

MOISTURE GAIN ANALYSIS

Vapour control layers reduce the diffusion of moisture vapour into the insulation of a warm roof system. It is not practical to prevent entirely the diffusion of moisture into the insulation but the extent of diffusion can be predicted by moisture gain analysis and the performance of vapour control layers can be assessed.

The diffusion of water vapour in building materials is generally very slow and a vapour control layer becomes necessary only as the anticipated relative humidity in a building increases. An increased efficiency of vapour control becomes more necessary with increasing relative humidity and temperature but to save unnecessary complications it is conventional to consider only two categories of efficiency; a vapour check to control low levels of humidity; and a vapour barrier to control high humidity.

A method for the calculation of moisture gain in roofs is given in BS 6229:1982 Code of practice for flat roofs with continuously supported coverings, and predicts the moisture gain in a 60 day period when the external temperature is -5°C . It also prescribes the amount of condensate which can be tolerated safely and checks that a suitable drying out occurs in summer so that moisture does not accumulate year on year.

More recently BS 5250:1989 Control of condensation in buildings, has been published and presents an improved calculation procedure. It is based on a 60 day period when the external temperature is $+5^{\circ}\text{C}$. No indication of safe levels of condensate is given and no check that there will be adequate drying out in summer.

The code of practice for built-up felt roofing BS 8217:1994 recommends vapour control determined as recommended in BS 6229 but with the calculation method modified to conform with BS 5250. Calculations in this guide follow this recommendation, using an external temperature of -5°C which is a realistic assumption for the surface temperature of flat roofs and takes account of solar and night sky radiation effects and safety margins. The safe levels of condensate prescribed in BS 6229 are adopted and also the procedure to ensure adequate drying out in summer.

GUIDANCE TABLES

As an aid to design, the results of moisture gain analysis for typical warm roof constructions have been calculated and are given in table 1.10. This shows the relative humidity and internal temperatures at which a vapour check or vapour barrier become necessary.

Correct use of the tables requires an assessment of the average internal conditions of the building over a typical 60 day period. In the absence of specific data, the average temperature and relative humidity given in the following table may be assumed.

TABLE 1.9

Type of Building	Temperature $^{\circ}\text{C}$	Relative Humidity %
Houses and flats	20	55
Offices	20	40
Schools	20	50
Factories and heated warehouses	15	35
Textile factories	20	70
Swimming pool halls	25	70

For the purposes of calculation, a vapour check is taken to be a single layer of bitumen felt and a vapour barrier as two layers of bitumen felt. If a single layer metal lined vapour barrier is to be used, then the vapour resistance of this can be taken as being equivalent to that of a two layer bitumen felt vapour barrier. The vapour resistance of these layers used to calculate the tables is as follows:

VAPOUR CHECK RESISTANCE

Metal deck	100MNs/g
All other decks	300MNs/g

VAPOUR BARRIER RESISTANCE

All decks	500MNs/g
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The above assumes that a single layer of felt used as a vapour check on metal deck is likely to be damaged or penetrated and the vapour resistance of this layer is taken as one third that of a fully supported layer.

The vapour resistance of the waterproofing membrane is so large compared with the resistance of the other components in the system, that its magnitude has very little effect on the calculation of the amount of condensate and it is assumed to be impermeable.

The moisture vapour flow assumed for the calculation is based on a 60 day winter period, with external conditions of -5°C and a 60 day summer period with external conditions of 18°C . The amount of condensate in winter and the amount of evaporation in summer have been taken into account and the calculation method used is set out in Appendix A2. The tables are relevant for a range of U-values from 0.25 to $0.6\text{W}/\text{m}^2\text{K}$.

Internal %RH at which a vapour check or vapour barrier is required

TABLE 1.10

METAL DECK	Internal Temperature °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Fibrous Insulation																
%RH Vapour Check Required	64	60	56	53	50	47	44	41	39	36	34	32	31	29	27	26
%RH Vapour Barrier Required	83	78	73	69	65	61	57	54	51	48	45	42	40	38	36	34
Non Fibrous Insulation																
%RH Vapour Check Required	73	69	65	61	57	54	51	48	45	42	40	38	36	34	32	30
%RH Vapour Barrier Required	88	82	77	73	68	64	60	57	54	50	48	45	42	40	38	36
TIMBER DECK	Internal Temperature °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Fibrous Insulation																
%RH Vapour Check Required	64	60	56	53	50	47	44	41	39	36	34	32	31	29	27	26
%RH Vapour Barrier Required		96	91	85	80	75	71	67	63	59	56	53	50	47	44	42
Non Fibrous Insulation																
%RH Vapour Check Required	73	69	65	61	57	54	51	48	45	42	40	38	36	34	32	30
%RH Vapour Barrier Required				96	90	85	80	75	71	67	63	59	56	53	50	47
CONCRETE DECK	Internal Temperature °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
Fibrous Insulation																
%RH Vapour Check Required	75	70	66	62	58	55	52	49	46	43	41	38	36	34	32	31
%RH Vapour Barrier Required		98	92	87	82	77	72	68	64	60	57	54	51	48	45	43
Non Fibrous Insulation																
%RH Vapour Check Required	76	72	67	63	59	56	53	50	47	44	41	39	37	35	33	31
%RH Vapour Barrier Required				98	92	87	82	77	72	68	64	61	57	54	51	48

GENERAL GUIDANCE

DECKS

The water vapour resistance of metal deck, timber decks, woodwool and aerated concrete slabs, taking into account their joints, is relatively low and does not contribute very much to the total resistance of the construction. A vapour check between these decks and the insulation would normally be required.

Concrete decks have a relatively high vapour resistance and to some extent the deck itself acts as a vapour check. It should however be remembered that concrete contains water during construction and an underlayer of bitumen felt is required to act both as a damp proof layer and temporary vapour check while the concrete dries out.

Generally, for an internal temperature of 20°C, a full two layer vapour barrier is only required on buildings with high continuous humidity. On metal deck the relative humidity at which a vapour barrier is required is in the order of 60% and for other decks 75%.

CEILINGS

The addition of a ceiling does not alter the internal temperature and humidity levels at which a vapour check or vapour barrier is required, but may introduce the possibility of surface condensation under the deck. The temperature in the ceiling space will be reduced if the ceiling has a significant insulation value but the

vapour pressure will remain the same as in the building below. It is necessary to check that the amount of insulation above the deck is sufficient to prevent condensation occurring on the underside of the deck. In order to do this it is necessary to ensure a proper balance of insulation above and below the deck. The balance of insulation can be read from tables 1.11 and 1.12. Table 1.11 relates to an external temperature of -5°C, and table 1.12 relates to an external temperature of -10°C to allow for severe conditions of exposure.

The procedure is to determine the thermal resistance below the deck by the summation of the thermal resistances of the air space, insulating materials, ceiling and the surface resistance of the underside of the ceiling. This total is multiplied by the appropriate balance of insulation factor from the tables. This gives the thermal resistance required above the deck soffit in order to prevent condensation occurring below the deck. An example of this procedure is shown in example 3 of Appendix A.2.

Balance of Insulation (minimum balance required to prevent condensation on the underside of the roof deck)

TABLE 1.11 External Temperature -5°C

%RH	Internal Temperature °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
30	0.2	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8
35	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.0
40	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3
45	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.5	1.6	1.6
50	0.9	1.0	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	2.0	2.0
55	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.3	2.4	2.5
60	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	3.0	3.1
65	2.1	2.2	2.3	2.4	2.6	2.7	2.8	2.9	3.0	3.2	3.3	3.4	3.5	3.6	3.7	3.8
70	2.7	2.8	3.0	3.1	3.3	3.4	3.6	3.7	3.9	4.0	4.1	4.3	4.4	4.5	4.6	4.8
75	3.6	3.7	3.9	4.1	4.3	4.5	4.7	4.8	5.0	5.2	5.3	5.5	5.7	5.8	6.0	6.1
80	4.9	5.1	5.3	5.6	5.8	6.0	6.3	6.5	6.7	6.9	7.1	7.3	7.5	7.7	7.9	8.1
85	7.0	7.3	7.7	8.0	8.3	8.6	8.9	9.2	9.5	9.8	10.1	10.4	10.7	11.0	11.2	11.5
90	11.3	11.8	12.3	12.8	13.3	13.8	14.3	14.7	15.2	15.6	16.1	16.5	17.0	17.4	17.8	18.2
95	24.2	25.2	26.3	27.3	28.3	29.3	30.3	31.2	32.1	33.1	34.0	34.9	35.7	36.6	37.5	38.3

TABLE 1.12 External Temperature -10°C

%RH	Internal Temperature °C															
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
30	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	0.9	1.0	1.0	1.1
35	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.3
40	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.4	1.5	1.5	1.6	1.6	1.7
45	1.1	1.2	1.2	1.3	1.4	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.9	1.9	2.0	2.0
50	1.4	1.5	1.6	1.6	1.7	1.8	1.9	1.9	2.0	2.1	2.1	2.2	2.3	2.3	2.4	2.5
55	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.7	2.8	2.8	2.9	3.0
60	2.2	2.4	2.5	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.6
65	2.8	3.0	3.1	3.2	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
70	3.6	3.8	3.9	4.0	4.2	4.3	4.5	4.6	4.7	4.9	5.0	5.1	5.2	5.4	5.5	5.6
75	4.7	4.9	5.1	5.2	5.4	5.6	5.7	5.9	6.1	6.2	6.4	6.5	6.7	6.8	7.0	7.1
80	6.3	6.5	6.8	7.0	7.2	7.4	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.4
85	9.0	9.3	9.6	9.9	10.2	10.5	10.8	11.1	11.4	11.7	12.0	12.2	12.5	12.8	13.0	13.3
90	14.4	14.9	15.4	15.8	16.3	16.8	17.2	17.6	18.1	18.5	18.9	19.3	19.8	20.2	20.6	20.9
95	30.5	31.5	32.5	33.4	34.4	35.3	36.3	37.2	38.1	38.9	39.8	40.7	41.5	42.3	43.1	43.9

TYPES OF BUILDING

The following general recommendations on the need for a vapour barrier or vapour check are made according to anticipated conditions of building use.

SWIMMING POOLS, TEXTILE MILLS, PAPER MILLS

In these buildings the conditions will be at or above 20°C and 70% RH and most swimming pools will be at 30°C and 60% RH. The conditions are generally continuous as opposed to intermittent, which makes them much more severe in terms of searching out weaknesses in vapour control layers.

It will be found that such conditions always call for an efficient vapour barrier and the choice of insulation should be restricted to those which are least affected by leaking water vapour.

Even with a two-layer vapour barrier, which is regarded as highly efficient, it would be unwise to assume that there will be no local leakage of water vapour. Experience has shown that cork or a polyurethane/cork composite insulation is a suitable choice under these conditions. They are resistant to

moisture and can be installed fully bonded between the vapour barrier and the waterproofing with no intervening air spaces or part bonded layers. It is therefore certain that moisture will only leak into these systems by diffusion. Insulations which require the waterproofing to be part bonded are rather more at risk because air and water vapour can circulate at the part bonded interface and it is more likely that condensation could be absorbed by the insulation.

HOUSING

The majority of families maintain a satisfactory level of ventilation in their homes to clear away steam and water vapour from washing, cooking and crowded conditions. Unfortunately there is a minority who live in high humidity conditions with little ventilation, either through thoughtlessness or in the belief that ventilation will increase the cost of heating. For this reason housing should be considered a fairly high humidity situation. The humid conditions are usually intermittent however and a vapour check would normally suffice.

Some families use oil or gas heaters continuously

without ventilation and they will be producing conditions equivalent to a textile mill or swimming pool. They would be well advised to introduce substantial ventilation or make sure that the heaters are used only intermittently to allow plenty of time for drying out.

SPORTS HALLS AND COMMUNAL SHOWERS, BATHS, TOILETS AND KITCHEN ACCOMMODATION
This group of buildings or parts of buildings produce high humidity but normally for intermittent periods, so that the average conditions for design are substantially less than the maximum that will be observed in service. The designer will normally have the opportunity to introduce substantial ventilation, which will control the relative humidity but it should be borne in mind that the management of some buildings can be careless with regard to the use of ventilation systems provided.

Analysis will usually show that a vapour check is necessary but a fully efficient vapour barrier may not be required. It is often extremely difficult to predict a suitable average humidity for calculation purposes and if the designer is in doubt, he will be well advised to allow for a vapour barrier as a precaution.

CLASSROOMS

Classrooms sometimes move towards high humidity because of the number of people in a relatively confined space. Humidity levels build up during the day with little ventilation unless the teacher opens a window. Nevertheless, large stocks of schools have been built with no vapour barrier or vapour check over metal decks on classrooms, corridors or halls and these have amply demonstrated a successful result.

FACTORIES WITH NORMAL DRY PROCESSES, WAREHOUSES

These are representative of a group of buildings which are operating under normal dry conditions and analysis will normally show that a vapour barrier or vapour check is not required. There may, however, be local parts of the building which are at high humidity. Small kitchen facilities and well ventilated toilets may usually be ignored but kitchens for commercial catering or shower rooms which are in frequent use need to be considered separately and will usually require a vapour check or vapour barrier.

SHOPS, SHOPPING CENTRES, COMMERCIAL BUILDINGS AND OFFICES

Conditions in these buildings will vary widely, and it would be difficult to make a general forecast of temperature and relative humidity. A vapour check will normally be incorporated but a full vapour barrier will seldom be necessary.

CHANGE OF BUILDING USE

Moisture gain analysis will also help those who wish to make allowance for occupancy changes during the life of the building by allowing for future high humidity operations. An efficient vapour barrier is an expensive precaution, but a vapour check is unlikely to be good enough in the event of a change to high humidity conditions. The building owner should specify the worst conditions to be allowed for in the design. If, for example, this is to allow for the possibility of installing a textile mill in an advance factory, the design conditions will probably be set at 20°C and 70% relative humidity. This will almost certainly call for a

full vapour barrier preferably with an insulation which is not moisture sensitive.

The cost of making such an allowance as a precaution against change of occupancy can be analysed, and the building owner can consider the options of spending extra money for the extra facility, against the alternative cheaper construction which would be appropriate for normal usage.

VAPOUR BARRIER/VAPOUR CHECK INSTALLATION

An efficient vapour barrier will require bonded overlaps, and penetrations should be effectively sealed. It should be applied with precautions to ensure that it is isolated from building movement where necessary, so that it maintains integrity in service. This will sometimes lead to the use of a partially-bonded two-layer barrier.

A vapour check is constructed from a single layer and partial bonding is not necessary as a small amount of damage from building movement would make little difference to the effectiveness of the vapour check. Unsealed laps and penetrations are accepted, and a small amount of physical damage can be tolerated.

The materials forming the vapour barrier or vapour check and their method of attachment will be determined by the nature of the deck, as described in the following pages.

CONCRETE DECKS

Vapour barrier

A vapour barrier is best provided either by a two layer system or a single layer of specialised metal lined vapour barrier material. The first layer can be type 5U or polyester 180 followed by a layer of BS 747 3B glass based material which seals the system and ensures lap security.

A single layer of metal lined vapour barrier material is normally full bonded.

Alternatively when mastic asphalt is specified, a vapour barrier can be formed with a single 13mm layer of mastic asphalt on glass tissue.

Vapour check

A vapour check can be provided by bitumen bonding a layer of glass based roofing BS 747 type 3B or similar to the deck. Polyester based roofing is also widely used.

PLYWOOD, WOODWOOL AND PARTICLEBOARD DECKS

Vapour barrier

Particleboard is not considered suitable for use as a structural deck when conditions of such high humidity are anticipated that a vapour barrier would be required.

Plywood and woodwool decks are likely to suffer significant joint movement and the first layer of a two layer system should be perforated glass base BS 747 type 3G followed by a polyester based roofing. This can be BS 747 type 5U or a polyester 180 which is made on a 180g/m² polyester base.

The manufacturers of metal lined vapour barrier material will advise whether part bonding is necessary on decks which might suffer joint movement. If this is the case a first layer of type 3G will prove the best method of achieving part bonded attachment.

Vapour check

A vapour check can be provided by bitumen bonding a layer of glass based roofing BS 747 type 3B or similar to the deck. Polyester based roofing is also widely used.

TIMBER DECKS*Vapour barrier*

Only the highest grade of structural timber with natural resistance to moisture is suitable for the high humidity conditions which require a full vapour barrier. Normal timber roofs should not be used above high humidity conditions.

When appropriate, a two layer vapour barrier should be chosen, with a nailed first layer of polyester or similar high strength material. A second layer of BS 747 type 3B or high performance layer should then be fully bonded to the first layer in hot bitumen.

Vapour check

A vapour check on timber can be formed by a single nailed layer of polyester base roofing or similar high strength material. The insulation is then bonded to the nailed layer in hot bitumen.

METAL DECKS*Vapour barrier*

The majority of high humidity buildings are likely to be of metal deck construction as these are particularly suited to high humidity.

The vapour barrier is normally bonded direct to the deck and will have to span the open troughs of the deck. This makes it difficult to ensure lap security in a single layer and thus a two layer system is generally to be recommended. The first layer may be BS 747 type 5U polyester based material, polyester 180 or similar. The second layer need only be BS 747 type 3B glass based roofing and the function of this layer is to seal the system and ensure lap security.

Some manufacturers are recommending a single layer of special metal lined vapour barrier material on metal deck but it is almost impossible to ensure lap security where a lap crosses or passes along the open troughs of the deck. For this reason all longitudinal laps should be 100mm and formed over the continuous top flats of the deck. The edges of the vapour barrier and all end laps should be fully supported using 150mm wide sheet metal strips to match the material of the deck and support the vapour barrier.

The standard of workmanship and supervision must be of the highest order to ensure lap security. On truly high humidity buildings it would be wise to incorporate the metal lined vapour barrier material into a two layer system by the addition of a bonded layer of BS 747 type 3B material.

Vapour check

In many buildings a full vapour barrier is unnecessary. A single layer vapour check will suffice although a conservative assessment of resistance to diffusion is necessary to allow for some damage to the vapour barrier on the metal deck and the risk of a lower level of lap security. This is allowed for in the data and procedures given in BS 6229.

The single layer should be a bonded layer of BS 747 type 5U or polyester 180.

MECHANICAL FIXINGS

It will sometimes prove necessary to avoid bitumen bonding to the deck in order to reduce the combustible content of the specification. It may also be necessary to supplement the strength of bitumen bonding in conditions of high wind forces. In these cases mechanical fixing may be necessary and they will penetrate the vapour control layer. It is now believed that no significant leakage of moisture vapour will take place through the penetrated vapour control layer. It does become even more desirable to use a moisture resistant insulation on high humidity buildings and a waterproofing fully bonded to the insulation to ensure a fully sealed and resistant system when continuous high humidity is anticipated.

An alternative solution is to mechanically fix a relatively thin layer of insulation to the deck before the application of the vapour barrier. This provides a fully fixed and fully supporting substrate to receive the vapour barrier. The safe positioning of the vapour barrier and the balance of insulation above and below the vapour barrier can be checked by moisture gain analysis.

A range of paper based vapour checks are available as an alternative to bitumen roofing and may be used on metal decks where they will reduce the combustible content of the materials below the insulation. These materials may be foil faced to provide reasonable impermeability to water vapour, and glass reinforced for strength. Laps may be bonded with proprietary adhesives or sealed with adhesive tapes. Although generally effective as underlays or vapour checks, these materials are necessarily applied as a single layer and are penetrated by the large number of mechanical fixings required for attachment. They should not be regarded as an efficient full vapour barrier on metal decks.

Vapour control Layers: Summary of recommendations

TABLE 1.13

Deck	Vapour Barrier	Vapour Check
CONCRETE DECK	<p>FIRST LAYER: Type 5U or polyester 180 fully bonded</p> <p>SECOND LAYER: Type 3B fully bonded</p> <p>OR:</p> <p>One layer polyester or glass based metal lined bitumen roofing fully bonded</p> <p>OR:</p> <p>13mm one coat mastic asphalt on glass fibre tissue</p>	One layer type 3B or 5U or polyester 180 fully bonded
PLYWOOD OR WOOD WOOL	<p>FIRST LAYER: Type 3G partially bonded</p> <p>SECOND LAYER: Type 5U or polyester 180 fully bonded</p> <p>OR:</p> <p>FIRST LAYER: Type 3G partially bonded</p> <p>SECOND LAYER: One layer polyester or glass based metal lined bitumen roofing fully bonded</p>	One layer type 3B or 5U or polyester 180 fully bonded
PARTICLEBOARD	Not recommended for high humidity applications	One layer type 3B or 5U or polyester 180 fully bonded
TIMBER DECK	<p>FIRST LAYER: Type 5U or polyester 180 nailed to deck</p> <p>SECOND LAYER: Type 3B fully bonded</p>	One layer type 5U or polyester 180 nailed to deck
METAL DECK	<p>FIRST LAYER: Type 5U or polyester 180 bonded to deck flats</p> <p>SECOND LAYER: Type 3B fully bonded</p> <p>OR:</p> <p>One layer metal lined polyester bitumen roofing. Side and end laps fully sealed. All laps supported on the flats of deck or additional sheet metal strips.</p>	One layer type 5U or polyester 180 bonded to deck flats

NOTE: For convenience, table 1.13 refers to bitumen felts in terms of BS 747 type 3B and 5U or Polyester 180. There are a large number of proprietary felts of equal or better performance which would be suitable alternatives.