Energy cost reduction from radiator reflectors: limits of plausibility

Vilnis Vesma

What is the proposition?

This article examines a class of energy-saving product consisting of reflective foil placed behind heating radiators. The argument goes that when a heating radiator is mounted on an outside wall it will transfer heat by radiation to the cold wall surface behind it, increasing the local rate of heat transfer through the wall at that point with no benefit to the conditions in the space. By inserting a reflective sheet between the radiator and the relatively cold wall surface, this radiative heat transfer will be all but eliminated.

The effect is no doubt real. But how significant is it? What order of magnitude of cost savings are likely to result from fitting foil? A theoretical model suggests that for 24-hour heating, annual savings of the order of only £2.50 per square metre can be expected (at 2015 energy prices, in the average UK climate). This is only if the wall is poorly insulated. The savings would be of a fraction of this figure for reasonably-insulated walls.

Methodology

My analysis considers a simple model of the process in which the radiator is treated as a flat plane facing the wall, and sufficiently close to it for any edge effects to be neglected. See figure 1 overleaf. Both the radiator and wall surfaces are assumed to have emissivities of 0.9 and the foil, when present, to have an emissivity of 0.1. Because it is likely to matter whether or not the wall is insulated to any extent, the analysis is carried for two typical U-values. A figure of 1.5 W/m^{2}K corresponds to a brick cavity wall or a 600mm solid stone construction with dense plaster in either case; a lower value of 0.6 W/m^{2}K represents a cavity wall with 50mm of glass fibre insulation.

The temperature of the radiator is a paramount factor in determining heat transfer and the implicit assumption is usually that it will be at full boiler temperature. This is not reasonable. Either because the heating system uses compensated-temperature control, or because a local control valve will be regulating the radiator, its surface temperature will vary with the weather. To facilitate the analysis I have assumed temperature-compensation curve with a maximum flow temperature of 80ºC at an outside-air temperature of 0ºC, and a slope of -3, which results in radiator temperature of 20ºC at 20ºC outside.

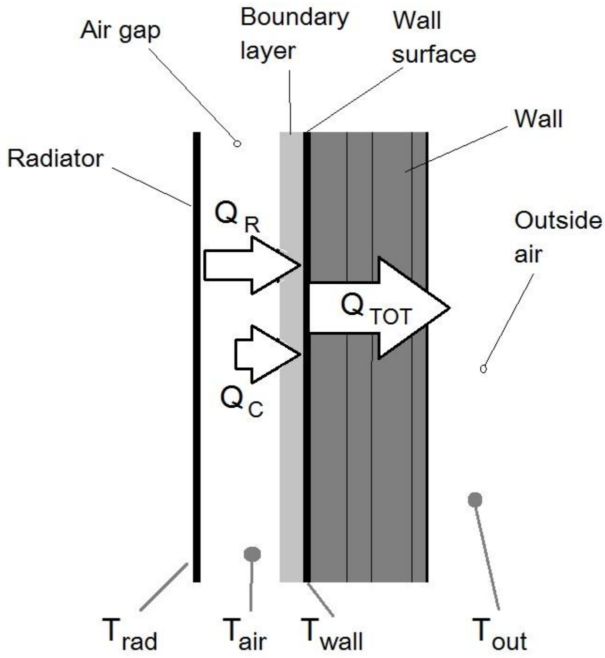

Figure 1

The wall structure can be considered as two layers when accounting for its thermal resistances: (a) the internal boundary layer; and (b) everything else from the inner surface to the outside air, including the outer boundary layer. Separating the internal surface boundary resistance is necessary because it affects convective transfer but not radiative transfer.

I took the inner boundary layer as having a resistance (R_{in}) of 0.12 m^2K/W, a commonly-assumed value. Thus for example if the overall conductance (U value) of the structure is 0.4 W/m^2K, the total resistance is 2.50 m^2K/W comprising 0.12 m^2K/W inside and 2.38 m^2K/W beyond the inner wall surface (R_{out}).

There must be a balance of energy arriving at and leaving the inner wall surface. Call the temperature of the outside air T_{out}, the inner wall surface T_{wall}, the air behind the radiator T_{air} and the radiator itself T_{rad}. There are two parallel inflows of heat, a convective flux Q_C and radiative flux $Q_{R.}$ Q_C is given by:

$$Q_C = (T_{air} - T_{wall})/ R_{in} \qquad \text{----------------------------------(1)}$$

While the radiative heat flux arriving Q_R is given by

$$Q_R = \sigma[(273+T_{rad})^4 - (273+T_{wall})^4]/(1/\varepsilon_{rad} + 1/\varepsilon_{wall} -1) \qquad \text{----------------------------------(2)}$$

Where ε_{rad} and ε_{wall} are the emissivities of the radiator and wall surfaces respectively and σ has the value $5.67x10^{-8}$. For simplicity in the model, T_{air} is set half-way between T_{wall} and T_{rad}.

The total heat flux leaving the wall surface Q_{TOT} meanwhile is given by

$$Q_{TOT} = (T_{wall} – T_{out})/ R_{out} \qquad \text{----------------------------------(3)}$$

And $Q_{TOT} = Q_C + Q_v$.

A numerical example will help. If T_{out} is 7.0ºC, the radiator temperature T_{rad} will be 59ºC (as defined by the compensator characteristic). For emissivities (ε_{rad} and ε_{wall}) of 0.9 and a U-value of 0.6 W/m²K it can be shown that an inner wall surface temperature of 56.08ºC satisfies the requirement for heat balance as follows:

a) The air temperature adjacent to the wall is (59 + 56.08)/2 = 57.54ºC

b) From equation 1, Q_C = (57.54 - 56.08)/0.12 = 12.17 W/m²

c) From equation 2, $Q_R = 5.67\times10^{-8}.\ [332^4 – 329.08^4]/(1/0.9 + 1/0.9 -1)$ = 19.56 W/m²

d) Hence total heat flux arriving at the wall surface is 12.17 + 19.56 = 31.73 W/m²

e) The wall's total thermal resistance is 1/0.6 = 1.667 m²K/W. Deducting the inner boundary resistance leaves R_{out} = 1.667 – 0.12 = 1.546 m²K/W

f) From equation 3, Q_{TOT} = (56.08 – 7)/1.546 = 31.75 W/m²

The heat flow into the wall (step d) matches the heat flow out of the wall (step f).

What does this imply?

To take account of the profile of prevailing temperatures through the year, the calculation shown above can be repeated, for combinations of U-value and wall-surface emissivity, at different outside air temperatures. In the table below this is done in 2-degree bands, and the annual hours spent in each temperature are included so as to compute a temperature-weighted annual heat loss for each permutation. The temperature profile for Midlands UK as been used:

		Total heat flux, W/m²			
Temperature band mid point (ºC)	hours per year	U = 1.5		U = 0.6	
		ε = 0.9	ε = 0.1	ε = 0.9	ε = 0.1
-5	38.4	134.8	114.2	52.2	48.8
-3	19.2	131.7	111.5	51.0	47.6
-1	81.6	128.5	108.9	49.7	46.5
1	206.4	120.3	102.0	46.6	43.6
3	384.0	107.2	91.1	41.6	39.0
5	686.4	94.2	80.2	36.7	34.4
7	1075.2	81.3	69.4	31.7	29.7
9	1022.4	68.5	58.6	26.8	25.1
11	1046.4	55.7	47.9	21.9	20.6
13	1161.6	43.2	37.2	17.0	16.0
15	1118.4	30.7	26.5	12.1	11.4
17	907.2	18.3	15.9	7.3	6.8
19	638.4	6.1	5.3	2.4	2.3
Heat flow kWh/m².year		469	402	184	172
Saving, kWh/m².year		67		12	

It can be seen that for U = 1.5 W/m^{2}K the annual reduction is 469-402 = 67 kWh per m^2. With heating-boiler efficiency of 80% and a fuel price of say £0.03 per kWh, the monetary value of savings is (67/0.8)x0.03 ≈ £2.50 per m^2 per year.

When the wall is insulated (U = 0.6 W/m^{2}K) the energy saving is only 12 kWh per m^2 and the monetary savings are proportionately lower at about £0.40 per m^2 per year.

Vilnis Vesma
Degree Days Direct Limited
15 November 2015

Final version 2 | File ref R107