Mineral Fibre Full Fill Batt Cavity Wall Insulation, Workmanship, Water & Heat Loss

A WHITE PAPER
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1 Executive Summary

1.1 Kingspan Insulation Ltd has carried out a photographic survey of a number of sites using mineral fibre full fill batt cavity wall insulation in London, Surrey, Oxfordshire, Humberside and Cheshire.

1.2 This survey uncovered endemic site practices which can be seen to be contrary to the requirements or recommendations laid down in many mineral fibre full fill batt cavity wall insulation manufacturers’ literature, manufacturers’ BBA Certificates, BS 6676: Part 2: 1986 (Code of practice for installation of batts (slabs) filling the cavity) or NHBC Standards (Vol. 2: Chapter 6.1).

1.3 These site practices can lead to construction defects which encourage water, from whatever source, to penetrate into the mineral fibre full fill batt cavity wall insulation.

1.4 This ‘White Paper’ goes on to show that it would be reasonable to expect that, in the UK, the average moisture content of installed mineral fibre full fill batt cavity wall insulation would be 1% water by volume for 75% of the year and that a moisture content of only 1% by volume can increase the thermal conductivity of man made mineral fibre by between 75 and 105%.

1.5 This thermal conductivity increase would cause an additional 1176 kWh of heat to be lost from a property of 115 m2 wall area in one year. This additional heat loss is responsible for 337 kg of CO₂ equivalent emissions per year and a financial loss of £26 per year.

1.6 The effects of this increased heat loss are graphically demonstrated in a thermographic survey on two houses, one insulated with mineral fibre full fill batt and the other with Kingspan partial fill slab.

1.7 Assuming this increase in thermal conductivity is representative of all buildings insulated in this way, the use of mineral fibre full fill batt cavity wall insulation could be regarded as wasting the UK 1764 GWh (million kWh) of heat per year.

1.8 That is equivalent to the output of 0.588 power stations at an average output of 3000 GWh.

1.9 Furthermore, this could be regarded as causing 505.5 million kg (505,500 T) of CO₂ equivalent emission to be pumped into the atmosphere per year with its consequent effects on global warming.

1.10 That is equivalent to 0.61% of the UK’s commitment to CO₂ equivalent emissions reduction under the 1997 Kyoto Protocol of 83 million T of CO₂ equivalent emissions (12.5% reduction from 1990 emission levels).

1.11 Finally, this could be regarded as costing occupiers of properties so insulated £39 million per year in wasted fuel bills.

1.12 Little can be done to remedy the effects that inadequate site workmanship and supervision have on walls insulated with mineral fibre full fill batt cavity wall insulation.

1.13 The only solution is to make the external leaf as impermeable to water as possible with renders, silicone treatments or other such remedies. All are expensive.
2 Introduction

2.1 This ‘White Paper’ from Kingspan Insulation is one of a series, highlighting the serious implications that inadequate site workmanship and supervision can have on the performance of insulation materials.

2.2 Most insulation materials perform as claimed under controlled installation conditions and when tested in a laboratory environment. However, when taken into the world of real site practices, not all may perform as predicted.

2.3 This ‘White Paper’ focuses on the implications that inadequate site workmanship and supervision can have on the performance of mineral fibre full fill batt cavity wall insulation. In particular it investigates the effects of inappropriate installation techniques and their consequences for exacerbated heat loss and the environmental and financial implications of this.

2.4 For the purposes of this ‘White Paper’ the definition of mineral fibre is taken from BS 3533: 1981 (Glossary of thermal insulation terms) and includes both glass fibre and rock fibre.
3 Thermal Insulation and Water

3.1 The thermal insulating property of a material is expressed as its thermal conductivity. The lower the thermal conductivity the greater the material’s ability to resist heat flow and therefore the better it will act as an insulant. The thermal conductivities for commonly used insulants typically lie in the range of 0.021 to 0.046 W/m.K. These values relate to the insulation product at a specific temperature in a dry and stable state.

3.2 The thermal conductivity of water (0.58 W/m.K) is significantly higher than the thermal conductivity of any commonly used insulant. Therefore if water is present the overall thermal conductivity of the material will increase significantly. The level of increase will be dependant on the volume of water present.

3.3 Water absorption by an insulant can be expressed as a percentage by volume or a percentage by weight. A percentage by volume is the normal expression and as the insulant itself has a certain solid volume the percentage of water is always less than 100%. If water content is expressed as a percentage weight, this can be greater than 100% as insulants generally tend to be significantly lighter than water. A 1% water content by volume could result in up to a 50% content by weight due to the lightness in weight of some insulants.

3.4 High performance closed cell insulants such as those supplied by Kingspan Insulation achieve much of their insulating qualities from the blowing agents which are trapped within the cells of the material. Water is not readily absorbed as it must penetrate through the cell walls to enter the material. This does not readily occur unless the cell walls have been damaged, e.g. at cut edges. Where it does occur under normal application conditions, the amount of water absorption is very low and is restricted to the outer cells, therefore having a minimal effect on the overall thermal conductivity of the material. Absorption is effectively eliminated if the insulant is faced with an impervious facing such as foil.

3.5 Mineral fibre insulants rely largely on entrapped air for much of their insulating properties. Their open structure may provide little resistance to water or vapour flow and the potential for water and water vapour penetration can therefore be high.
4 Rain Penetration and Cavity Walls

4.1 Cavity walls are designed such that the outer face is allowed to ‘fail’ and act solely as a first means of defence against rain penetration.

4.2 The whole purpose of the ‘cavity’ is to act as a zone where penetrating water can freely drain to controlled exit points without crossing to the interior. By introducing full fill insulation the basic function of the cavity wall construction can be compromised.

4.3 ‘Rainwater will penetrate the outer leaves of masonry walls under certain conditions of driving rain. This can lead to dampness reaching the inside causing damage to the wall and decorations and reducing thermal performance’. ‘The performance of the wall in resisting water crossing the cavity is affected by the amount of wind driven rain, the presence of a finish or cladding which protects the wall and the quality of the design, specifications and workmanship’. ‘Moisture transmission to the inner leaf of cavity walls is more likely where walls contain building defects and cavity insulation’. (Thermal Insulation: avoiding risks. BRE/HMSO. 1994)

4.4 Mineral fibre manufacturers’ BBA Certificates for full fill batt cavity wall insulation permit the products’ use subject to a height limitation of 25 m and an exposure limitation for buildings over 12 m in height. However, they state that it is essential that the walls are built in accordance with the conditions set out in the Design Data and Installation sections of the Certificates. Stringent design and workmanship requirements are made in these sections. Buildings over 12 m in height are also required to have site supervision from the manufacturer.

4.5 ‘Thermal insulation: avoiding risks’ (BRE/HMSO. 1994) gives a height limitation of 12 m for the use of mineral fibre full fill batt cavity wall insulation and gives the following guidance.

- Determine the national exposure zone from the map opposite and apply it to the table. Where necessary modify zone to allow for the factors given below, or local knowledge and practice.
- Add one to the map zone where conditions accentuate wind effects such as on open hillsides or in valleys where the wind is tunnelled onto the wall.
- Subtract one from the map zone where walls are well protected by trees or buildings or do not face the prevailing wind.
- Consider restricting use to zones in brackets if design or construction standard cannot be relied on.

If in doubt, these factors are fully described in BS 8104, with worked examples.

### Proposed wall constructions

<table>
<thead>
<tr>
<th>Construction type and insulation method</th>
<th>Minimum width of cavity (mm)</th>
<th>Impervious cladding Full height of wall</th>
<th>Rendered finish Full above facing masonry</th>
<th>Facing masonry Full above facing masonry</th>
<th>Tooling flush joints</th>
<th>Recessed mortar joints</th>
<th>Flush sills copings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral fibre full fill batts</td>
<td>50 (filled)</td>
<td>4</td>
<td>3</td>
<td>3 (2)</td>
<td>2 (1)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>75 (filled)</td>
<td>4</td>
<td>3</td>
<td>4 (3)</td>
<td>3 (2)</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>100 (filled)</td>
<td>4</td>
<td>4 (3)</td>
<td>3 (2)</td>
<td>3 (2)</td>
<td>1</td>
<td>2 (1)</td>
</tr>
</tbody>
</table>

**Note:**

“Approximate wind driven rain” equates to “maximum wall spell index” derived from Figure 1 in BS 8104: 1992 (Code of practice for assessing exposure of walls to wind driven rain.)

The wall spell index can be more accurately calculated from the large scale maps and correction factors given in BS 8104, then interpreted using the values in the key to the map above and table above.

4.6 Recognising the consequent need for exposure limitations on mineral fibre full fill batts the NHBC state that under their standards “In Scotland, it is not permissible to fill the full width of the cavity with any thermal insulant at the time of construction”. (NHBC Standards. Volume 2, Chapter 6.1. 1992.)

4.7 They go on to say that for any part of the UK, a very high standard of workmanship is required to ensure that cavities are not bridged and to minimise the risk of damp penetration to the inside of the dwelling where cavity insulation is used. (NHBC Standards. Volume 2, Chapter 6.1. 1992.)

4.8 Indeed, following record claims for damage caused by rain penetration during the storms of 1989-1991, the NHBC have demanded that builders “Do not use (full fill) cavity wall insulation unless your standards are very high” (NHBC Standards Extra. Issue 1. September 1991.), and have stated that “The problems stem from poor quality of workmanship in the cavities.” (Ian Davis, NHBC Director of Standards. Building Magazine. Sept 27, 1991.)

4.9 Even Eurisol, the mineral fibre manufacturers trade association, recognises that walls insulated with full fill batts can suffer rain penetration because of bad workmanship, and that in this case dirty cavities are one of the main causes.
5 Condensation and Cavity Walls

5.1 Rain penetration is not the only source of water in a cavity wall. Walls built with mineral fibre full fill batt cavity wall insulation can suffer from the formation of interstitial condensation.

5.2 Interstitial condensation calculations are performed to BS5250: 2002 (Code of practice for control of condensation in buildings). An example calculation for a brick / block wall insulated with mineral fibre full fill batt cavity wall insulation is shown below.

**Internal conditions:** 20.0°C @ 55.0%RH
**External conditions:** 0.0°C @ 90.0%RH

Calculated U-value = 0.37 W/m².K (Based on the proportional area calculation method for determining U-values of structures containing repeating thermal bridges.)

Condensation calculations performed in accordance with BS 5250: 2002
Calculated 'Q' value under notional winter conditions over 60 days = 0.414 kg/m²

<table>
<thead>
<tr>
<th>Element Description</th>
<th>Element Thickness (mm)</th>
<th>Thermal Conductivity (W/m.K)</th>
<th>Thermal Resistance (m²K/W)</th>
<th>Vapour Resistivity (MNs/gm)</th>
<th>Vapour Resistance (MNs/g)</th>
<th>Vapour Pressure (kPa)</th>
<th>Condensation Risk (kg/60 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside surface resistance</td>
<td>-</td>
<td>-</td>
<td>0.040</td>
<td>-</td>
<td>-</td>
<td>0.549</td>
<td>0.3</td>
</tr>
<tr>
<td>Brickwork facing</td>
<td>102.5</td>
<td>0.770</td>
<td>0.133</td>
<td>42.00</td>
<td>4.31</td>
<td>0.669</td>
<td>1.3</td>
</tr>
<tr>
<td>Mineral fibre full fill batt</td>
<td>75.0</td>
<td>0.037</td>
<td>2.027</td>
<td>10.00</td>
<td>0.75</td>
<td>0.750</td>
<td>16.1</td>
</tr>
<tr>
<td>Blockwork 600 Kg</td>
<td>100.0</td>
<td>0.400</td>
<td>0.250</td>
<td>45.00</td>
<td>4.50</td>
<td>1.234</td>
<td>71.9</td>
</tr>
<tr>
<td>AIR 10mm U/V; HOR FLOW; HI EM.</td>
<td>10.0</td>
<td>-</td>
<td>0.110</td>
<td>0.00</td>
<td>1.234</td>
<td>18.7</td>
<td>19.1</td>
</tr>
<tr>
<td>Plasterboard</td>
<td>9.5</td>
<td>0.190</td>
<td>0.050</td>
<td>50.00</td>
<td>0.47</td>
<td>1.234</td>
<td>19.1</td>
</tr>
<tr>
<td>Inside surface resistance</td>
<td>-</td>
<td>-</td>
<td>0.130</td>
<td>-</td>
<td>-</td>
<td></td>
<td>10.7</td>
</tr>
</tbody>
</table>

5.3 The amount of condensate predicted to accumulate over a 60 day winter period is 427 g/m² wall area.

5.4 This condensation will be worse at the time of year when the insulating performance of the mineral fibre full fill batt cavity wall insulation is most required, when external temperatures are coldest.
6 Workmanship and Cavity Walls

6.1 Installation of mineral fibre full fill batt cavity wall insulation in accordance with BS 6676: Part 2: 1986 (Code of practice for installation of batts (slabs) filling the cavity.) requires that the outer leaf of the cavity wall be built as the leading leaf so that mortar snots can be cleaned off its inner surface. The same is recommended by manufacturers’ BBA Certificates.

6.2 This is contrary to the practice adopted at many sites in the UK where work is usually undertaken from the outside face of the wall, as constructing the outer leaf as the leading skin would require work to be undertaken from within the building, reducing accessibility for following trades.

6.3 Many mineral fibre full fill batt cavity wall insulation manufacturers’ literature endorses this construction sequence contrary to the Code of Practice.

6.4 It is also recommended by many mineral fibre full fill batt cavity wall insulation manufacturers that cavity battens / boards be used to keep mineral fibre full fill batt junctions and wall ties free from mortar droppings. The same is required by manufacturers’ BBA Certificates and BS 6676: Part 2: 1986 and is recommended by NHBC Standards (Volume 2, Chapter 6.1).

6.5 Cavity battens or boards are used.

6.6 The effect of the above can be to create dirty cavities, mortar snots on the inner faces of outer leaves and mortar droppings between mineral fibre full fill batts, all encouraging water, from whatever source, to penetrate into the full fill batts.

6.7 Other site practices which can lead to water penetration include:
- installation of small pieces of mineral fibre full fill batt with fibres in incorrect orientations;
- installation of mineral fibre full fill batts that are wet or weathered resulting from poor storage or protection;
- badly fitted mineral fibre full fill batts with fibres in incorrect orientations or folded;
- installation of torn or damaged mineral fibre full fill batts;
- missing mineral fibre full fill batts;
- gaps left between mineral fibre full fill batts; and
- construction of both skins above the top of the mineral fibre full fill batts creating a trough and making proper installation of full fill batts impossible (mineral fibre full fill batts will require forcing into the gap, cleaning of the mineral fibre full fill batts’ surfaces and ensuring no gaps between mineral fibre full fill batts will be extremely difficult).

6.8 It is recommended by many mineral fibre full fill batt cavity wall insulation manufacturers that sites are kept free of these practices. The same is required by manufacturers’ BBA Certificates, BS 6676: Part 2: 1986 and NHBC Standards (Volume 2, Chapter 6.1).
7 Case Studies - Workmanship

7.1 Kingspan Insulation Ltd has carried out a photographic survey of a number of sites using mineral fibre full fill batt cavity wall insulation. The sites surveyed were in London, Surrey, Oxfordshire, Humberside and Cheshire.

Image 1
This image is of the London site. There is no evidence of a cavity board or batten in use. This has led to the accumulation of mortar on the top surface of the mineral fibre full fill batts. The inner leaf of blockwork has been built up first which has prevented the striking of mortar from the joints on the cavity face of the brickwork, leaving mortar snots projecting into the cavity depth. Both leaves have been constructed above the top of the mineral fibre full fill batts leaving a trough which makes the proper installation of full fill batts impossible (mineral fibre full fill batts will require forcing into the gap, cleaning of the mineral fibre full fill batts' surfaces and ensuring no gaps between mineral fibre full fill batts will be extremely difficult).

Image 2
This image is of the London site. Comments as for Image 1, with the addition of dirty wall ties caused by the lack of use of a cavity board or batten.
7 Case Studies - Workmanship

Image 3
This image is of the London site. Comments as for Image 1. The wall tie in the foreground of the picture makes remedial action even more difficult if not impossible. There are large gaps between the mineral fibre full fill batts and over compression of mineral fibre full fill batts contrary to BS 6676: Part 2: 1986.

Image 4
This image is of the London site. It illustrates the construction sequence of erecting the inner leaf of blockwork as the lead leaf. At this location it was possible to feel down within the cavity and establish the existence of mortar accumulation between the visible mineral fibre full fill batts and those below. This image also shows poor positioning of mineral fibre full fill batts, stopping 50 mm short of the window reveal (arrowed).
Image 5
This image is of the Surrey site. Comments as for Image 1.

Image 6
This image is of the Surrey site. There is no evidence of a cavity board or batten in use. This has led to the accumulation of mortar on the top surface of the mineral fibre full fill batts. It illustrates the construction sequence of erecting the inner leaf blockwork as the lead leaf. It also displays small pieces of mineral fibre in the wrong orientation that have been shoved into the cavity between the top surface of the mineral fibre full fill batt below and the cavity closer.

Image 7
This image is of the Surrey site. Comments as for Image 1, with the addition of extremely large mortar droppings engulfing wall ties caused by the lack of use of a cavity board or batten.
This image is of the Surrey site. There is no evidence of a cavity board or batten in use. This has led to the accumulation of large mortar droppings on the top surface of the mineral fibre full fill batts. The mineral fibre full fill batt in the upper zone of the cavity has been partially folded leading to incorrect fibre orientation and the mineral fibre full fill batt protruding from the lower zone has been weathered quite severely resulting in a partial opening of the mineral fibre matrix.

This image is of the Surrey site. It shows a large section of mineral fibre full fill batt which has been dislodged and torn. It would be impossible to use this full fill batt in its position without leading to fibre mis-orientation.
This image is of the Surrey site. It shows a particularly wet mineral fibre full fill batt which is sagging and has suffered damage to its matrix. The mineral fibre full fill batt also exhibits a fold running vertically down its centre.

This image is of the Oxfordshire site. The inner leaf of blockwork has been built up first which has prevented the striking of mortar from the joints on the cavity face of the brickwork, leaving mortar snouts projecting into the cavity depth. Both leaves have been constructed above the top of the mineral fibre full fill batts leaving a trough which makes the proper installation of full fill batts impossible (mineral fibre full fill batts will require forcing into the gap, cleaning of the mineral fibre full fill batts' surfaces and ensuring no gaps between mineral fibre full fill batts will be extremely difficult). The mineral fibre full fill batt in the foreground has been weathered resulting in a partial opening of the mineral fibre matrix.
Image 13
This image is of the Oxfordshire site. The mineral fibre full fill batts have been weathered quite severely resulting in partial opening of the mineral fibre matrix. They have also been partially folded leading to incorrect fibre orientation.

Image 14
This image is of the Cheshire site. The holes in the outer leaf are the fixing positions of removed scaffolding. This image displays sections of missing, torn and folded mineral fibre full fill batts.

Image 15
This image is of the Cheshire site. The holes in the outer leaf are the fixing positions of removed scaffolding. This image displays clear gaps between mineral fibre full fill batts and displaced / damaged mineral fibre.
This image is of the Humberside site. It shows at the top of the image a mineral fibre full fill batt that has been torn rather than cut and inserted with fibres in incorrect orientation. The image also shows a gap between mineral fibre full fill batts, evidence of mortar snots penetrating mineral fibre full fill batts and dirty mineral fibre full fill batt junctions.

This image is from the Humberside site. It shows a large trough below an opening for a proposed window. The trough is completely missing insulation. Both leaves have been constructed above the top of the mineral fibre full fill batts leaving a trough which makes the proper installation of full fill batts impossible (mineral fibre full fill batts will require forcing into the gap, cleaning of the mineral fibre full fill batts’ surfaces and ensuring no gaps between mineral fibre full fill batts will be extremely difficult).
8 Case Studies - Summary of Results

8.1 The procedure used in erecting the cavity walls at the London, Surrey and Oxfordshire sites involved building the inner leaf blockwork as the lead leaf. See Images 4 & 6. The Humberside and Cheshire sites were too advanced for the wall construction sequence to be ascertained.

8.2 At the London, Surrey and Oxfordshire sites, no cavity boards or battens were being used to protect the top edge of the mineral fibre full fill batts or the wall ties from mortar droppings. See Images 1-13. The Humberside and Cheshire sites were too advanced for the use of cavity boards or battens to be assessed.

8.3 All sites displayed mortar remaining on top of the mineral fibre full fill batts and the London and Surrey sites had wall cavities where mortar had covered a number of wall ties. At the London, Surrey and Humberside sites it was found by manual or visual inspection that this debris was not removed prior to installation of subsequent mineral fibre full fill batts, and that the top surfaces of full fill batts were significantly dirtier below window positions than elsewhere. See Images 1, 2, 4-8 and 16.

8.4 Installation of small pieces of mineral fibre full fill batt with fibres in incorrect orientations were seen on the Surrey site. See Image 6.

8.5 Wet or weathered mineral fibre full fill batts were seen on the London, Surrey and Oxfordshire sites. See Images 9 and 11-13.

8.6 Badly fitted mineral fibre full fill batts with fibres in incorrect orientations or folded were seen on all but the London site. See Images 9, 11, 13, 14 and 16.

8.7 Torn or damaged mineral fibre full fill batts were seen at the Surrey, Cheshire and Humberside sites. See Images 10, 14 and 16.

8.8 The construction of both leaves above the top of mineral fibre full fill batts leaving a trough was seen on all sites with the exception of Cheshire. See Images 1-3, 5, 7, 8, 12 and 17.

8.9 Both gaps left between mineral fibre full fill batts and missing mineral fibre full fill batts were seen at the London, Cheshire and Humberside sites. See Images 4 and 14-16.

8.10 These practices can all be seen to be contrary to the requirements or recommendations laid down in many mineral fibre full fill batt cavity wall insulation manufacturers’ literature, manufacturers’ BBA Certificates, BS 6676: Part 2: 1986 (Code of practice for installation of batts (slabs) filling the cavity) or NHBC Standards (Vol. 2: Chapter 6.1).
9 Consequences

9.1 A study by Sandberg has stated that wet mineral fibre full fill batt cavity wall insulation will dry out in two stages. During the first stage, which will last for a couple if hours, gravity action will cause drainage of the material to a water content of 3-5% by volume except in the lower 10-20 cm, where the material remains saturated. During the second stage which will last from a couple of days to a couple of months, the drying mechanism is vapourisation of water and diffusion of water vapour out of the material. He states that a water content of 3.8% by volume drying in 25 days would be consistent with the effects of heavy rain and a water content of 0.5% by volume drying in 4 days would be consistent with the effects of light rain. (Sandberg, P.I. Thermal Resistance of a Wet Mineral Fibre Insulation. Thermal Insulation: Materials and Systems. ASTM STP 922, pp 394-404. Powel, F.J. and Matthews, S.L., Eds. ASTM, Philadelphia, 1987.)

9.2 While dry mineral fibre insulants are air permeable, when wet this characteristic is partially reduced which explains why drying out can take some considerable time. The mineral fibre relies on air movement to evaporate water and remove it. In full fill situations this effect is limited and thus mineral fibre can remain with increased moisture content for longer periods. Since there is a relatively impervious layer (e.g. a brick wall) on the cold side of the insulation the water vapour may condense on it.

9.3 Sandberg goes on to state that during the drying of moisture in the second stage, heat flows and temperatures in the material are affected by phase changes (i.e. additional heat is taken up from the warm side of the wall to vapourise the water and this heat is liberated on the cold side if and when the water vapour condenses on the inner side of the brick outer leaf). These must also be considered when thermal conductivity design values are assessed.

9.4 Estimating UK weather patterns is a black art, but if we assume that from September to May there was a light rain event every four days with no rain from June to August, installed mineral fibre full fill batt cavity wall insulation would have an average background moisture content of 0.25% water by volume for 75% of the year (275 days). If five of these light rain events were heavy rain events, the average moisture content of the installed mineral fibre full fill batt cavity wall insulation would be 1% water by volume for 75% of the year (150 days at an average of 0.25% by volume and 125 days at an average of 1.9% by volume).

9.5 A study by Weiland has highlighted the fact that a moisture content of only 1% by volume can increase the thermal conductivity of man made mineral fibre by up to 75%. (Weiland H. Building Physics in a Roof with Two Trapezoidal Sheets. Weiland Engineering AG, Maienfeld. 1993.)

9.6 A further study by Achtziger and Cammerer for the German Urbanism and Building Ministry has concluded that 1% of moisture by volume in mineral fibre can lead to an increase in thermal conductivity of up to 105%. (Achtziger J. & Cammerer J. Einfluss des Feuchtegehaltes auf die Wärmeleitfähigkeit von Bau - Und Dämmstoffen. Bauforschungsberichte des Bundesministers für Raumordnung, Bauwesen und Städtebau. 1988.)
9.7 Taking an average of Weiland's and Achtziger and Cammerer's results yields a 90% increase in thermal conductivity from 0.036 W/m·K to 0.068 W/m·K for a typical 75 mm mineral fibre full fill batt. In the brick / block wall detailed in Section 5 of this 'White Paper' this increase in thermal conductivity would increase the wall U-value from 0.36 W/m²·K to 0.55 W/m²·K.

9.8 Assuming that this increase in thermal conductivity occurs over 75% of a year and over 75% of a building surface area (56.25% of area and time combined), and using the methodology detailed in the Kingspan Insulation document ‘Lifetime Energy, CO2 and Financial Balances for Insulation Materials - A White Paper’, this thermal conductivity increase would cause an additional 1176 kWh of heat to be lost from a property of 115 m² wall area in one year. This is a 30% increase in heat loss for the wall as a whole. This additional heat loss would be responsible for 337 kg of CO₂ equivalent emissions per year and a financial loss of £26 per year.

9.9 Extrapolating data published by Eurisol (Cavity wall insulation. Eurisol. October 1990.) 1.5 million properties in the UK have been insulated with mineral fibre full fill batt cavity wall insulation. (Assumed 75,000 properties insulated with full fill batt cavity wall insulation per year post 1988/89.)

9.10 Assuming this increase in thermal conductivity is representative of all buildings insulated in this way, the use of mineral fibre full fill batt cavity wall insulation could be regarded as wasting the UK 1764 GWh (million kWh) of heat per year.

9.11 That is equivalent to the output of 0.588 power stations of an average output of 3000 GWh.

9.12 Furthermore, this could be regarded as causing 505.5 million kg (505,500 T) of CO₂ equivalent emissions to be pumped into the atmosphere per year with its consequent effects on global warming.

9.13 That is equivalent to 0.61 % of the UK's commitment to CO₂ equivalent emissions reduction under the 1997 Kyoto Protocol of 83 million T of CO₂ equivalent emissions (12.5% reduction from 1990 emission levels).

9.14 Finally, this could be regarded as costing occupiers of properties so insulated £39 million per year in wasted fuel bills.

9.15 These figures would be even worse if the effects of dynamic heat transfer from phase changes and additional water content from condensation were taken into account.

9.16 It could be argued that if the thermal conductivity of the mineral fibre full fill batt cavity wall insulation were to be debased, the risk of condensation would disappear, but this is not the case. It is simply lessened. A calculation using an identical construction and conditions to that used in Section 5, but with a $\lambda$-value of 0.068 W/m·K for the mineral fibre full fill batt cavity wall insulation is shown opposite.
9.17 The amount of condensate predicted to accumulate over a 60 day winter period is 347 g/m² wall area.
10 Case Study – Consequences

10.1 Kingspan Insulation converted a housebuilder in East England from the use of mineral fibre full fill batt cavity wall insulation to a Kingspan partial fill cavity wall insulation product. This conversion was effected part way through the construction of a particular site and, consequently, the builder constructed one show home with mineral fibre full fill batt cavity wall insulation and one with the Kingspan partial fill cavity wall insulation product.

10.2 As part of the conversion, Kingspan completed a thermographic survey of the two show homes.

10.3 Show home A, (See Image 18), insulated with mineral fibre full fill batt cavity wall insulation, had a designed U-value of 0.38 W/m².K, whereas show home B (See Image 19), insulated with a Kingspan partial fill product, had a designed U-value of 0.44 W/m².K (i.e. to a lower nominal standard).

10.4 The heating regimes of the two properties were the same for the two day time period preceding the survey and the heating systems themselves were the same.

10.5 As can be seen from the images, the surface temperature of show home A was approximately 1°C higher than that of show home B.

10.6 One would expect a higher surface temperature for a wall with a higher (worse) U-value and this is contrary to the designed U-values of the two show homes.

10.7 The thermographic survey was conducted at the end of April 1998 during a sustained period of wet weather, although it had been dry for at least 12 hours prior to the survey.

10.8 Kingspan Insulation could not investigate the walls further at the time of the thermographic survey, in order to ascertain if the mineral fibre full fill batt cavity wall insulation was wet, but on the basis of the results of the thermographic survey, wet mineral fibre is the most plausible explanation.

Image 18
This image shows the upper section of the front wall of show home A insulated with mineral fibre full fill batt cavity wall insulation. The average surface temperature is 8.5°C.

Image 19
This image shows the front elevation of show home B insulated with a Kingspan partial fill cavity wall insulation product. The average surface temperature is 7.5°C.
11 Remedies

11.1 Little can be done to remedy the effects that inadequate site workmanship and supervision have on walls insulated with mineral fibre full fill batt cavity wall insulation.

11.2 The only solution is to make the external leaf as impermeable to water as possible with renders, silicone treatments or other such remedies. All are expensive.
12 Kingspan Insulation Solutions

12.1 There are a number of solutions to the problems identified in this 'White Paper' that can be employed using Kingspan Insulation products.

12.2 One of Kingspan Insulation's products for partial fill cavity wall insulation can be used. The product is Kingspan Kooltherm® K8 Cavity Board. Thermographic images of walls so insulated are shown below.

12.3 This product design's out the risk of condensation formation. Calculations using an identical construction and conditions to that used in Sections 5 and 9, but using Kingspan Kooltherm® K8 Cavity Board shown on the next two pages. This product is chosen because it is characterised by having the lowest and highest λ-values of the three Kingspan Insulation products for partial fill cavity wall insulation. Both products have the same vapour resistance as they both have an integral foil facing.

12.4 Kingspan Insulation's product for insulated dry lining, Kingspan Kooltherm® K17 Insulated Dry-lining Board can also be used.

12.5 This product also designs out the risk of condensation formation. A calculation using an identical construction and conditions to that used in Sections 5 and 9 above, but using Kingspan Kooltherm® K17 Insulated Dry-lining Board is shown on page 26.

12.6 All of the Kingspan Insulation solutions detailed above retain an empty cavity within the structure of a cavity wall. Water has a negligible effect on the thermal performance of Kingspan Insulation products. These two factors combined mean that rain penetration is not an issue with Kingspan Insulation products.

Image 20
The image shows a gable wall with a relatively even surface temperature. It is insulated with Kingspan partial fill insulation. There are well insulated lintels with no debris. Very little thermal bridging at this position can be identified. There is also very little air leakage at the verge. It should be noted that the rooms behind are well heated which further displays the well insulated nature of the construction.

Image 21
This image displays the uniform thermal patterns which are associated with a well performing wall insulation system. It is insulated with Kingspan partial fill insulation. Some localised surface cooling is noticed due to wind effects.
Internal conditions: 20.0°C @ 55.0%RH
External conditions: 0.0°C @ 90.0%RH

Calculated U-value = 0.038 W/m².K (Based on the proportional area calculation method for determining U-values of structures containing repeating thermal bridges.)

Condensation calculations performed in accordance with BS 5250: 2002

<table>
<thead>
<tr>
<th>Element Description</th>
<th>Thickness (mm)</th>
<th>Thermal Conductivity (W/m.K)</th>
<th>Thermal Resistance (m².K/W)</th>
<th>Vapour Permeability (MNs/gm)</th>
<th>Vapour Resistance (MNs/g)</th>
<th>Vapour Pressure (kPa)</th>
<th>Structure Temperature (°C)</th>
<th>Dewpoint Temperature (°C)</th>
<th>Condensation Risk (kg/60 days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside surface resistance</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.549</td>
<td>0.3</td>
<td>-1.3</td>
<td>-</td>
</tr>
<tr>
<td>Brickwork Facing</td>
<td>102.5</td>
<td>0.770</td>
<td>0.133</td>
<td>42.00</td>
<td>4.31</td>
<td>0.578</td>
<td>1.3</td>
<td>-0.7</td>
<td>-</td>
</tr>
<tr>
<td>UNV. A/SPACE low emissivity</td>
<td>50.0</td>
<td>-</td>
<td>0.350</td>
<td>-</td>
<td>0.00</td>
<td>0.578</td>
<td>4.6</td>
<td>-0.7</td>
<td>-</td>
</tr>
<tr>
<td>Kingspan Kooltherm® K8 Cavity Board</td>
<td>30.0</td>
<td>0.023</td>
<td>1.522</td>
<td>-</td>
<td>100.0</td>
<td>1.252</td>
<td>16.0</td>
<td>10.3</td>
<td>10.3</td>
</tr>
<tr>
<td>Blockwork 600 Kg</td>
<td>100.0</td>
<td>0.400</td>
<td>0.250</td>
<td>45.00</td>
<td>4.50</td>
<td>1.282</td>
<td>17.8</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>AIR 10mm U/V; HOR FLOW; HI EM.</td>
<td>10.0</td>
<td>-</td>
<td>0.110</td>
<td>-</td>
<td>0.00</td>
<td>1.282</td>
<td>18.7</td>
<td>10.7</td>
<td>10.7</td>
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<tr>
<td>Plasterboard</td>
<td>9.5</td>
<td>-</td>
<td>50.00</td>
<td>0.47</td>
<td>-</td>
<td>1.285</td>
<td>19.0</td>
<td>10.7</td>
<td>10.7</td>
</tr>
<tr>
<td>Inside surface resistance</td>
<td>-</td>
<td>-</td>
<td>0.120</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Values at Interfaces:

25°C
20°C
15°C
10°C
5°C
0°C
-5°C
-10°C
-15°C
-20°C
-25°C

Inside

Outside
Internal conditions: 20.0°C @ 55.0%RH  
External conditions: 0.0°C @ 90.0%RH  

Calculated U-value = 0.38 W/m².K (Based on the proportional area calculation method for determining U-values of structures containing repeating thermal bridges.)  

Condensation calculations performed in accordance with BS 5250: 2002

<table>
<thead>
<tr>
<th>Element Description</th>
<th>Element Thickness (mm)</th>
<th>Thermal Conductivity (W/m.K)</th>
<th>Thermal Resistance (m²K/W)</th>
<th>Vapour Resistivity (MNs/gm)</th>
<th>Vapour Resistance (MNs/g)</th>
<th>Values at Interfaces</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Vapour Pressure (kPa)</td>
</tr>
<tr>
<td>Outside surface resistance</td>
<td>-</td>
<td>-</td>
<td>0.040</td>
<td>-</td>
<td>-</td>
<td>0.549</td>
</tr>
<tr>
<td>Brickwork Facing</td>
<td>102.5</td>
<td>0.770</td>
<td>0.133</td>
<td>42.00</td>
<td>4.31</td>
<td>0.579</td>
</tr>
<tr>
<td>UNV. A/SPACE high emissivity</td>
<td>50.0</td>
<td>-</td>
<td>0.180</td>
<td>-</td>
<td>-</td>
<td>0.579</td>
</tr>
<tr>
<td>Blockwork 600 Kg</td>
<td>100.0</td>
<td>0.400</td>
<td>0.250</td>
<td>45.00</td>
<td>4.50</td>
<td>0.609</td>
</tr>
<tr>
<td>AIR 10mm U/V; HOR FLOW; HI EM.</td>
<td>10.0</td>
<td>-</td>
<td>0.110</td>
<td>-</td>
<td>0.00</td>
<td>0.609</td>
</tr>
<tr>
<td>Kingspan Kooltherm® K17 Insulated Dry-lining Board</td>
<td>52.5</td>
<td>1.805</td>
<td>100.00</td>
<td>1.285</td>
<td>19.0</td>
<td>10.7</td>
</tr>
<tr>
<td>Inside surface resistance</td>
<td>-</td>
<td>-</td>
<td>0.120</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Calculated U-value = 0.38 W/m².K (Based on the proportional area calculation method for determining U-values of structures containing repeating thermal bridges.)

Condensation calculations performed in accordance with BS 5250: 2002
## Appendix A – Energy, CO₂ and Financial Calculations

### Fuel Source CO₂ eq. Cost Mix Contribution to 1 kWh Total

<table>
<thead>
<tr>
<th>Fuel Source</th>
<th>CO₂ eq.</th>
<th>Cost</th>
<th>Mix</th>
<th>Contribution to 1 kWh Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>g/kWh</td>
<td>£/kWh</td>
<td>MJ</td>
<td>kWh</td>
</tr>
<tr>
<td>Solid Fuels</td>
<td>389.1</td>
<td>0.0176</td>
<td>76.0</td>
<td>21.11</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>227.2</td>
<td>0.0185</td>
<td>953.7</td>
<td>264.92</td>
</tr>
<tr>
<td>Electricity</td>
<td>896.9</td>
<td>0.0769</td>
<td>79.3</td>
<td>22.03</td>
</tr>
<tr>
<td>Oil</td>
<td>290.3</td>
<td>0.0177</td>
<td>91.9</td>
<td>25.53</td>
</tr>
<tr>
<td>Total</td>
<td>333.58</td>
<td>1.00</td>
<td>286.50</td>
<td>0.022238</td>
</tr>
</tbody>
</table>

### Insulation Surface Area
- Insulation Surface Area a m²: 115

### Heating Efficiency
- Heating Efficiency yr %: 0.8

### Degree-Days Base
- Degree-Days Base deg C: 18

### Degree-Day
- Degree-Day DD days K/yr: 3190

### Degree-Hour
- Degree-Hour DH = DD * 24 hrs K/yr: 76560

### % of Area and Time Covered
- % of Area and Time Covered: 43.75 56.25

### U-value
- U-value U W/m².K: 0.36 0.55

### Energy Lost per Year
- Energy Lost per Year Q = (U*a*h)/1000r kWh/yr: 3962 6053 5138 1176 30

### CO₂ Equivalent Emissions of Lost Energy
- CO₂ Equivalent Emissions of Lost Energy kg: 1135 1734 1472 337 30

### Cost of Energy Lost per Year
- Cost of Energy Lost per Year £: 88 135 114 26 30
Contact Details

Customer Service
For quotations, order placement and details of despatches please contact the Kingspan Insulation Customer Services Department on the numbers below:

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- Fax: +44 (0) 870 850 8666
- email: commercial.uk@insulation.kingspan.com

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Tapered Roofing
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Details of the fuel mix and costs are as detailed in the Kingspan Insulation White Paper “Lifetime Energy, CO₂ and Financial Balances for Insulation Materials”.

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