Energy saving performance of Tenmat Firefly 120 loft covers in the UK climate

Commercial in Confidence

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Prepared for:	Tenmat Ashburton Road West Trafford Park Manchester M17 1RU
Prepared by:	Tom Wylot

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1 Introduction

This report details the work undertaken under contract number TT//F09323-1 on behalf of Tenmat Ltd. The work involves calculating the energy saving performance of Tenmat loft covers. In particular the energy saving performance under the UK climate was considered. To avoid overheating insulation is normally installed leaving an un-insulated around and over the down-lighter. The Tenmat loft cover allows for continuous insulation over the lights without overheating.

The energy saving performance was assessed by calculating the conduction and air-tightness heat loss components through a down-light installed according to standard UK practice and a down-light with Tenmat loft cover installed with insulation over the top.

The heat loss components were used along with average heating requirements for 18 UK regions to produce measures of energy saved when using the Tenmat loft cover.

Note that the energy savings shown here only apply to a situation where a down light is installed in a surface bounding a heated and un-heated zone.

2 Methodology

In order to assess the energy savings due to the Tenmat loft cover, two situations are examined:

1. A down light with no cover and insulation removed from around the downlight
2. A down light with a Tenmat loft cover and insulation over the top

The total heat loss co-efficient based on conduction and air-tightness was calculated for both situations as detailed in sections 2.1 to 2.4 below, using the thermal material properties given in Table 1.

Table 1 Materials

Material	Thermal conductivity/ $Wm^{-1}K^{-1}$	Thickness/ m
Glass wool insulation	0.040	0.300
Plasterboard	0.21	0.013
Down-light	50.00	0.001

The thermal conductivity values in Table 1 come from BS EN 10456:2007. Note that due to the lack on any down-light R-values, it has been assumed to be equivalent to a 1mm thick sheet of steel.

The heat loss co-efficient was used to calculate heating energy requirements, energy costs, and CO_2 savings for 18 UK regions with the intention of producing a representative measure of the energy saving performance of the Tenmat loft cover under the UK climate.

In addition a calculation has been made for what thickness of insulation would be required to save an equivalent amount of energy to that saved with the use of the Tenmat loft cover.

2.1 Calculation of conductive losses for down-light only

For the down light with no cover there are effectively two paths for the conduction losses:

1. The un-insulated area surrounding the down-light

2. The down-light

In order to calculate the conductive heat losses, the areas and thermal resistances are calculated for the two conduction paths. For the purposes of these calculations it is assumed that the down light has a diameter of 90mm (a size commonly used in the UK). As the UK building standards only specify that a safe distance should be left in between the down light and insulation, the area of the un-insulated area is assumed to be a 350mm^2 square, based on discussions Tenmat have had with a large insulation installer on standard insulation procedure.

Hence the area of the down-light is given by equation 1.

$A_{dl}=\pi x 0.045^2=6.36x10^{-3}\ m^2$ *Equation 1*

The area of the un-insulated area is given by equation 2

$A_{un}=.350^2-A_{dl}=0.116m^2$ *Equation 2*

Now the thermal resistance of each heat flow path is given equation 3:

$R_p=t_m\lambda_m^{-1}+R_{sf1}+R_{sf2}$ *Equation 3*

Where: t_m is the thickness of the material making up the conduction path
λ_m is the thermal conductivity of the material making up the conduction path
R_{sf1} and R_{sf2} are the surface resistances on the two faces of the material. These are taken to be internal surface resistances according to BS EN ISO 6946:1997 the surface resistance is given as 0.10Km^{2}W^{-1} for upwards heat flow.

The R-values in for the paths calculated according to Equation 3 with the values in Table 1 are given in Table 2.

Table 2 R-values

Conduction path	**R-value/ m^{2}KW^{-1}**
Un-insulated area (13mm plasterboard)	0.262
Down light	0.200

Using these values, the thermal transmittance times total area (UA) is calculated according to Equation 4. The UA value gives the amount of heat flowing through the down light and un-insulated area per Kelvin of temperature difference.

$UA = A_{un} R_{un}^{-1} + A_{dl} R_{dl}^{-1}$ *Equation 4.*

Which yields: UA= 0.475WK^{-1}

2.2 Calculation of conductive losses for down-light and Tenmat loft cover

For the conductive losses of the ceiling with loft cover the simplifying assumption is made that a loft cover with 300mm of insulation over the top is equivalent to simply laying a continuous layer of 300mm of insulation. In practice this will be a conservative assumption as it ignores the insulating performance of the loft cover and trapped air underneath. Using this assumption the R-value is given in Table 3.

Table 3 R-values

Path	**R-value/ m^2KW^{-1}**
plasterboard and insulation	7.762

The UA values are then calculated according to Equation 4

Which yields: UA= 0.0157WK^{-1}

2.3 Calculation of air tightness losses

Air-tightness tested according to the principles of BS EN 1026 have been performed on a down-light with and without a Tenmat loft cover. The results are given in the Chiltern Dynamics report Chilt/P09020/01. The results from these tests have been used as the basis for the air-tightness calculations.

The air-leakage value used in the calculations is taken as the measured leakage at 2Pa, which is 1.55m^3h^{-1} for no cover, and 0.05 m^3h^{-1} with the Tenmat loft cover on. Note that the air-tightness at 2Pa figures have been taken from the actual experimental data points, not the results derived from the best fit curve. This is because, the best fit curves are inaccurate at the lower limits of the range. This is particularly in the case of the downlighter only results, where the best fit curve suggests that the air-tightness should be 1.9m^3h^{-1}, where as the experimental results show an air tightness of 1.55m^3h^{-1} which is a 25% percent difference. As a matter of principle experimental data should always be preferred over empirically derived values.

The ventilation heat losses are then calculated according to Equation 7.

$H_{vn} = \rho_a C_{va} V_{av} (3600)^{-1}$ *Equation 7*

Where: H_{vn} is the ventilation heat loss in WK^{-1}
ρ_a is the density of air equal to 1.23 kgm^{-3}
C_{va} is the specific heat capacity of air equal to 1008 $Jkg^{-1}K^{-1}$

Which yields:

No cover H_{vn} = 0.534WK^{-1}
Tenmat Loft Cover H_{vn}=0.017WK^{-1}

2.4 Total heat loss co-efficient

The total heat loss co-efficient as given by the sum of the ventilation and conduction losses calculated in the previous sections and are shown in Table 4.

Table 4 Total heat loss

	Total Heat loss/ WK^{-1}
No cover	1.009
Tenmat Loft Cover	0.033

3 Results and discussion

3.1 Percentage reduction in heat losses

The heat loss co-efficients given in Table 4 show that the Tenmat loft covers give a significant reduction in energy use compared with down lights with no cover. The percentage energy reduction can be calculated according to Equation 8.

Percentage reduction= $100\text{-}100H_{cover}H_{nocover}^{-1}$ Equation 8

Which yields:

Percentage energy reduction, heating = 96.8%

3.2 Performance of covers in UK climate

The real world energy saving performance of the Tenmat loft covers in the UK can be examined by looking at the heating and cooling requirements in various UK regions.

Heating degree day figures have been taken from the monthly figures produced by the Carbon Trust. These figures give 20 year average degree days for the UK which are split into 18 regions, with the degree days broken down on a monthly basis. The degree days have a base temperature of $15.5^{0}C$. For the purposes of these calculations the heating season has been assumed to run from October to April inclusive and the figures taken are 20 year averages 1980 to 2009.

The degree day figures uses can be found at the following URL http://www.carbontrust.co.uk/SiteCollectionDocuments/Degree%20Days%20Data/June10_Degree_Days.pdf.

Table 5 shows the degree days for the 18 regions.

Table 5 Heating degree days

	Region	Heating degree days
1	London (Thames Valley)	1658
2	South Eastern	1804
3	Southern	1837
4	South Western	1585
5	Severn Valley	1815
6	Midland	1871
7	West Pennines	1973
8	North Western	2046
9	Borders	1888
10	North Eastern	1930
11	East Pennines	1859
12	East Anglia	1876
13	West Scotland	1953
14	East Scotland	2033
15	North East Scotland	2059
16	Wales	1742
17	Northern Ireland	1841
18	North West Scotland	1962
	Average	**1874**

The heating energy loss per down light per year can be calculated by multiplying the degree days figure by the heat loss coefficient and converting Watts into kWh. Results are displayed in Table 6. Note that implicit in this assumption is that the heating is left permanently on during the heating season. In practice the actual energy savings will depend on the occupancy and heating patterns in individual households, however, correcting for this requires a large amount of work including the effects of thermal mass on heating cycles and is outside the scope of this report.

Tables 6 also below displays various measures of energy performance for the Tenmat loft cover based on the values in Table 6. The calculated values are:

- Energy saved per year per down-light with cover. This is the difference between the energy with and without the cover.

- CO_2 saved per down light per year. This is calculated is calculated for three fuel types:

1. Gas heating where 0.184kg of CO_2 is created for each kWh of gas burnt Taking into account the boiler efficiency, assumed to be 90%, this gives a final CO_2 figure of 0.204kg of CO_2 per kWh of heating energy.

2. Electric heating where 0.544kg of CO_2 is created for each kWh of electricity used. Taking into account the efficiency, assumed to be 100%.

3. Oil heating is used where 0.247kg of CO_2 is created for each kWh of oil burnt Taking into account the boiler efficiency, assumed to be 90%, this gives a final CO_2 figure of 0.274kg of CO_2 per kWh of heating energy.

All CO_2 conversion figures are taken from the Carbon Trust, the Figures can be found at: http://www.carbontrust.co.uk/publications/pages/publicationdetail.aspx?id=CTL085 .

Table 6 Energy and CO_2 use and savings per cover fitted per year

	Region	Energy use no cover/kWh	Energy with cover/kWh	Energy savings/ kWh	Gas CO_2 Savings / kg	Electricity CO_2 Savings / kg	Oil CO_2 Savings / kg
1	London (Thames Valley)	40.15	1.31	38.84	7.92	21.13	10.64
2	South Eastern	43.69	1.43	42.26	8.62	22.99	11.58
3	Southern	44.48	1.45	43.03	8.78	23.41	11.79
4	South Western	38.38	1.26	37.13	7.57	20.20	10.17
5	Severn Valley	43.95	1.44	42.51	8.67	23.13	11.65
6	Midland	45.31	1.48	43.83	8.94	23.84	12.01
7	West Pennines	47.78	1.56	46.22	9.43	25.14	12.66
8	North Western	49.55	1.62	47.93	9.78	26.07	13.13
9	Borders	45.72	1.50	44.22	9.02	24.06	12.12
10	North Eastern	46.74	1.53	45.21	9.22	24.59	12.39
11	East Pennines	45.02	1.47	43.55	8.88	23.69	11.93
12	East Anglia	45.43	1.49	43.94	8.96	23.91	12.04
13	West Scotland	47.29	1.55	45.75	9.33	24.89	12.53
14	East Scotland	49.23	1.61	47.62	9.71	25.91	13.05
15	North East Scotland	49.86	1.63	48.23	9.84	26.24	13.22
16	Wales	42.18	1.38	40.80	8.32	22.20	11.18
17	Northern Ireland	44.58	1.46	43.12	8.80	23.46	11.82
18	North West Scotland	47.51	1.55	45.96	9.38	25.00	12.59
	Average	**45.38**	**1.48**	**43.90**	**8.95**	**23.88**	**12.03**

3.3 Performance of covers in a representative ceiling configuration

For these calculations the representative ceiling will have total area 16m^2 with 10% timber joists covered with 200mm glass wool insulation by area and the remaining area made up of 300mm glass wool insulation and 6 down lights. The bottom of the ceiling is faced with 13mm plasterboard. Joists will have insulation covering. One layer between the joists and 2 layers over the top.

The R-values and relative areas can be seen in Table 7.

Table 7. R-values and areas

	R value/ m^2KW^{-1}	Area, no down lights/m^2	Area with down lights/ m^2
Insulation	7.76	14.4	13.27
Timber+200mm insulation	6.4	1.6	1.6

Now using the values in Table 7 and the heating total heat loss co-efficients given in Table 4 the UA values for three ceiling configurations are calculated and displayed in Table 8.

Table 8 UA values for 3 ceiling configurations

Configuration	**UA/ WK^{-1}**
Ceiling	2.11
Ceiling with down lights	8.01
Ceiling with down lights and loft cover	2.16
Percentage energy saved with Tenmat loft covers, compared to ceiling with down lights only	73%

Based on the figures in Table 10 it can be demonstrated that it would be impossible to achieve the same UA value as the ceiling with loft covers by increasing the insulation thickness in the case of the ceiling with 6 down lights only. This is because even with zero heat loss through the insulated area (infinite thickness insulation) the UA value would still be $6.05WK^{-1}$ (based on 6 times the no cover figure given in Table 4) due to the losses through the down lights, which is greater than the UA value for the ceiling with Tenmat covers of $2.16WK^{-1}$.

4 Conclusion

Based on the assumptions detailed in this report, calculations have shown that a down-light with a Tenmat loft cover with 300mm of glass insulation over the top will reduce heat flow through each down lighter due to conduction and air-tightness losses by 96.8% over a down-light installed in a way representative of standard building practice.

Based on the heat loss calculations and when used under the 1980-2009 average heating requirements of the UK. The Tenmat loft cover will on average save 43.9kWh of energy per year per down-light, assuming continuous heating through the October to April heating period.

The corresponding CO_2 savings for three fuel types can be seen in Table 9.

Table 9 CO_2 savings for three fuel types

Fuel Type	Assumed heating efficiency	kWh to CO_2 conversion factor/ kg $(kWh)^{-1}$	Yearly CO_2 savings per year per down-light/ kg
Gas	0.9	0.204	8.95
Electricity	1.0	0.544	23.88
Oil	0.9	0.274	12.03

The total savings per dwelling can be calculated by multiplying these figures by the total number of down lights. For example based on the assumptions in this report a house with 10 down-lights (which are located in a divide between a heated and un-heated area) would save 10x43.9=439kWh of electricity per year, 10x8.95=89.5kg of CO_2 per year for Gas heating, 10x23.88=238.8kg of CO_2 per year for Electric heating and 10x12.03=120.3kg of CO_2 per year for Oil heating.

When calculations were made on a representative ceiling of area of 16m^2 with 6 down lights, it was found that it would be impossible to achieve a similar heat loss reduction as the ceiling with Tenmat covers by increasing the insulation thickness in the case of the ceiling with un-covered down lights.

It should be noted that the heat loss due to convection from the hot light fitting has been neglected in the calculation, as there is currently no standard test method for assessing this convection.

Neglecting this component of heat loss means that the figures presented in the report for energy saving with the Tenmat loft cover will be conservative. This is because in practise the convection will significantly increase the energy loss in the down-light only case and it is expected that the Tenmat loft cover will eliminate or significantly reduce this convection.

5 Authorisation

	Issued by:	Under the authority of:
Signature:	T. Wylot	Victor Kearley
Name:	Tom Wylot	Dr Vic Kearley
Title:	Research Physicist	Section Leader Consulting/ Product Services