GLC BULLETIN 142

ITEM 8 (COMMITTEE DATE 5/84)

Condensation: prevention better than cure

ABSTRACT

This item describes in detail a computer-based technique for predicting the risk of condensation occurring in building structures. The technique has been devised by an architect on the staff of the Technical Policy Division of the Department of Architecture and Civic Design who is available to other members of staff for consultation on this and related problems. The technique not only indicates the position at which condensation is likely to occur, but also puts a figure on the risk of decay in timber within the structure. In the case of ventilated roofs or walls it gives the minimum sizes for ventilation openings.

INTRODUCTION

This article is a summary of a procedure for avoiding risks from condensation in buildings, arrived at as the result of the author being forced to deal with this problem from time to time over the last 25 years.

Two immediate points: the mere occurrence of any condensation is not necessarily a disaster; if there is occasionally some on a window pane (provided there is a window cill to catch it) this is not a defect, nor is it a defect when some water vapour condenses, say, in the outer brick leaf of a cavity wall which will in any case become wet from driving rain. Conversely, where timber is involved in any form of construction, even high relative humidities without actual condensation may lead to unacceptably high moisture contents.

We therefore need a concept of *harmful condensation* which needs to be avoided with a view to overall economy.

HARMFUL CONDENSATION

Some of the harmful effects of condensation include:

- ☐ loss of insulation properties
- ☐ rot
- ☐ corrosion
- ☐ mould growth
- ☐ loss of structural strength
- ☐ liberation of chemicals
- ☐ migration of salts
- ☐ dimensional changes
- ☐ electrical failure.

Harmful condensation is any which may cause damage to the building fabric or its contents.

AVOIDANCE OF CONDENSATION

The avoidance of surface condensation is very simple, in principle: heating and ventilation — and building users who employ them — are usually all that is required.

Unfortunately heating buildings and the air for their ventilation costs money, which is why users do not employ enough for either purpose and why we often have a problem in practice.

Permanent ventilation

To reduce heating costs arising for ventilation losses, draughtstripping has been invented and has found widespread use. If it is too effective it may reduce ventilation to such an extent that harmful increases in internal moisture content combined with higher odour levels are introduced. To overcome these side effects, trickle ventilators are introduced. As a rule of thumb, and for the case of dwellings where the bulk of condensation problems exist, trickle ventilators should permanently provide about 10 mm^2 opening for each m^3 of room volume in living rooms and bedrooms, and 20 mm^2/M^3 for bathrooms and kitchens, which should also be provided with local extract fans.

Insulation

To reduce heating costs arising from fabric losses, higher insulation standards are employed. These are governed either by the maximum U-values set by building regulations or by economically justifiable lower U-values, for which an increasing case can be made in an era when fuel costs are rising faster than general inflation.

Current legal, or lower, U-values almost always mean multi-layer constructions, of which one layer is a specific insulating material. As the vast majority of building materials and insulants are vapour permeable, condensation may occur within the structure — interstitial condensation.

Assuming that cold bridges are avoided, surface condensation is usually not a problem during periods of occupation in new constructions employing current U-values — provided they are heated and ventilated to comfort levels.

Setback heating

Few buildings are used and heated 24 hours a day, every day, and intermittent heating rules the day (or night, or weekend, as the case may be). What is the background heating required during unoccupied times to maintain the fabric? To avoid mould growth problems (which start above 75%RH), ie long before condensation may arise, the setback temperature is given by allowing the relative humidity reached during occupied times to rise to 75%. Assuming, in the case of occupied dwellings conditions of 20°C/60%RH, this gives a setback temperature of about 16°C; in the case of schools (occupied conditions 19°C/40%RH), the setback temperature is about 10°C. Such setback temperatures are conveniently established by use of a psychrometric chart, as for example in BS 5250.

Owner/user conflicts, fuel poverty

Every building owner should maintain such setback temperatures in the interest of maintaining his building fabric. Where owner and user are one and the same person, this should not be too great a problem once it is understood. But in rented accommodation the fabric owner usually has no say in the matter — the most popular form of heating being individually tenant-controlled. Compound this with low household income and heating is an adjustable expense, and savings may be made by reducing it. Summarised in the term 'fuel poverty', there may not only be little comfort but also increased damage to the fabric. Only investment in high levels of insulation can alleviate this problem.

Existing buildings

The problem is further compounded by the majority of building stock consisting of structures erected before U-values had entered anyone's vocabulary, let alone construction practice. Retrofit insulation is called for.

NEED FOR PREDICTION AT DESIGN STAGE

It is the current increased experimentation with higher insulated building enclosures, whether new or retrofit, which led the author to concentrate on predictive methods to avoid problems of interstitial condensation which may all too easily be introduced in this connection.

The method of prediction

Predictive methods need to be as simple and practicable as possible while not oversimplifying an inherently complex inter-relationship of humidity, temperatures and ventilation. BS 5250, first issued in 1975, gave the basis of steady state analysis of condensation risks. In 1982, BS 6229 arrived to deal with condensation problems associated with flat roofs by adding quantitative condensation predictions to the state of the art, at least for 'warm roofs'.

It is this latter approach which is capable of expansion to deal with all forms of construction — walls, roofs, floors — in similar manner. While the arrival of pocket calculators made it possible to perform the necessary calculations with relative ease, it is the arrival of cheap computing which now makes it possible to consider further calculation procedures.

So as not to repeat what is already available, I have taken the principles of condensation predictions as given in the appendices to BS 5250 and BS 6229 as already accepted and as the starting point from which to expand. Reliable quantitative predictions of winter condensation and summer evaporation for the purposes of assessing risks may be obtained by calculating these quantities over 60 days each, using the January and August means of temperatures and relative humidities applicable to the location of the building in question (Table 1).

To give safety from condensation over the years, one condition to be satisfied is that summer evaporation must equal or exceed the amount of winter condensation.

Harmful condensation

The nature of the two materials adjoining any interface at which condensation is calculated to occur determines whether this condensation is harmful or not. BS 6229 proposes some upper limits and related considerations.

A special case is timber, where risks are more appropriately assessed by calculating the equilibrium moisture content (emc) from temperature and vapour pressure.

A suitable equation for this is:

$$\ln(\text{emc}) = 1.24 + 2.3\,(10 \times V_p) \times \exp[-(1.96 + 0.069t)] \quad (1)$$

where:

ln	is the natural logarithm
V_p	is the vapour pressure in kPa with the proviso that in a condensation plane the actual vapour pressure is the saturation vapour pressure V_{ps} to be used in lieu of V_p
t	is the temperature in °C
exp	= 2.7182818

Condensation quantity

A condensation plane is any interface between two materials at which the theoretically predicted vapour pressure (V_p') is higher than the possible saturated pressure (V_{ps}) determined by the temperature at the interface. There may be more than one condensation plane in multi-layer constructions, identified by any interface where $V_p' > V_{ps}$.

When counting interfaces of materials from 1 to n, and the number of identified condensation planes from c_1 to c_f, the equations for assessing the amounts of condensation are:

$$q_{c1} = s \times 10^{-6} \left\{ \frac{(p_i - ps_{xc1})}{\sum_{1}^{xc1} R_{vx}} - \frac{(ps_{xc1} - ps_{xc2})}{\sum_{(x-1)c1}^{xc2} R_{vx}} \right\} \quad (2a)$$

$$q_{c2} = s \times 10^{-6} \left\{ \frac{(ps_{xc1} - ps_{xc2})}{\sum_{(x-1)c1}^{xc2} R_{vx}} - \frac{(ps_{xc2} - ps_{xc3})}{\sum_{(x-1)c2}^{xc3} R_{vx}} \right\} \quad (2b)$$

$$q_{c3} = s \times 10^{-6} \left\{ \frac{(ps_{xc2} - ps_{xc3})}{\sum_{(x-1)c2}^{xc3} R_{vx}} - \frac{(ps_{xc3} - ps_{xc4})}{\sum_{(x-1)c3}^{xc4} R_{vx}} \right\} \quad (2c)$$

$$q_{cf} = s \times 10^{-6} \left\{ \frac{(ps_{xc(f-1)} - ps_{xcf})}{\sum_{(x-1)c(f-1)}^{xcf} R_{vx}} - \frac{(ps_{xcf} - p_e)}{\sum_{(x-1)c1}^{n} R_{vx}} \right\} \quad (2d)$$

$$q = \sum_{q_{c1}}^{q_{cf}} q_c \quad (3)$$

Evaporation, however, can only occur from the two outermost condensation planes, so that

$$E = s \times 10^{-6} \left\{ \frac{(ps_{xc1} - p_i)}{\sum_{1}^{xc1} R_{vx}} + \frac{(ps_{xcf} - p_e)}{\sum_{cf}^{n} R_{vx}} \right\} \quad (4)$$

In the case of a single identified condensation plane:

$$q = s \times 10^{-6} \left\{ \frac{(p_i - ps_{xc1})}{\sum_{1}^{xc1} R_{vx}} - \frac{(ps_{xc1} - p_e)}{\sum_{(x-1)c1}^{n} R_{vx}} \right\} \quad (5)$$

$$E = s \times 10^{-6} \left\{ \frac{(ps_{xc1} - p_i)}{\sum_{1}^{xc1} R_{vx}} + \frac{(ps_{xc1} - p_e)}{\sum_{xc1}^{n} R_{vx}} \right\} \quad (6)$$

where:

- q_{c1} — the amount of condensate at condensation plane 1, in g/m^2
- s — the condensation period, in seconds. For 60 days $s = 5.184 \times 10^6$.
- p_i — the internal vapour pressure
- p_e — the external vapour pressure
- ps_x — the saturated vapour pressure at interface X
- E — the amount of evaporation, in g/m^2

reading (for example):

- ps_{xc3} — the saturated vapour pressure at interface X which constitutes condensation plane number 3.
- $\sum_{(x-1)c2:}^{xc3} R_{vx}$ — the sum of vapour resistances between one layer before condensation plane 2 and condensation plane 3.

The conditions to be statisfied are:

1 $E \geq q$

2 material limits not to be exceeded.

TYPES OF CONSTRUCTION

Generalised descriptions of enclosure types suitable for walls, roofs or floors are as follows:

TYPE A constructions: all those which do not contain any airspaces (voids or cavities).

TYPE B constructions: those containing voids of cavities which are ventilated (by external air).

TYPE C constructions: those which contain unventilated voids or cavities.

The above equations hold for all TYPE A and TYPE C constructions where all layers figure in all equations.

TYPE B constructions are different because of the introduction of a ventilated void or cavity. Recourse to the equations for unsealed joints in BS 6229 will show, when allowing for the typical size of ventilation openings required, say, for pitched roofs under the Building Regulations, that the compound resistance of any layers beyond the ventilated void or cavity is practically zero. All that is necessary, therefore, is to set the vapour resistances of ventilated voids or cavities and of all layers beyond to zero in the equations for condensation or evaporation given above. They will then remain valid also for TYPE B constructions.

ESCAPE OF MOISTURE FROM THE VOID

What happens to the vapour that migrates from the inside towards the void? We know what is supposed to happen, namely that the ventilation by external air will carry it away without condensation in the void or cavity.

The condition to be satisfied can then be stated in the form that the amount of vapour migrating through the inner leaf must be mixed with sufficient external air so that the carrying capacity of the incoming air is not exceeded. The carrying capacity is then given by the difference in moisture content of average winter air and its saturation moisture content.

The moisture content of air can be calculated with sufficient accuracy by

$$M_e = (624.7308 \times V_p) \times (101.325 - V_p)^{-1} \quad (7)$$
$$M_{se} = (624.7308 \times V_{ps}) \times (101.325 - V_{ps})^{-1} \quad (8)$$

where:

- M_e — moisture content of external air calculated from its temperature and relative humidity, in g/kg of dry air
- M_{se} — moisture content of saturated air at the external temperature, in g/kg of dry air
- V_p — vapour pressure
- V_{ps} — saturated vapour pressure.

The amount of vapour reaching the cavity from the inside is given by

$$q = 3.594 \times (p_i - p_e) / (\sum_{1}^{n'} R_v) \quad (9)$$

where:

- q — the amount of vapour diffusing through 1 m^2 in g/m^{2}h
- p_i — the internal vapour pressure in kPa
- p_e — the external vapour pressure in kPa
- n' — the number of layers from inside to cavity

The amount of air required to carry that vapour away within the limits of its carrying capacity is then given by

$$Q_c = q \times A \times 1.2^{-1} \times (M_{se} - M_e)^{-1} \quad (10)$$

Flow chart of activities

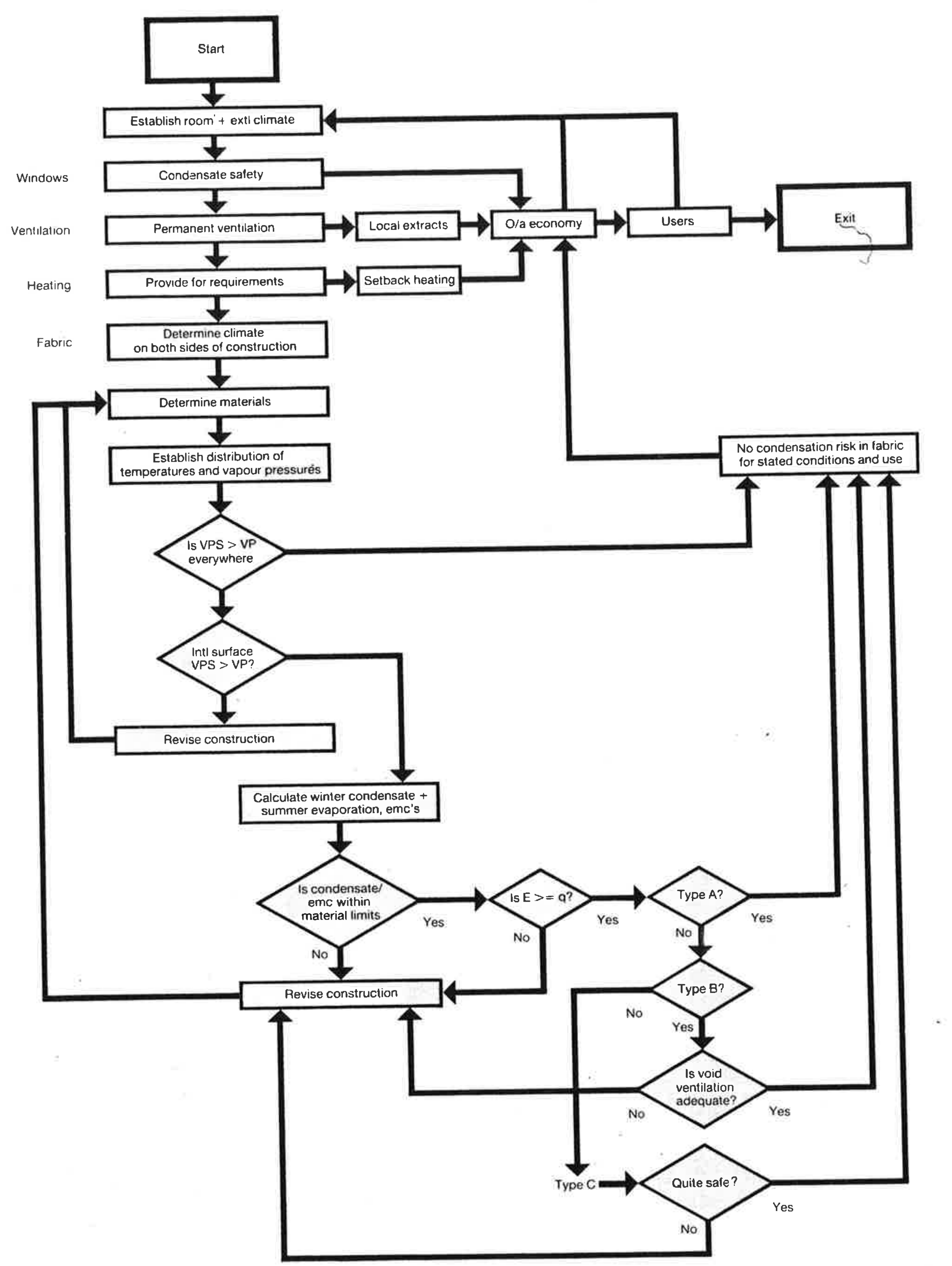

Fig 1:

<Fig 1: Flowchart of activities

where:

Q_c — ventilation rate in m^3/h

q — quantity of vapour penetrating the inner leaf in g/m^2h

A — the area of the fabric element under consideration in m^2

Relying on natural forces to provide this required ventilation rate, the two available driving forces are:

1 wind driven ventilation
2 temperature stack driven ventilation.

BS 5925 gives appropriate equations for both of these.

Reference wind speeds calculated for use with this method of calculating condensation are given in Table 2.

EXAMPLES

Fig 1: Flowchart of activities
This gives an overview of the steps involved in preventing condensation. It will be seen that overall economy and user requirements and behaviour form as much a part of the initial design brief as they do ultimately in preventing condensation. 'Mis-use', that is practical usage of buildings significantly differing from those that were part of the design brief or user's handbook, can nullify any prediction, however correct at the time.

Fig 2 - 5: Calculated example: Duo-pitch roof
No roof is allowed to be constructed without cross-ventilation, according to the building regulations. Adequate ventilation of the roof void forms, therefore, part of the initial assumption.

Figs 2 and 3 show the winter and summer distribution of temperatures and vapour pressures throughout the roof. No condensation is indicated.

Fig 4 shows the minimum eaves ventilation slots for the inner city location and two-storey terraced house with 30° pitch roof chosen. The result of 21.5 mm is practically equivalent to the 20 mm minimum width empirically adopted by the GLC some eight years ago.

Fig 5 shows the required ventilation opening sizes if ridge ventilation is planned, with ridge ventilation equivalent to half the size of eaves vents. Eaves ventilation is always to be provided on opposite sides of the roof, in size equal to each other and each to the calculated amount shown.

Fig 6 - 10: Calculated example: Timber-frame wall
Building type and location are the same as in the roof example.

Figs 6 and 7 assume that the cavity is not ventilated and show the distribution of temperatures and vapour pressures through the wall in winter and summer respectively. A small amount of condensation is indicatd on the inner face of the plywood, together with a winter

Table 1 UK climate
Averages of temperature and humidity for Great Britain and Northern Ireland, 1961-70 (Calculated from Climatological Memorandum 103, Met Office, 1976)

Location	National Grid Reference	Altitude m	January t°C	January RH (%)	August t°C	August RH (%)
Scotland East:						
Aberdeen/ Dyce Airport	38/883125	58	2.2	93.9	12.8	82.8
Edinburgh/ Turnhouse Airport	36/159739	35	2.6	90.2	13.6	81.5
Scotland West:						
Glasgow/ Abbotsinch Airport	26/480667	5	3.1	91.3	14.0	81.8
England East & North East:						
Acklington	46/225007	42	2.8	91.6	13.5	85.5
Whitby	45/904115	60	3.5	90.2	13.3	85.5
East Anglia:						
Cardington	52/081464	29	2.6	93.4	15.4	79.5
Shoeburyness	51/948857	2	3.4	91.3	16.0	81.0
Stansted Airport	52/531226	101	2.3	94.4	15.3	79.3
Midland Counties:						
Abingdon	41/479991	69	2.8	92.3	15.7	77.5
Birmingham/ Elmdon Airport	42/176839	96	2.6	92.6	15.2	78.0
Gloucester	32/851179	23	3.7	90.9	16.2	77.8
England South East & Central Southern:						
Dungeness	61/091171	3	4.0	92.0	16.4	83.3
Gatwick Airport	51/265407	59	2.7	93.4	15.4	82.5
Kew	51/171757	8	3.9	88.9	16.4	75.5
London/ Heathrow Airport	51/077767	25	3.3	91.7	16.5	76.0
England North West						
Liverpool/Speke Airport	33/436821	22	3.6	90.6	15.4	79.0
Manchester/ Ringway Airport	33/821849	75	3.0	90.6	14.9	77.5
North Wales:						
Valley	23/310758	10	4.8	90.9	14.8	85.5
South Wales:						
Glamorgan/ Rhoose Airport	31/064679	67	3.7	93.0	15.2	83.3
Milford Haven	12/892054	37	6.1	90.9	15.6	84.5
England South West:						
Bournemouth/ Hurn Airport	40/117978	10	3.7	92.0	15.7	80.8
Plymouth/ Mountbatten	20/492529	27	5.4	92.3	15.4	86.0
Scilly/St Mary's	00/913121	48	7.5	89.2	15.6	88.3
Northern Ireland:						
Belfast/ Aldergrove Airport	33/147798	68	3.5	92.7	13.8	84.0

Note: January given values approximate to 75% of time for the ten-year period covered. August given values are mean averages of six-hourly values.

Table 2 Wind speeds for use in calculating wind driven ventilation rates

Terrain categories
1 Open flat country (cliffs and hills)
2 Rural with few wind breaks
3 Urban
4 Inner cities

Reference wind speeds:

Height above ground m	Ur 1 m/s	2 m/s	3 m/s	4 m/s
1	2.14	1.64	1.11	0.67
2	2.41	1.88	1.31	0.83
3	2.58	2.04	1.45	0.95
4	2.71	2.16	1.56	1.04
5	2.81	2.26	1.65	1.13
6	2.91	2.35	1.73	1.20
7	2.98	2.42	1.79	1.26
8	3.05	2.49	1.86	1.32
9	3.12	2.54	1.91	1.37
10	3.17	2.60	1.96	1.41
15	3.40	2.81	2.17	1.62
20	3.56	2.98	2.33	1.78
25	3.70	3.12	2.46	1.91
30	3.82	3.23	2.58	2.03

Note: For pitched roofs the height above ground is the mean between eaves and ridge height

moisture content of timber at that location of 25.5%. The summer-on-winter balance is more than safe, but the indicated risk is not acceptable if the risks of 'wet occupancy' (see BRE Information Paper IP 21/82) are to be covered — as they ought to be because there is no safe way of knowing usage over the life of the building.

To eliminate this risk, recourse might be had to changing the plywood sheathing to impregnated fibreboard with lower vapour resistivity. Cavity ventilation has been chosen in this example.

Figs 8 and 9 show the winter and summer results of the same construction with cavity ventilation. Condensation is no longer indicated and winter 'emc' has dropped to 23.1% at the mineral wool/plywood interface, but this level will only be reached periodically and is unlikely to lead to practical difficulties when compared with the summer value of 14.4%.

Fig 10 shows the required amount of cavity ventilation. This is to be provided separately at the top and bottom of each storey height due to the fire-stopping at floor levels blocking the cavity. In the central London location chosen, this works out at every fifth perpend required to be left open in one course each at the top and bottom of each storey when using stretcher bond. (In other parts of the UK these requirements will differ; in fact, calibrating the calculation method to the vagaries of UK weather was more complicated than originally thought — resolved through Table 1. Scandinavian or Canadian precedents or rules-of-thumb are most misleading for UK conditions.)

POSTSCRIPT

The procedures and opinions outlined above are the author's and not necessarily GLC policy, though the method is currently in use, and available to all Council staff in the Technical Policy Division of the department. They are also part of the author's proposals for the revision of BS 5250.

Fig 2 Duo-pitch roof — winter

Job:	Example	Terrain:	Inner city
Item	Duo-pitch roof	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 1: Winter condensation

Climate:

	air temp (deg C)	RH (%)	V_p (kPa)	V_{ps} (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	Description	Lx (m)	kx W/mK	rvx GNs/Kg-m)	tx (deg C)	Vpx (kPa)	Vpsx (kPa)	
-	inside air				20.000	1.401	2.335	
-	surface res				19.430	1.401	2.254	ok
1	Plasterboard	0.013	0.160	52.000	18.967	1.039	2.190	ok
2	Mineral wool	0.100	0.040	6.000	4.722	0.717	0.855	ok
3	Void vent'd	0.600	6.000	0.000	4.153	0.717	0.821	ok
4	Shthg felt	0.001	1.000	0.000	4.147	0.717	0.821	ok
5	Conc tiles	0.020	1.500	0.000	4.071	0.717	0.816	ok
-	surface res				3.900	0.717	0.807	ok
-	ext air				3.900	0.717	0.807	

U - Value (BS 5250) — 0.354 W/m²K

Condensation Quantities		kg/m² during 60 days	at interface:	emc of timber (if any)
at intl surface	ok	0.000		11.3%
at interface 1/2	ok	0.000	1/2	8.6%
2/3	ok	0.000	2/3	18.5%
3/4	ok	0.000	3/4	19.8%
4/5	ok	0.000	4/5	19.8%
5/6	ok	0.000	5/6	20.0%
at extl surface	ok	0.000		20.0%
Total condensate:		0.000 kg/m²	0.000 kg/m²	

Check calculated condensate against material tolerances (Table 3.12) at each interface! Check 'emc' of timber!

Fig 3 Duo-pitch roof — summer

Job:	Example	Terrain:	Inner city
Item	Duo-pitch roof	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 2: Summer evaporation

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)
Internal	20.0	60.0	1.401	2.335
External: Winter	3.9	88.9	0.717	0.807
Summer	16.4	75.5	1.406	1.863

Layer no	Description	Lx (m)	kx W/mK	rvx GNs/Kg-m)	tx (deg C)	Vpx (kPa)	Vpsx (kPa	
-	inside air				20.000	1.401	2.335	
-	surface res				19.873	1.401	2.317	ok
1	Plasterboard	0.013	0.160	52.000	19.769	1.404	2.302	ok
2	Mineral wool	0.100	0.040	6.000	16.584	1.406	1.885	ok
3	Void vent'd	0.600	6.000	0.000	16.456	1.406	1.870	ok
4	Shthg Felt	0.001	1.000	0.000	16.455	1.406	1.869	ok
5	Conc tiles	0.020	1.500	0.000	16.438	1.406	1.867	ok
-	surface res				16.400	1.406	1.863	ok
-	ext air				16.400	1.406	1.863	

U - value (BS 5250) — 0.354 W/m²K for other purposes different surface resistances may apply)

Condensation quantities		kg/m² during 60 days Winter:	emc of timber (if any) Winter	Summer:	Evaporation: kg/m² 60 days Summer:
at intl surface	ok	0.000	11.3%	10.9%	0.000
at interface 1/2	ok	0.000	8.6%	11.1%	0.000
2/3	ok	0.000	18.5%	14.7%	0.000
3/4	ok	0.000	19.8%	14.9%	0.000
4/5	ok	0.000	19.8%	14.9%	0.000
5/6	ok	0.000	20.0%	15.0%	0.000
at extl surface	ok	0.000	20.0%	15.0%	0.000

Total condensate: 0.000 kg/m² Total evaporation 0.000 kg/m²

Annual balance: 0.000 kg/m² Compare evaporation to condensation at each interface! Totals alone may not reflect interface conditions!

Fig 4 Calculation of ventilation required at the eaves of pitched roof

Job:	Example	Terrain:	Inner city
Item	Duo-pitch roof	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 3 (A): Type 'B' construction: wind driven ventilation
Note: all calculations apply to 1 m width of construction.

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	description	Lx (m)	Kx W/mK	rvx (GNs/kgm)	Rvx (GNs/kg)	SumxRvx (GNs/kg)
1	Plasterboard	0.013	0.16	52.000	0.676	0.676
2	Mineral Wool	0.100		6.000	0.600	1.276

The amount of vapour migrating through the inner skin into the ventilated void
q — 1.9270 g/m²h (Winter)
q¹ — - 0.0146 g/m²h (Summer)

The equilibrium moisture content of timber in or bordering the void is
emc — 20.39% (Winter)
emc — 15.02% (Summer)

The amount of ventilation required for a depth of
10.00 m is Qc — 28.65 m³/h (Winter)

When the reference wind speed Ur — 1.26 m/s
When the ridge/eave (1) ratio G — 0.00 (enter 0 if no ridge ventilation)

When: Cpe(1) — 0.10 (positive eave coefficient) Then: Cpi — - 0.13
Cpe(2) — - 0.35 (negative eave coefficient)
Cpe(3) — - 1.20 (ridge coefficient; always state)

Then: the required vent opening at each eave is equivalent to a continuous slot of 21.6 mm at each eave;
The required vent opening at the ridge is equivalent to a continuous slot of 0.0 mm at the ridge
Note: minimum equivalent slot width at eaves is 10 mm, use calculated value if higher.

Fig 5 Calculation of ventilation required at the eaves of pitched roof

Job:	Example	Terrain:	Inner city
Item	Duo-pitch roof	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 3 (A): Type 'B' construction: wind driven ventilation
Note: all calculations apply to 1 m width of construction.

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	description	Lx (m)	Kx W/mK	rvx GNs/kgm)	Rvx (GNs/kg	SumxRvx (GNs/kg
1	Plasterboard	0.013	0.16	52.000	0.676	0.676
2	Mineral wool	0.100		6.000	0.600	1.276

The amount of vapour migrating through the inner skin into the ventilated void
q — 1.9270 g/m²h (Winter)
q' — - 0.0146 g/m²h (Summer)

The equilibrium moisture content of timber in or bordering the void is
emc — 20.39% (Winter)
emc' — 15.02% (Summer)

The amount of ventilation required for a depth of
10.00 m is Qc — 28.65 m³/h (Winter)

When the reference wind speed Ur — 1.26 m/s
When the ridge/eave (1) ratio G — 0.50 (enter 0 if no ridge ventilation)

When: Cpe(1) — 0.10 (positive eave coefficient) Then: Cpi — - 0.32
Cpe(2) — - 0.35 (negative eave coefficient)
Cpe(3) — - 1.20 (ridge coefficient; always state)

Then: the required vent opening at each eave is equivalent to a continuous slot of 16.0 mm at each eave
the required vent opening at the Ridge is equivalent to a continuous slot of 8.0 mm at the ridge
Note: minimum equivalent slot width at eaves is 10 mm, use calculated value if higher.

Fig 6 Accumulation of moisture in a timber-frame wall having a sealed cavity during winter

Job:	Example	Terrain:	Inner city
Item	Timber-frame wall	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 1: Winter condensation

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	description	Lx (m)	kx W/mK	rvx GNs/kgm)	tx (deg C)	Vpx (kPa)	Vpsx (kPa	
-	inside air				20.000	1.401	2.335	
-	surface res				19.425	1.401	2.254	ok
1	Duplex board	0.013	0.160	1153.846	18.958	0.975	2.189	ok
2	Mineral wool	0.089	0.040	6.000	6.167	0.960	0.945	**cond**
3	Plywood	0.009	0.140	500.000	5.797	0.832	0.921	ok
4	Breather	0.001	1.000	100.000	5.792	0.830	0.921	ok
5	Cvty not Vtd	0.050	0.278	5.200	4.757	0.822	0.857	ok
6	Brickwork	0.100	0.840	37.000	4.072	0.717	0.816	ok
-	surface res				3.900	0.717	0.807	ok
-	ext air				3.900	0.717	0.807	

U - Value (BS 5250) — 0.357 W/m²K

Condensation quantities		kg/m² during 60 days	at interface:		emc of timber (if any)
at intl surface	ok	0.000			11.3%
at interface 1/2	ok	0.000	1/2		8.1%
2/3	**cond**	0.014	2/3	0.014	25.5%
3/4	ok	0.000	3/4		21.1%
4/5	ok	0.000	4/5		21.0%
5/6	ok	0.000	5/6		23.5%
6/7	ok	0.000	6/7		20.0%
at extl surface	ok	0.000			20.0%
Total condensate:		0.014 kg/m²	0.014 kg/m²		

Check calculated condensate against material tolerances (Table 3.12) at each interface! Check 'emc' of timber!

Fig 7 Evaporation of moisture from a timber-frame wall having a sealed cavity during summer

Job:	Example	Terrain:	Inner city
Item	Timber-frame wall	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 2: Summer evaporation

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps kPa)
Internal	20.0	60.0	1.401	2.335
External: Winter	3.9	88.9	0.717	0.807
Summer	16.4	75.5	1.406	1.863

Layer no	description	Lx (m)	kx W/mK	rvx (GNs/kgm)	tx (deg C)	Vpx (kPa)	Vpsx (kPa)	
-	inside air				20.000	1.401	2.335	
-	surface res				19.871	1.401	2.317	ok
1	Duplex board	0.013	0.160	1153.846	19.767	1.404	2.302	ok
2	Mineral wool	0.089	0.040	6.000	16.907	1.405	1.924	ok
3	Plywood	0.009	0.140	500.000	16.824	1.406	1.914	ok
4	Breather	0.001	1.000	100.000	16.823	1.406	1.914	ok
5	Cvty not Vtd	0.050	0.278	5.200	16.592	1.406	1.886	ok
6	Brickwork	0.100	0.840	37.000	16.439	1.406	1.867	ok
-	surface res				16.400	1.406	1.863	ok
-	ext air				16.400	1.406	1.863	

U - Value (BS 5250) — 0.357 W/m²K (for other purposes different surface resistances may apply).

Condensation quantities		kg/m²during 60 days Winter:	emc of timber (if any) Winter:	Summer:	Evaporation: kg/m² 60 days :Summer
at intl surface	ok	0.000	11.3%	10.9%	0.000
at interface 1/2	ok	0.000	8.1%	11.1%	0.000
2/3	**cond**	0.014	25.5%	14.3	0.488
3/4	ok	0.000	21.1%	14.4%	0.000
4/5	ok	0.000	21.0%	14.4%	0.000
5/6	ok	0.000	23.5%	14.7%	0.000
6/7	ok	0.000	20.0%	15.0%	0.000
7/8		0.000			0.000
8/9		0.000			0.000
9/10		0.000			0.000
at extl surface	ok	0.000	20.0%	15.0%	0.000

Total condensate: 0.014 kg/m² Total evaporation: 0.488kg/m²
Annual balance: 0.473 kg/m² Compare evaporation to condensation at each interface! Totals alone may not reflect interface conditions!

Fig 8 Accumulation of moisture in a timber-frame wall having a ventilated cavity during winter

Job:	Example	Terrain:	Inner city
Item	Timber-frame wall	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 1: Winter condensation

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	description	Lx (m)	kx W/mK	rvx (GNs/kgm)	tx (deg C)	Vpx (kPa)	Vpsx (kPa)	
-	inside air				20.000	1.401	2.335	
-	surface res				19.408	1.401	2.251	ok
1	Duplex board	0.013	0.160	1153.846	18.927	0.892	2.185	ok
2	Mineral wool	0.089	0.040	6.000	5.760	0.873	0.919	ok
3	Plywood	0.009	0.140	500.000	5.380	0.721	0.895	ok
4	Breather	0.001	1.000	100.000	5.374	0.717	0.894	ok
5	Cavity Ventd	0.050	0.500	0.000	4.782	0.717	0.858	ok
6	Brickwork	0.100	0.840	0.000	4.078	0.717	0.817	ok
-	surface res				3.900	0.717	0.807	ok
-	ext air				3.900	0.717	0.807	

U — value (BS 5250) — 0.368 W/m²k

Condensation Quantities		kg/m² during 60 days	at interface:	emc of timber (if any)
at intl surface	ok	0.000		11.4%
at interface 1/2	ok	0.000	1/2	7.6%
2/3	ok	0.000	2/3	23.1%
3/4	ok	0.000	3/4	17.3%
4/5	ok	0.000	4/5	17.2%
5/6	ok	0.000	5/6	18.4%
6/7	ok	0.000	6/7	20.0%
at extl surface	ok	0.000		20.0%
Total condensate:		0.000 kg/m²	0.000 kg/m²	

Check calculated condensate against material tolerances (Table 3.12) at each interface! Check 'emc' of Timber!

Fig 9 Evaporation of moisture from a timber-frame wall having a ventilated cavity in Summer

Job:	Example	Terrain:	Inner city
Item	Timber frame wall	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 2: Summer Evaporation

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps kPa)
Internal	20.0	60.0	1.401	2.335
External: Winter	3.9	88.9	0.717	0.807
Summer	16.4	75.5	1.406	1.863

Layer no	Description	Lx (m)	Kx W/mk	rvx (GNs/kgm)	tx (deg C)	Vpx (kPa)	Vpsx (kPa	
-	inside air				20.000	1.401	2.335	
-	surface res				19.868	1.401	2.316	ok
1	Duplex Board	0.013	0.160	1153.846	19.760	1.405	2.301	ok
2	Mineral Wool	0.089	0.040	6.000	16.816	1.405	1.913	ok
3	Plywood	0.009	0.140	500.000	16.731	1.406	1.902	ok
4	Breather	0.001	1.000	100.000	16.730	1.406	1.902	ok
5	Cvty Ventd	0.050	0.500	0.000	16.597	1.406	1.886	ok
6	Brickwork	0.100	0.840	0.000	16.440	1.406	1.868	ok
-	surface res				16.400	1.406	1.863	ok
-	ext air				16.400	1.406	1.863	

U - Value (BS 5250) — 0.368 W/m²k (for other purposes different surface resistances may apply).

Condensation Quantities		kg/m2 during 60 days Winter:	enc of timber (if any) Winter:	Summer:	Evaporation: kg/m2 60 days Summer
at intl surface	ok	0.000	11.4%	10.9%	0.000
at interface 1/2	ok	0.000	7.6%	11.1%	0.000
2/3	0k	0.000	23.1%	14.4	0.000
3/4	ok	0.000	17.3%	14.5%	0.000
4/5	ok	0.000	17.2%	14.5%	0.000
5/6	ok	0.000	18.4%	14.7%	0.000
6/7	ok	0.000	20.0%	15.0%	0.000
at extl surface	ok	0.000	20.0%	15.0%	0.000

Total condensate: 0.000 kg/m² Total evaporation 0.000kg/m²

Annual Balance: 0.000 kg/m² Compare evaporation to condensation at each interface!Totals alone may not reflect interface conditions!

Fig 10 Calculation of the required cavity ventilation for a timber-frame wall

Job:	Example	Terrain:	Inner city
Item	Timber-frame wall	Building type:	Dwelling
Location:	London	Climate:	Kew

Part 3 (B): Type 'B' Construction: Temperature Stack Driven Ventilation
Note: all calculations apply to 1 m width of construction.

Climate:

	air temp (deg C)	RH (%)	Vp (kPa)	Vps (kPa)	M(e) g/kg	MS(e) g/kg
Internal	20.0	60.0	1.401	2.335		
External: Winter	3.9	88.9	0.717	0.807	4.453	5.013
Summer	16.4	75.5	1.406	1.863	8.794	11.701

Layer no	Description	Lx (m)	Kx W/mK	rvx (GNs/kgm)	Rvx (GNs/kg	SumxRvx (GNs/kg)
1	Duplex Board	0.013	0.16	1153.846	15.000	15.000
2	Mineral Wool	0.089	1.04	6.000	0.534	15.534
3	Plywood	0.009	0.14	500.000	4.500	20.034
4	Breather	0.001	1.00	100.000	0.100	20.134

The amount of vapour migrating through the inner skin into the ventilated cavity q — 0.1221 g/m²h (Winter)
q¹ — - 0.0009 g/m²h (Summer)

The equilibrium moisture content of timber in or bordering the cavity is
emc — 20.39% (Winter)
emc — 15.02% (Summer)

Ventilation req'd if cavity 'height' (distance A1-A2) — 2.4 m will be
Qc — 0.44 m³/h (Winter)

Note: tc from 'Winter', H1 — height between centre of top & bottom vents (no cavity barriers between!).
When the cavity temperature (interface inner skin/cavity)
tc — 5.08 C+273.15— 278.23 K
When the external temperature (January mean Table 3.5)
te — 3.90 C+273.15— 277.05 K
When the vertical distance between vent openings
H1 —2.30 m

Then:the required vent opening at top and bottom of cavity is equal to a continuous slot of 0.6 mm
or is, for each 1 m length of wall/roof, equal to 642 mm²/m

That means, for example, in a brick outer skin to a vented cavity, One open perpend every 1.169 m top + bottom
(which is app equivalent to every 5th perpend left open, stretcher bond)