

BS 5250:2011+A1:2016



BSI Standards Publication

Code of practice for control of condensation in buildings

bsi.

AVA Documents
Document Sharing Hub

Publishing and copyright information

The BSI copyright notice displayed in this document indicates when the document was last issued.

© The British Standards Institution 2016

Published by BSI Standards Limited 2016

ISBN 978 0 580 93804 7

ICS 91.120.99

The following BSI references relate to the work on this document:

Committee reference B/540/2

Drafts for comment 11/30171810 DC; 16/30339578 DC

Publication history

First published October 1975

Second edition June 1989

Third edition November 2002

Fourth edition December 2011

Amendments issued since publication

Date	Text affected
July 2016	A1. See foreword

Contents

Foreword *iii*

1	Scope	1
2	Normative references	1
3	Terms and definitions	2
4	Design to avoid moisture related problems	4
5	Guidance to builders and owners	11
6	Remedial works	12

Annexes

Annex A (informative)	Moisture in buildings	13
Annex B (informative)	Diagnosis of dampness problems	17
Annex C (informative)	The temperature and moisture content of air	21
Annex D (normative)	Calculating condensation risk	24
Annex E (informative)	Properties of materials	33
Annex F (normative)	Application of design principles – Floors	40
Annex G (normative)	Application of design principles – Walls	45
Annex H (normative)	Application of design principles – Roofs	62
Annex J (informative)	Application of design principles at junctions	82
Annex K (informative)	Application of design principles – Occupied space ventilation	84
Annex L (normative)	Application of design principles – Heating	89
Annex M (informative)	Guidance for builders	91
Annex N (informative)	Guidance for occupiers on how to avoid damaging condensation	93

Bibliography 95

List of figures

Figure C.1	Psychrometric chart showing the derivation of relative humidity from temperature and vapour pressure	22
Figure D.1	Variation of internal humidity classes with external temperature	32
Figure F.1	Groundbearing floor with insulation beneath the floor slab	42
Figure F.2	Groundbearing floor with insulation above the floor slab	43
Figure F.3	Suspended concrete floor with insulation above the floor slab	44
Figure F.4	Suspended concrete floor with insulation below the floor slab	44
Figure F.5	Suspended timber floor with insulation above the joists	45
Figure F.6	Suspended timber floor with insulation between the joists	45
Figure F.7	Timber suspended floor with a soffit of high vapour resistance	45
Figure G.1	Solid masonry wall – External insulation and protective finish with low vapour resistance	49
Figure G.2	Solid masonry wall – External insulation with high vapour resistance	49
Figure G.3	Solid masonry wall – Internal insulation	51
Figure G.4	Masonry wall with cavity – External insulation	52
Figure G.5	Masonry wall with cavity – Insulation partially filling the cavity	53
Figure G.6	Masonry wall with cavity – Insulation filling the cavity	53
Figure G.7	Masonry wall with cavity – Internal insulation	54
Figure G.8	Masonry wall – Concrete with insulating formwork	54
Figure G.9	Framed wall – External insulation	56
Figure G.10	Framed wall – Insulation between framing members	56
Figure G.11	Framed wall – Internal insulation	57
Figure G.12	Framed wall – External sheathing – Thermal insulation between the framing and on the outside of the sheathing	58
Figure G.13	Framed wall – External sheathing – Thermal insulation between on the inside of the framing	59
Figure G.14	Framed wall – Internal sheathing – Thermal insulation between and to the inside of the structural framing	59

Figure G.15 – Cladding systems – Integral thermal insulation – Prefabricated	60
Figure G.16 – Cladding systems – Integral thermal insulation – Built in situ	61
Figure G.17 – Structural insulated panel	62
Figure H.1 – Roofs categorized by position of the insulation	65
Figure H.2 – Cold pitched roof – LR underlay – Permeable external covering	71
Figure H.3 – Cold pitched roof – LR underlay – Impermeable external covering	71
Figure H.4 – Warm pitched roof with HR underlay – Any roof covering	74
Figure H.5 – Warm pitched roof with LR underlay and permeable roof covering	75
Figure H.6 – Warm pitched roof with LR underlay and impermeable roof covering	75
Figure H.7 – Routing insulation and AVCL in a hybrid pitched roof to achieve continuity	76
Figure H.8 – Cold flat roof – Framed structure	77
Figure H.9 – Cold flat roof – Dense structure	77
Figure H.10 – Warm flat roof – Framed structure	78
Figure H.11 – Warm flat roof – Dense structure	78
Figure H.12 – Inverted flat roof – Framed structure	79
Figure H.13 – Inverted flat roof – Dense construction	79
Figure H.14 – Site assembled metal roof	80
Figure H.15 – Composite panel roof	80
Figure J.1 – Temperature contours and heat flow lines at a corner on a masonry wall with insulated cavity	82
Figure J.2 – Temperature contours and heat flow lines through a concrete lintel in a masonry wall with insulated cavity	83

List of tables

Table A.1 – Effect of condensate on impermeable surfaces	15
Table D.1 – Monthly mean temperature and relative humidity for interstitial condensation calculations	27
Table D.2 – Corrections to monthly mean temperatures and relative humidities to create condensation risk years with various return periods	28
Table D.3 – Example of the calculation of estimated ground temperatures	29
Table D.4 – Moisture production rates in housing	30
Table D.5 – Typical moisture production rates from fuels	30
Table D.6 – Typical moisture generation rates for household activities	31
Table D.7 – Internal humidity classes: building types and limiting relative humidities at $T_3 = 0\text{ }^{\circ}\text{C}$	32
Table E.1 – Thermal conductivity and vapour resistivity of building materials	34
Table E.2 – Vapour resistances of thin membranes and foils	37
Table E.3 – Thermal resistance, in $\text{m}^2\text{K/W}$, unventilated cavities 5 mm and 25 mm wide with high emissivity surfaces	38
Table E.4 – Thermal resistance of roof spaces	39
Table E.5 – Thermal resistances of surfaces	39
Table E.6 – Factors for converting permeance units to $\mu\text{g/N}\cdot\text{s}$	40
Table F.1 – Calculation methods required for different ground or exposed floor types	42
Table G.1 – Calculation methods appropriate for different wall types	47
Table H.1 – Calculation methods appropriate for different roof types	66
Table H.2 – Minimum low level loft space ventilation openings	72

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 98, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution and came into effect on 31 December 2011. It was prepared by Subcommittee B/540/2, *Building performance – Moisture*, under the authority of Technical Committee B/540, *Energy performance of materials, components and buildings*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This British Standard supersedes BS 5250:2011, which is withdrawn.

Information about this document

Text introduced or altered by Amendment(s) No. 1 is indicated in the text by tags  . Minor editorial changes are not tagged.

This is a full revision of the standard, and includes a complete re-structuring intended to make the standard more usable.

Moisture in buildings arises from several sources: if not properly controlled it can lead to mould growth and condensation – problems which affect about 15% of homes in England to some degree [1].

The requirement for more efficient use of energy in the operation and use of buildings has led to increased levels of thermal insulation and airtightness in both new and refurbished buildings; this has led to an increased risk of damage from condensation.

The occurrence of condensation is governed by complex interrelationships between heat, moisture, air movement, building layout and the physical properties of building materials. The designer's choice of plan form, envelope materials, construction details and systems of heating and ventilating can ensure the risk of damaging condensation is minimized under reasonable conditions of use. The builder's understanding of the design intent, together with good workmanship under proper supervision, can then result in a healthy environment within a durable building envelope.

Bearing in mind that occupants often fail to use buildings in the manner intended, be it by choice, lack of understanding or force of circumstance, designers are advised to err on the side of caution and adopt robust fail-safe solutions.

When it is proposed to re-furbish a building or make changes to its use, the risk of condensation has to be re-assessed in the light of the new usage.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

1 Scope

This British Standard gives recommendations and guidance on avoiding problems with high moisture levels and condensation in buildings. Recommendations given are based on forms of construction commonly adopted in the UK.

This British Standard gives guidance on the risks associated with excessive humidity in buildings, notably mould growth and condensation, which can endanger the health and well-being of building occupants and the integrity of the building fabric. It describes the principal sources of water vapour, its transportation and deposition and provides guidance on how to manage those risks during the design, construction and operation of buildings.

The guidance contained in this standard is relevant to buildings of all types, whatever their form, construction and occupancy. However, this standard does not cover buildings used for storage at sub-zero temperatures.

Recommendations and guidance on how to avoid penetration of the building envelope by water is contained in other British Standards, for example BS 8103-1, BS 8103-3 and BS 8103-4 for floors, BS 8103-2 and BS 8104 for walls, BS 5534 for pitched roofs and BS 6229 for flat roofs.

Essential design data are contained in the annexes to this standard, including:

- the essential relationship between temperature and moisture content of air;
- methods of calculating the risk of surface and interstitial condensation;
- typical quantities of moisture generated in buildings of various uses and levels of occupation;
- thermal conductivity and vapour resistivity values of common building materials;
- factors for the conversion of common units.

2 Normative references

BS 3533, *Glossary of thermal insulation terms*

BS 5534, *Code of practice for slating and tiling (including shingles)*

BS 5720, *Code of practice for mechanical ventilation and air conditioning in buildings*

BS 5925, *Code of practice for ventilation*

BS 6229, *Flat roofs with continuously supported coverings – Code of practice*

BS 8104, *Code of practice for assessing exposure of walls to wind-driven rain*

BS 8297, *Code of practice for Design and installation of non-loadbearing precast concrete cladding*

BS 8298, *Code of practice for design and installation of natural stone cladding and lining*

BS 9250, *Code of practice for the design of the airtightness of ceilings in pitched roofs*

BS EN 490, *Concrete roofing tiles and fittings for roof covering and wall cladding – Product specifications*

BS EN 1279 (all parts), *Glass in building – Insulating glass units*

BS EN 14783, *Fully supported metal sheet and strip for roofing, external cladding and internal lining – Product specification and requirements*

BS EN ISO 6946:2007, *Building components and building elements – Thermal resistance and thermal transmittance – Calculation method*

BS EN ISO 10211, *Thermal bridges in building construction – Heat flows and surface temperatures – Detailed calculations*

BS EN ISO 13788, *Hygrothermal performance of building components and building elements – Internal surface temperature to avoid critical surface humidity and interstitial condensation – Calculation methods*

BS EN ISO 13789, *Thermal performance of buildings – Transmission and ventilation heat transfer coefficients – Calculation method*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS 3533 and the following apply.

3.1 air and vapour control layer

AVCL

continuous layer of impermeable material

3.2 breather membrane

membrane with water vapour resistance greater than 0.25 MN·s/g and less than 0.6 MN·s/g

3.3 condensate

liquid water produced by condensation

3.4 condensation

conversion of water vapour to liquid water

3.5 conditioned space

occupied space in which the temperature and humidity are controlled

3.6 damp proof membrane

membrane which is intended to resist the passage of moisture from the ground to a floor

NOTE It will also constitute an AVCL.

3.7 dewpoint

temperature at which air becomes saturated with water vapour

3.8 dry bulb temperature

temperature of the air as measured by a dry thermometer

3.9 emissivity

ratio of radiant energy emitted by a surface to that emitted by a black body at a given temperature

3.10 evaporation

conversion of liquid water to water vapour

3.11 humid

quality of air or weather being moist or damp

3.12 humidity

moisture content of air

- 3.13 hygroscopic**
readily taking up water vapour from the air
- 3.14 hygrothermal**
pertaining to the simultaneous movement of moisture and heat
- 3.15 interstitial condensation**
condensation which occurs within or between layers of a construction
- 3.16 membrane**
thin layer of material
- NOTE The resistance of a membrane to the passage of air and water vapour is dependent on its composition and has to be specified according to the required performance in each application.*
- 3.17 moisture**
water in solid, liquid or gaseous phase
- 3.18 relative humidity**
amount of water vapour contained within a given volume compared with the maximum amount at the given temperature (usually expressed as %rh)
- 3.19 saturation vapour pressure**
maximum vapour pressure over a plane water surface, at any given temperature
- 3.20 stack effect**
tendency of air in a building to rise as a result of differential temperatures and air density
- 3.21 surface condensation**
condensation which occurs on a visible surface within a building
- 3.22 thermal bridge**
part of a construction with thermal resistance significantly lower than that of the surrounding construction
- 3.23 underlay, HR**
membrane with water vapour resistance greater than 0.25 MN•s/g
- 3.24 underlay, LR**
membrane with water vapour resistance not exceeding 0.25 MN•s/g
- 3.25 vapour**
substance in its gaseous phase
- 3.26 vapour diffusivity**
rate of diffusion through unit thickness of material at unit water vapour pressure difference
- 3.27 vapour pressure**
that part of atmospheric pressure which is due to the presence of water vapour
- NOTE Expressed in kPa (1 kPa = 10 millibars = 1000 N/m²)*
- 3.28 vapour resistance**
resistance of a material to the diffusion of water vapour
- NOTE Expressed in MN•s/g*

3.29 vapour resistivity

resistance of unit thickness of material to the diffusion of water vapour at unit vapour pressure difference

NOTE Expressed in MN·s/g·m

3.30 vent

opening provided for the passage of air

3.31 vented cavity

volume of air with openings to the outside air so placed as to allow some limited, but not necessarily through, movement of air

3.32 ventilate

expose to a current of fresh air

3.33 ventilated cavity

volume of air with openings to the outside air so placed as to promote the through passage of air

3.34 ventilated void

large volume of air with openings to the outside air so placed as to promote the through passage of air

3.35 ventilation

- a) circulation of air
- b) systems or means of providing fresh air

3.36 water vapour

water in its gaseous phase

3.37 well-sealed ceiling

ceiling incorporating seals which prevent the transfer of warm, moist air into the loft or roof space in accordance with the recommendations of BS 9250

3.38 wet bulb temperature

temperature of the air as measured by a thermometer cooled by evaporation of water

4 Design to avoid moisture related problems

4.1 General

In order to avoid the occurrence of excess condensation, which can result in mould growth and damage to building fabric and/or contents, designers should assess the amount of water vapour likely to be generated within the building and determine the resultant increase in internal vapour pressure above that of external air. They should then give careful consideration to the physical properties of the construction separating inside from outside.

Designers should consider the effects of the external climate, which, being site related, is beyond direct control but may be moderated by the building's form and orientation in relation to topography, prevailing winds, sunlight and over-shadowing.

Designers should also bear in mind that the rate at which humidity is generated can change over time as buildings are adapted to different functions or levels of occupancy; furthermore, the cost of energy might well deter occupants from maintaining an adequate heating regime.

COMMENTARY ON 4.1

Once moisture from the construction phase has been removed, the rate at which humidity is generated within a building is determined by the occupants and their activities: swimming pools, some industrial processes, laundries, canteens and food factories, for example, generate very large amounts of moisture.

In order to avoid surface condensation the appropriate relationship between internal vapour pressure and the temperature of internal surfaces has to be achieved. In buildings with high internal humidity all surfaces have to be kept at a higher temperature than those in buildings with low internal humidity; they therefore require a higher level of insulation or greater use of energy, be it for heating or for the removal of excess moisture.

4.2 Assessing the likelihood of condensation

A1 Text deleted. **A1**

Designers should assess the risk of surface condensation, mould growth and interstitial condensation using the methods described in BS EN ISO 13788, which determines three criteria for assessment.

- 1) The design of the structure and the heating system should ensure that, over the coldest month, the average relative humidity at internal surfaces does not exceed 80%, the limit for mould growth (but see also 4.5.2).
- 2) Any interstitial condensation which might occur in winter should evaporate during the following summer, preventing an accumulation of moisture year on year.
- 3) The risk of degradation of materials should be assessed in terms of the maximum level of condensate which might occur.

NOTE 1 Software programs are available to perform the calculations.

If an assessment indicates condensation is likely to occur, then the designer should assess the likelihood of it causing damage to the materials used and if necessary modify the design. Organic materials should not be exposed to harmful and prolonged condensation.

Designers should be aware that BS EN ISO 13788 considers only the risks arising from the diffusion of water vapour through the building fabric; it does not take account of the much greater risk of condensation occurring as a result of air leakage, which transports water vapour through gaps, joints and cracks in the building fabric.

Whilst external climate data from an average year should be appropriate for the calculation of long-term energy demand, its use for condensation risk analysis might not be appropriate since years worse than average will occur and might result in damaging condensation. For most buildings, a once-in-ten-year climate year will be appropriate. For particularly sensitive constructions or buildings with vulnerable contents, a once-in-twenty or once-in-fifty-year climate year may be considered more appropriate.

NOTE 2 Guidance is given on the selection of more severe years in D.3.2.

4.3 Internal climate

4.3.1 General

The appropriate operational conditions of a building should first be determined by reference to user requirements and then maintained by controlling the internal temperature, relative humidity and air movement.

NOTE 1 Human comfort conditions lie in the range of 45%rh to 60%rh at 18 °C to 24 °C.

The internal climate of a building should be controlled in order to ensure the health, well-being and comfort of its occupants and the proper functioning of equipment such as boilers, fires and cookers. Air which is contaminated by combustion products, bacteria, mould, smoke, smells, high levels of CO₂, excess water vapour and heat should be removed and replaced by fresh air. The temperature and distribution of that incoming fresh air should be considered in order to avoid it being perceived as an unwanted draught.

NOTE 2 Such an exchange of air removes not only the contaminants but also heat, which can be beneficial in summer, but undesirable in winter.

If, at the designed operational temperature, relative humidity is likely to exceed 70% (see A.5) it will be necessary to extract water vapour from the air; that may be achieved by ventilation or by dehumidification.

NOTE 3 Historically, sufficient fresh air for the building occupants and their activities was available as a result of air leakage through the gaps, cracks and openings in the building envelope, such unintentional air movement is no longer acceptable in buildings which require a heated interior because it is wasteful of energy. The ventilation rate to avoid excessive humidity in a dwelling will normally provide sufficient fresh air for healthy indoor conditions.

4.3.2 Ventilation

Designers should ensure the external envelope of the building is as airtight as practicably possible and then make provision for the required level of ventilation. Ventilation systems should be designed to extract moist air as close as possible to the point of generation and to discharge it to the outside, preferably away from the prevailing wind.

Designers may specify natural or mechanical ventilation systems which may rely on the uncontained movement of air from one space to another or on ducts to transport air.

Natural systems allow air to move through a building in response to pressure differential across the building envelope, which is generated by internal/external temperature differences, together with wind forces; such systems use no electrical energy. The recommendations in BS 5925 should be followed when designing natural ventilation systems, including passive stack systems.

Mechanical systems may be designed to extract air from a building, allowing replacement air to be drawn in through vents, or they may be designed to force external air into the building, allowing stale air to pass out through vents. Alternatively, the system may be designed to move balanced volumes of air in and out of the building. All mechanical systems rely upon the use of electrical energy; the recommendations in BS 5720 should be followed when designing a mechanical ventilation system.

Any ventilation system requires the provision of vents, which may be manually controlled or regulated by thermostatic or hygrostatic means.

Where a domestic heated drying cupboard is provided it should be ventilated to discharge moisture directly to outside air, but where that is not practicable it may be vented to a room which is provided with an extractor fan controlled by a humidistat.

NOTE Detailed guidance on ventilation can be found in Annex K.

4.3.3 Dehumidification

The process of mechanical dehumidification may be beneficial in the short term, for example to remove entrapped construction moisture or moisture introduced by flooding or broken pipework, but it cannot remove contaminants such as CO₂ and smells.

COMMENTARY ON 4.3.3

Electrically powered dehumidification units, running on a closed cycle, draw air from a given space, heat and dry it, and then return it to the same space, the moisture being discharged to drain. Dehumidification units are more effective where excess moisture is caused by high vapour pressure in well heated buildings; they are less effective at low temperature.

4.3.4 Heating

Heating should maintain air and surface temperatures sufficient to prevent problems associated with excessive humidity. To be effective, the heating regime should be matched to the construction as described in 4.5.2.

COMMENTARY ON 4.3.4

Less heat is required to prevent moisture related problems in a building which is well-designed and well-insulated: a well-insulated building is more energy efficient, more economical to run and, when not heated as intended, less prone to condensation. If the heating system maintains comfort conditions in the whole building at all times, condensation problems are minimized, but costs are relatively high. If all or part of a building is used and heated infrequently the construction remains cold, increasing the risk of severe condensation: that risk is greatest if the construction has high thermal mass and heating is purely convective. If some rooms are unheated then water vapour which moves from other rooms can raise the relative humidity high enough to cause condensation or mould growth.

4.4 External climate

Designers should assess and document the factors likely to affect the formation and persistence of condensation in buildings, including exposure to sunlight, clear night skies, wind and driving rain, the potential effects of which are as follows.

- a) *Solar gain.* The external surface temperature of roofs and walls can be increased several degrees above the external air temperature, even in winter, by direct sunlight. This can promote rapid drying of any condensation which has occurred within the structure, it can also drive moisture towards the interior of the building where it might condense on any AVCL. The degree of exposure to direct sunlight can be affected by neighbouring buildings and/or trees.
- b) *Night sky radiation.* On clear nights at any time of year the radiative temperature of the sky is much less than the external air temperature; the external surface of roofs cool rapidly overnight, which means interstitial condensation can occur on the underside of an external weatherproof layer. Although this might evaporate rapidly the next day, there can be sufficient accumulation of condensate to cause running or dripping overnight.
- c) *Exposed positions.* High wind speeds, especially when accompanied by precipitation, chill the external surface of the building, thereby significantly increasing the risk of interstitial condensation within the structure.

4.5 The external envelope**4.5.1 General**

All elements of building construction should meet their functional requirements, which include the avoidance of damaging surface and interstitial condensation. The choice of materials used to form the external envelope of a building should be determined by considerations of appearance, construction requirements and cost. When selecting and positioning materials within an element, designers should consider the performance characteristics of those materials in relation to heat, air and water vapour.

COMMENTARY ON 4.5.1

In the UK climate the essential functional requirement of the external envelope is to provide protection to the occupants by excluding rain and wind whilst moderating the flow of heat.

Most elements of construction (floors, walls and roofs) consist of several layers, each chosen to perform specific functions, be it external appearance, loadbearing, fire protection, airtightness, energy conservation, sound attenuation or internal appearance: some materials have a single function, others might perform several functions. The rate at which heat, air and moisture are transferred through the building envelope and the risk of interstitial condensation are determined by the properties of the various layers of construction and their position relative one to another.

The risk of condensation occurring at any point in a construction is determined by the differences between the internal and external temperature and vapour pressure, the materials which make up the building envelope (including any cavities) and the relative positions of those materials.

Lightweight constructions (those with low thermal mass inside the insulated envelope) have a rapid thermal response rate; they heat up and cool down quickly. Massive constructions (those with high thermal mass inside the insulated envelope) have a slow thermal response rate; they heat up and cool down slowly.

Depending upon their nature, the durability and performance of all building materials are adversely affected by moisture to some degree; notably, the rate of heat flow through any material is greater in the presence of moisture. Hygroscopic materials such as plaster, masonry and timber will absorb moisture, but might release it without suffering structural damage: non-hygroscopic materials such as metals, glass and plastics are impervious but might suffer damage from prolonged exposure to moisture.

Heat is transferred through materials and constructions by conduction, by convection and by radiation. Water vapour is transferred through materials by diffusion, but much more significant water vapour transfer occurs as a result of air movement; therefore, when designing to avoid the risk of damaging condensation, air filtration into and air leakage through the construction are the most important mechanisms to be considered. Consideration also has to be given to the fact that different materials offer different degrees of resistance to the various forms of transfer of both heat and moisture.

4.5.2 Arrangement of materials in constructions

In order to avoid interstitial condensation in any element, materials with the highest vapour resistance should be located on the warm side, and those with lower vapour resistance on the cold side, of any thermal insulation.

Constructions which incorporate an impervious external weathering layer (such as sheet metal or glass) contravene those basic recommendations: in such constructions provision should be made for ventilation behind/beneath the impervious layer to allow any moisture to disperse to atmosphere.

The position of thermal insulation in relation to the thermal mass of a building will determine whether or not that mass is warmed by the heating system; designers should consider the relative position of structural layers, thermal insulation layers and AVCLs in order to avoid damaging condensation.

In a building which is occupied and heated only intermittently, thermal insulation should be applied as close as possible to the internal surface and be protected by an AVCL. Designers should, however, bear in mind that in such constructions any layers outside the insulation will be isolated from the heating systems and therefore present a greater risk of interstitial condensation occurring. Conversely, in a building which is occupied and heated continuously any thermal insulation is best applied outside the thermal mass and should have low vapour resistance.

Designers should bear in mind that if the thermal mass is adjacent to the occupied space it will have a beneficial effect, tending to reduce fluctuations in internal temperature and minimizing the risk of surface condensation. However, a building with such a construction, which is occupied and heated only intermittently, is likely to experience low internal surface temperatures, leading to a greater risk of mould growth and of surface condensation.

With all forms of construction particular care should be taken to minimize the effects of thermal bridges at junctions between building elements (wall/floor, wall/wall, wall/roof) and those between building elements and components (wall/window, wall/door, roof/rooflight); at such junctions there is a higher rate of heat loss which results in lower surface temperatures and an increased risk of mould growth and surface condensation. See guidance in Annex J.

The air permeability of the external envelope should be as low as practically possible to minimize heat loss from the building by air leakage and to facilitate control of the internal climate. An airtight layer on the warm side of the envelope will minimize the penetration of warm moist air into the construction and so reduce the risk of interstitial condensation. Air movement from a heated building into a cold cavity will greatly increase the risk of condensation and should be avoided.

4.5.3 Cavities

Designers should recognize that most conventional forms of construction, including suspended floors, masonry walls and pitched roofs, contain cavities which are likely to have a significant effect on the risk of condensation occurring.

Air movement from within the building into any cavity should be avoided by the adoption of airtight construction.

COMMENTARY ON 4.5.3

Water vapour can be transferred across any cavity by air movement. Air movement from inside a heated building into a cold cavity will not only increase the rate of heat loss from the building, but also greatly increase the risk of interstitial condensation. Calculations suggest that even minimal air movement will have a significant effect on the risk of condensation occurring.

Air flows in lofts are well understood, but little is known about air movement rates in smaller cavities, such as those in masonry walls and flat roofs. Such cavities, particularly if vented only at one end, offer significant resistance to the through flow of air.

Even in sealed cavities, water vapour and heat are transferred by convection currents generated by temperature differences between the two surfaces of the cavity. Any surface facing a cavity will radiate heat across that cavity, the rate of transfer being dependent upon the emissivity of the surface: a low emissivity surface reduces the rate of heat transfer by radiation.

4.5.4 Thermal insulants

Thermal insulants should always be selected by matching their performance characteristics to the specific requirements of their application, with particular regard to their hygrothermal characteristics. Designers should bear in mind that different insulants offer different degrees of resistance to the transfer of both heat and moisture. When thermal insulation is provided in more than one layer, it is essential that their relative physical characteristics be carefully evaluated and the risk of interstitial condensation assessed.

Gaps in the thermal insulation and between that insulation and adjacent materials such as rafters, joists and studs, can give rise to localized condensation.

4.5.5 Low emissivity materials

When considering the use of low emissivity materials designers should carefully assess the risk of condensation occurring, using the method described in Annex D, with performance data which has preferably been evaluated and certified by an accredited third-party. In order to obtain the stated level of performance of any low emissivity material, it is essential that the material is installed facing a cavity; designers should pay particular attention to the practicability of forming and maintaining those conditions throughout the life of the building.

COMMENTARY ON 4.5.5

Low emissivity materials, such as aluminium foil or metalized plastics, have a highly reflective surface which can reduce the rate of heat transfer by radiation when installed facing a cavity: preferably one not less than 25 mm wide. The vapour resistance of such materials can be very high, as in the case of aluminium foil, or low, as in the case of metalized non-bonded polyolefin membranes.

In terms of transfer of heat, air and moisture the overall performance of low emissivity materials when installed in the building, will depend upon the treatment of laps and joints. When wrongly placed, or not properly sealed at joints, low emissivity materials can greatly increase the risk of interstitial condensation occurring.

4.5.6 Air and vapour control layers

For each element of construction (floors, walls and roofs) the designer should determine the vapour control plane upon which the movement of water vapour is to be controlled: it is essential those planes be continuous over the whole of the element and that they be joined to the vapour control planes of adjoining elements. Any AVCL should be located on the warm side of the insulation layers.

Impervious materials of construction, such as glass, metal or plastics sheet floor covering, may of themselves constitute all or part of a vapour control plane.

Depending upon the materials forming an element and their disposition in relation one to another, it might be necessary to provide a layer of material specifically to control the movement of water vapour; such a layer will constitute an AVCL, forming a barrier to both water vapour and air.

The selection of vapour control materials should be determined by:

- a) the degree of vapour resistance required (determined by assessing the likelihood of interstitial condensation using the method and guidance in Annex D and the vapour resistance values of various materials given in Annex E);
- b) the practicability of installation, including the formation of sealed laps and joints;
- c) the anticipated life to renewal.

An AVCL may consist of:

- 1) materials of construction with an inherently high vapour resistance such as glass, plastics sheet floor covering or steel liner in insulated twin skinned panel;
- 2) an applied surface coating;
- 3) an integral barrier, such as a board with an applied film or foil;
- 4) an impermeable membrane.

Designers should determine the performance standard required in any given situation and ensure the specified AVCL will meet that standard over the life of the building. It should be borne in mind that some membranes offer high resistance to the passage of water vapour and air, whilst others offer high resistance to air leakage but low resistance to the passage of water vapour.

In order to form an effective AVCL, side and end joints should be kept to a minimum, joints in flexible membranes should be formed over solid backing members or a rigid substrate, be lapped at least 50 mm and be sealed. Any damage should be repaired using matching material and jointing techniques. Unstabilized plastics-based sheeting should be protected from heat and sunlight to prevent degradation.

Penetrations through an AVCL by pipes and services will compromise its performance; they should preferably be eliminated at the design stage: if that is not possible they should be adequately sealed by means of proprietary seals and collars, or liquid-applied sealants, which should be able to accommodate thermal and other movements, likely to occur during the life of the building.

A void should be formed behind the internal surface finish to enable services to be installed without compromising the AVCL (see 4.2).

Building owners/occupants should be made aware of the importance of maintaining AVCLs throughout the life of the building, particularly when repairs, alterations and extensions are made.

4.6 Alterations and extensions to buildings

Where a building is to be altered or extended it is essential to determine what precautions to prevent condensation were included in the original building: those precautions should be retained, adapted and, if necessary, improved. The new work should follow the guidance set out in this standard. If the building is merely to be repaired, then a diagnosis of its existing condensation problems should be made and remedial action should be taken in accordance with Clause 6.

5 Guidance to builders and owners

5.1 Builders

Builders should be instructed to take appropriate steps to minimize the likelihood of damaging condensation, for example, by protecting the construction from precipitation.

NOTE Annex M contains draft guidance which may be modified for inclusion in sitework instructions.

5.2 Building owners and occupiers

Building owners and occupiers should be given information about the control of condensation so as to enable them to use the building within its design limit, and, by following some simple rules, to minimize the risk of condensation occurring.

NOTE Annex N contains suggested text for inclusion in an owner's manual.

6 Remedial works

6.1 Action to control condensation

Any action to control condensation should take account of the intended use of the building and involve comprehensive consideration of heating, ventilation and thermal insulation.

6.2 Heating

All surface condensation problems may, in principle, be solved by the application of heat to raise temperatures above the dewpoint, coupled with adequate levels of ventilation.

A common cause of harmful condensation in existing buildings is lack of adequate heating. If the existing system is inadequate, a heating system designed in accordance with the guidance given in Annex L should be installed.

Heating and insulation should always be considered together as the provision of adequate insulation ensures both capital and running costs are kept to a minimum.

6.3 Ventilation

In order to keep the internal relative humidity low enough to prevent a build-up of harmful condensation, it is essential that adequate ventilation be provided (see Annex K).

6.4 Insulation

 **NOTE** Adding insulation to the fabric of the building can raise the internal surface temperatures, and is likely to allow the interior to be heated adequately at reasonable cost. However unless the occupants provide adequate ventilation as well as heating, there is still a risk of condensation and mould growth. 

Any additional insulation should be located with regard to 4.5.4.

Annex A
(informative)
A.1

Moisture in buildings

General

Excess moisture in a building can lead to condensation and mould growth which represent risks to the structural integrity of the building and the health of its occupants. In order to manage those risks the designer has to first recognize the relationship between heat, air and moisture, consider likely sources of moisture and the generation of water vapour, its transportation and deposition.

It is essential that moisture entrapment during construction and water vapour generation during occupation is minimized, and that excess moisture is removed as close to source as possible.

A.2 Sources of moisture

The sources of moisture in buildings are numerous and varied and include the following.

- a) *Water used in construction*: materials such as masonry, concrete and plaster require the addition of water for the purposes of hydration; surplus moisture will migrate to atmosphere. The design and construction processes have to facilitate the safe removal of such moisture.
- b) *Ground water*: groundbearing floors and walls in contact with the ground have to be capable of resisting all ground-borne moisture; this is normally achieved by using over-site waterproofing membranes and damp-proof courses. Constructions below ground have to be protected – three methods are recommended in BS 8102.
- c) *Flooding*: flood water can be absorbed into the fabric of a building, causing damage and creating a health hazard. In addition, as that water is released it can create an acute increase in the risk of condensation.
- d) *Precipitation*: rainwater is a primary source of moisture, the effects of which have to be considered both during construction and post completion. Construction work in progress has to be protected against precipitation which is likely to damage materials and increase the risk of subsequent condensation. The design and detailing of the external envelope, once completed, has to provide protection against precipitation, in particular against wind-driven rain, which can be absorbed into masonry, reducing the overall thermal resistance of walling. Careful attention has to be paid to joints and junctions in and between components and elements. Refer to BS 8104 for climate data; to BS 8204 (all parts) for floors; to BS 8104 for walls; to BS 6229 for flat roofs and to BS 5534 for pitched roofs.
- e) *Spillages and leaks*: damage or defects in the external envelope and defective joints or fractures in water or waste pipes will lead to damage to water-sensitive materials and finishes, and are likely to increase the risk of condensation. Prompt attention is required to remedy such damage and defects.
- f) *Flueless heating appliances*: supplementary space heating appliances, such as flueless gas fires or free-standing units burning LPG, produce large volumes of water vapour.
- g) *Air-borne moisture*: during spells of warm, humid weather the air entering the building from outside contains relatively high levels of moisture.
- h) *Building use*: once the building is occupied and in use, activities within the building, at different times, generate variable amounts of water vapour (see Annex D for details). The amount of water vapour is determined by the number of occupants and the activities they undertake. The water vapour which is generated (for example by breathing, washing, drying clothes,

cooking) results in an increase in internal vapour pressure. Some industrial processes including laundries, canteens, food factories and swimming pools generate very large amounts of water vapour.

The internal vapour pressure in a typical UK dwelling in winter will be some 1.0 kPa to 1.2 kPa, against an external vapour pressure of 0.5 kPa to 0.6 kPa. However, in an air-conditioned building, in a warm humid climate, then the internal vapour pressure might be lower than that outside.

The relative humidity of the ambient air determines the water content of hygroscopic materials; that moisture might later be released back to atmosphere as the relative humidity is lowered, but if the humidity level remains high it will increase the risk of surface mould growth, the corrosion of metals and the decay of timber-based products.

A.3 Movement of moisture within structures

 Moisture moves within a building structure by a combination of vapour diffusion, liquid flow through material pores and air movement through gaps, penetrations and cavities. 

Water vapour diffuses through most building materials, the rate of diffusion being dependent upon the difference in vapour pressure between inside and outside and the vapour resistance of each layer of material in the construction.

 Many materials are porous and absorb moisture from the air at a rate that depends on the ambient relative humidity. They can also absorb water from driving rain on the outside surface, and contain large amounts of water included during construction. This water then moves through the structure under relative humidity gradients.

During the winter, heat and moisture are generated within the building, raising the internal temperature and vapour pressure above the outside causing water vapour to diffuse outwards.

However solar gain on the outside, especially on south facing walls, can cause moisture to move inwards through the pores.

Wind acting upon a building produces, on the leeward side, a negative pressure zone. Also higher internal temperatures in cold weather increase the air pressure in the upper storeys inside the building relative to the outside leading to a circulation of air through the building (commonly called stack effect). Both these processes drive air carrying water vapour through the gaps and cracks in the structure. It is important to recognize that the rate at which moisture is transported by air movement, where it occurs, is much greater than the rate of transportation by diffusion. 

 Text deleted. 

A.4 Hygroscopic materials

Most materials are hygroscopic (able to absorb and desorb water vapour). This can have a beneficial buffering effect, reducing the risk of both surface and interstitial condensation during rapid fluctuations of temperature and vapour pressure. However, hygroscopic materials exposed to high levels of humidity can, over time, absorb sufficient moisture to cause damage to elements of structure, to finishes, to furniture and to furnishings.

A.5 Mould

Large numbers of mould spores are always present in the atmosphere. In order to germinate those spores require warmth, a source of nutrition, oxygen and moisture; because they are hygroscopic they do not require liquid water. Many mould spores can germinate if the relative humidity at the surface exceeds 80%. Once established mould spores can continue to grow at a moisture level lower than 80%.

Buildings provide many sources of nutrition, and oxygen is always present, consequently the growth of moulds depends on moisture conditions at internal surfaces. In winter the internal surfaces of the external walls can be colder than the air in the room and the relative humidity at the face of the wall is about 10% greater than that in the room. As a result, if the relative humidity of the room stays at 70% for long periods of time the external wall surfaces will be sufficiently humid to support the growth of mould.

Mould presents a hazard to health; it is closely associated with respiratory allergies, especially asthma, in sensitive (atopic) individuals. Mould growth within a building can cause significant distress to the occupants even in the absence of any physical symptoms, it can damage the building fabric, surface finishes, fittings, clothing and furnishings, particularly those in unheated spaces such as lofts or parts of rooms sheltered from heating systems, such as cupboards or wardrobes placed against external walls.

A.6 Surface condensation

Warm humid air within buildings, if cooled to its dewpoint by contact with cold, non-absorbent surfaces, such as window glass, un-insulated pipework and cisterns, will deposit excess moisture on those surfaces as condensate. Whilst that condensate might not damage the material on which it occurs, if sufficient accumulates it will run or drip onto other materials where it might cause damage (see Table A.1).

Table A.1 Effect of condensate on impermeable surfaces

Amount of condensate g/m ²	Effect
< 30	A fine mist which does not run or drip
30 – 50	Droplets form and begin to run down vertical surfaces
51 – 250	Large drops form and begin to run down sloping surfaces: • 70 g/m² will run down a 45° slope • 150 g/m² will run down a 23° slope
> 250	Drops form and drip from horizontal surfaces

A.7 A1 Moisture within structures A1

A1 NOTE As described in A.2, moisture can enter a structure from a number of sources. This can then move within the materials (A.3) to cause problems. A1

Interstitial condensation occurs within a construction when water vapour moving through that construction comes into contact with a material which is at or below the dewpoint of the vapour. Such condensation is more likely to occur on the surfaces of materials but can occur within the body of a material if that is where dewpoint occurs. In a multi-layer structure it is also possible for condensate to be deposited on more than one plane as moisture evaporates from one surface and re-condenses on a colder one.

Interstitial condensation can cause deterioration of the building fabric, through corrosion, rot and decay. It can also reduce the thermal resistance of materials thus adversely affecting energy efficiency.

Direct solar radiation on moist building fabric can have the effect of driving moisture into the building fabric, leading to interstitial condensation on the external face of any vapour-tight inner layer.

This standard addresses the common condition in the UK, where buildings are occupied and heated during the winter months, creating a vapour pressure drive through the building envelope from the warm inside to the cold outside. By contrast, in warm moist climates, where it is common for buildings to be air conditioned, the vapour pressure drive will be from the warm outside to the cold inside: the external envelopes of such buildings have to be designed with this difference in mind. The increasing use of air conditioning units within existing buildings in the UK might well result in similar “outside to inside” vapour drives, creating an unforeseen risk of interstitial condensation.

A1 Moisture moving through the pores of materials under temperature or relative humidity gradients can also accumulate in specific areas of the structure.

The intensity of driving rain varies markedly depending on:

- a) the location of the building in the UK: amounts are higher in the west than the east;
- b) the orientation of the wall: south and west are typically more exposed than north and east;
- c) the degree of shelter from the surroundings: a building on a hill by the coast is typically more exposed than in a city centre.

Capillary action causes water to rise up from the ground into porous materials. The significance of this depends on the nature of the building materials and the height of the water table in the ground.

Moisture from all of these sources moves through the structure under humidity and particularly temperature gradients. In many cases this causes no problems, but sensitive materials can become wet enough to promote rot or corrosion, reduce the performance of thermal insulation and interior decoration might be stained.

Potential problems can be reduced if building materials are kept dry before and during construction to avoid trapped construction water, which could otherwise exacerbate condensation risks and can take a long time to dry out. Adequate ventilation and, where necessary, heating of the completed building will also reduce the risk of problems

A full moisture risk assessment takes account of the multiple sources of moisture described in **A.2** along with multiple mechanisms of moisture transport described in **A.3**. An awareness that, in some cases, multiple sources and mechanisms can interact and cannot be accounted for separately can aid designers and practitioners. **A1**

Condensate which accumulates in the building fabric during winter can evaporate, partially or totally, during the following summer. Partial evaporation will lead to a long-term build up of condensate.

Annex B
(informative)**Diagnosis of dampness problems****COMMENTARY ON ANNEX B**

It is not possible to devise an infallible system for differentiating between condensation and other sources of dampness. A building element can be damp for a number of reasons, e.g. because of rising damp, condensation, water penetration, or presence of hygroscopic salts.

The following recommendations and guidance are intended to assist in an investigation.

B.1 History

It is advisable to make enquiries into the recent history of the building to determine whether it has been left unoccupied for any length of time or whether it has been open to the weather or flooded. If the building has remained unoccupied for some time, it will not be possible to determine every area in which condensation problems relating to occupancy have previously occurred; potential areas of risk should therefore be discovered by examination of the structure taking into account the proposed use of the building.

COMMENTARY ON B.1

The risk of interstitial condensation within the structure might need to be assessed using the methods set out in BS EN ISO 13788 (see Annex D).

Areas showing the effects of condensation, such as mould growth and staining, are more easily identified where a building has been occupied recently. If the inspection takes place during cold weather, while the premises are occupied or soon after they are vacated, damp patches might be evident.

B.2 Information from the occupants

The opportunity ought to be taken to obtain as much relevant information as possible from the occupants.

For example, the following factors may be considered.

- a) The number and ages of the occupants.
- b) The occupancy pattern.
- c) The heating pattern.
- d) Family economics, including how much is spent on heating.
- e) Types of domestic appliances which are likely to generate water vapour such as cookers, washing machines, driers and free-standing room heating equipment such as portable gas or paraffin heaters.
- f) Whether the system for washing and drying clothes is one that will generate a lot of moisture within the dwelling.
- g) The weather and seasonal dependency of the phenomena.
- h) What means of ventilation is installed and whether it is used.
- i) Whether or not the family open the windows and when.

This information should be considered in the light of the principles outlined in Annex D to assist in an assessment of the building.

B.3 Monitoring temperatures and humidities

COMMENTARY ON B.3

Small, self contained, battery operated data loggers are now available which can record temperature and relative humidity at 15 min intervals for several months. These can be placed in each room in positions chosen as far as possible to represent the overall room conditions, and are small and robust enough to be returned by post to the surveyor, if it is not possible to revisit the house.

Data loggers should be placed against an internal wall between one metre and two metres above the floor. They should not be exposed to direct sun or heat from heating appliances, or other equipment such as a television. In many cases they may be placed on an appropriate item of furniture, but this is not always possible (some living rooms, for example have only a suite and television). It may be possible to fix the loggers to the wall with a picture hook, or with a suitable non-damaging adhesive.

At the end of the monitoring period, the recorded data may be downloaded from the loggers to a PC or laptop, using the software provided with the logger, and then transferred to a spreadsheet for analysis. The recorded temperatures and relative humidities may then be used to calculate the vapour pressure, an index of the amount of water vapour in the air using the equations in Annex C.

The simplest summary of the data collected is the overall means of the temperature and humidity in each room, however more information about the performance of the house may be gained from calculating daily means and the difference between the daily maximum and minimum temperature.

B.4 Causes of dampness

The causes of any dampness other than that resulting from condensation should first be determined. The following may be used as a checklist.

- a) Roof leaks, e.g. valleys, flashings around parapets and chimneys, and roof windows.
- b) Defects in the rainwater drainage system.
- c) Defects in wastepipes
- d) Leaks in the plumbing system.
- e) Rain penetration around the door and window openings.
- f) Defects in the damp-proof courses and membranes.
- g) Area of wall surface affected by hygroscopic elements, e.g. parapets, balconies and porches.

B.5 Recognition of surface condensation

Surface condensation occurs where the temperature falls below the dewpoint temperature of the adjacent air and can result in mould growth; this should be checked for in the following locations.

- a) Corners of rooms, especially corners of external walls.
- b) Lintels, reveals and sills.
- c) Behind furniture placed against external walls.
- d) Within built-in furniture on external walls.
- e) Floor/external wall junctions especially those containing ring beams.
- f) On the internal surface of north facing walls.

B.6 Recognition of hygroscopic effects

COMMENTARY ON B.6

Certain salts will absorb moisture from the atmosphere to such an extent that, if they are present in brickwork, damp patches will appear in plaster covering the bricks every time the weather becomes sufficiently humid and will fade away when dry weather returns.

The affected areas can relate to a single brick and such areas often show a well-defined edge. Typical locations to be affected are chimney breasts, brickwork previously affected by rising damp or damp penetration through the walls from adjoining structures.

B.7 Recognition of rising damp

COMMENTARY ON B.7

Water travelling through a wall contains dissolved salts and organic matter from the ground, particularly sulfate, chloride and nitrate salts. Sulfates are efflorescent and as the water evaporates at or just below the surface of the wall, these crystals form. When this occurs at the surface, the crystal forms a fragile feathery crystalline growth, usually white in colour and often forming "tide" marks. When it occurs below the surface, e.g. behind a paint film or plaster, the crystals grow and can disrupt the paint film or force the plaster off the wall. Chlorides and nitrates are hygroscopic and do not appear as crystals on the surface, rather they tend to show as tide marks at the maximum height of rise. Decorations are usually discoloured, wallpaper can be bleached or stained a brownish colour in these areas. The presence of chlorides tends to inhibit the growth of moulds, in effect producing saline conditions locally.

Rising damp gives a decreasing amount of free moisture from ground level upwards, when measured by gravimetric methods; care should be taken with a chemical absorption type meter as it will give high readings in regions contaminated by hygroscopic salts. Seawater flooding, for example, will give permanent high readings by chemical absorption due to the salt content of seawater, and the use of contaminated or unwashed sea-dredged materials in construction should also be borne in mind.

Care should be taken to differentiate between dampness due to condensation and due to rising damp; for example, because of the presence of a thermal bridge, or because of variations in air temperature or humidity at different points in a room, water can condense on a non-absorbent surface and form droplets. Rising damp should not be expected to appear in this form.

One of the most reliable ways that may be used to differentiate between dampness due to condensate and that due to rising damp is to compare moisture contents of samples of masonry, or preferably mortar, from within the depth of the wall and near the inner surface of the wall; samples from within the wall will not be damp if surface condensation is the sole cause.

NOTE More details of damp proofing treatments are given in BS 6576.

B.8 Measurement of dampness

Accurate measurements of the moisture content of brick or mortar cannot be obtained by the use of electrical moisture meters because the presence of salts increases the electrical conductance of the water, giving falsely high readings. Gravimetric methods carried out on samples taken from the fabric give the most reliable results. The use of chemical absorption type moisture meters will give a result in a short space of time and be almost as reliable.

Measurement methods for dampness in walls are discussed in more detail in BRE Digest 245 [2] and BRE Report 466 [3].

B.9 Damage caused by dampness

B.9.1 Damage to structure

Where inspection reveals damage, appropriate replacement, repair or preservative treatment ought to be carried out.

Any precautions against future condensation ought to ensure that further structural damage will be prevented. It is essential, therefore, that remedial treatment is directed to overcoming harmful interstitial condensation as well as surface condensation; freedom from the latter does not necessarily ensure that the former does not occur.

COMMENTARY ON B.9.1

The most likely forms of damage to a structure are decay in the timber or cellulose products, corrosion of metals, or excessive moisture movement of materials. Dampness can cause distortion and in some cases serious weakening of sheet or thin slab materials, e.g. in roof decks and ceilings. Moisture trapped beneath impermeable roof finishes can, in hot weather, cause vapour pressure high enough to cause damage to the roof finish.

B.9.2 Damage to finishes

COMMENTARY ON B.9.2

Damage to decoration occurs mainly from surface condensation, but occasionally can be caused by interstitial condensation, for example condensation dripping from an underlay onto a ceiling, or condensation in a wall moving inward and damaging surface finishes.

Mould growth on room surfaces, particularly in room corners, first appears as spots or small patches, which can spread to form a furry layer usually grey-green, black or brown in colour. On paint, it can show as pink or purple.

Soft distempers are liable to flake if repeatedly wetted and dried, whilst emulsion paints are more likely to remain undamaged. Moisture on the exposed surfaces tends to reduce the gloss of some impervious paints but otherwise does not cause damage. If moisture penetrates behind impervious paint films, blistering of the paint can occur. In extreme cases, the plaster can break down and/or lose its adhesion.

Repeated or prolonged absorption of condensate can cause distortion of sheet materials, e.g. plasterboard or fibreboard. Water absorbed from a surface can reach and break down an adhesive by which a surface finish is fixed. This can occur on floors or walls, but is more likely to be harmful in the case of ceilings when the effect of gravity adds to the risk of displacement of adhesive fixed tiles.

B.10 Mould growth

COMMENTARY ON B.10

Mould growth is often associated with surface condensation. Damp houses provide good conditions for its development. Mould spores exist in large numbers in the atmosphere and, to germinate, need a nutrient, oxygen, a suitable temperature and moisture. Sources of nutrition are widespread in buildings and the internal environment provides a suitable temperature for growth. As oxygen is also always present, mould growth is principally dependent upon the moisture conditions at surfaces and the length of time these conditions persist.

Studies have shown that moulds do not necessarily require the presence of water. As a guide, if the average relative humidity within a room stays above 70% for several days, the relative humidity at external wall surfaces will be above 80%, which is high enough to support the germination and growth of moulds.

Although the symptoms of mould growth may be fairly easily dealt with by either washing with a household bleach diluted 1:4, followed by clean water, or the use of a proprietary toxic wash, it is better to remove the cause of the mould growth, i.e. the high relative humidities. Proprietary anti-fungal paints and wallpaper pastes, which may be used in areas where condensation occurs regularly, are also available (see BRE Digest 139 [4]).

Annex C
(informative)

The temperature and moisture content of air

All air supports water as an invisible vapour: the maximum amount of water vapour the air can support is determined by the temperature of the air – the warmer the air the more water vapour it can support. When air at a given temperature can support no more water vapour, that air is said to be saturated. When air which is not saturated is cooled, it will eventually reach the temperature at which it becomes saturated (that temperature is the dewpoint). Dewpoint for a given volume of air is solely dependent upon the quantity of water vapour which that air is supporting. The amount of water vapour present in a given volume of air can be expressed in kg/m^3 , and the vapour pressure it exerts can be expressed in kPa.

If the temperature of a given volume of saturated air is lowered, or more moisture is added, the air is unable to support the excess water vapour: liquid water will then appear, either as a fine mist or fog in the air or as condensate on any surface at or below dewpoint with which the air comes into contact.

The term relative humidity (usually expressed as %rh) is used to describe the amount of water vapour the air contains relative to that which would produce saturation at the given temperature.

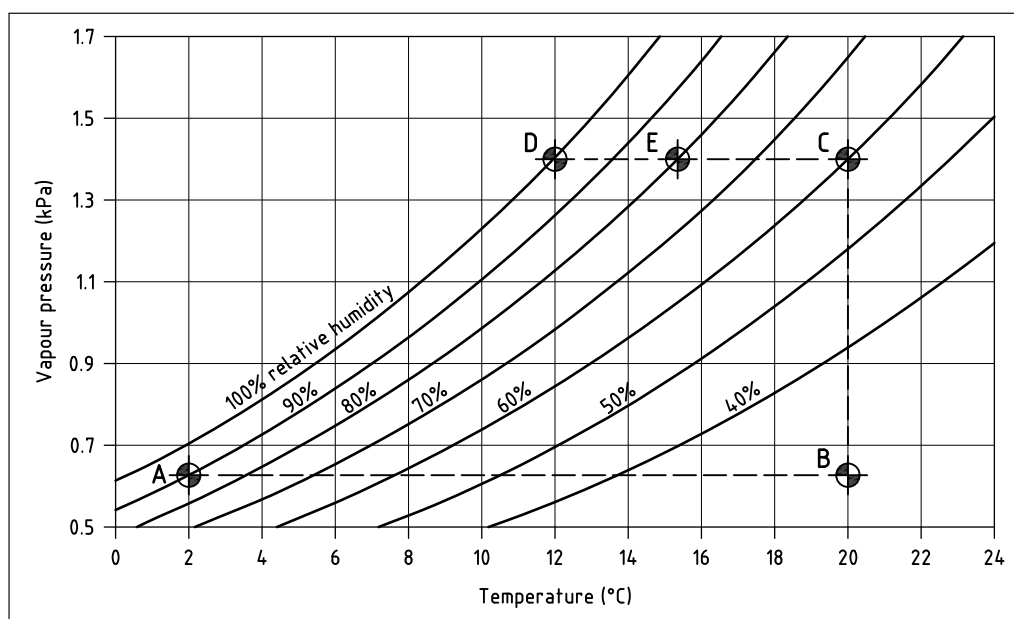
Differences in the temperature and relative humidity of air in adjacent volumes create different vapour pressures as a result of which water vapour is transferred from areas of higher vapour pressure to those of lower vapour pressure. Vapour pressure is directly proportional to the amount of water vapour present.

Virtually all activities within buildings generate water vapour which increases the vapour pressure within the building (see Annex A).

Relative humidity and dewpoint are the two most important parameters which determine whether condensation occurs. Although dewpoint is expressed as a temperature, it is dependent upon the amount of moisture present in the air. Air moisture content and percentage relative humidity may be determined by using a wet and dry bulb psychrometer or electronic hygrometer.

The relative humidity of the ambient air determines how much moisture will be absorbed by hygroscopic materials; this in turn determines the risk of mould growth on surfaces and the decay of materials. The psychrometric chart in Figure C.1 demonstrates the relationship between relative humidity and dewpoint. The curved lines show relative humidity, the 100% line being saturation (dewpoint).

Figure C.1 Psychrometric chart showing the derivation of relative humidity from temperature and vapour pressure



Point A represents a given volume of air at temperature 2 °C with a vapour pressure of 0.60 kPa: its relative humidity is therefore 90%.

Point B represents that same volume of air, with the same moisture content (and, therefore, the same vapour pressure) but heated to 20 °C; its relative humidity will now be approximately 24%. This illustrates what happens when outside air enters a building and is warmed.

Point C indicates that same volume of air at 20 °C, to which moisture has been added to bring its vapour pressure to about 1.4 kPa. That increase in moisture with no change in temperature means the relative humidity of the air has increased to about 60%. This illustrates what happens when that warmed incoming air absorbs moisture from activities within a building, but is not heated.

Point D illustrates that saturation of that air will occur if it is cooled to its dewpoint temperature of about 11.9 °C; any further reduction in temperature will result in condensation occurring.

Point E on the chart indicates that 80%rh will occur if the temperature of the given volume of air falls to approximately 15 °C. The risk of mould growth occurring when relative humidity at a surface reaches 80%, as described in **A.5**. This illustrates that designing to avoid surface mould growth is more onerous than designing to avoid condensation.

Equations C.1 to C.10 may be used to model the behaviour of water vapour in air inside and outside buildings; the most important relationship is that between air temperature T and saturation vapour pressure SVP. In the following equations vapour pressure is expressed in kilopascals (kPa) ¹⁾.

Equation C.1 and Equation C.2 are used in BS EN ISO 13788 to produce a close approximation to the SVP over the normal range of temperatures found in UK buildings. They may be inverted to calculate dewpoint from vapour pressure (see Equation C.3 and Equation C.4).

¹⁾ To convert kPa to millibars (mb) multiply by 10.

$$\text{SVP} = 0.6105 \exp\left(\frac{17.269T}{237.3 + T}\right) \quad (\text{for } T \geq 0^\circ \text{C}) \quad (\text{C.1})$$

$$\text{SVP} = 0.6105 \exp\left(\frac{21.875T}{265.5 + T}\right) \quad (\text{for } T < 0^\circ \text{C}) \quad (\text{C.2})$$

where:

T is the dry bulb temperature in $^\circ\text{C}$.

NOTE The figure 237.3 in Equation C.1 is correct, it is not to be confused with the figure 273.3 used to convert degrees centigrade to Kelvin.

To calculate dewpoint T_{dp} from vapour pressure p in kPa:

$$T_{\text{dp}} = \frac{237.3 \log_e\left(\frac{p}{0.6105}\right)}{17.269 - \log_e\left(\frac{p}{0.6105}\right)} \quad (\text{for } p \geq 0.6105 \text{ kPa}) \quad (\text{C.3})$$

$$T_{\text{dp}} = \frac{265.5 \log_e\left(\frac{p}{0.6105}\right)}{21.875 - \log_e\left(\frac{p}{0.6105}\right)} \quad (\text{for } p < 0.6105 \text{ kPa}) \quad (\text{C.4})$$

To calculate vapour pressure p from dry bulb temperature T_d and percentage relative humidity φ .

$$p = \text{SVP}(T_d) \times \frac{\varphi}{100} \quad (\text{C.5})$$

where:

$\text{SVP}(T_d)$ is the saturated vapour pressure at the dry bulb temperature calculated from Equation C.1 or Equation C.2.

To calculate vapour pressure from dry bulb T_d and wet bulb T_w temperatures:

$$p = \text{SVP}(T_w) - AP(T_d - T_w) \quad (\text{C.6})$$

where:

$\text{SVP}(T_w)$ is the saturated vapour pressure at the wet bulb temperature calculated from Equation C.1 or Equation C.2.

A is a constant equal to 0.000 666

P is the total atmospheric pressure in kPa

Equation C.6 can usually be simplified by assuming that $P = 100$ kPa giving:

$$p = \text{SVP}(T_w) - 0.0667(T_d - T_w) \quad (\text{C.7})$$

To calculate percentage relative humidity from dry bulb temperature T_d and vapour pressure p :

$$\varphi = 100 \frac{p}{\text{SVP}(T_d)} \quad (\text{C.8})$$

where:

$\text{SVP}(T_d)$ is the saturated vapour pressure at the dry bulb temperature calculated from Equation C.1 or Equation C.2.

To calculate the moisture content of the air v , in g/m³, from vapour pressure p , in kPa:

$$v = \frac{2170p}{T_d + 273.3} \quad (\text{C.9})$$

where:

T_d is the dry bulb temperature in °C.

To calculate the moisture content of the air x , in g/kg of dry air, from vapour pressure p , in kPa:

$$x = \frac{622p}{P - p} \quad (\text{C.10})$$

where:

P is the total atmospheric pressure in kPa.

Annex D (normative)

D.1

Calculating condensation risk

General

BS EN ISO 13788 contains recommended procedures for the assessment of the risk of:

- *mould growth;*
- *surface condensation;*
- *interstitial condensation.*

D.2 Mould growth and surface condensation

If the relative humidity of the air in a room exceeds 70%, the surface relative humidity of an external element is likely to exceed 80%. If that occurs for more than two or three days, mould is likely to develop on the surface. Surface relative humidity is determined by the internal vapour pressure and the surface temperature of the external element, which depends upon the nature of the construction. The presence of thermal bridges such as those around doors and windows produces lower local temperatures.

BS EN ISO 13788 contains a method for calculating monthly mean surface temperatures of a building element or component given internal and external temperatures, which can be combined with information on moisture production and ventilation rate to calculate the surface relative humidity. The method uses three parameters, together with external climate data, to determine the risk of mould growth and surface condensation, those parameters are:

- a) the internal moisture supply (see **D.3.3**);
- b) the internal air temperature;
- c) the temperature factor of the internal surface f_{Rsi} , which takes account of the thermal resistance and geometry of the materials present and the internal surface resistance R_{si} (see Table E.5); f_{Rsi} is defined by Equation D.1.

$$f_{Rsi} = \frac{\theta_{si} - \theta_e}{\theta_i - \theta_e} \quad (\text{D.1})$$

where:

θ_i is the internal air temperature in °C;

θ_e is the external air temperature in °C;

θ_{si} is the temperature of the internal surface in °C.

The design requirements for avoidance of mould growth are more onerous than those for the avoidance of surface condensation.

The principal steps in the design procedure are to determine, for each month of the year:

- 1) the internal air vapour pressure;
- 2) the vapour pressure p_{sat} at the surface, which will result in a surface relative humidity not greater than 80%;
- 3) the minimum surface temperature and hence the required temperature factor f_{Rsi} of the building envelope.

D.3 Assessment methods

D.3.1 Principles

D.3.1.1 General

Moisture can enter a structure from a number of sources and be transported by a number of mechanisms (see **A.1**, **A.2** and **A.3**). The most appropriate of the four approaches described in **D.3.1.2** to **D.3.1.6** should be used to identify and minimize the risks of moisture problems in specific construction details.

The selection of the appropriate approach to use in any situation should be guided by the principles described in Annex A, the nature of the materials as existing in the building and to be used, the use and condition of the building and the external environment to which it is exposed.

NOTE These approaches can supplement a principles-based understanding, but not replace it. They can be regarded as a hierarchy of increasing complexity requiring more complex input data and understanding to implement.

D.3.1.2 Prescriptive guidance.

In many cases the recommendations in Annexes F, G and H, which are based on practical experience, which are sufficient to provide robust designs to minimise moisture problems, should be followed without the need for any further analysis.

D.3.1.3 Simplified modelling to BS EN ISO 13788

COMMENTARY ON D.3.1.3

BS EN ISO 13788 describes a method (known as the “Glaser method”) for predicting the risk of interstitial condensation occurring under specified environmental conditions. The method indicates how much condensate will be deposited, how much will evaporate and any balance which might accumulate year on year. The method uses monthly mean external conditions to calculate the amount of condensate deposited and/or evaporated in each of 12 months, following the first predicted occurrence of condensation.

The method is a useful assessment tool, suitable for comparing different constructions and assessing the effects of design changes. It assumes one-dimensional, steady state conditions and does not consider air movements within or through the construction and makes no allowance for the moisture in the materials or rainwater absorbed during construction. Consequently, while it is useful for comparing the performance of different structures, it does not provide an accurate prediction of moisture conditions within the structure under service conditions.

Tables F.1, G.1 and H.1 should be consulted for the types of floor, wall and roof where it is appropriate to use the BS EN ISO 13788 method.

D.3.1.4 Full modelling to BS EN 15026**COMMENTARY ON D.3.1.4.**

BS EN 15026 specifies a system of equations for calculating one-dimensional, non-steady heat and moisture flows through a structure made up of a number of different materials, each with complex transport properties. This takes account of heat storage in dry building materials and also absorbed water, heat transport by moisture-dependent thermal conduction, latent heat transfer by vapour diffusion, moisture storage by vapour sorption and capillary forces, moisture transport by vapour diffusion, and moisture transport by liquid transport (surface diffusion and capillary flow). The following climatic variables are used as input: internal and external temperature, internal and external humidity, solar and longwave radiation, precipitation (normal and driving rain), and wind speed and direction. It is important to note that BS EN 15026 does not allow for airflow through components, which can be the dominant mechanism for moisture movement in some structures. The model proposed is a one dimensional model which cannot deal with interfaces and junctions, where many moisture problems commonly arise. It is also important to note that there is currently no background guidance for the use of BS EN 15026:2007 and that its correct use requires expertise as well as an understanding of the principles underlying moisture movement in buildings and the specific context and condition of the building, or building element being assessed.

In those cases where the approaches described in **D.3.1.1**, **D.3.1.2** and **D.3.1.3** cannot be used, full modelling to BS EN 15026 should be used.

D.3.1.5 Structures whose performance is dominated by air movement**COMMENTARY ON 3.1.5**

*The performance of certain structures is dominated by the transport of moisture by air movement from within the building into the structure. Neither of the methods described in sections **D.3.1.3** and **D.3.1.4** take account of air movement.*

In these cases the prescriptive guidance described in **D.3.1.2** should be followed; if necessary, this should be backed up by the non-standardized modelling described in **D.3.1.6**.

NOTE More complex two- and three-dimensional models of heat, air and moisture movement in building structures are available, which have not been standardized. Interfaces and effects at junctions can be examined, and air flows through building structures can be calculated using methods such as computational fluid dynamics (CFD) modelling. These methods are very difficult to specify and implement and need input from research staff from universities, or from specialized consultants. In many cases the results from these methods do not give a clear cut pass or fail, but require interpretation based on a full understanding of the nature of the structure and the processes involved. 

D.3.2 External climatic data**D.3.2.1 Walls, roofs and exposed floors**

The calculation method described in BS EN ISO 13788 requires monthly mean external temperature and vapour pressure data. Monthly mean temperature data for many locations may be obtained relatively easily, but vapour pressure data are much more difficult to obtain. The most useful source is the CD ROM *International Station Meteorological Climate Summary, Version 3.0* available from the US National Climate Data Centre, which contains information from many weather stations around the world, including 43 in the UK. Table D.1 summarizes mean temperatures and relative humidities (calculated from the mean temperature and mean vapour pressure) for London, Manchester and Edinburgh.