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Sempatherm metalised saw-tooth radiator panels

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Executive Summary

This report provides an analysis of the expected energy savings from metalised saw-tooth panels placed behind radiators on external walls. The analysis is supported by *in-situ* and laboratory test data.

It is a slightly revised version of an analysis first prepared for the Energy Saving Trust in 2000.

The analysis indicates that typical savings for the installation of radiator panels are 93 kWh per year per square metre of panel behind radiators on uninsulated external walls. This takes account of the distribution of houses in the stock having wall U-values between 1.0 and 2.1 W/m²K.

Contents

1 Introduction

This report relates to Sempatherm metalised saw-tooth radiator panels, constructed in a louvered or saw toothed fashion (with raised ridges) with a reflective surface.

When placed behind radiators, radiator panels restrict the heat transfer to the wall by:

a) the introduction of an essentially closed airspace between wall and panel;

b) its reflective surface reducing heat transfer by radiation.

The analysis in this report provides estimates of the annual energy savings for radiator panels installed in housing.

2 Analysis of the effect of radiator panels

2.1 Effect of panels when heating is on

BRE conducted an *in-situ* test of a radiator panel placed behind a radiator against an external wall. The wall was of cavity brick construction with an estimated U-value of 1.5 W/m²K. The tests involved the measurement, under essentially steady-state conditions, of the heat flow into the wall with and without the panel in place, using a heat flow meter.

The thermal resistance of the panel itself, primarily as a result of the enclosed airspace behind it introduced by the louvres was obtained from the measured heat flux and the temperature difference across the panel. This gave a value of 0.16 m²K/W.

The surface emissivity of the panel was measured separately and found to be 0.38.

Temperature conditions vary throughout the year and analysis needs to be based on suitably representative conditions that correspond to average conditions over the heating season. The mean external temperature during the BRE tests was 5°C, slightly less than the seasonal average (usually 6°C as a representative UK figure) but sufficiently close to the average for present purposes. The mean radiator temperature was 50°C, which is also reasonable for average conditions during heating periods.

The thermal resistance of the panel was measured *in-situ* under the temperature conditions stated above, and so does not require further adjustment.

The radiant transfer from the radiator to the wall surface (no panel) or to the panel surface (with panel) is given by:

$$q_r = E h_r (T_{rad} - T_s)$$

$$h_r = 4 \sigma T_m^3$$

$$T_m = 273.16 + 0.5 (T_{rad} + T_s)$$

$$E = 1 / (1/\varepsilon_1 + 1/\varepsilon_2 - 1)$$

where

q_r = radiant heat transfer rate (W/m^2)

h_r = radiative heat transfer coefficient (W/m^{2}K)

σ = Stefan-Bolzmann constant (5.67 x 10^{-8} W/m²K^4)

T_{rad} = surface temperature of radiator (°C)

T_s = surface temperature of wall or panel (°C)

T_m = average of T_{rad} and T_s (K)

ε_1, ε_2 = emissivity of surfaces.

The radiant heat flow is calculated in Table 1 on the basis of the measured surface temperatures. The emissivities were taken as 0.9 for the radiator and wall surfaces, and 0.38 for the panel surface.

Table 1 : Calculation of radiant heat flow

	T_{rad}	T_s	T_m	E	h_r	ΔT	q
No panel	49.90	35.12	315.67	0.82	7.13	14.78	86.4
With panel	50.37	26.99	311.84	0.36	6.88	23.38	57.9

h_c is the convective coefficient (W/m²K) and q is the total heat flow due to convection and radiation (W/m²).

The introduction of the panel thus reduced radiative transfer by (86.4 - 57.9) = 28.5 W/m^2. The change in the heat flow into the wall is less than this, however, because the lower surface temperature of the panel (compared to the plain wall) means that there is less convective heat re-gain from the surface. The change in heat flow through the wall was measured separately and found to be 21 W/m^2 less with the panel than without it.

These data provide an approximate basis for assessing the effect of the reflective surface. The effective radiative resistance, $1/Eh_r$ from the data in the table above, is 0.17 m^{2}K/W without the panel and 0.40 with it, a difference of 0.23 m^{2}K/W. To allow for the difference in convective re-gain a lower figure, say 0.14 m^{2}K/W, is appropriate.

The overall effect of the panel is then its resistance (0.16 m^{2}K/W) plus the change in effective surface resistance (0.14 m^{2}K/W), making 0.3 m^{2}K/W.

2.2 Effect of panels when heating is off

This is more straightforward to assess. With equal radiant and air temperatures the surface resistance is[1]

$$R_{si} = \frac{1}{h_c + Eh_r}$$

where h_c = 2.5 for vertical surfaces. This gives a difference in R_{si} of 0.08 for the two emissivity factors considered.

The overall effect is an increased resistance of 0.16 + 0.08 = 0.24 m^{2}K/W.

[1] Unlike most cases of surface resistance the form of E for the parallel planes is appropriate here.

2.3 Effect of wall U-value

By ascribing an effective additional thermal resistance to the panel, as above, its effect as a function of wall U-value is readily assessed.

Table 2: Wall U-value

Plain wall without panel	With panel (heating on)		With panel (heating off)	
U	U	ΔU	U	ΔU
0.5	0.43	0.07	0.45	0.05
1.0	0.77	0.23	0.81	0.19
1.5	1.03	0.47	1.10	0.40
2.0	1.25	0.75	1.35	0.65
3.8	1.78	2.02	-	-

2.4 BSRIA tests

BSRIA carried out tests in a "radiator test room" which was designed for measuring the thermal output of radiators to BS 3258:1977.[2]

Measurements were made under three test conditions, labelled A, B and C, in which the radiator temperatures were respectively 50°C, 40°C and 30°C.

In tests B and C it indicated that the panel had no effect. Test A, however, with the radiator temperature of 50°C, is the most relevant. The results were:

Table 3 : BSRIA test results, set A

	No panel	With panel
Radiator output (W)	701.8	619.6
Radiator temperature T_{rad} (°C)	50.10	51.05
Mean room temperature T_{ai} (°C)	19.12	19.83
External air temperature T_{ae} (°C)	6.60	6.61

The heat loss coefficient for all surfaces of the test room excluding that behind the radiator was 52.55 W/K. The area of the radiator was 1.32 m^2 and thus the expected heat loss rate is:

$$q = 52.55\,(T_{ai} - T_{ae}) + 1.32\,U_{wall}\,(T_{rad} - T_{ae})$$

[2] BSRIA Report 52300/1, March 1988.

The U-value of the wall behind the radiator was 3.8 W/m^{2}K, giving a predicted loss rate without the panel of 876 W.

With the panel in place the effective U-value of the wall behind the radiator becomes 1.78 W/m^{2}K according to the preceding analysis, giving a predicted loss of 799 W.

In both cases the predicted heat losses based on the measured temperatures are higher than the measured losses. Assuming that a constant term is the cause of the difference, the change in heat flow on introduction of the panel, $\Delta\Phi$, can be considered for the predicted and measured results:

$\Delta\Phi$ (predicted) = 876 - 799 = 77 W

$\Delta\Phi$ (measured) = 702 - 620 = 82 W

The very close similarity of these figures gives support for the present basis of assessment of the panels. The basis was derived from data on a wall of U-value 1.5 W/m^{2}K, and appears to be consistent with data measured on a wall of much higher U-value of 3.8 W/m^{2}K.

3 Annual energy savings

The preceding analysis indicates that when the heating is on, a reduction in heat flow rate of 21 W/m^2 is reasonable for a wall of U-value 1.5 W/m^{2}K, and that this can be scaled to other U-values using the data for ΔU in Table 2. For example for a U-value of 2.0 W/m^{2}K, the reduction in heat transfer flow rate would be 21 x 0.75/0.47 = 34 W/m^2.

When the heating is off the reduction in heat flow rate is given by the right-hand column of Table 2 multiplied by an appropriate temperature difference. This will be taken as 9 K (internal 15°C, external 6°C).

This leads to the values in Table 4.

Table 4: Reduction in heat flow rate due to radiator panel

Wall U-value W/m^{2}K	Heating on W/m^2	Heating off W/m^2
0.5	3	0
1.0	10	2
1.5	21	4
2.0	34	6

The annual savings depend on the hours of heating. For housing using the standard heating pattern generally used for energy assessments in housing (an average of 11 hours/day) and a 30-week heating season gives 2310 hours of heating and 2730 hours when the heating is off.

Table 5 gives the reduction in heat loss in kWh/m^2/annum, by applying the data in Table 4.

Table 5: Reduction in energy loss due to radiator panels

Wall U-value W/m^2 K	Reduction in energy loss kWh/m^2/annum
0.5	6.9
1.0	28.6
1.5	59.4
2.0	94.9

The savings in energy use depend on the efficiency of the heating system. Table 6 gives values for 78% efficiency.

Table 6: Reduction in energy use due to radiator panels for 78% efficiency

Wall U-value W/m^2K	Reduction in energy use $kWh/m^2/annum$
0.5	9
1.0	37
1.5	75
2.0	121
2.1	131

Savings for U-values less than 1.0 W/m^2K are very small, and panels are only worthwhile for walls of higher U-value.

The installation of radiator panels is recognised as an energy efficiency measure in the Energy Efficiency Commitment 2005-2008 (EEC2)[3], which states:

"...for all radiator panels constructed in a louvered or saw toothed fashion (with raised ridges) with a reflective surface, the energy saving attributable is 93 kWh/m^2 per annum. If a panel is used which does not have a reflective surface, the energy saving should be taken as a half of the above value."

The figure of 93 $kWh/m^2/annum$ is a weighted average for U-values of 1.0 (1.9 million households), 1.5 (4.6 million households) and 2.1 (5.0 million households), where the number of households are those estimated for the housing stock in 2010.

[3] Energy Efficiency Commitment 2005-2008, Technical Guidance Manual Issue 1, OFGEM, March 2005 (www.ofgem.gov.uk)

4 Other considerations

Internal walls. The analysis is for panels behind radiators against an external wall. A panel behind a radiator against an internal wall will reduce the heat flow through the internal wall, but since this serves mainly to reduce the heat input needed to the adjacent room, its effect on energy use is expected to be small.

Party walls.. In the calculation of energy use, an adjacent dwelling is taken to be heated to the same temperature as the one under consideration. Thus the effect for panels behind radiators against party walls is also expected to be small.

Reflective surface. Panels may or may not have a reflective surface. If the panel surface has high emissivity the panel does not reduce the radiant heat transfer to the wall and its effect on energy use will be less. The analysis in section 2.1 of this paper indicates that roughly half the total effect is a result of radiative effects and half due the introduction of airspaces behind the louvres. That is the basis of OFGEM's allowance mentioned above of half the savings attributable to metalised panels. However, corresponding measurements on a non-reflective panel to confirm this have not been made. (Note that it is the emissivity at infra-red wavelengths, not optical wavelengths, that is relevant here.)

The emissivity was measured on a new panel. Degradation of the surface due to dirt, oxidation, etc. would increase the emissivity over time. At present there is no information on the maintenance or otherwise of the emissivity of radiator panels in typical usage.

5 Conclusions

From an analysis of measured results on the effect of metalised saw-tooth radiator panels, the savings per square metre of panel behind radiators on external walls is estimated as:

- 37 kWh/m^2/annum for walls of U-value 1.0 W/m^2K

- 75 kWh/m^2/annum for walls of U-value 1.5 W/m^2K

- 121 kWh/m^2/annum for walls of U-value 2.1 W/m^2K

An average of 93 kWh/m^2/annum, based on the prevalence within the housing stock of walls with those U-values, is currently used for the purposes of the Energy Efficiency Commitment 2005-2008.

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