentage saturation'. Strictly speaking, relative humidity (RH) is slightly different from this because it is measured as the ratio of the vapour pressure of water in the air to the vapour pressure of water in saturated air.

For most purposes this difference is not at all important. Towards the two ends of the scale, i.e. 0 per cent and 100 per cent, saturation and relative humidity are identical, but in the middle of the scale they differ slightly. For example, at 20°C, if the dew point is 10°C, percentage saturation is 52 per cent but relative humidity is 52.5 per cent, a negligible difference for practical purposes. But at higher temperatures the difference is greater: at 30°C and dew point 18.8°C, percentage saturation is 50 per cent but relative humidity is 51.1 per cent.

The term 'vapour pressure' needs some explanation. The moisture in air contributes to the total atmospheric pressure; this contribution is called the 'vapour pressure' of the water. It is commonly measured in millibars, though formerly millimetres of mercury was used. It is this vapour pressure which causes water vapour to move through building elements to regions of lower vapour pressure and determines the evaporation or condensation of water.

We prefer to use the rather imprecise term 'amount' in the text, because it is shorter and easier to understand than 'vapour pressure'. But we use the latter for all calculations.

slow circulation will thus transfer water continually to the cold wall, gradually drying the air in the room. But so long as the water is continually replaced (by drying washing, washing up or cooking, burning paraffin in an oil stove and by people breathing) the process of wetting the wall will continue even though other parts of the room may feel comfortably warm and dry.

In discussing condensation we shall from time to time refer to a 'vapour barrier'. British Standard 5250:1975 defines this as follows:

> Part of a constructional element through which water vapour cannot pass. In practice this is nearly impossible to achieve and in the text 'vapour barrier' refers to a constructional element which approximates well to the theoretical definition.

For example, vinyl wallpaper is a 'vapour barrier' (*see* p. 74).

The use of psychrometric charts

The relationship between relative humidity, dew-point and air temperature can be looked up in psychrometric charts or hygrometric tables published by HMSO or the Chartered Institution of Building Services (CIBS) or tables issued by Protimeter Ltd.

A psychrometric chart is reproduced by permission from British Standard 5250:1975 as *Figure 6.3*. The main curve shows the amount of water in the air when this is saturated, at each of the temperatures given along the bottom axis. The vertical axis shows this 'amount' of water on two scales; grams per kilogram of dry air, and water vapour pressure in millibars (*see* Box 4). The curved lines below the main curve represent various percentages, from 10 to 90, of the vertical axis and may be taken to represent percentages relative humidity. The sloping straight lines, which represent 'wet bulb temperature', can be ignored.

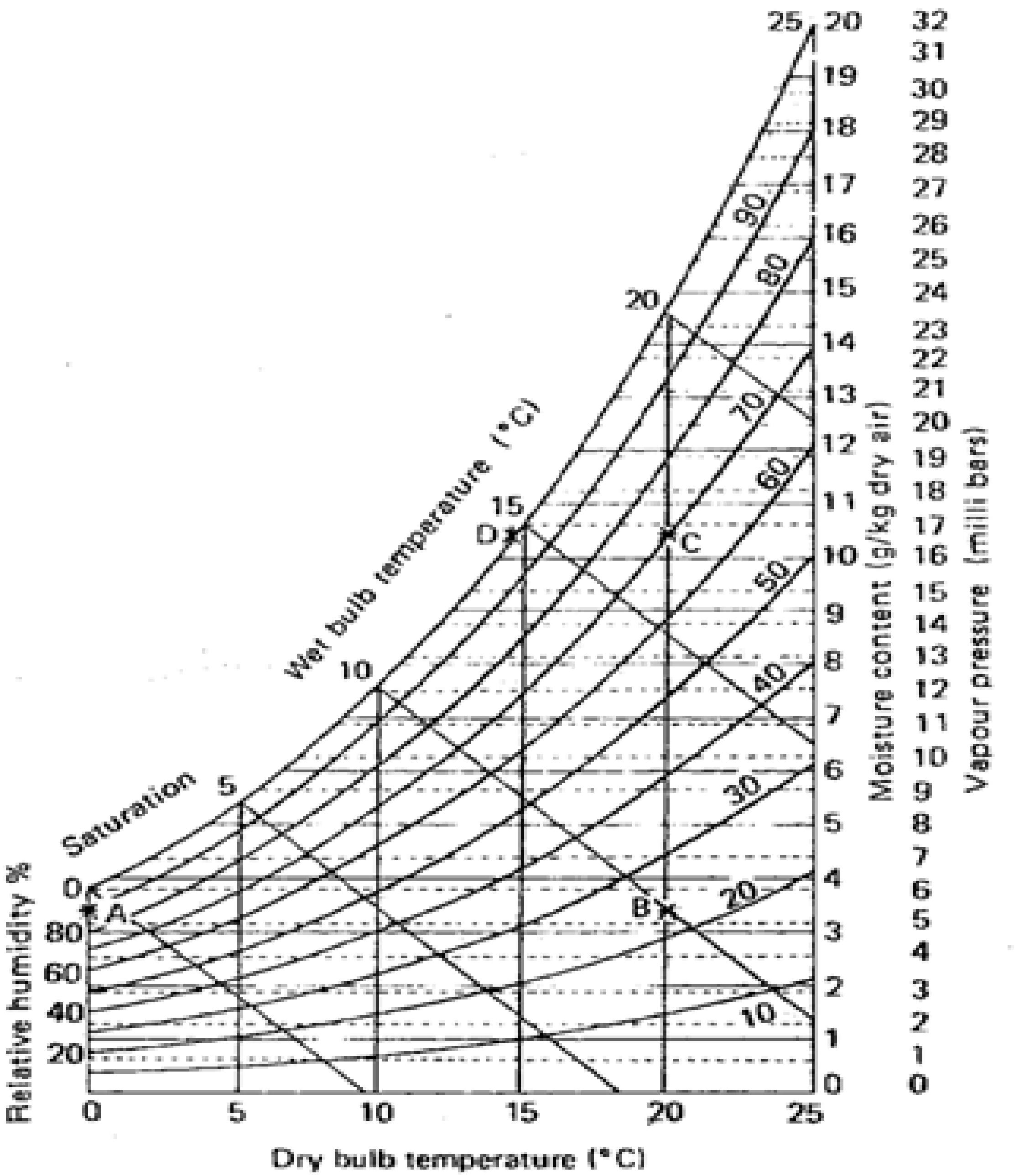

Figure 6.3 A psychrometric chart; the interrelationship between moisture contents and temperature (BS 5250:1975)

Following is an example of the use of a psychrometric chart, also taken from BS 5250:1975:

Consider point A. This represents an outdoor air condition in winter of 0°C and 90 per cent relative humidity. Point B indicates air with the same moisture content but as it is now at 20°C its relative humidity has changed to approximately 23 per cent. This shows what happens to the outdoor air after it enters a building and is warmed, if no other change occurs.

Point C indicates air still at 20°C, but with moisture content raised. The increase in moisture without change in temperature means that relative humidity has risen, and the curved lines show this now to be about 70 per cent. This is what might occur when the incoming air has picked up moisture from activities within the building.

Reading horizontally to the left from C, point D indicates when saturation would occur, i.e. when the air is cooled to a temperature of about 14.5°C, which happens when the air from C comes into contact with a cool surface at that temperature. Result: 100 per cent relative humidity = condensation.

This example emphasizes that condensation in buildings is not caused by high humidities outside. So long as buildings are even slightly warmer inside than outside, air which comes in can never reach saturation indoors. The only exception is when, in early summer, a sudden change to wet warm weather may cause condensation on cold interior walls or water pipes. But this is always transient and does not cause a persistent problem.

Why condensation has become a very common cause of dampness

If all the water vapour released into the air of a home could escape somewhere, condensation would not occur. When homes were more draughty and open fires were common, this water used mainly to go up the chimneys. Now that chimneys are mostly closed and draughts prevented, condensation problems are the result (*see Figures* 6.4 and 6.5).

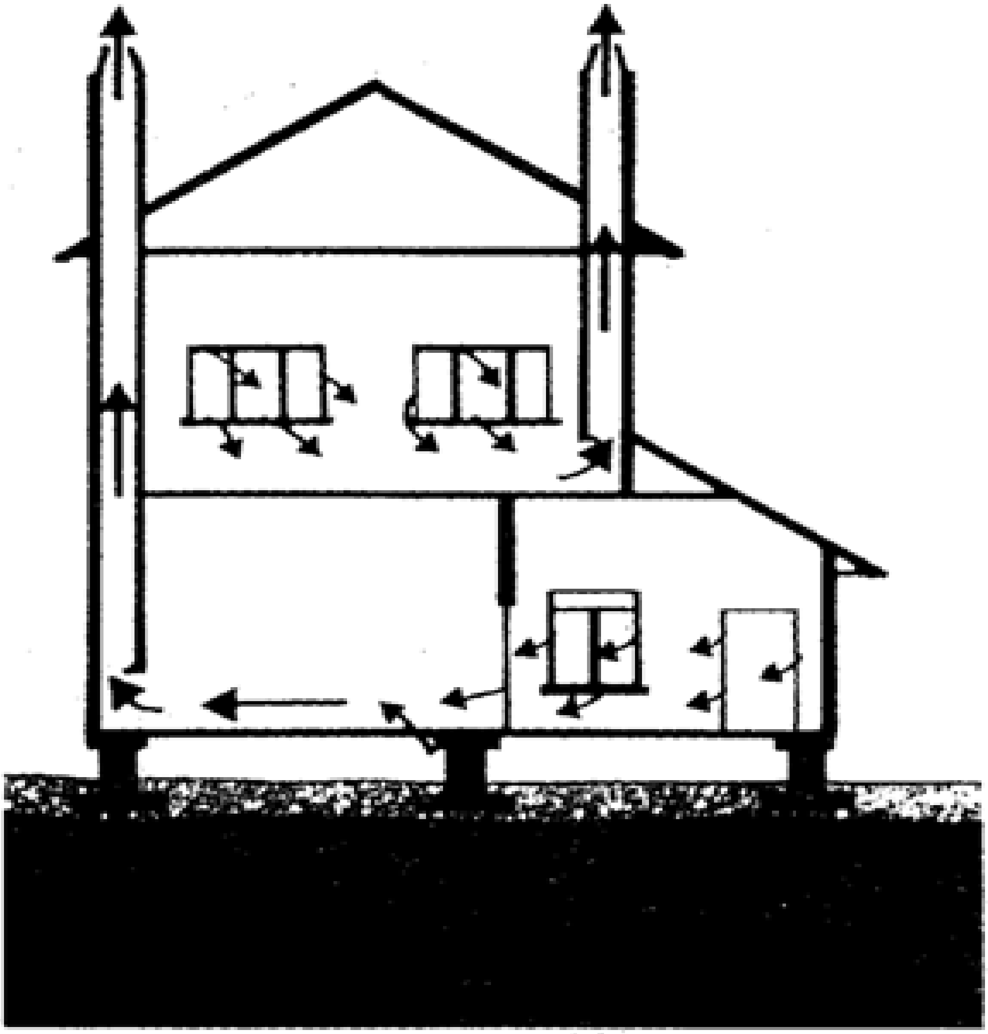

Figure 6.4 Escape of moist air in older houses

Condensation does not necessarily occur in the rooms where the water vapour is produced. A kitchen or bathroom in which vapour is produced may be warm enough to remain free from condensation except perhaps on cold, single-glazed windows, cold-water pipes and other cold surfaces. But if this water vapour is allowed to disperse through the dwelling into colder spaces such as the stair-well and unheated bedrooms, condensation will occur on the cold surfaces of those rooms, which may be remote from the source of the moisture. Soft furnishings,

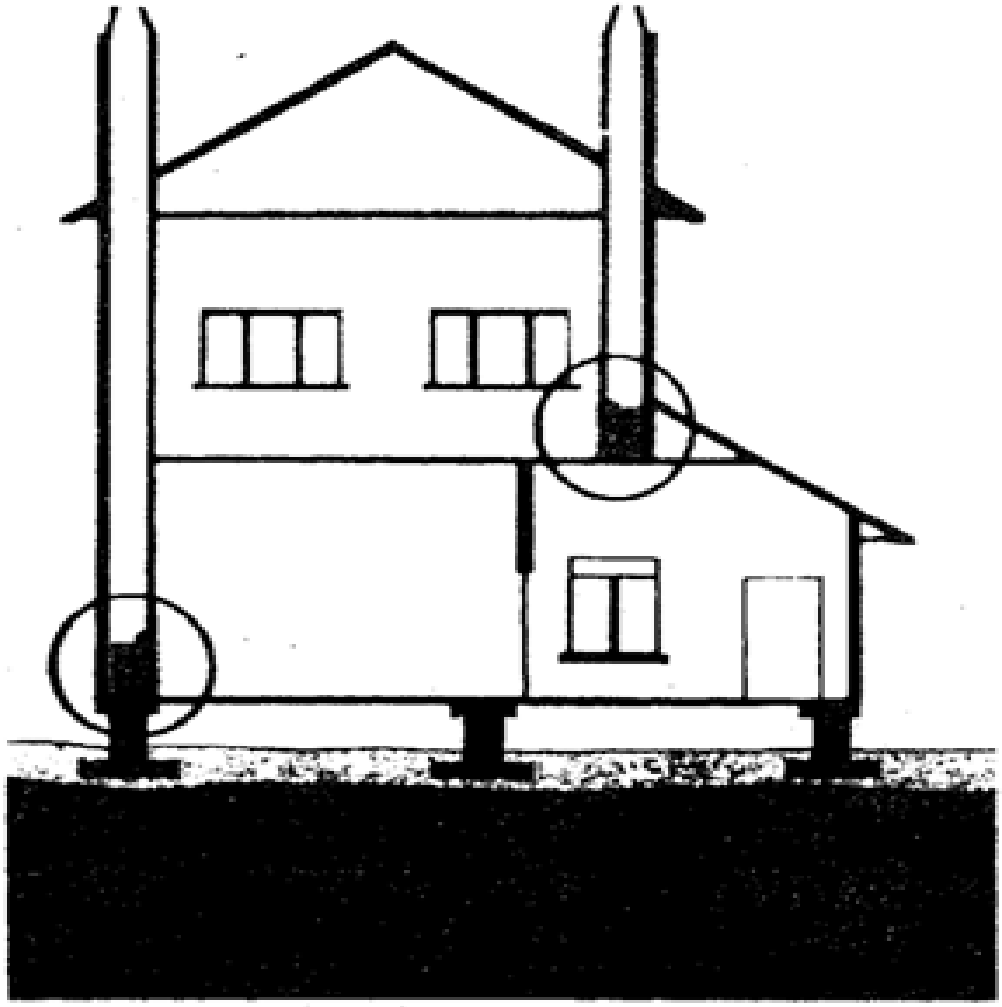

Figure 6.5 Closed chimneys and airtight windows seal the air into modern houses

including bedding, and clothing may become damp because of this, especially as some of these materials are slightly hygroscopic (taken from BRE Digest 110).

Windows

Condensation on single glazed windows is not a serious problem provided the window frames are properly painted and the condensate is wiped up regularly and not allow to soak into the wood frame and to wet the wall. In fact condensation on single glazed windows can remove quite a lot of water from the air (acting as a dehumidifier) and hence, by lowering the dew-point, may reduce .condensation elsewhere. But modern man requires double glazing, which will reduce the risk of condensation on the glazing and if any metal frames are fitted with a thermal break this will prevent condensation on these also. However, this reduction in condensation, combined with the reduction in draughts which usually results from the use of closer fitting frames, tends to increase the risk of condensation elsewhere.

Cold areas

Another phenomenon causing condensation is cold-bridging. This means production of local cold areas on otherwise warm walls by the proximity of highly conductive building elements. For example, the inside surface temperature of a solid concrete lintel or similar structure member may be as much as 5°C colder than the surrounding wall surface. Such cold areas may be found in a number of places on a building; for instance where structural members such as a column or ring beam of a dense material bridge a cavity without additional thermal insulation having been provided to compensate for the loss of cavity insulation value. Another example is the bridging of a cavity with a dense floor slab which may result in condensation on the surface of the slab and possibly on the walls within the room.

Condensation in roof spaces

Water vapour will also reach roof spaces where condensation is not uncommon. In fact, the roof space may be the only place to which water vapour can escape in modern housing. With all draughts sealed and walls quite frequently covered with vinyl papers (which, as we have said, are considerably resistant to the passage of water vapour) the water vapour which is inevitably produced by occupants must escape somewhere. It will largely pass from the ground floor to upper floors and then through the ceilings to the roof space. Note that thermal insulation which is frequently applied to ceilings is fully permeable to water vapour.

Roofs with a non-absorbent lining

These types of roof include conventional constructions with a sarking felt or plastic sheeting under the tiles or slates, and constructions with metal or asbestos decks. Condensation can occur on the underside of the sheeting. This is not damaged itself, but the condensed water can then wet rafters in contact with the sheet, increasing the risk of rot. It can also drip and soak any insulation ultimately damaging the plasterboard; electrical services on the ceiling may also be wetted causing shorting. The water can also run into the eaves to soak wallhead plates and might cause corrosion to punched metal plate-fasteners in trussed rafter roofs, especially in roof members treated with a waterborne preservative based on copper–chrome–arsenate.

Problems of condensation in roof spaces may be especially severe during a thaw after large amounts of ice have built up on the sheeting as a result of condensation during a prolonged cold spell. The volume of water released may be large enough to give the impression of a major leak in the roof.

Roofs with an absorbent lining

This section is reproduced from BRE Digest 270:

> Included in these types are roofs with timber or timber-based sarking boards under the tiles or slates, or roofs with sarking boards covered with impermeable waterproofing materials. In these cases, any water condensing on the underside of the roof covering may be absorbed by the board. This may either cause moisture-swelling in materials such as chipboard or may result in rot. Under such conditions the boards may lose their strength and fall into the roof space.

If the relative humidity in the roof is persistently high, mould and mildew can grow on furniture, clothes, luggage or other materials stored in the roof. This is often the first sign of the problem and the first cause of complaint by the occupants.

Roofs with an insulated lining

The relative humidity in a roof space may be kept from rising too high by lining the roof under the tiles with an insulating material, in addition to, or instead of, insulation at ceiling level. This is sometimes done as a 'belt and braces' approach to insulation, but it is unwise and unnecessary. The insulating material may become saturated losing much of its insulating property. Also, because the roof space is kept relatively warm, air with a high dew-point can pass into the eaves, especially if these are wide, and cause condensation leading to decay of fascia and soffit boards, and rafter ends. If in spite of this, the roof surface is insulated, it is wise to provide ventilation to any enclosed eaves spaces by means of holes or grills in the soffits.

Ventilation of roof spaces

The best policy is to ensure free movement of outside air through roof spaces. This will dissipate water vapour and avoid the condensation problems described. Goods stored in the roof space will not become unduly damp; they will follow the normal outside atmosphere which, taking the year round, is far below saturation. If there is any sarking, or indeed any underlining of slates or tiles, spaces should be left at the eaves to permit free entry and exit of air. Remember that the function of a roof is to keep the rain out, like an umbrella, not to keep the warmth in (which should be done at ceiling level), still less to keep in the moisture produced in the house.

Flat roofs

The problem with flat roofs is usually one of interstiti condensation (see the following section). The extern waterproof finish forms a barrier resistant to outwar escape of water vapour. Prevention of this problem aided by providing a vapour barrier located benea sufficient thermal insulation to ensure that the unde side of the vapour barrier is kept above dew-point.

Interstitial condensation

This term refers to condensation which occurs actua within the thickness of a wall or ceiling. Any wall whi is porous must allow water vapour to diffuse throu it; indeed this is one of the routes by which excessi water vapour within a building normally escapes to t exterior. Very nearly always there is a temperatu gradient within the wall. The inner surface of the wal close to the temperature of the room while the ou surface is close to that of the outside temperature.

Although a wall may be porous, it imposes so resistance to the diffusion of water through Therefore the water vapour content of the air in pores declines from the relatively high level whicl normal in a warmed, inhabited space towards lower level which is usual in the colder outside air. dew-point temperature is directly related to the m of water vapour in the air, so 'dew-point' may substituted for 'water vapour content' in the ab statement.

So we have both the actual temperature and dew-point temperature declining through the v Normally, with ordinary porous building mate such as brick, the decline in actual temperature is m rapid than the decline in dew-point temperature that they cross somewhere within the wall and at point condensation occurs.

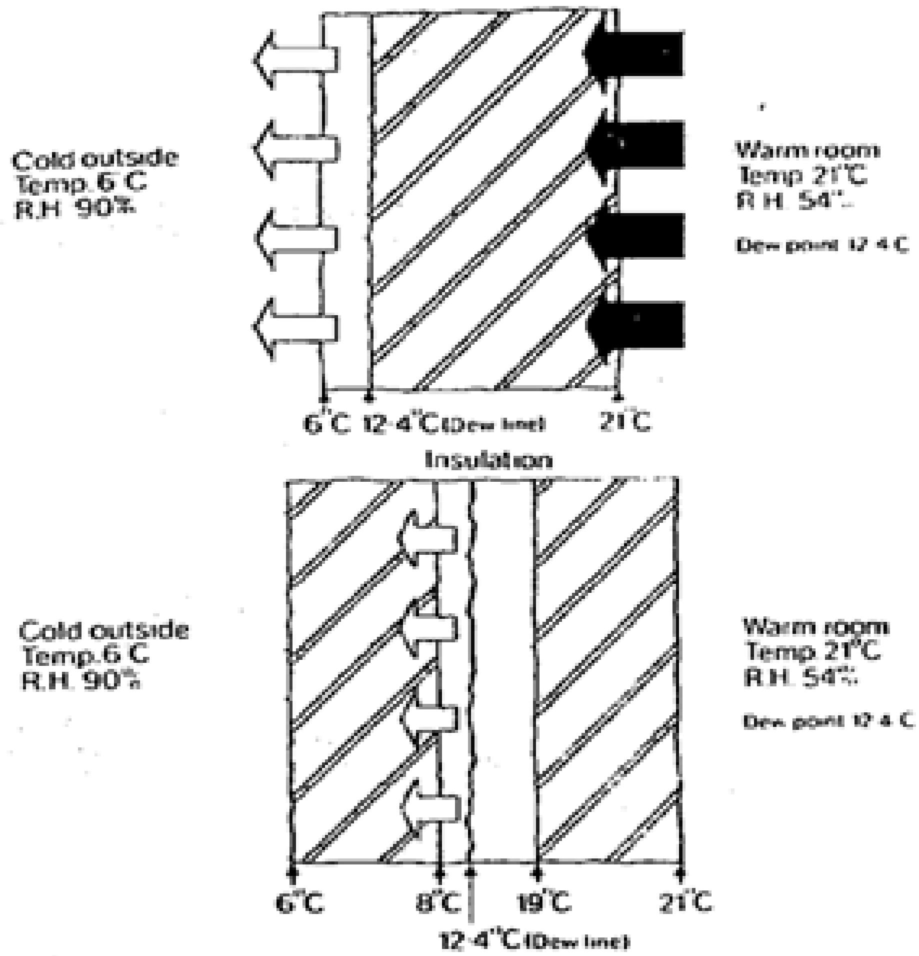

Figure 6.6 Two wall sections illustrating interstitial condensation. For simplicity of explanation it is assumed that water vapour passes freely through these walls so that dew-point is unchanged; in practice it would be somewhat lowered. The upper section shows a solid wall. The black arrows represent water vapour passing from the warm room. The air reaches its dew-point somewhere near the outer face of the wall and here deposits its excess of moisture. Evaporation (white arrows) continues towards the exterior and in warmer weather will normally escape harmlessly. The lower section shows the possible effect of insulating a cavity. Because of the insulation, the temperature falls most rapidly in the cavity and hence dew-point may be reached in the filling. Conditions could occur in which this filling became saturated because there is little opportunity for evaporation in drier weather. A porous filling which allows water to drain away, or a water-vapour-proof filling (acting as a vapour barrier) would not be liable to this possible hazard.

Note that an effective vapour barrier on the warm side of the wall would prevent interstitial condensation

This probably happens normally in the walls of most ordinary houses. If it occurs near the outer face of the wall, no trouble is caused. The excess of water evaporates quite easily at times when condensation is not occurring. Frequently, with cavity walls, interstitial condensation occurs within the cavity, because the still air presents an effective resistance to movement of heat but permits easy movement of water vapour. Such condensation normally escapes freely enough if the cavity is ventilated or may evaporate at favourable times through the outer leaf. Condensation may be more frequent, and perhaps potentially more troublesome, when the cavity is filled with an insulating material. These conditions are illustrated in *Figure 6.6.* If the resistance of each component of a wall to water vapour penetration, and to heat movement, is known it is possible to calculate exactly where interstitial condensation will occur. This will vary according to the weather outside and the room conditions inside so that it is usual to calculate for extreme conditions only. This is often done in the design stage for important buildings.

Vapour barriers

If the outer surface of a wall is covered with a water vapour barrier, heat can escape but water vapour cannot. Therefore interstitial condensation will normally occur under most conditions and the wall beneath the barrier will become saturated. A cavity will avoid the worst consequences of this, but a solid wall will suffer considerably. For this reason it is an accepted rule that vapour barriers must always be placed on the warm side of any insulating layer. A vapour barrier on the inside face of a wall (for example foil, polythene or several layers of gloss paint) will reduce the risk of interstitial condensation. For most brick or masonry walls this is probably not worth doing, but for wood frame construction it is usual considered to be essential because condensation within the wall can cause decay of the wood. However, since a total vapour barrier cannot be assured, provision should be made for moisture to escape outwards. If vapour barriers are used on all walls and ceilings, there will be no channel for escape of the water vapour which all human beings must generate in the ordinary course of their lives. If draughts are also excluded, condensation must inevitably occur.

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Sources of water vapour

It is important to identify the major sources of water vapour. Some are unavoidable, but others can perhaps be eliminated or reduced and this should be done as far as possible. It is helpful when considering which sources could, perhaps, be reduced or eliminated, to know their relative importance. *Table 6.1*, reprinted with permission from British Standard 5250:1975, gives the estimated production of water vapour by a typical family of five. These sources are illustrated in *Figure 6.7*.

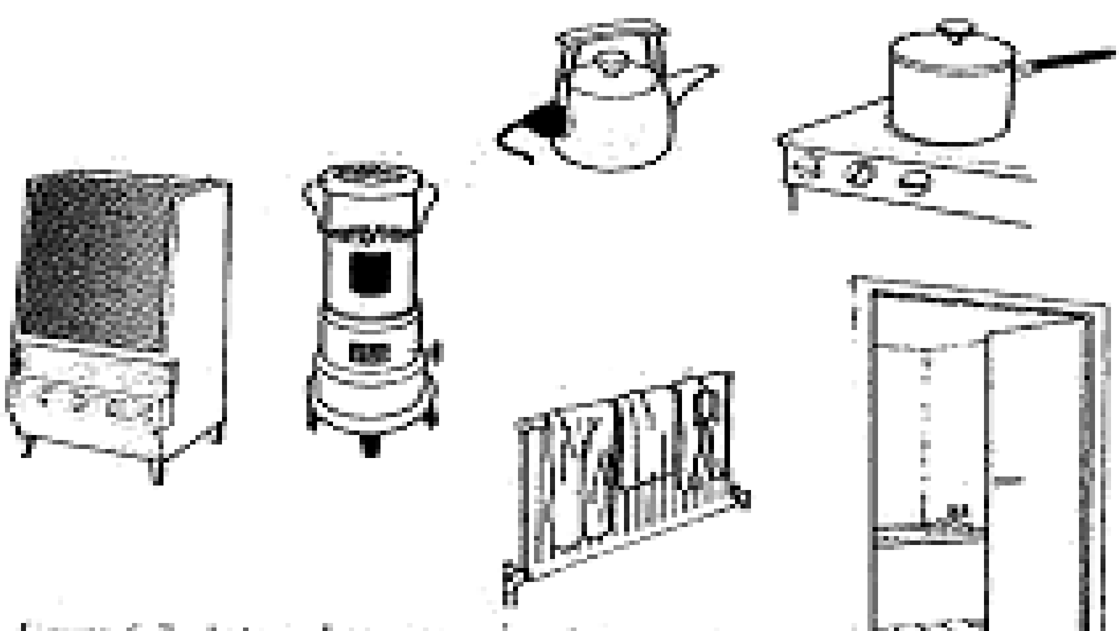


Figure 6.7 Internal sources of water vapour

(1) Flueless oil or gas heaters which discharge their combustion gases directly into the air inside the building can be a major contributor to condensation. This is because the burning of oil (paraffin, kerosene) or gas involves burning of hydrogen and hence production of water vapour. One litre of paraffin (kerosene) produces about 1 litre of water as water vapour (see page 84).

(2) If there is a condensation problem in the lounge, for example, and the smell of cooking gets there too, the kitchen is highly likely to be a significant source of water vapour. The obvious recommendation is to keep the kitchen door closed, as far as possible, while cooking, washing or clothes drying is in progress.

Table 6.1 shows what a large proportion of the total water vapour produced by a typical family could thereby be contained. Another effective recommendation is to install an extractor fan which will remove moisture-laden air from the kitchen.

It has been found that people are generally unwilling, or do not remember, to switch on extractor fans at the right times and hence much better results are obtained if the fan is controlled by a humidistatic switch. Also, if a fan is to be used it must be quiet and unobtrusive, and it should be provided with flaps which keep out the wind when it is not in use. Otherwise its nuisance value may be rated higher than that of condensation. If an extractor fan is not fitted, a tumble dryer should always be vented to the exterior.

(3) Large damp areas due to rising or penetrating damp, especially in warm rooms, can contribute significantly to the amount of water vapour in a building. A damp floor, if it is not covered with water-vapour-proof tiles or sheeting, can be an even more significant source. If the premises are newly constructed, time must be allowed for the

Table 6.1 Typical moisture production within a five person dwelling

Regular daily emission sources	*Moisture emission per day/kg or litre*
Five persons asleep for 8 h	1.5
Two persons active for 16 h	1.7
Cooking	3.0
Bathing, dish washing, etc.	1.0
Total, regular sources	7.2
Additional sources	
Washing clothes	0.5
Drying clothes	5.0
Paraffin heater (if used)	1.7
Total, additional sources	7.2
Combined total	14.4

NOTE 1. The table does not include moisture introduced or removed by ventilation.
NOTE 2. The high moisture input from clothes drying shows the importance of designing for its control.
NOTE 3. The considerable emission during cooking, which is of short duration, indicates a need for local control.
NOTE 4. The water vapour emitted by flueless oil stoves significantly increases condensation risk. (Flueless gas appliances also produce a considerable quantity of water vapour.)
[Taken from BS 5250: 1975]

fabric of the building to dry properly before it is inhabited or condensation will be inevitable.

Heating

Heating of the air is in itself insufficient, although it may help to reduce condensation, since the warmed air will take longer to cool at any cold surface and give the existing ventilation more time to replace the wet air by dry air. In bad cases, however, heating can only be effective in reducing condensation if it is used long enough to raise the temperature of the cold surfaces. This seldom happens if heating is used intermittently during the evenings and mornings, as is so often the case.

In the absence of a continuous heating programme it is an advantage to place the available heat directly against the cold areas in order to warm them as efficiently as possible and to keep the air moving over the cold surfaces so that it is not in contact with them long enough to be cooled to a temperature below its dew-point. A fan heater positioned so as to blow on to the cold exterior wall would, for example, be more effective than a simple electric fire of the same wattage, but naturally would be less effective in heating the room. In the absence of any form of heating, the walls can be insulated by lining. Even a thin film of foam plastic material, such as polystyrene which is available in roll form, can improve matters to a significant extent.

Dehumidification

A dehumidifier is theoretically the ideal cure for condensation, since it removes water directly from the air and does not involve any draughts or loss of heat. Indeed, a dehumidifier warms the air by slightly more than the same amount of electricity would do if working directly through an electric heater. However, too much must not be expected of a dehumidifier. Usually the capacity of a domestic dehumidifier unit is insufficient to cure condensation in a typical house, although it will lower the general dew-point level and thus help to reduce condensation. In a single room subject to condensation a dehumidifier can be a complete cure, but as it is usually a bedroom which suffers most severely, the noise which such a machine inevitably makes requires it to be switched off at night, thereby reducing its efficacy.

In a small flat, a dehumidifier placed centrally may be effective in curing condensation completely. But this may require that the temperature within the flat is not allowed to fall too low, because the moisture removal capacity of a dehumidifier is much reduced at low temperatures. A domestic dehumidifier cannot be expected to make much contribution towards drying out large volumes of brick or concrete. Much larger (and correspondingly noisy and expensive) machines are needed to hasten drying out of new construction effectively.

The three principal objections to widespread use of domestic dehumidifiers are:

(1) High cost of installation and high running costs.
(2) Noise.
(3) Need to empty the reservoir frequently.

In the future both cost and noise can be expected to decrease, and in many circumstances it is possible to plumb the waste directly to a drain. Hence, dehumidification may become a more widely accepted treatment for condensation in the future.

Mould growth

As explained in Chapter 9, mould growth is a typical consequence of condensation. This is because intermittent periods of high moisture with intervening drier periods are especially suitable for the growth of moulds and development of the coloured spores which are principally responsible for the mould 'stain'. The distribution of mould growth can be a useful guide to the areas in which condensation is occurring, although moulds can and do develop in dampness due to some other sources of water. A mouldy area due to condensation may sometimes be found to be relatively dry when inspected with a moisture meter, because condensation has not occurred for several days. Moulds are often most severe in room corners of external walls. This is mainly because insufficient ventilation creates pockets of stagnant air in such corners. Built-in cupboards, particularly when located against external walls, suffer from the same disadvantage.

Recommendations for occupiers

British Standard 5250:1975 includes a suggested form of explanatory leaflet which can be supplied to occupiers of premises who are bothered by condensation. This leaflet contains a lot of useful advice and we therefore quote it in full here.

(1) It is well known that in recent years some houses and flats have suffered from condensation. Walls and ceilings, and sometimes floors, become damp and sometimes discoloured and unpleasant as a result of mould growing on the surfaces.

(2) *Why condensation occurs.* Condensation occurs when warm moist air meets a cold surface. The risk of condensation therefore depends upon how moist the air is and how cold the surfaces of rooms are. Both of these depend to some extent on how a building is used.

(3) *When condensation occurs.* Condensation occurs usually in winter, because the building structure is cold and because windows are opened less and moist air cannot escape.

(4) *Where condensation occurs.* Condensation which you can see occurs often for short periods in bathrooms and kitchens because of the steamy atmosphere, and quite frequently for long periods in unheated bedrooms; also sometimes in cupboards or corners of rooms where ventilation and movement of air are restricted. Besides condensation on visible surfaces, damage can occur to materials which are out of sight, for example from condensation in roofs.

(5) *What is important.* Three things are particularly important:

(a) To prevent very moist air spreading to other rooms from kitchens and bathrooms or from where clothes may be put to dry.

(b) To provide some ventilation to all rooms so that moist air can escape.
(c) To use the heating reasonably.

The following notes give advice on how you can help to prevent serious condensation in your home.

(6) Reduce moisture content of room air

(a) Good ventilation of kitchens when washing or drying clothes or cooking is essential. If there is an electric extractor fan, use it when cooking, or washing clothes, and particularly whenever the windows show any sign of misting. Leave the fan on until the misting has cleared.

(b) If there is not an extractor fan, open kitchen windows but keep the door closed as much as possible.

(c) After bathing, keep the bathroom window open, and shut the door for long enough to dry off the room.

(d) In other rooms provide some ventilation. In old houses a lot of ventilation occurs through fireplace flues and draughty windows. In modern flats and houses sufficient ventilation does not occur unless a window or ventilator is open for a reasonable time each day and for nearly all the time a room is in use. Too much ventilation in cold weather is uncomfortable and wastes heat. All that is needed is a very slightly opened window or ventilator. Where there is a choice, open the upper part, such as a top-hung window. About a 10 mm opening will usually be sufficient.

(e) Avoid the use of portable paraffin or flueless gas heaters as far as possible. Each litre of oil used produces the equivalent of about a litre of liquid water in the form of water vapour. If these heaters must be used, make sure the room they are in is well ventilated.

(f) If condensation occurs in a room which has a gas, oil, or solid fuel heating appliance with a flue the heating installation should be checked, as the condensation may have appeared because the appliance flue has become blocked.

(g) Do not use unventilated airing cupboards for clothes drying.

(h) If washing is put to dry, for example in a bathroom or kitchen, open a window or turn on the extractor fan enough to ventilate the room. Do *not* leave the door open or moist air will spread to other rooms where it may cause trouble.

(7) Provide reasonable heating.

(a) Try to make sure that all rooms are at least partially heated. Condensation most often occurs in unheated bedrooms.

(b) To prevent condensation the heat has to keep room surfaces reasonably warm. It takes a long time for a cold building structure to warm up, so it is better to have a small amount of heat for a long period than a lot of heat for a short time.

(c) Houses and flats left unoccupied and unheated during the day get very cold. Whenever possible, it is best to keep heating on, even if at a low level.

(d) In houses, the rooms above a heated living room benefit to some extent from heat rising through the floor. In bungalows and in most flats this does not happen. Some rooms are especially cold because they have a lot of outside walls or lose heat through a roof as well as walls. Such rooms are most likely to have condensation and some heating is therefore necessary. Even in a well insulated house and with reasonable ventilation it is likely to be necessary during cold weather to maintain all rooms at not less than 10 °C in order to avoid condensation. When living rooms are in use their temperature should be raised to about 20 °C.

(8) *Mould growth.* Any sign of mould growth is an indication of the presence of moisture and if caused by condensation gives warning that heating, structural insulation or ventilation, or all three, may require improvement.

(9) *New buildings.* New buildings often take a long time before they are fully dried out. While this is happening they need extra heat and ventilation. At least during the first winter of use many houses and flats require more heat than they will need in subsequent winters. Allowance should be made for this. It is important that wet construction should be free to dry out. In some forms of construction, especially flat roofs of concrete, final drying may only be able to take place inwards. Ceiling finishes which would prevent such drying out should not be added unless expert advice has been given that this would not matter.

(10) *Effect of increased ventilation on fuel burning appliances.* If an occupier proposes to fix an extractor fan or otherwise change the ventilation in a room containing a gas or solid fuel appliance, he should obtain advice from the installer of the appliance about the risks from toxic fumes.

Dampness associated with flues

The problem

There are two ways in which flues (chimneys) can be responsible for dampness in buildings:

(1) By conveying rain into the building.
(2) By condensation of water vapour
  (a) formed by burning of fuel (solid, liquid or gas), or
  (b) in a disued flue, from a warm domestic atmosphere.

Rainfall

Some rain will fall into an open chimney unless it is fitted with a cowl, and this will lodge at any horizontal part of the flue including the fireplace itself. If the flue is disused, this will not be evaporated and will penetrate the brickwork into inhabited areas. Also, a chimney stack which extends more than about 1 m above the roof and does not have a damp-proof course, or is poorly flashed where it passes through the roof, provides a channel through its brickwork for downward movement of rainwater into upper floors. Good protection should be provided at the top of the stack.

Condensation

Any fuel which contains hydrogen, which in practice means all except coke and anthracite, produces water as it burns, because part of the burning process is combination of hydrogen with oxygen (from the air) to form 'H_2O', the oxide of hydrogen which we know as water. In addition, solid fuels including coke and anthracite contain some water (for they are never quite dry) which is evaporated by the fire. Water from both sources is in the form of water vapour because of the heat of the fire and is therefore invisible. This gives a flue gas a high dew-point temperature. If the flue gas remains hot, all the water vapour escapes from the chimney and no harm is done. Also, if the flue gas is mixed with a large volume of room air, as happens over an old fashioned open fire, this lowers the dew-point and all the water vapour will usually escape from the chimney. With a closed stove, burning solid fuel, gas or oil, the flue gas retains its high dew-point and if the flue is cool, some of the water vapour will condense out on the walls of the flue. This will happen even if the flue is quite warm if the dew-point is very high. The worst case is burning wet wood.

Modern boilers and stoves restrict the air flow to little more than is necessary for the fire itself. Also, they are designed to extract as much heat as possible from the fire, which means that the flue gases enter the flue as cool as it is practicable to make them. It is not surprising that if a flue connected to a closed stove or boiler passes next to an exposed wall, or through cold bedrooms or loft space, it is cooled below dew-point and condensation occurs. Water deposited here, and in the exposed chimney stack above, will run back down the flue and will often penetrate the thin brickwork into inhabited rooms.

Condensed water and rainwater take up soluble salts and coloured tarry substances inside the flue and carry these through the wall where they are deposited in and on the plaster and decorations. The soluble salts are products of combustion, the most troublesome being sulphates derived from the sulphur in the fuels. All fuels contain some sulphur, but the amount varies very widely depending on the source of the fuel. Sulphates disrupt plaster and cement mortar causing it to crumble. Coloured hygroscopic deposits in walls resulting from flue condensation may cause trouble long after a flue has been disused, or even demolished.

The answer

High humidity under suspended floors

The problem

Unless subfloor ventilation of suspended ground floors is adequate, decay is very common, because the moisture content of the joists and floorboards can become very high. This is caused by the subfloor atmosphere having a persistently very high relative humidity. Wood absorbs water from air of high relative humidity and if the condition persists, the wood can become very wet indeed.

The high humidity in the subfloor space is produced by evaporation of water from the soil under the building and from the walls below the damp-proof course. This includes both the structural walls and any dwarf walls provided to support the floor. The soil is often covered with a layer of oversite concrete, but this makes little difference unless it is laid on a damp-proof membrane.

Moisture meter readings can be taken by pressing the needle electrodes through the floor covering into the floor timbers below. The pattern of dampness often follows the pattern of poor ventilation below. Typical moisture contents in wood floors moistened by subfloor humidity are 18–30 per cent; if the moisture content is 20 per cent or above, an examination of the underside of the floor is advisable. The higher figures occur when the floor is covered with a waterproof covering such as linoleum, vinyl or rubber sheet or tiles, or some types of carpet underlay.

The answer

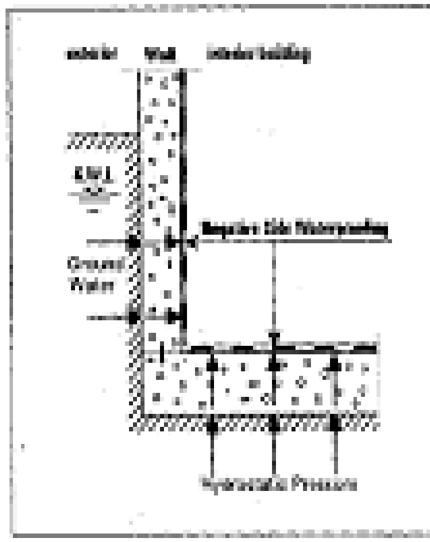


Figure 1. Location of negative side waterproofing.

Negative side waterproofing

[illegible]

Negative side waterproofing is the general term used to describe a waterproof barrier applied to a concrete, masonry, or brick substrate opposite the expected source of water or moisture. For water-containing structures such as tanks, negative side waterproofing would be applied to the outside of the structure. For foundations, the waterproofing would be applied on the interior surface of the structure.

Negative side waterproofing materials are generally easy and safe to apply and can be used for a variety of different applications. Although used extensively in new construction, they are especially suited to remedial work such as foundations, water storage tanks, pipe galleries, crack repairs, and any other surface not accessible on the positive water pressure side.

There are three basic types of negative side waterproofing materials: metallic waterproofing, capillary/crystalline waterproofing and cementitious waterproofing.

Negative side waterproofing is spray applied to an old, natural stone wall.

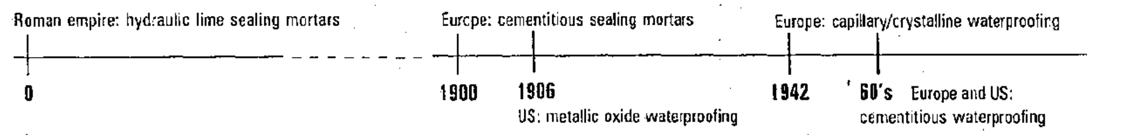
Metallic waterproofing

Metallic oxide waterproofing was developed and patented in the United States in 1906. It is still used today for elevator pits and other related applications.

"Metallic waterproofing consists of finely graded iron particles combined with an oxidizing catalyst. When mixed with water (or water, cement and sand), the finely distributed particles oxidize, creating an impervious waterproof layer that actually becomes a part of the surface to which it is applied." A normal application consists of two to three coats of metallic compound, followed by a sand/cement protection course which seals the metallic waterproofing, preventing brown colored oxidation or leaching through subsequent finishes and protecting against excessive wear on horizontal surfaces. This protection course generally ranges in thickness from 5 – 16 mm on walls, to 18 – 50 mm on traffic bearing slabs."

"A successful metallic application depends, to a great extent, on workmanship, requiring highly skilled masons. Not only is it the oldest of the modern negative side waterproofing materials, it is also the most expensive, due to the protection course. The difficulty of finding skilled masons often discourages applicators from using this otherwise effective waterproofing system.

History of cementitious waterproofing



Romans used cementitious mortars as positive-side waterproofing to line aqueducts, tanks and canals with hydraulic lime sealing mortars.

Capillary/crystalline waterproofing

Cementitious capillary/crystalline waterproofing was developed by the Danish chemist Lauritz Jensen in 1942.[2] His original formulation, adapted to today's technology, is used for a variety of applications.

This type consists of portland cement and quartz or silica sand which function as a carrier for a compound of proprietary active chemicals. It is supplied in powder form, and for most applications is mixed with water, and in some cases an acrylic additive, to form a brushable or sprayable slurry. Freshly-poured slabs can also be waterproofed on the negative side using the "dry shake" method, in which the dry waterproofing material is distributed over the concrete and trowelled in, similar to a shake-on hardener. In this case the capillary/crystalline waterproofing becomes a monolithic part of the slab, thus avoiding subsequent deterioration from abrasion or flaking.

As the name implies, capillary/crystalline waterproofing achieves its effectiveness not only through the waterproof coating, but primarily by the activation of the proprietary chemicals which penetrate the capillary cavities in the cement paste by the osmotic pressure of water. Here they react with calcium hydroxide and the capillary water to form insoluble crystalline complexes. These crystals block the capillary cavities and minor shrinkage cracks, preventing the passage of water but still allowing water vapor to escape. These crystals normally expand up to 0.3 mm—much larger than the maximum size of capillary cavities, which ACI gives as 0.01 mm.[3] Capillary/crystalline waterproofing is not a vapor barrier; it lets the concrete "breathe." This is especially important in situations where a vapor barrier type waterproofing has already been applied to the positive side of the structure.

Chemical activation of the proprietary chemicals begins immediately, and may take up to one month to reach maximum efficiency. Both activation and depth of penetration depend on various factors, such as ambient temperature, density and moisture content of the concrete, additives, and environmental conditions. While the depth of penetration will vary from one application to another, capillary/crystalline waterproofing will seal or post-seal hairline cracks which appear on the surface after the waterproofing has been applied. Tests have measured penetration depth as much as 150 mm over a period of nine weeks in a 16 MPa (2,300 psi) concrete,[4] whereas it may be less than 25 mm in a 40 MPa (6,000 psi) silica fume concrete.

The chemicals, once penetrated, become an integral part of the concrete. In the absence of water they lie dormant, but they reactivate whenever moisture or water returns. Being an integral part of the concrete, they are able to withstand strong negative water head pressures. The negative side performance of capillary/crystalline materials has been tested at hydrostatic pressures equivalent to 180 m of water head. This far exceeds the requirements of US Army Corps of Engineers Test CRD-C 48-73 which calls for testing at 1.38 MPa (200 psi) or 140 m water head pressure over a period of 20 days.[5]

Capillary/crystalline waterproofings are thin coat materials, ranging in thickness from 0.5 to 1.5 mm, which can be applied by relatively unskilled workers with proper supervision. Most capillary/crystalline waterproofing products do not provide a decorative finish. Due to the chemical reaction with the free lime and iron oxide in the concrete one can expect a certain amount of efflorescence or splotching, but this can be remedied by painting or coating after curing.

Dry waterproofing material is distributed over the concrete and troweled in (dry-shake method).

3 Cementitious waterproofing

In the sixties, further developments in both Europe and the U.S. produced a range of cementitious coatings and waterproof repair mortars suitable for negative side applications.

This type should be termed "cementitious membrane" or "cementitious barrier" waterproofing to properly distinguish it from capillary/crystalline, which is also cementitious in nature. However, not to confuse the reader with technicalities, the author will use the term "cementitious waterproofing" as it is generally used in the industry to refer to this type of waterproofing.

Cementitious waterproofing consists of portland cement, quartz or silica sand, and various chemical ingredients blended in powder form. Depending on the product, the powder may be mixed with water only, a mixture of water and acrylic additives, or a polymer additive, to achieve a brushable, sprayable or trowelable consistency. The waterproofing effect is achieved by the various chemical ingredients which activate as soon as they come in contact with the mixing liquid. Once activated they expand and fill the pores within the cementitious waterproofing, creating a water-impermeable barrier. Cementitious waterproofing differs in two major ways from capillary/crystalline waterproofing:

1. The waterproofing chemical ingredients in cementitious waterproofing do not penetrate into the concrete.
2. Cementitious waterproofing does not reseal or post-seal cracks which may appear after the waterproofing has been applied.

Cementitious waterproofing is efflorescence-free and provides a more aesthetic finish. It can be applied to a wider variety of substrates than capillary/crystalline waterproofing, including brick and some natural stone surfaces.

Cementitious waterproofing can be subdivided into four categories:

- inorganic or non-polymer cementitious waterproof coatings
- polymer-modified cementitious waterproof coatings
- elasticized cementitious waterproof coatings
- traffic-bearing cementitious waterproof overlays

Inorganic and polymer-modified materials account for approximately 90% of the negative side cementitious waterproofing market. There is a wide range of products—available in many different colors and finishes—for use in both commercial and residential applications. These products are generally applied in one or more coats at a thickness of 0.8 to 3 mm and achieve their waterproofing effect by creating a surface barrier which stops the flow of water. The required thickness and degree of waterproofing resistance varies considerably between products, as does pricing.

Elasticized cementitious waterproofing materials create a flexible surface waterproof barrier, used in zones of potential cracking or deforming problems, e.g. around PVC pipe penetrations in high-stress zones. These products offer varying crack-bridging capabilities with elongation up to 20% and are typically applied at a thickness of 1.5 to 3 mm in one or two coats.

Traffic-bearing, thin, bonded cementitious waterproof overlays have been used extensively in Europe for the past 20 years. They are applied as negative side waterproofing to the top of new or existing slabs subject to vehicular traffic in parking garages and other areas subject to high mechanical wear. In addition to waterproofing against strong hydrostatic pressure they also provide abrasion and freeze-thaw resistance. They are generally applied in one layer 6 to 12 mm in depth. These products are not widely used in the United States at this time.

Advantages

Negative side waterproofing offers the following advantages:

- Applicable to old or new substrates
- Provides economical solutions for rehabilitation work
- Eliminates the need for costly excavations on the outside of a building
- Allows above-grade water storage tanks to remain in operation while repairs are carried out on exterior surfaces
- Withstands high hydrostatic pressures
- Allows access to repaired areas after installation
- Provides a long lasting solution to waterproofing problems

Disadvantages

Negative side waterproofing tends to have the following disadvantages:

- With the exception of the elasticized materials, most negative side waterproofing materials are rigid, and thus will crack when the concrete cracks
- It should not be used where thermal movement is a major factor, unless a sufficient number of movement joints are installed
- In below-grade applications it does not protect the substrate or reinforcing steel from ground water and chemicals
- It can be difficult to achieve uniform color and texture

One disadvantage of negative side waterproofing materials—their tendancy to crack when concrete cracks—can actually be turned into an advantage. With negative side waterproofing, any leaks that occur are located at the exact area where the concrete has cracked. The cracks can easily be repaired using the same material or a high pressure chemical injection grout. On the other hand, positive side waterproofing may leak due to faulty workmanship or some type

Table 1. Product application comparison

	Metallic	Capillary/ crystalline	Cementitious: inorganic & polymer	Cementitious: elasti- cized	Cementitious: traffic bearing
Substrate					
Concrete	●	●	●	●	●
Masonry	●	●	●	●	●
Brick			●	●	●
Natural Stone (some)			●	●	●
Walls (negative side)	●	●	●	●	●
Floors					
• non-trafficable	●	●	●	●	●
• pedestrian traffic	●	●	●	●	●
• car traffic	●				●
• car traffic – dry shake		●			
• truck & forklift traffic	●				●
Crack sealing & post sealing capability		●			
Application Method					
Brush	●	●	●		
Trowel	●		●	●	●
Spray		●	●	●	●
Dry-shake		●			

Table 2. Cost comparison

Metallic		Capillary/crystalline		Cementitious	
$/ft²	$/m²	$ft²	$/m²	$/ft²	$/m²
4.00–8.00	43.00–86.00	1.00–2.50	11.00–27.00	1.50–3.50	16.00–38.00

Note: Installed costs are based on minimum area of 10,000 ft² (930 m²), and do not include removal costs for old coatings, paints, etc.

ɔf damage. When this occurs, water will ɔften travel a considerable distance along ·einforcing bars, PVC waterstops or such to inally appear at the weakest spot of the nterior surface, which may be 6 – 9 m away rom the point of entry. Repairing this leakge can prove to be a costly nightmare for the wner of the structure or for the applicator if is still under warranty. The active leak can e stopped on the interior surface, but since ater travels unhindered within the con·rete it often reappears at another weak spot hich must also be repaired. This cycle can en continue, creating a situation where the aterproofing contractor is "chasing water" ıtil most of the surface is repaired with a gative side waterproofing.

stalled costs

stalled costs vary extensively based on ctors such as geographic location, labor or prevailing rates, and the size and type of the application. *Table 2* shows an average range for the three main types of negative side waterproofing.

Standards

To the best knowledge of the author there are no established material or installation standards in the United States for negative side waterproofing materials. As a result, each manufacturer tests its own products and attempts to find a unique test that will differentiate it from others during the specification process. This makes it extremely difficult for the specifier to compare "apples with apples" during the design stage. It is even harder for the architect or engineer to make a fair judgement when substitutes are submitted for approval. In the author's opinion, we in North America would benefit from the introduction of a system of material standards such as that used in Germany,[6] or technical guidelines similar to those for concrete repair materials introduced by ICRI.[7]

Conclusion

Wherever possible, structures requiring waterproofing should be waterproofed from the positive or active water pressure side. However, negative side waterproofing provides a viable alternative for the many situations where this is impossible or impractical. Negative side waterproofing materials have proven themselves in a variety of different applications, and some modern products have track records going back as much as 90 years.❑

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Pressure on Coated Concrete

62.4 lb/in² = 1 gm/cc.

by Tom Dudick

The force of water, whether from the outside of a concrete slab or internally, is sufficient to disbond a topping. However, this force alone generally does not cause a coating/topping failure. The primary cause is installation errors. Provided that a concrete substrate has been properly prepared and the coating or topping is correctly installed and cured, there is no reason for coating disbondment.

In flooring systems, coatings or toppings are generally applied for spill protection, mechanical durability, and aesthetics. For these applications, the one property that is common in coating systems is the coating's relative impermeability. That is to say that these coating systems do not "breathe"—they actually hinder water and other chemicals from passing through. It has been correctly assumed that any pressure in the form of liquid or vapor from below or within the concrete slab will not pass through and therefore will build up pressures. If these pressures are not relieved or prevented from accumulating they could build up sufficiently to disbond the coating. The most frequently cited water force is hydrostatic pressure. However, capillary and osmotic pressures, not often spoken of, are just as common and may contribute significantly to the problems.

Hydrostatic Pressure

Hydrostatic pressure is thought of as the force exerted by a column or head of water. This force is caused by the differential between the highest point of a column of water and the low point of a structure. Further, this pressure will be transferred evenly to every portion of the fluid throughout the column. Therefore, the only variable is the column height and not the volume or shape of the column. To calculate the pounds per square inch per foot of water, we divide the weight of water—62.4 lbs. per cubic foot—by 144 sq. in. per sq. ft. This gives us the pressure of 0.43 psi per foot of water being exerted on a substrate.

Now let us assume the bond strength of thick coatings and toppings to be the manufacturer's minimum, or 250 psi. What head of water is required to push the topping off the substrate? Divide the bond strength which in this case is 250 psi by 0.43 psi/ft. which results in 581 feet (177 m). This means that a column of water would have to be 581 feet (177 m) tall to exert enough pressure to equal the bond of the topping to concrete (Figure 1).

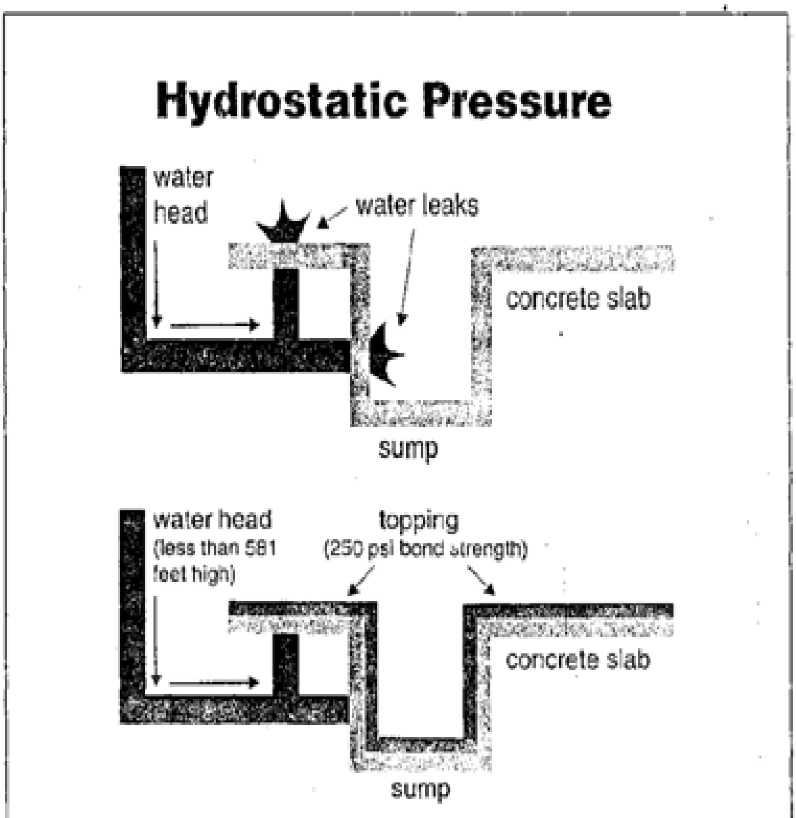


Figure 1.

Capillary Pressure

Capillary flow can be described as the ability of a liquid to wet a surface. The wetting of the surface is directly related to the surface tension of the liquid. The lower the surface tension the greater the capillary flow. The principle of capillarity can be demonstrated using an ink well and blotting paper. Those of you old enough to remember fountain pens surely marveled at this phenomenon when the edge of the blotter was touched to the ink. Almost magically the ink climbed the blotting paper.

How does this affect concrete and toppings? Concrete is a matrix of sand, cement, stone and air pockets. Water or other similarly low surface tension fluids will "wick" their way through the concrete matrix. The rate at which this happens will depend, at least partially, on the size of the capillary passages as well as the surface tension of the fluid (Figure 2, page 14). It has been documented by soil and concrete experts that the

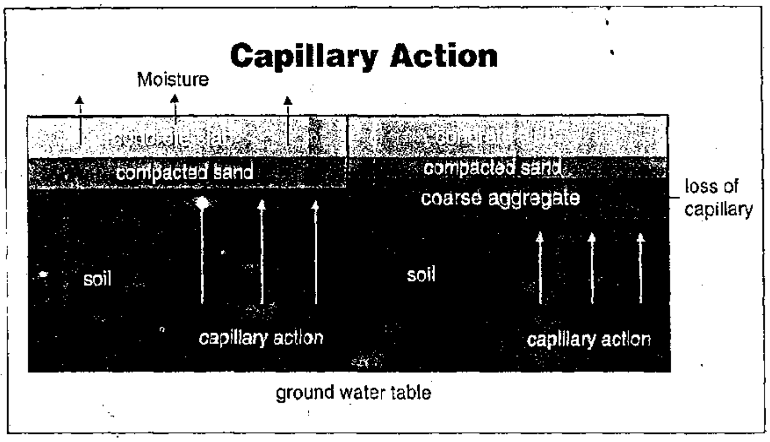


Figure 2.

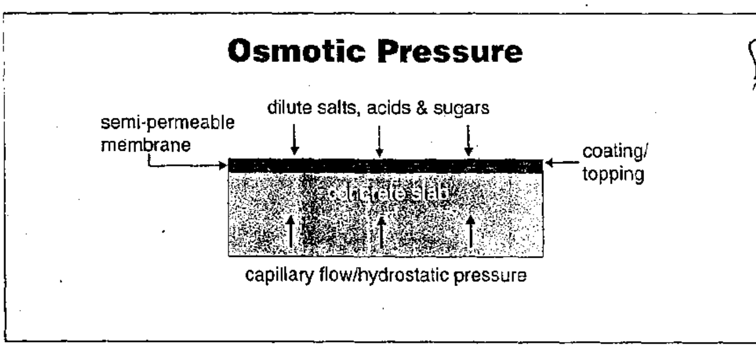


Figure 3.

smaller the particles and the smaller the capillaries, the higher the moisture level will rise above the "reservoir level".

In the case of capillary action, if a coating or topping is applied to the concrete, the capillary flow will give rise to a pressure that is representative of hydrostatic pressure.

Osmotic Pressure

Osmosis and osmotic pressure are more difficult to define for the layman than the earlier forces. Osmosis is defined as the passage of a pure solvent into a solution, through a semipermeable membrane. This flow will cause a dilution of the chemical solution by the pure solvent. This can be best demonstrated by a Chemistry 101 experiment using a sugar solution and water. How does this affect toppings? In certain industries the exposure or spills may be relatively weak solutions of water, salts, sugars and acids being dumped on a semi-permeable membrane (Figure 3).

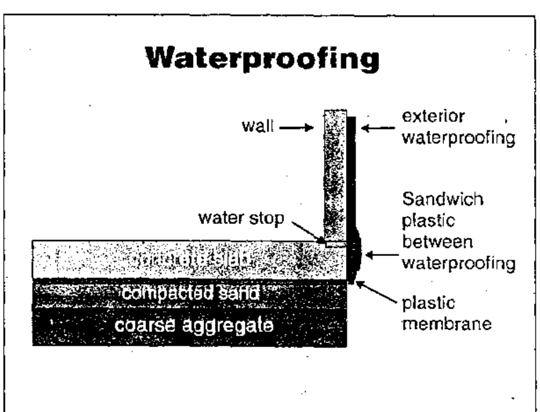


Figure 4.

The concrete slab contains a mixture of salts, minerals and water. Under certain conditions and depending on the selective porosity of the coating, substantial pressures can build up on the underside of the coating through osmosis.

Coating/Topping Criteria

In addition to these water forces we also have installation variables such as old and contaminated concrete, limited time schedules for application and unsuspecting manufacturers and applicators. It's no wonder that some 2-4 million square feet per year of topping fails.

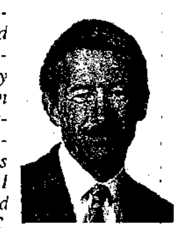
In establishing the criteria for coating/topping installation we should first concentrate on eliminating hydrostatic, capillary and osmotic pressures by (Figure 4):

- Placing a layer of 1/4 inch (6 mm) minimum size gravel 8 to 12 inches (200 to 300 mm) thick under the slab.
- Placing a plastic membrane over the compacted fill to block the flow of water.
- Waterproofing exterior walls.

In cases of existing structures:

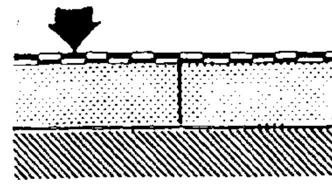
- If at all possible, excavate the structure and waterproof the walls.
- Sink well points to relieve the pressure from the slab underside.
- Use penetrants such as sodium or potassium silicates that react with soluble calcium compounds in the concrete—largely calcium hydroxide—to form insoluble calcium silicates in the concrete.
- Test all structures at or below grade with the ASTM D-4263 plastic sheet test for the presence of moisture before coating.

Hydrostatic, capillary, and osmotic pressures are substantial water forces at work in and on concrete. When properly applied and cured, a coating or topping will withstand these forces without disbondment. However, if application procedures are poor, hydrostatic, capillary and osmotic pressures may be high enough to cause premature coating failure.❒

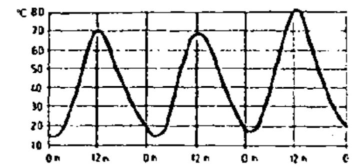


Tom Dudick is President of Dudick, Inc., a manufacturer of coating and toppings. He is a graduate chemist with nearly 30 years of experience in formulating and application of heavy duty corrosion resistant coatings and linings. An ICRI member, he has served on various NACE, SSPC, and ASTM committees, and has presented papers at conferences in Brazil and Taiwan as well as National NACE and SSPC conferences and many local and regional meetings.

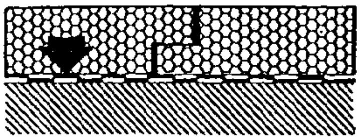
Conventional Roof العزل التقليدى



تغيرات دراجات الحرارة على العزل المائى .

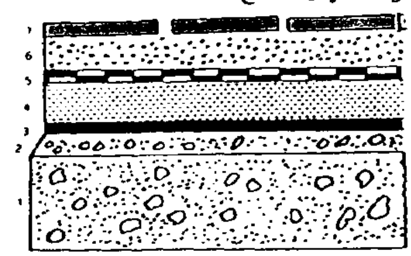


Protected Membrane العزل المحمى



Temperature fluctuations on membrane itself.

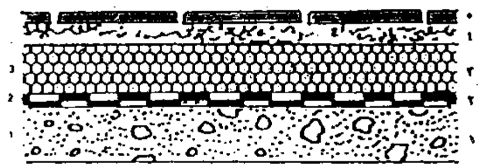
Conventional Roof Insulation العزل التقليدى للاسطح



1 Concrete Surface.
2 Inclined Screed.
3 Vapour Barrier.
4 . Thermal Insulation.
5 . Waterproofing.
6 Sand.
7 . Tiles.

١ - السطح الخرسانى
٢ - خرسانة الميول .
٣ - طبقة عدم نفاذية البخار
٤ - العزل الحرارى التقليدى
٥ - طبقة عزل المياه .
٦ - رمل .
٧ بلاط

Protected Membrane العزل المحمى



5 Tiles.
4 Lean mortar
3 ADVEFOAM Thermal Insulation.
2 Waterproofing.
1 Concrete Surface.

٥ - بلاط .
٤ - مونة أسمنتية خفيفة .
٣ - العزل الحرارى « ادفى فوم »
٢ - عزل المياه .
١ - السطح الخرسانى .

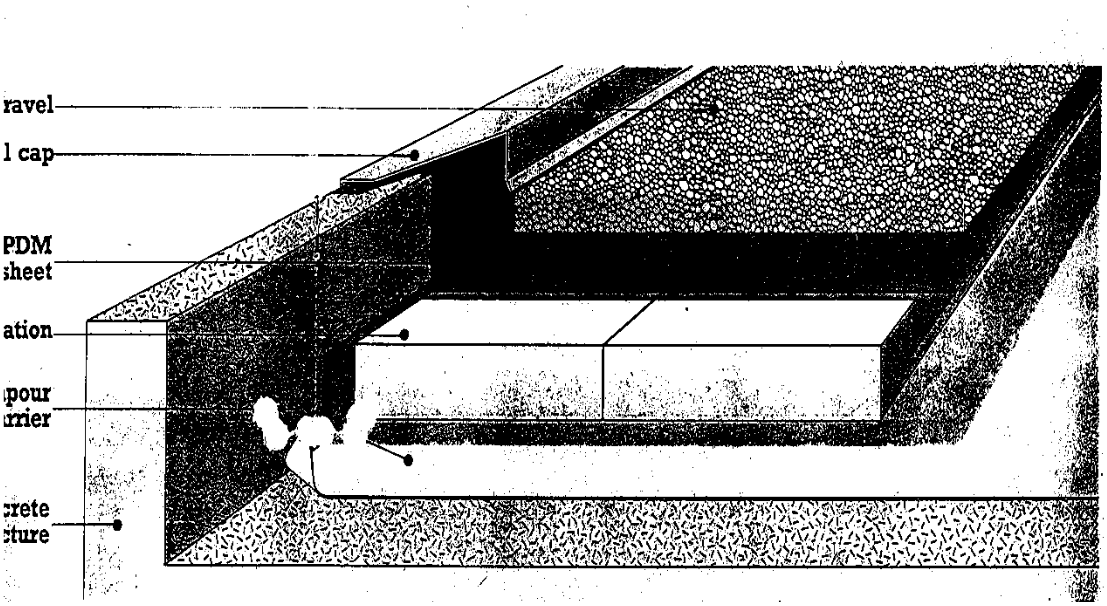
المقارنة بين العزل التقليدى للأسطح ونظام المحمى

العزل التقليدى

- العزل الحرارى أسفل عزل المياه .
- خرسانة الميول أساسية ولا يمكن الاستغناء عنها .
- عزل المياه ذو كفاءة عالية لتحمل التمدد والانكماش
- طبقة عدم نفاذية البخار ضرورية .
- خطوات عديدة تصل إلى ٧ خطوات
- تكلفة الصيانة مرتفعة جداً .
- عمالة ماهره لتنفيذ الخطوات .
- العمر الافتراضى قصير

العزل المحمى

- العزل الحرارى فوق عزل المياه فبالتالى عزل المياه فى حماية دائمة من التلف نتيجة العوامل الجوية المختلفة .
- خرسانة الميول غير أساسية ويمكن الاستغناء عنها .
- توفير طبقة عدم نفاذية البخار ، فهى غير مستخدمة .
- قلة خطوات عزل الأسطح .
- تكلفة الصيانة قليلة .
- سرعة أكبر فى التنفيذ ولا تحتاج إلى عمالة عالية التدريب .
- العمر الافتراضى اطول بكثير .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DE NORA PERMELEC KEEPS THE WALLS SOUND BY DAMPNESS ELIMINATION

CASE STUDY: RESTORATION OF A COUNTRY-HOUSE

Before the system installation

After the system installation

DE NORA PERMELEC S.p.A.
Cathodic Protection Division

Via Bistolfi, 35 - 20134 Milano - Tel. (02) 21291
Telex 310552/322231 ODENOR I - Fax (02) 2154953

HOW TO INSTALL THE SYSTEM

The system dries the walls by creating an electrical field between one anode, placed in the wall, and one or more cathodes placed in the ground, at a distance of a few metres from building.

The system installation procedure is as follows:

A - installation into the wall can be made according to either one of two procedures

• Procedure 1

— a groove is cut along the perimeter of the building to a height above the level reached by the dampness;

— a titanium activated wire is laid into the groove, around the perimeter of the building;

— the groove is then filled with a special conductive mortar.

• Procedure 2

— a number of holes are drilled into the wall, having a depth equivalent to wall thickness and with a spacing of 1 meter;

— into each hole a titanium activated wire anode is placed;

— each hole is then filled with a special conductive mortar;

— all wire anodes are connected by welding to a titanium strip which is also laid into the wall.

B - installation into the ground surrounding the building

— at a distance of a few meters from the walls, one or more cathodes, made of galvanized strips or spikes, are buried into the ground.

C - electrical installation

— a low output transformer/rectifier is placed inside the building, with its negative pole connected to the cathodes, and with its positive pole connected to the two ends of titanium wire ring for procedure 1 or to one or more points of the titanium strip for procedure 2.

The system will have a low voltage and current operating range.

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RESULTS AND APPLICATION FIELDS

SYSTEM PERFORMANCE RESULTS

For the installed system a monitoring device has been used to verify the drying effect, by measuring the electrical resistance between two preset points of the damp wall.

For one particular installation the following results were obtained:

— before the installation	resistance = 50 ohms
— three months later	resistance = 1380 ohms
— ten months later	resistance = 5550 ohms
— eighteen months later	resistance = 6200 ohms
— thirty-two months later	resistance = 6550 ohms

The constant increase in the resistance values indicates that the wall is drying since the electrical conductivity of the wall will be decreasing as the moisture level also decreases.

APPLICATION FIELDS

The system is generally applicable to the drying of walls in:

- country-houses
- industrial buildings
- hospitals
- schools
- churches
- castles
- historical palaces
- artistic buildings

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THE PROBLEM OF DAMP WALLS

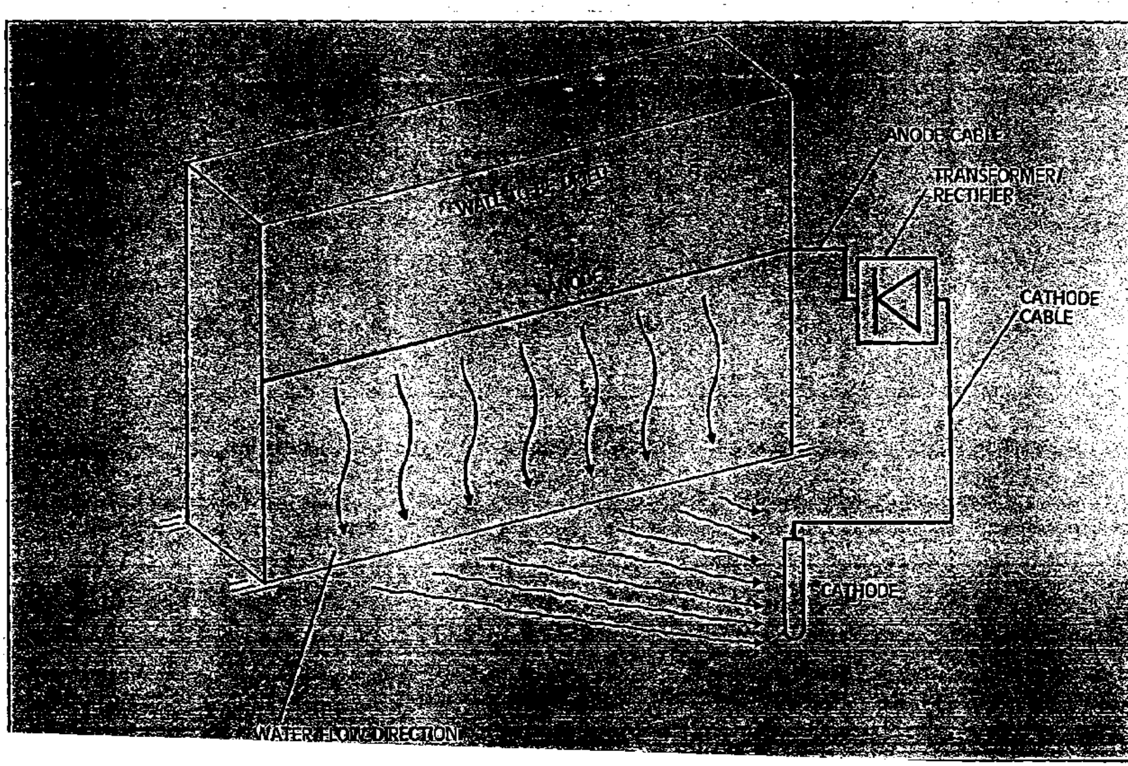
One of the main causes of building decay is due to dampness coming from the surrounding ground. This dampness absorption is caused by capillary action, through the pores in the bricks and mortar.

The dampness penetrates the bulk of the walls and when it evaporates, it causes spots, efflorescence and plaster disbonding.

In addition to any aesthetic aspects, there may be added hygiene considerations due to mould formation. Dampness also causes wasted energy due to increased thermal conductivity of damp walls, requiring a greater heating of premises.

THE SOLUTION OF THE PROBLEM: DE NORA PERMELEC WALL DRYING SYSTEM BY ELECTROOSMOSIS.

THE SCHEMATIC DIAGRAM BELOW SHOWS THE OPERATING PRINCIPLES FOR THE SYSTEM:



Technical Information

PRACTICAL INFORMATION ON THE KLEER G DAMP-COURSE INJECTION SYSTEM

1. Application Areas:

The product is used as a vapour barrier against rising damp in cavity walls and solid walls of up to 60 cm. thick. The respiratory (breathing) action of which is retained.

2. Description:

A clear liquid on Kleer G Super Concentrated , in a white spirit solution.

3. Packing:

In metal drums of 25 and 200 litres.

4. Warning:

a) Kleer G is flammable - (flash point 41°C.) during application and equal: so immediately after application: it should be protected from heat, sparks and flames.

b) Whilst working indoors, there must be adequate ventilation for 2 days and one must adhere closely to the precautions mentioned above.

c) Polystyrene foam will be attacked by the white spirit and walls insulated in this way cannot, therefore, be treated. However, after treating with Kleer G, it is possible to proceed to insert polystyrene foam insulation in the wall cavity.

5. Use and Instructions:

It is necessary to completely saturate the masonry with the solution. Finish off by plugging the holes made by the drill with sand/cement mortar containing a salt retarding additive or based on CHEMBOND SBR polymer admixture.

a) Preparation

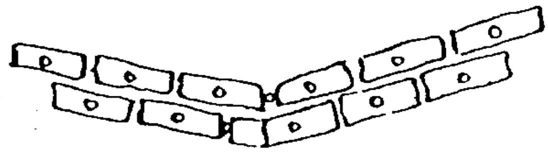
- Drill the holes at a minimum height of 15 cm. above ground level.

- Remove coatings, pebble-dashing, plaster etc., or paint up to a minimum of 30 - 40 cm. above holes and leave to dry for 3 to 4 weeks.

- Plaster coatings must be removed up to a minimum of 3 cm. above all visibly damp areas.

2/ ...

(4)



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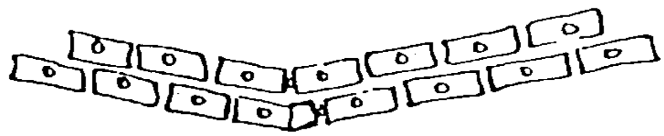

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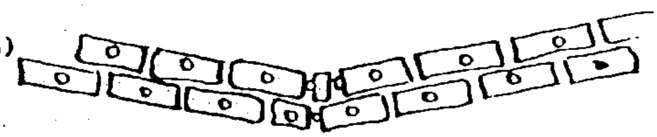


c) Injection

- Where a loss of pressure is noticed in a hole, plug it immediately and drill a new hole.

- 10 mm. holes are drilled to predetermined depths along the selected course. Two holes are drilled in each stretcher and one in each header at a maximum spacing of 125 mm. If a brick course proves too dense to allow adequate penetration of fluid, drilling may be carried out in the two adjacent horizontal mortar courses at the same spacing. Walls 115 mm. thick are injected from one side only. Solid walls of 230 mm. are normally injected from both sides. If access is restricted they can be drilled and injected from one side by a series of injections at increasing depths. Solid walls of greater thickness are treated from both sides, one side being treated by a series of injections at increasing depths. Cavity walls are normally treated from both sides, but, if the thicknesses of the individual leaves permit it, injection from one side, at increasing depths, is conducted.

d) Additional Information

- The pressure must be approx. 100 p.s.i. (700 k Pa or 7 atmospheres)

- Inject until complete saturation point is reached or until all the surface appears damp.

- Leave for a minimum of 14 days before plugging the holes using a sand/cement mortar containing CHEMBOND SBR polymer admixture or Plastic plugs can also be used.

- Where the earth has been covered on the inside by wood or parquet flooring, take care that the injections are made below this level.

- Where, after treatment, the wall is banked up, this must first be carefully treated with CHEMSEAL cementitious coating.

b) <u>Drilling the holes</u>

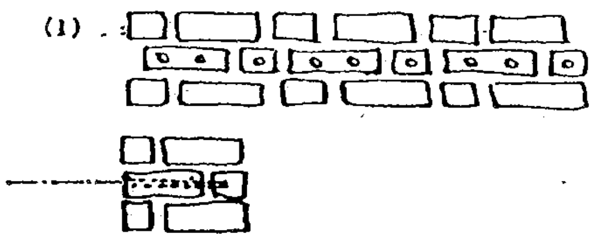
- Preferably make the holes 10 - 12 mm. in diameter, horizontally or up to an angle of 30°.

- Normally the drilling is done into the brick (and not into the joints). Where the stone is very hard (e.g. granite) the injection can be done through the two adjacent joints.

- The distance between the holes should be a maximum of 12.5 cm.

- The following alternatives are available:

(1)



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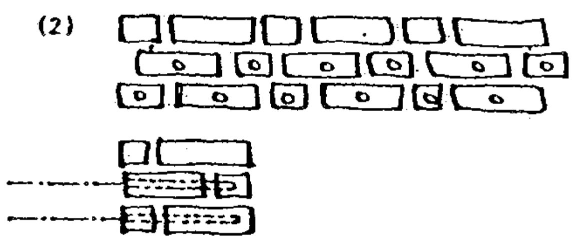
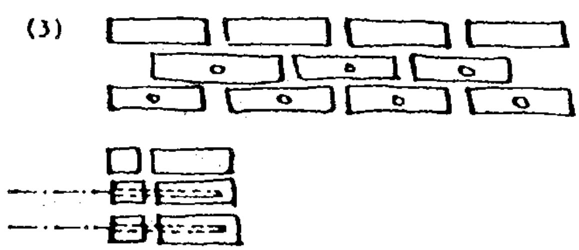


(3)



TANKING GUIDE

Basement tanking procedure

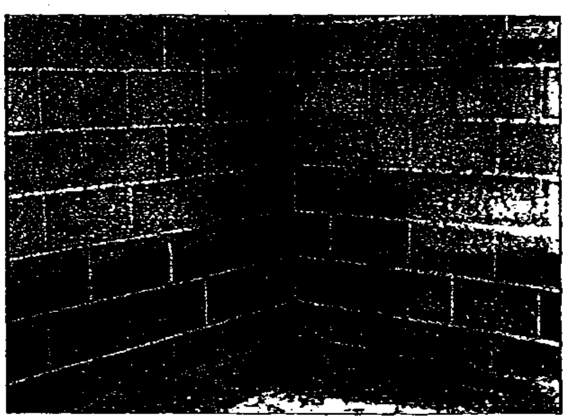
OPERATIVES ARE ADVISED
TO READ THIS DOCUMENT THROUGH TO COMPLETION.

PREPARATION

A. BRICK/BLOCKWORK

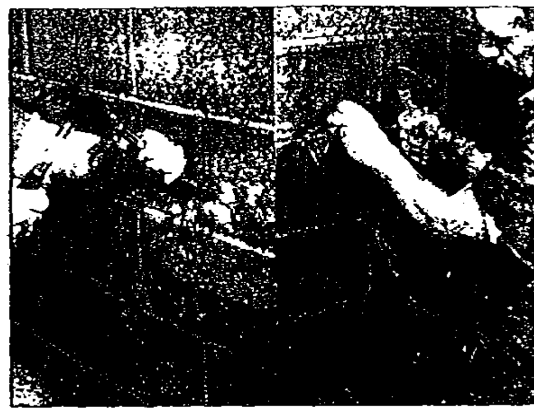
New: Ensure that all joints are filled solid and remove mortar droppings from the surface. Thoroughly hose down surface with clean water.

CAUTION
It is recommended that the glaze on engineering bricks be removed by grit blasting or needle gunning and that the proportion of CHEMBOND liquid bonding agent used in the application be increased.



Old: Remove ALL surface coatings back to sound brick/blockwork. The surfaces to be treated must be clean and sound. This is best achieved by grit blasting, wet blasting or needle gunning. Wire brushing is rarely sufficient and can be detrimental on some types of substrate.

All renders and plasters should be removed back to a clean, sound surface. Mortar joints must be sound. If they are soft or loose then they should be raked out to a depth of 20mm and repointed with CHEMJOINT C or mortar prepared as prescribed for



render in the Pretreatment section of this docu ment.

B. CONCRETE

New: Remove all traces of mould oil, for treatments and laitence by high pressur water jetting, grit or wet blasting, acid e ching or thorough wire brushing. Clea down well with a hose and clean water. F all tie or bolt holes with WATERPLUG.

Old: Remove all surface treatments as descril ed above. Remove all fungi and oth organic growth by acid or fungicidal wash Cut out any leaking static joints or cracks 1 20mm by 20mm making the sides c square as possible. Wash thoroughly wit clean water and fill with WATERPLUG. Fc dynamic joints consult the Area Thoro Pro ducts Distributor or Thoro System Produc Ltd. After completion of all repairs was down all surfaces thoroughly

C. STONEWORK

The types and condition of stonework found in th U.K. and Ireland are very varied and it is therefore only possible to generalise on surface prepara tion. Each specific application should be referre

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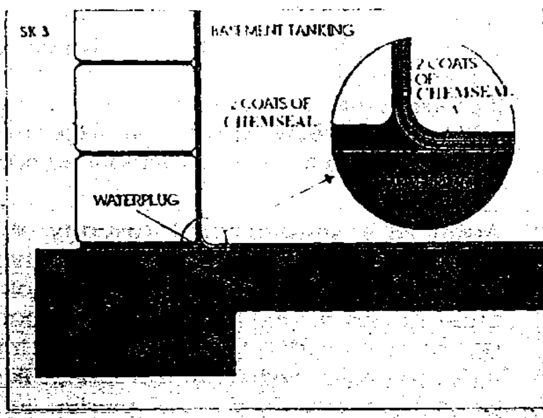
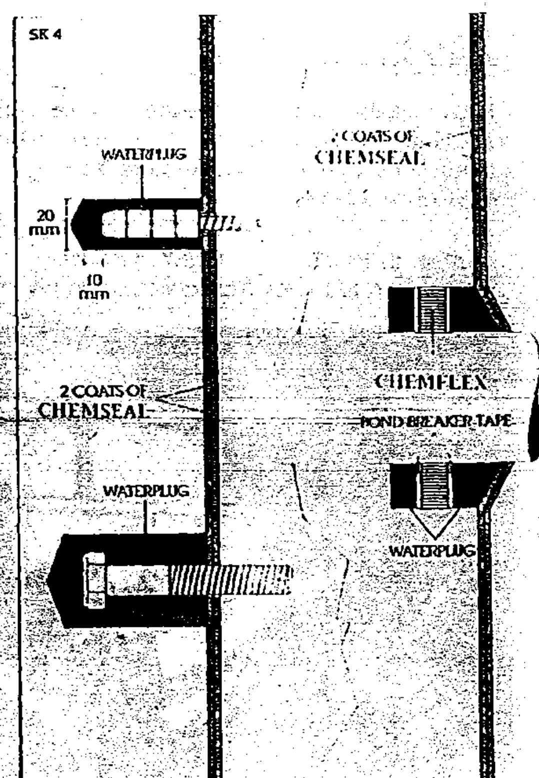
TANKING GUIDE





Curing

In most basements there are no special requirements for curing provided CHEMBOND has been included in the applied CHEMSEAL. The exceptions are

1. Under hot conditions (boiler rooms etc.) fog spray all applications after the initial set for as long as practicable.
2. In cold, humid or unventilated areas it may be necessary to leave the application for a longer curing period or to introduce forced air movement. **NEVER** use dehumidifiers during curing periods or within 28 days of completion of the work.

FIXINGS

A great advantage of the " PK " System is the ease of providing fixings after the work is complete whilst maintaining the completeness of the tanking. See diagram SK4 for details.
Skirting is best replaced with adhesives.

P R O K E M

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TANKING GUIDE

Condensation

It is advisable to point out to clients that a tanked basement will be prone to condensation unless sufficient ventilation is provided. A render or plaster finish will reduce the problem but there is no substitute for good ventilation

Decoration

If THOROSEAL is left as the finish in the basement it should not be decorated until it has completely cured and dried. This process could take several months in damp conditions with little ventilation. The decoration applied should be restricted to a coating or a paint with a high-breathing capacity.
Oil-based paints and wallpapers in general are not recommended

Please consult our Technical Services Department for further information.

Your distributor

Thoro System Products Ltd Unit B1 Harris Road Wedgnock Ind Est Warwick [illegible] United Kingdom
Tel 0926 410030 Telex 94015917 tspl g. Fax 0926 410031

Service pipes or ducts entering through external walls

See diagram SK4 for installation details.

NOTES FOR SURVEYORS

When surveying a basement for tanking the following points need to be taken into consideration

1. FLOOR

A. Does the floor need treatment?

YES. Then is there a floor screed? If so it should be removed. Once removed is the concrete base thick enough and strong enough to receive CHEMSEAL ? A minimum of 100mm of good quality concrete is likely to required to withstand hydraulic press Consult a structural engineer for an e specification. Once CHEM sealed the f should be rescreeded to protect the surf against wear.

NO But a wall/floor WATERPLUG fillet is requi If there is a floor screed then remov 150mm band around the perimeter treat with WATERPLUG.

B. Does the floor need screeding?

YES: Is there sufficient headroom to lay a 40 screed?

NO. Then use CHEMSEAL self levelling screed to an average dept of 6m

YES Before placing your normal sc brush on a bonding slurry coat com ing of neat cement and CHEMBON may be cheaper to use CHEMSEAL

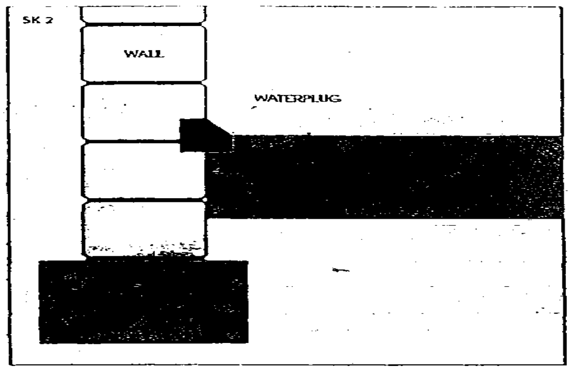
2. WALLS

How far should the treatment go?

As the name "tanking" implies the treat must be extended to form a "tank". Do patch or one wall may merely push the wat ther round the walls to reappear elsewhere application must be extended up to a wo DPC. Always check the joist ends of the ing/floor above as they may need additiona tection if built into damp masonry

Running Water

Tanking basements which are subject to a water pressure requires specialised techn and equipment. Advice should be sought the Area 'PK' Products Distributor or from System Products Ltd



of sulphates or nitrates. Sulphates may also be present in certain types of brick or be impregnated into walls in coal cellars etc. To overcome the aggressive effects of these elements it may be necessary to apply a salt inhibiting render before the CHEMSEAL application. (This treatment is not normally required on concrete). If in doubt seek the advice of the Area "PK" Products Distributor or "PK" System Products Ltd. To be certain that the correct specification is followed it may be necessary to have samples of the ground water and/or brickwork tested in a laboratory. The results obtained should be compared with the table in the CHEMSEAL.

If pre-treatment is required then follow the specifications below.

Bricks, Blocks and Porous Stonework

Thoroughly mix a render consisting of
3 parts clean rendering sand
1 part Sulphate Resisting Ordinary Portland Cement. DO NOT USE HIGH ALUMINA CEMENT.

The gauging liquid should contain CHEMBOND liquid bonding and plasticising agent diluted on part to two parts water.
The surface should be pre-dampened and th render applied to a thickness of 5-7mm. The su face of the render should be finished with a woo float to leave an open surface.

Dense Non Porous Stonework and Engineerin Bricks

Thoroughly wet the prepared surface but do n leave free water. Apply a bonding slurry co consisting of CHEMBOND and sulphate resisting o dinary portland cement. This slurry should b brushed firmly into the surface and the rend mixed as described above applied immediat ly whilst the bonding coat is still wet.

Friable Substrates

It is necessary on soft crumbling substrates to ap ly a render as detailed above reinforced wi galvanised, stainless expanded metal polypropylene mesh secured firmly at 300m centres with galvanised or stainless fixings. T fixings should penetrate the substrate at lea 100mm or to sound material whichever is t greater. The thickness of the applied rend should be increased to ensure comple coverage of the mesh

MIXING INSTRUCTIONS

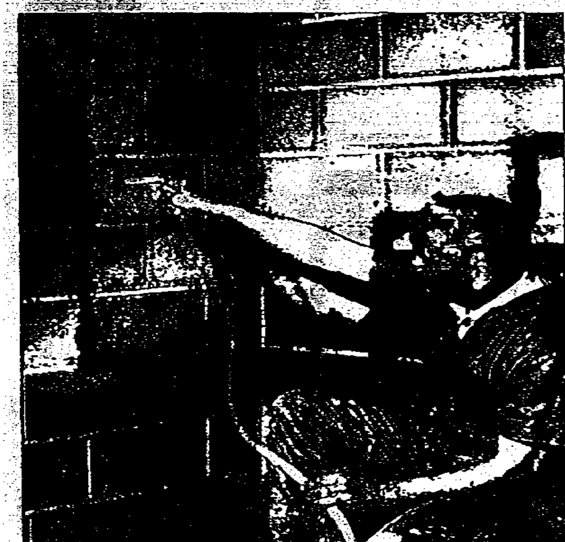
Mixing CHEMSEAL

Dilute CHEMBOND 1 to 3 parts with water, addi the CHEMBOND to the water to prevent foamir

APPLICATION

Always apply to a pre-dampened surface using a stiff-fibred brush such as the NYLON BRUSH. High suction substrates will require more dampening than dense substrates.

In most instances the GREY CHEMSEAL is applied as a first coat. This coat should be well



brushed into the surface but care should be taken not to brush the material out, a typical application being 1.5mm thick. Finish the first coat with vertical brush strokes. This technique makes it easier for the operative to easily trace any possible pin-hole leaks

Leave at least overnight to cure before apply second coat. In very humid and cold conditi and/or with high concentrations of CHEMBON w the mixing water curing may be delayed. The cond coat should be applied when the first c is hard enough to receive it without damage

Apply the second coat (usually WH CHEMSEAL) to an approximate thickness 1 mm (see diagram SK3). Finish this coat w brush strokes in one direction for a neat a pearance. If CHEMSEAL is to be the final finis may be textured with a brush or sponge floa to give an even surface. If plaster, renc SUPER PLASTER Mix or CHEM Stucco is to be a plied then finish the CHEMSEAL with horizor brush strokes to give more grip.

In most situations the plaster or render car applied next day. If finishing is likely to delayed for some time then the THOROS should be sand dashed immediately a application to aid adhesion. If using plaster t use a "renovating plaster" based on cem Never use a gypsum based plaster. It is advis to use CHEMBOND in the mixing water for the pla at a ratio of 1 part to 3 parts water.

TANKING GUIDE

PROKEM

(Care should be taken with the proportions although exact measurement is not necessary). For dense, low suction substrates it is advisable to increase the CHEMBOND content of the gauging liquid to 1 part to 2 parts water. CHEMBOND is not recommended when the CHEMSEAL tanking is likely to come into contact with hydrocarbons such as diesel or petrol.

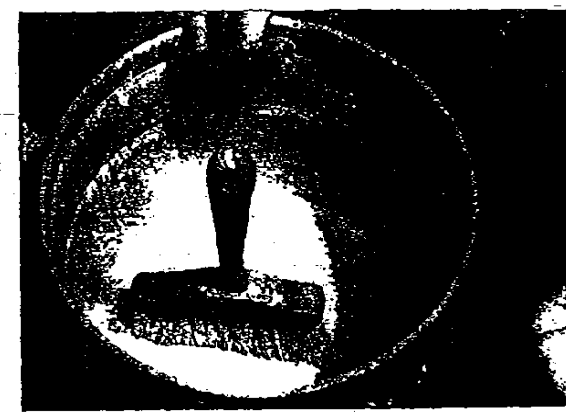
The following table is a usage guide for CHEMSEAL and CHEMBOND
Application rates will vary depending on the porosity and roughness of the substrate.

	CHEMSEAL	COVERAGE	CHEMBOND	CHEMBOND + WATER
1st coat	25kg	16-18 sq m	1.5ltr	6ltr
2nd coat	25kg	20-25 sq m	1.5ltr	6ltr

Power Mixing

Blend the powder into the mixing liquid using the specially designed EZ mixer in a slow speed drill (400-600 r.p.m.).

Air driven drills tend to give better service. An electric drill of at least 600 watts and with a 1/2 inch chuck is required. The material is mixed to a thick batter consistency, stiff enough to just support the weight of the Thoro hand brush. The material is ready for instant use.



Hand Mixing

Add the liquid to the powder whilst stirring wi a trowel or paddle. Mix to a thick batter consiste cy, stiff enough to just support the weight of th Thoro hand brush. Let the CHEMSEAL stand f 20 minutes to allow full saturation to take plac Re-mix adding a small amount of liquid necessary to restore the consistency to th required for application.

Note: The volume of mixing liquid will va slighly depending on weather conditio In all cases it is the consistency of the mi ed material that is important as this will d tate the ease of application and the corre application rate. Any quantity of materi may be mixed at one time provided th consistency is correct.

Mixed material must be used within 90 minut

DO NOT RETEMPER THE MIX

TANKING GUIDE

to the Area " PK " Products Distributor or to " PK " System Products Ltd.

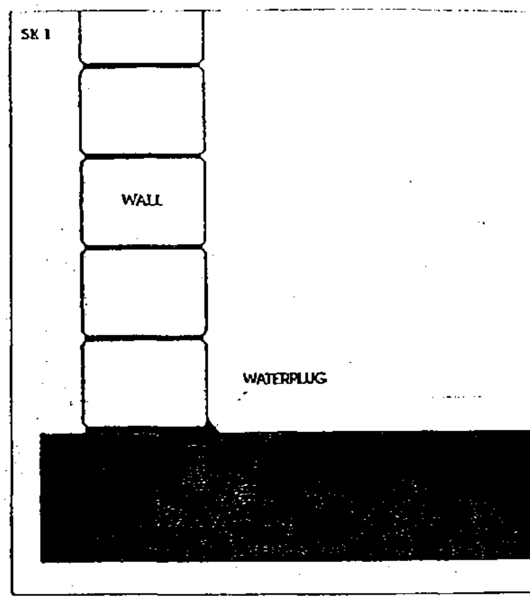
Remove all surface treatments, fungi and organic growth as described above. Remove any render or plaster back to a clean sound surface. Throughly wash down with a hose and clean water.

Rake out all loose or soft joints to a minimum depth of the width plus 50%. Repoint with CHEMJOINT C or mortar prepared as prescribed for rendering in the Pretreatment section of this document. Use the pointing material as dry as possible and pay particular attention to the bond in large joints.

Note : It is important that the stonework has sufficient strength to accept a CHEMSEAL coating. Soft stone and delaminating sandstones or limestones require special attention. Specifications and advice are available from the Area 'PK' Products Distributor or from 'PK' System Products Ltd.

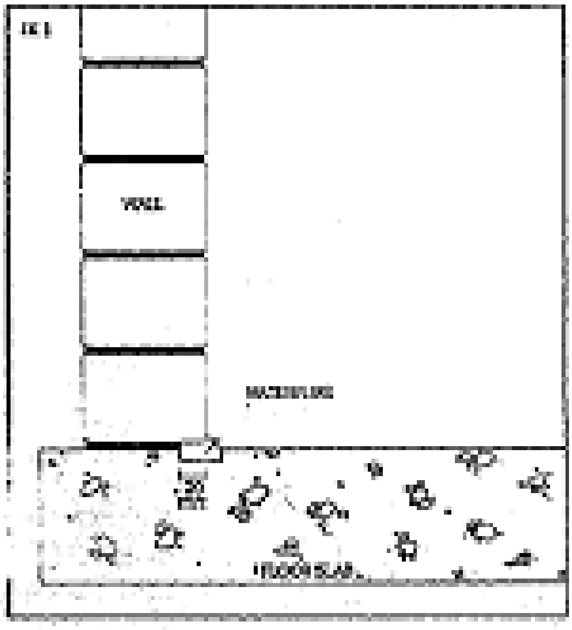
Wall/floor or kicker joint

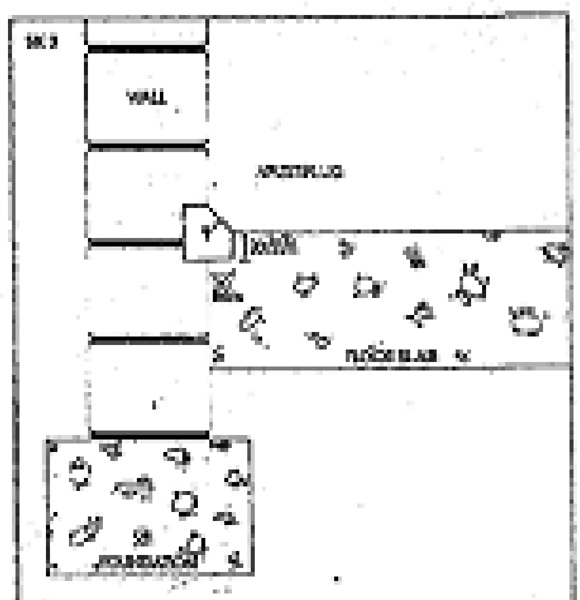
This is usually the point of greatest water ingress. The joint should be cut out, thoroughly cleaned with water and filled with WATERPLUG as shown in drawing SK1 & 2.



PRE-TREATMENTS

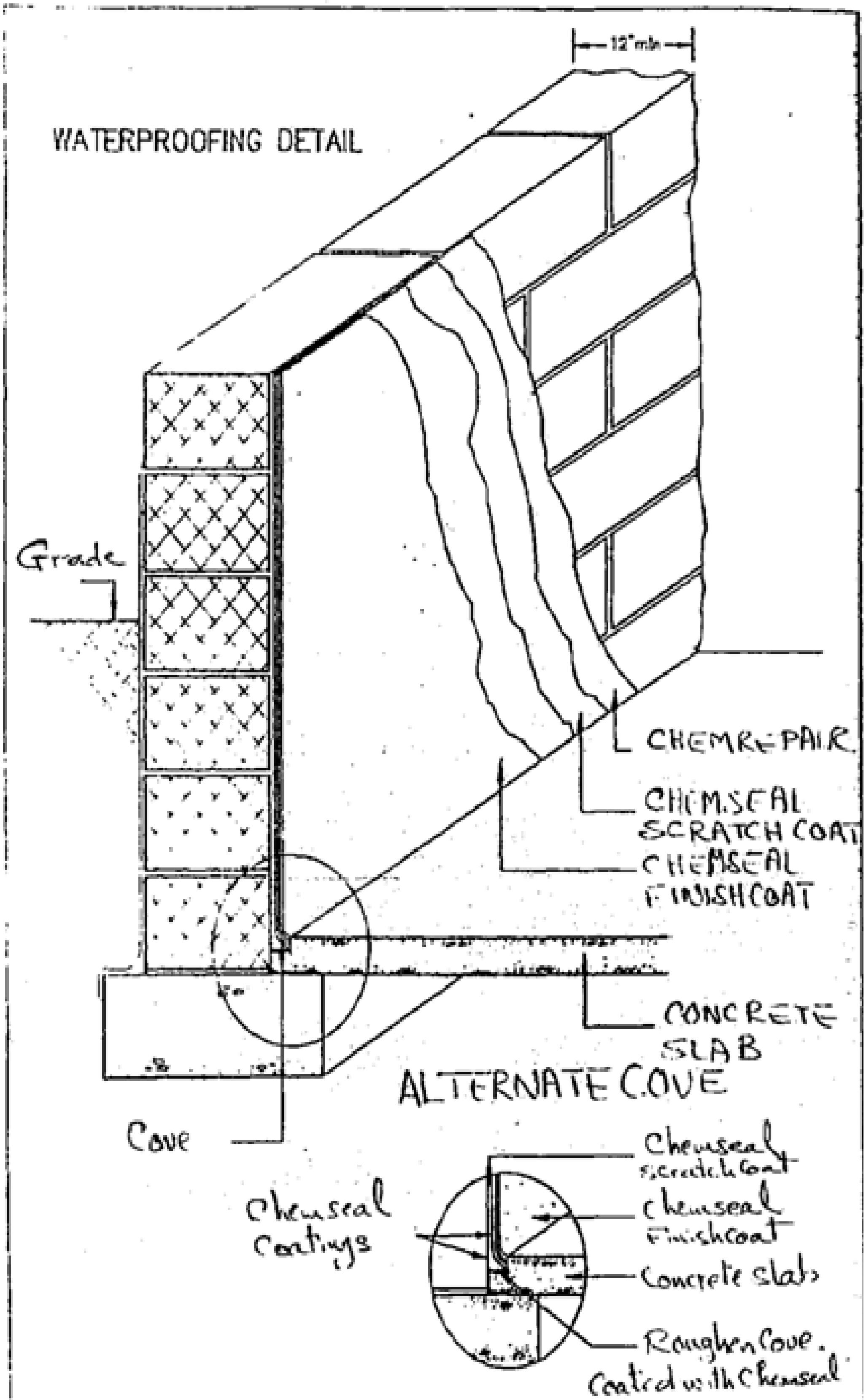
Some areas of the U.K. & Ireland have groun water conditions that contain high leve


WALL
FLOOR SLAB

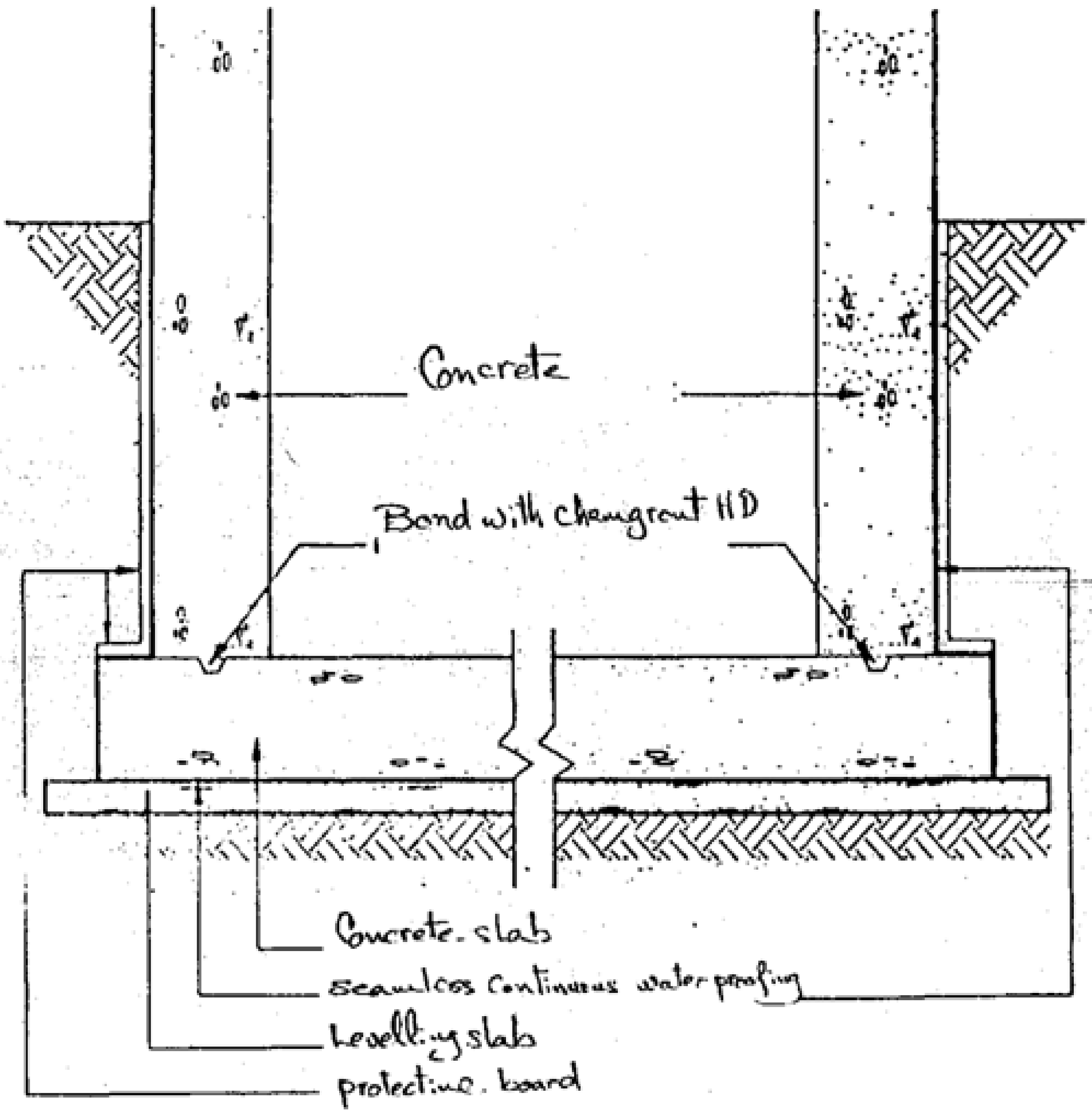

WALL
FLOOR SLAB
FOUNDATION

Prokem
SPECIALITY CHEMICALS

PROKEM

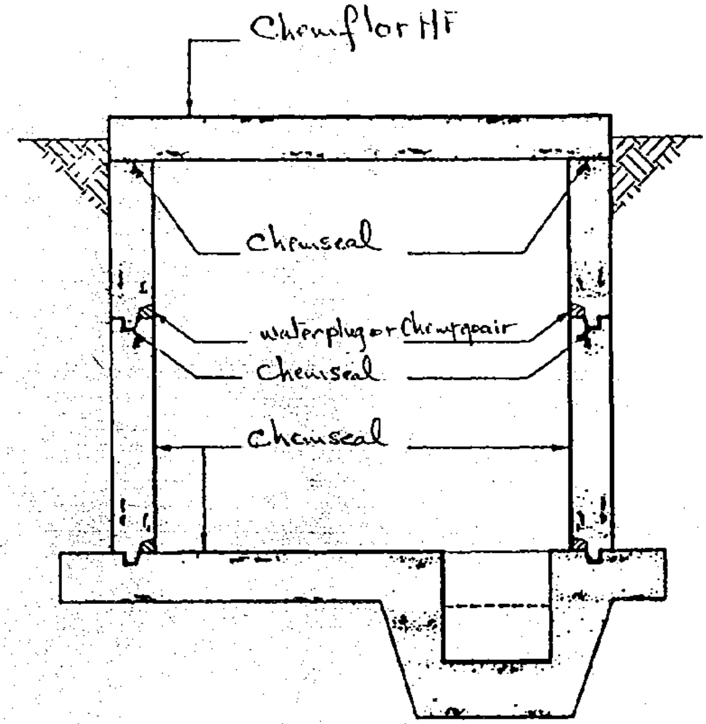


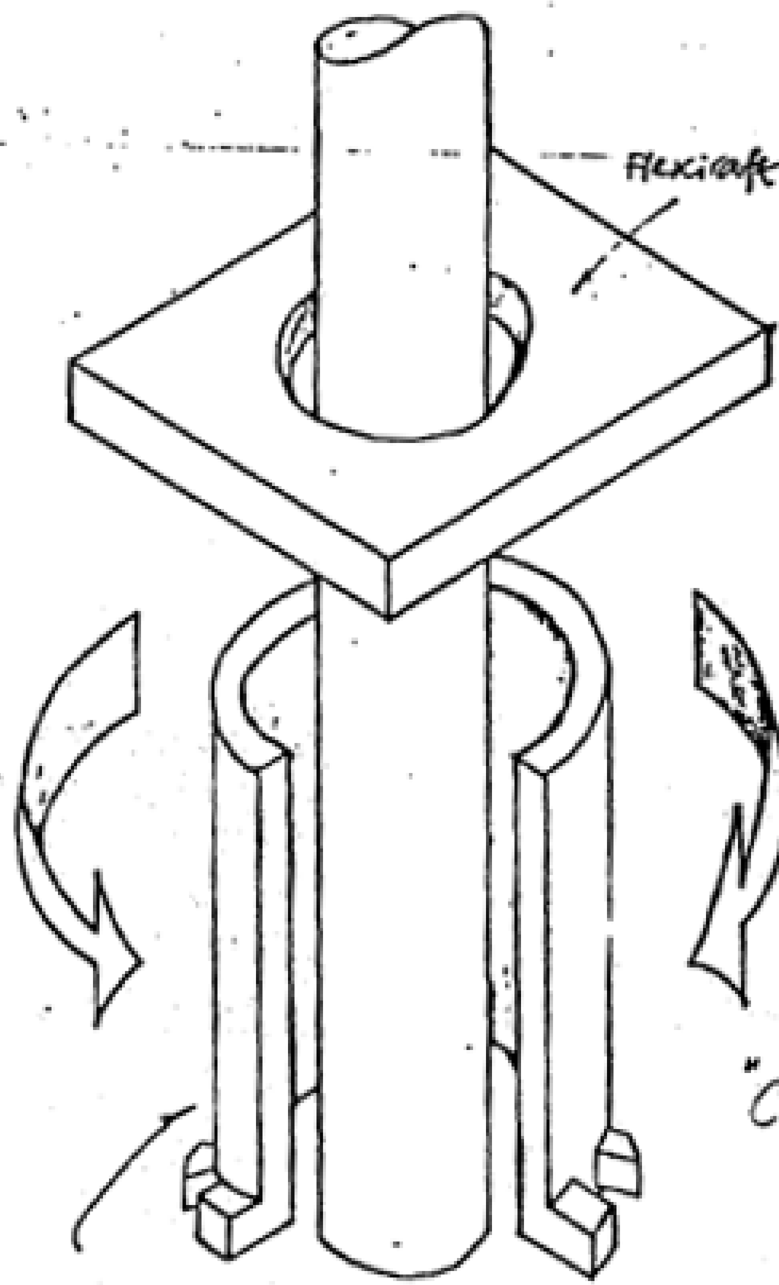
BASEMENT



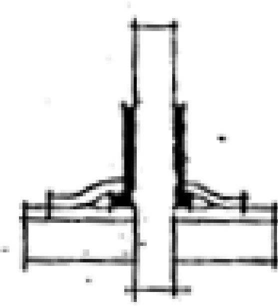
Concrete
Bond with chemgrout HD
Concrete slab
Seamless continuous water proofing
Levelling slab
protective board

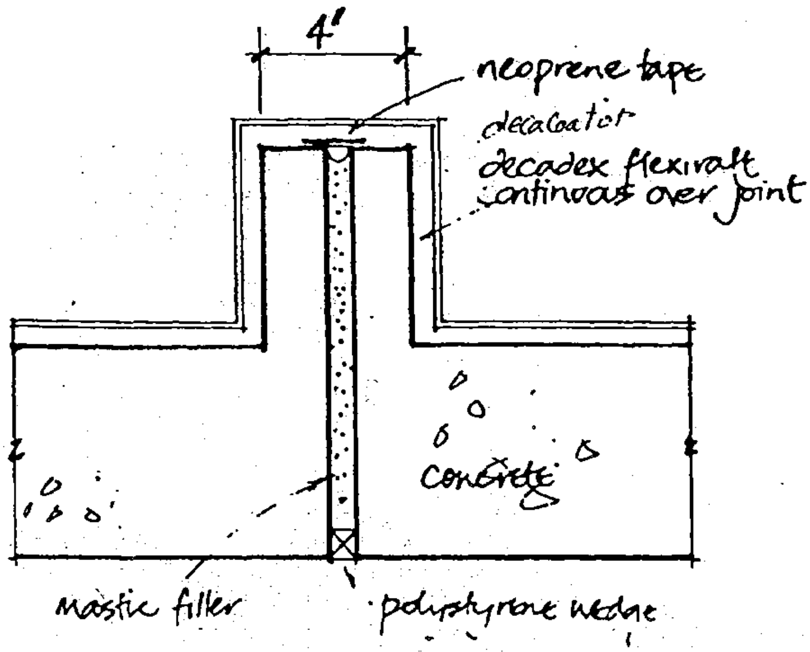
RESERVOIR – Fountain

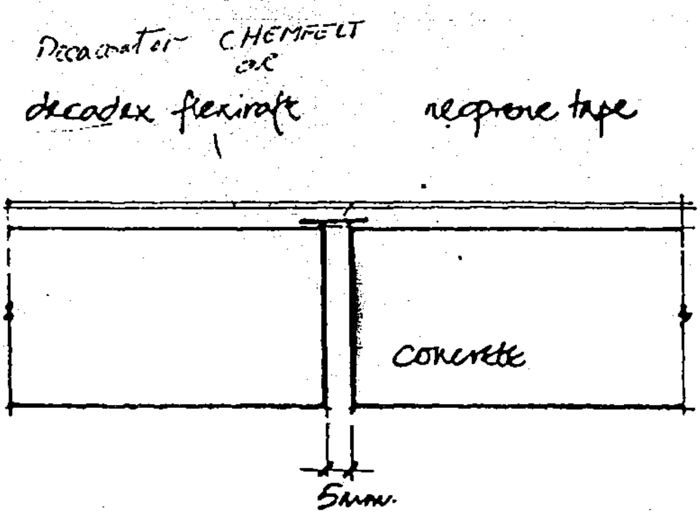




VENT PIPE -DETAIL

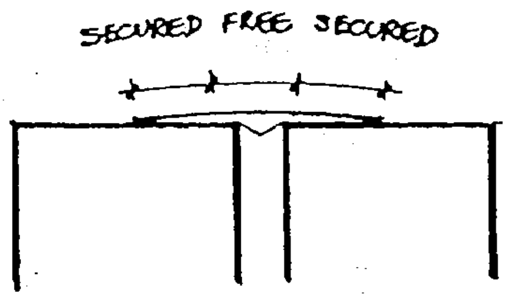






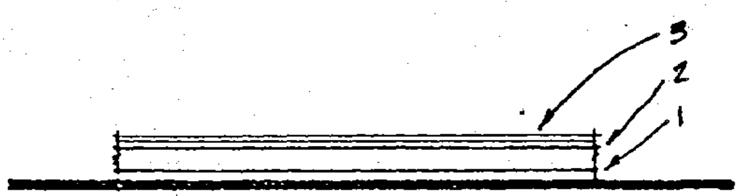
EXPANSION JOINT DETAIL

ref MKTG/PH/5



FORMATION OF NEOPRENE EXPANSION JOINT:

EMBED EACH SIDE OF TAPE (APPROX 1/3 WIDTH) IN WET DECADEX – ALLOW TO CURE – CONTINUE WITH DECADEX FLEXIRAFT SYSTEM AS DETAILED

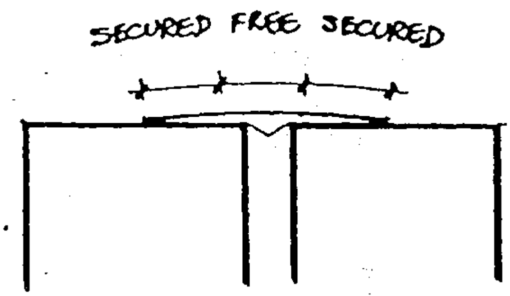


TYPICAL FLEXIRAFT DETAIL

1. EMBED FLEXIRAFT MATTING INTO ONE COAT OF WET DECADEX
2. APPLY OVER FLEXIRAFT MATTING SATURATION COAT OF DECADEX
3. FINISH WITH ONE FULL COAT OF DECADEX PREFERABLY IN A DIFFERENT COLOUR.

GENERAL FORMATION DETAILS NEOPRENE TAPE AND FLEXIRAFT

ref MKJG/PM/1



FORMATION OF NEOPRENE EXPANSION JOINT:

EMBED EACH SIDE OF TAPE (APPROX 1/3 WIDTH) IN WET DECADEX – ALLOW TO CURE – CONTINUE WITH DECADEX FLEXIRAFT SYSTEM AS DETAILED

TYPICAL FLEXIRAFT DETAIL

1. EMBED FLEXIRAFT MATTING INTO ONE COAT OF WET DECADEX
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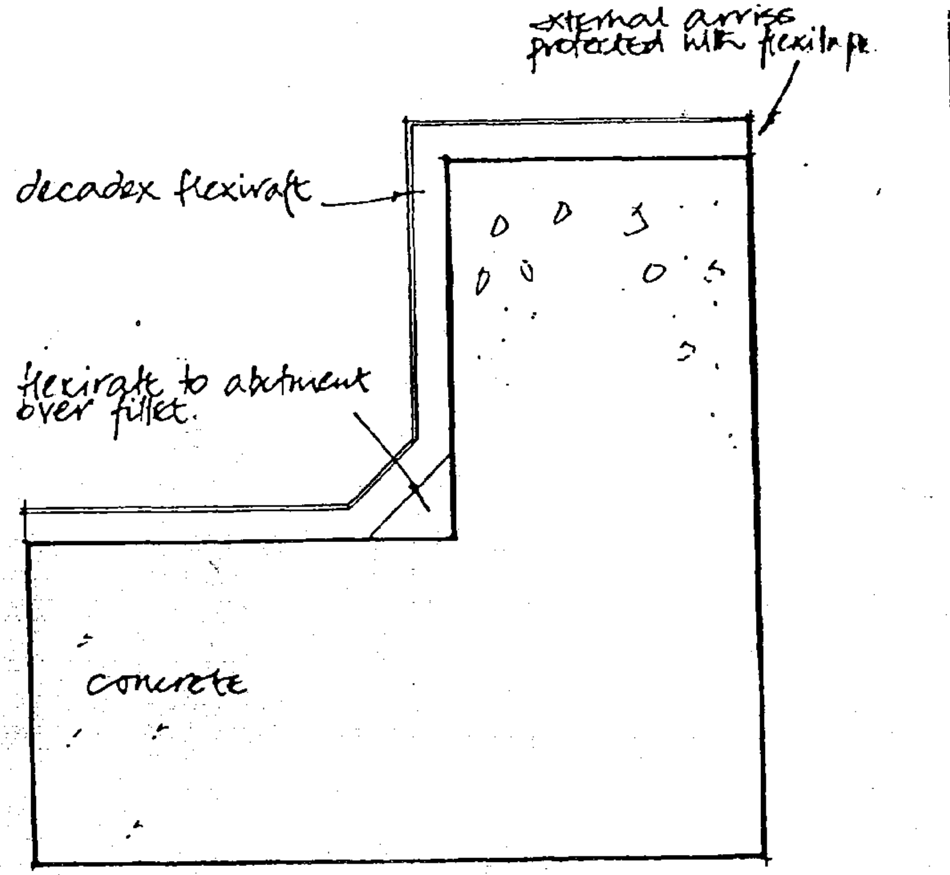
3 FINISH WITH ONE FULL COAT OF DECADEX PREFERABLY IN A DIFFERENT COLOUR.

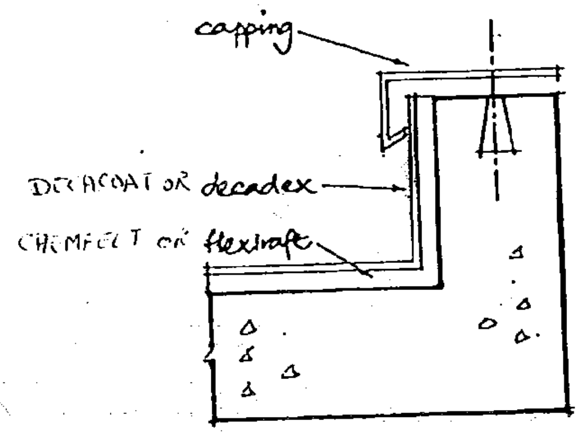
GENERAL FORMATION DETAILS NEOPRENE TAPE AND FLEXIRAFT

ref MKJG/PM/1



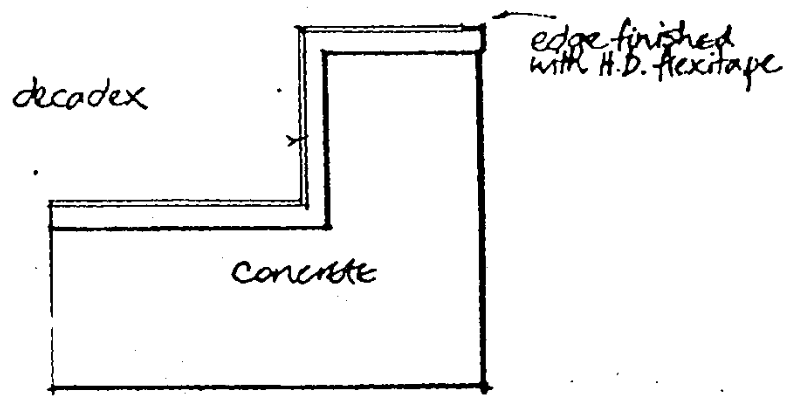
PARAPET DETAIL

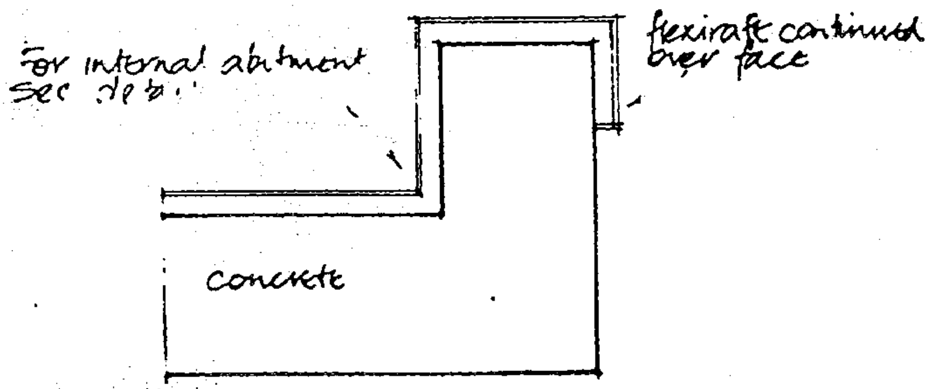
ref MKTG/PM/6



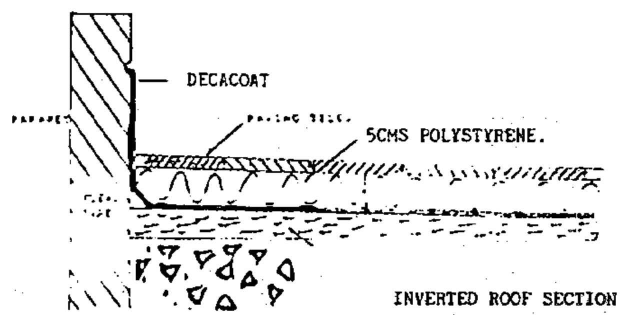
CAPPED PLINTH DETAIL

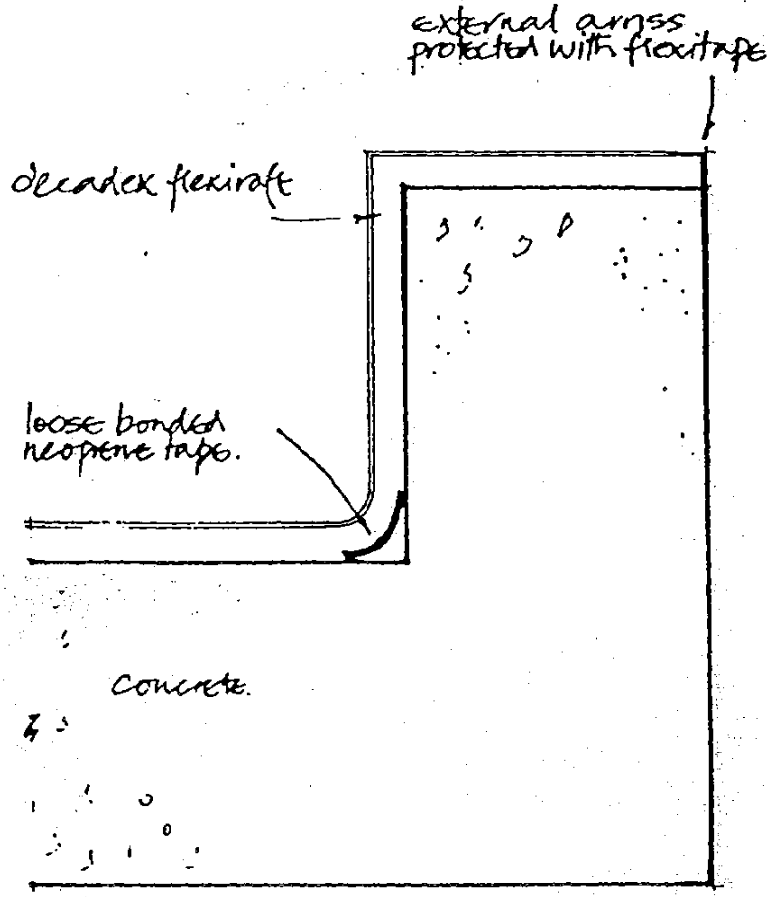
ref MKTG/PM/





PARAPET DETAIL ref MKTG/PM/8


DECACOAT
5CMS POLYSTYRENE.
INVERTED ROOF SECTION



PARAPET DETAIL

KG MKTG/PM/T