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The Engine House Swindon

Thermal performance of energy efficiency improvements to timber windows

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Thermal performance of energy efficiency improvements to timber windows

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Front cover: Reception Area window after installation of double glazing (at The Engine House, Swindon).

SUMMARY

This report describes tests carried out at the Engine House, Swindon to compare three proprietary retrofit systems for improving the thermal performance of traditional timber windows. To assess their performance U-values of glazing (centre of pane) were measured *in situ* before and after the systems were installed. The results showed that all three systems reduced heat loss by more than 50%. The report also discusses impact of each system on heritage values, operation and maintenance of the windows.

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IMAGES

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1. INTRODUCTION

'The Engine House' is a Grade II listed building dating from the 1840s that once formed part of the Great Western Railway Locomotive Works (Figure 1). Since 1992 it has been one of the main national offices of Historic England (formerly English Heritage) and is home to the Historic England Archive. In 2014 the existing single glazed timber sash windows were upgraded by installing secondary glazing and, in some areas, a system of retrofitted double glazing. The improvements were intended to enhance comfort levels for the occupants, improve the energy performance of the windows, and reduce noise penetration without harming the heritage significance of the building. To assess the effectiveness of the improvements, *in-situ* U-value measurements were made of the glazing both before and after the works.

Figure 1: West elevation of the Engine House, Swindon.

2. 19TH-CENTURY SASH WINDOWS

There are over two hundred windows at The Engine House, most of which date from the 1840s. They are timber double-hung subdivided sashes (typically eight-over-eight) in box frames with cambered or square heads. The majority are 1850mm wide x 3200mm high. Some of the windows on the elevation facing the railway incorporate original secondary counterbalanced sashes on the inside to provide a degree of soundproofing. In general, the 19th-century windows are in very good condition.

3. IMPROVEMENTS TO THE WINDOWS

Three proprietary systems were used to improve the performance of the windows:

1. An aluminium-framed secondary glazing system.
2. A retrofit double glazing system designed for windows divided into small panes.
3. A variant of (2) above, designed for windows with large, undivided panes.

Technical details of these systems are as follows.

3.1 Secondary glazing system

A heavy-duty, aluminium-framed secondary glazing system incorporating pre-tensioned spring-balanced vertical sliding sashes, twin brush draught seals, and low emissivity glass. The frames were polyester powder-coated to match the colour of the existing window frames. Secondary glazed units were fixed to the internal window reveals some 75–100 mm behind the existing windows (Figures 2–4).

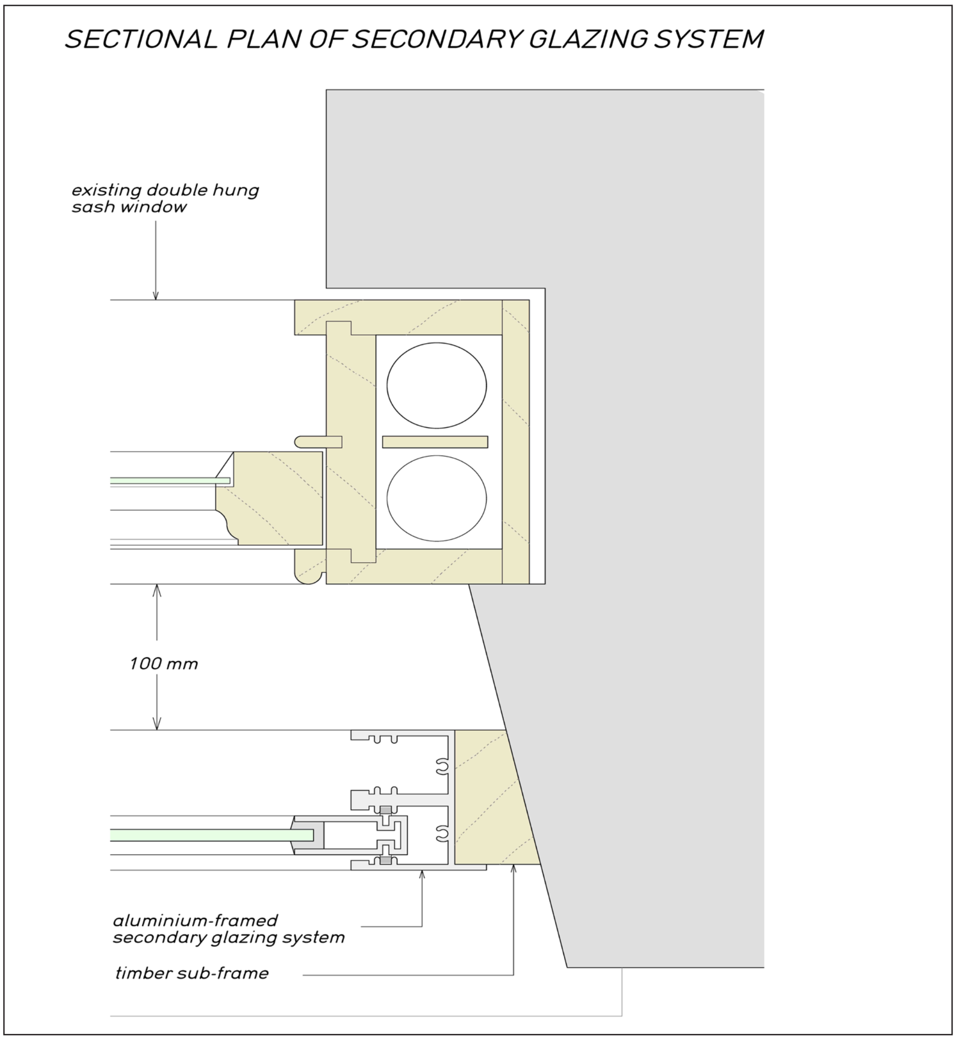

Figure 2: Diagram of secondary glazing system.

Figure 3: Typical secondary glazing installation in The Engine House.

Figure 4: Typical secondary glazing installation – detail at sill level.

3.2 Retrofit double glazing system – small panes

An innovative retrofit double glazing system ('Conservation Glazing') designed for traditional windows with small panes and glazing bars (Figure 5). This system consists of scratch-resistant acrylic panes that are accurately cut by laser, and fitted between the glazing bars, approximately 20mm behind the existing glass (Figure 6). The panes are fixed to the glazing bars with a white-coloured butyl mastic sealant, and a perimeter silica gel desiccant strip is provided between the inner and outer panes to control the humidity of the air trapped between them (Figures 7 and 8). The system is designed to improve the thermal performance of traditional windows with minimal impact on their appearance or historic fabric (Figures 9–12). In addition, the system does not add substantially to the weight of the sashes, thereby avoiding the need to re-balance them.

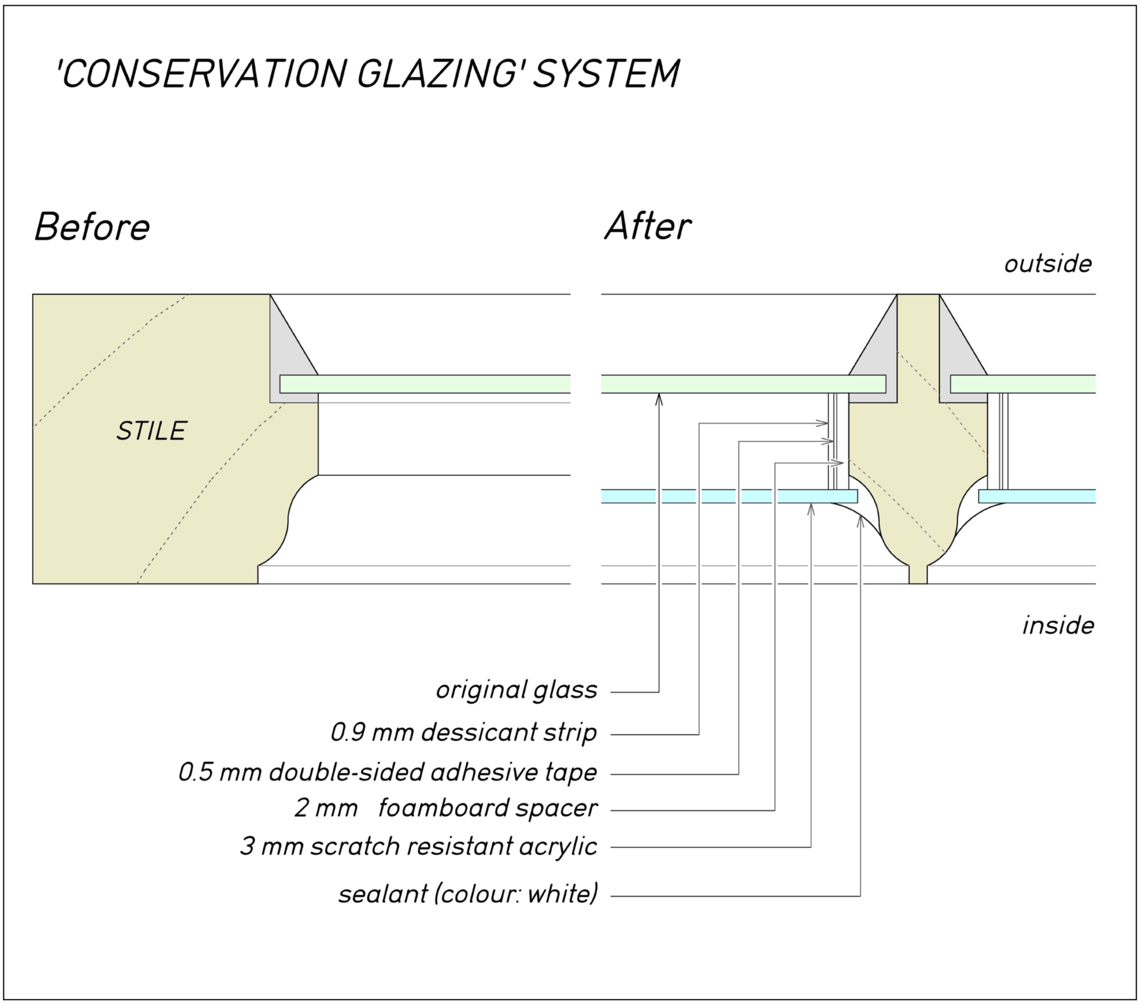

Figure 5: Diagram of retrofit double glazing system for small pane windows.

Figure 6: An acrylic pane being fitted between the glazing bars of the original wndow.

Figure 7: The application of butyl mastic sealant to the glazing bars prior to the fitting of the acrylic pane.

Figure 8: The application of the dessicant strip between the two panes to aid the control of humidity.

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Figure 9: Reception Area windows after installation of double glazing system.
Figure 10: Typical window pane before installation (interior view).
Figure 11: Typical window pane after installation (interior view).
Figure 12: Interior of the Reception Area window after installation.

3.3 Retrofit double glazing system – large panes

A variant of the system described above intended for windows with large-paned (undivided) sashes. The desiccant strip is augmented by a 'breather system' to control moisture in the air contained between the panes (Figure 13). Unlike the system for small paned windows, the 'breather system' can be re-charged for re-use.

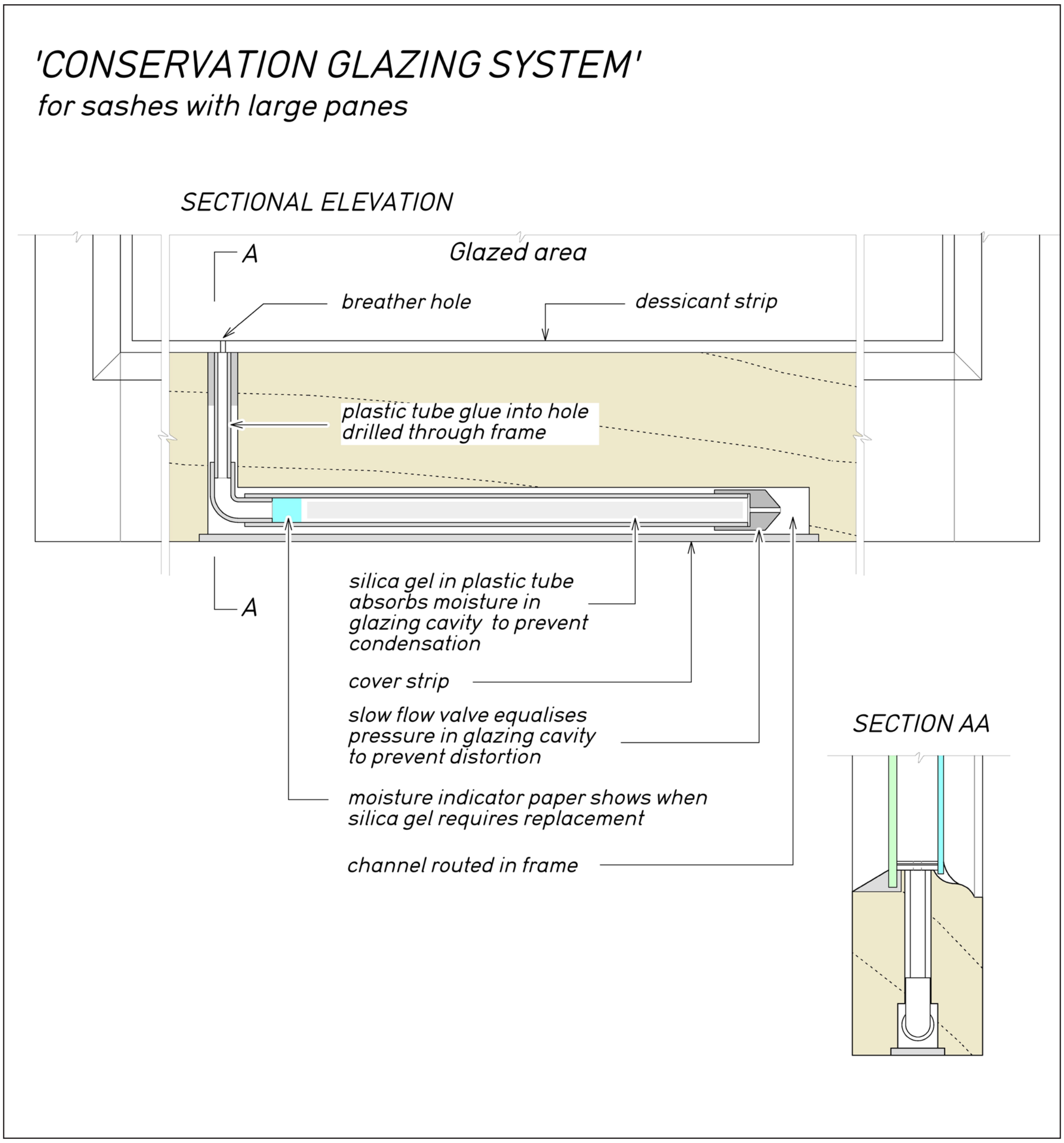


Figure 13: Diagram of double glazing system for large pane windows.

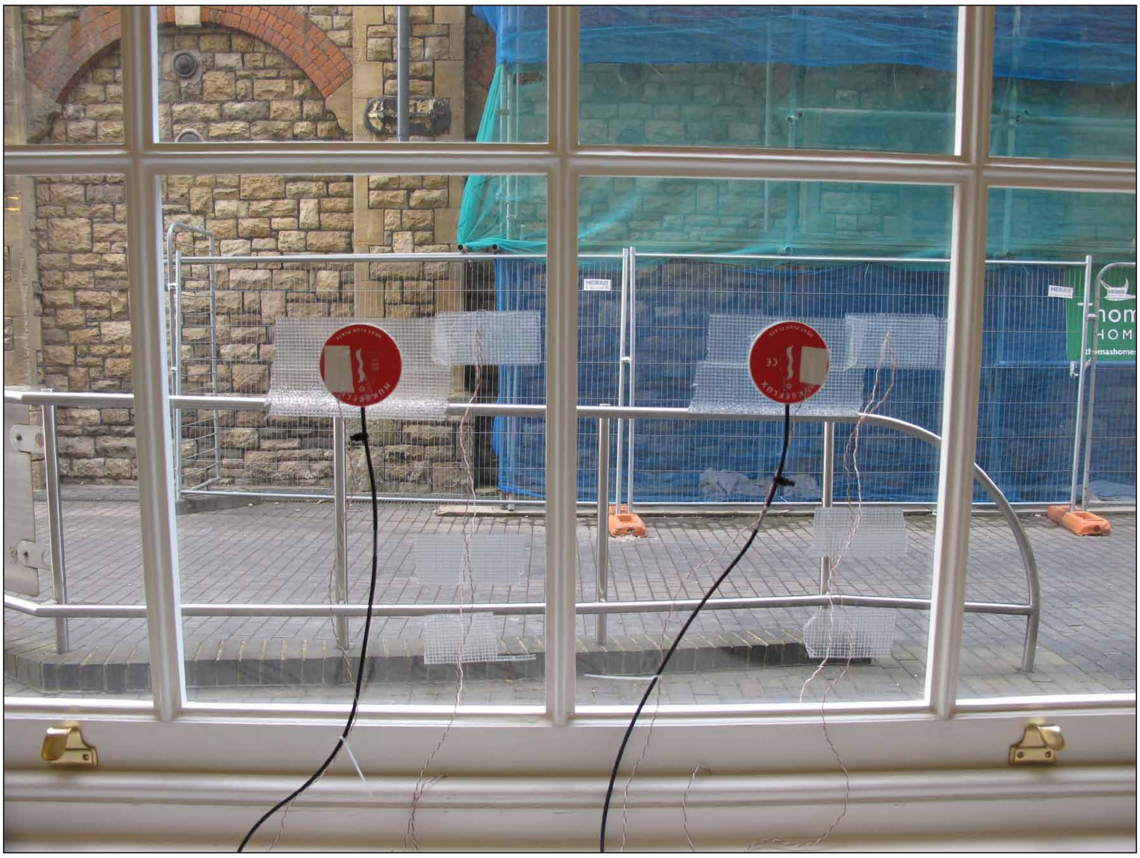


Figure 14: In-situ U-value measurements of the double glazing system. Heat flux and surface temperature sensors are attached to the acrylic panes.

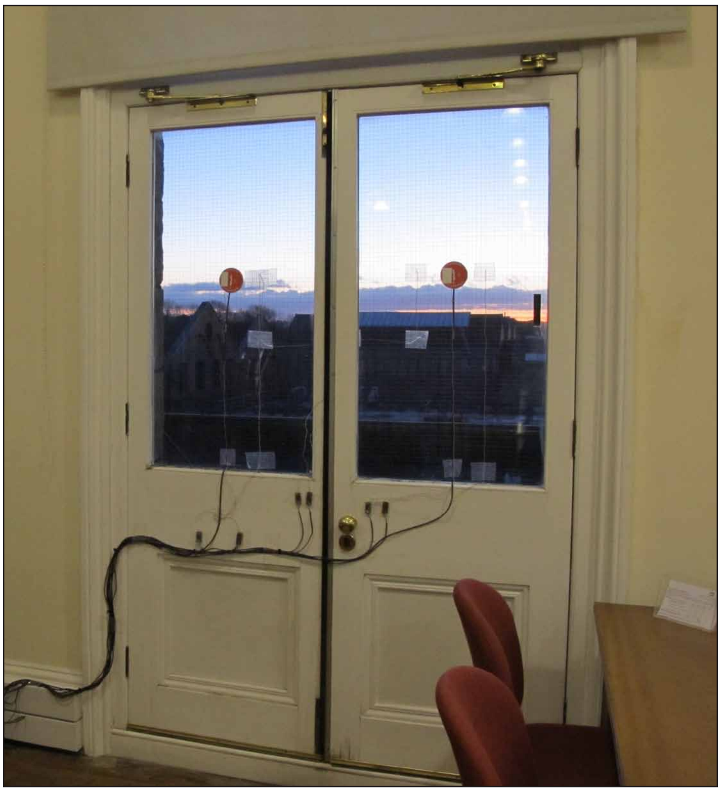


Figure 15: In-situ U-value measurements of the double doors in the Public Search Room before installation of the 'breather' double glazing system.

4. THERMAL PERFORMANCE TESTS

In-situ U-value (W/m^{2}K) measurements were carried out on three windows, before and after installation of the systems described above to compare the respective improvements in thermal performance. Heat flux sensors, surface temperature and air temperature sensors were installed and monitored for a period of one month during each stage of testing. The gathered data was then used to calculate centre of pane *in-situ* U-values. Further details of methodology are provided in Appendix 1.

The three monitored locations were: Room 1/24 where a secondary glazing system was installed; the ground floor Reception Area where the 'Conservation Glazing' double glazing system was installed (Figure 14); the Public Search Room where the breather system of 'Conservation Glazing' double glazing was used for the large panes of glass on the double doors (Figure 15).

The pre-installation monitoring was carried out between December 2013 and January 2014. Post-installation monitoring was carried out from March to April 2014.

In addition, humidity cards were inserted between the original glazing and acrylic panes of the two 'Conservation Glazing' double glazing systems to assess the performance of the desiccant strips (Figure 16).

Figure 16: A humidity card inserted between the original glazing and the acrylic pane of the double glazing system in the ground floor reception area.

5. RESULTS

Only centre-of-pane *in-situ* U-value measurements were obtained. This is a standard approach, as the U-values of entire doors and windows cannot easily be measured *in situ*, and the main conductive heat loss is through the glazing. The results showed that both secondary glazing and double glazing systems reduced heat loss by more than half. The greatest improvement was observed in Room 1/24 where the secondary glazing system reduced the *in-situ* U-value from 5.0 W/m^{2}K to 1.7 W/m^{2}K, a 66% reduction in heat loss. Both the small pane and breather double glazing systems showed significant improvement in their thermal performance with over 50% reductions in heat loss. The Reception Area window dropped from 5.2 W/m^{2}K to 2.3 W/m^{2}K and the Public Search Room doors dropped from 5.0 W/m^{2}K to 2.2 W/m^{2}K. The results are given in Table 1.

CENTRE OF PANE *IN-SITU* U-VALUE RESULTS				
Room	**System**	**Before W/m^{2}K**	**After W/m^{2}K**	**% reduction in heat loss**
1/24	Heavy duty secondary glazing with low-e glass	5.0	1.7	66
Reception	Conservation glazing	5.2	2.3	56
PSR doors	Breather system Conservation Glazing	4.9	2.2	55

Table 1. Before and after works in-situ U-value results from the windows tested at The Engine House.

6. CONCLUSIONS

The results of the *in-situ* U-value tests show that the secondary glazing system with low-emissivity glass and the innovative double glazing system both significantly improve the thermal performance of timber sash windows. Of the two systems, secondary glazing will increase energy performance to a greater degree. This is because heat losses are reduced not only through the glass, but also through frame and glazing bars, and uncontrolled air infiltration/exfiltration is lessened. The low emissivity coating further improves thermal efficiency, provided cleaning is carried out in accordance with the manufacturer's instructions.

Though not as thermally efficient as secondary glazing, the 'Conservation Glazing' system is less visually obtrusive, and there is no conspicuous double reflection when viewed from outside. However, the moulding profiles of glazing bars are rendered less legible internally by the sealant used to fix the acrylic panes. The system is advantageous in that it does not interfere with the operation of windows, and because it adds little weight to the sashes they do not have to be rebalanced. However, its long-term satisfactory performance will depend greatly on the condition and adequate maintenance of external putties and paintwork to prevent moisture ingress. Also, care is needed to avoid surface abrasion of the acrylic panes during cleaning.

Traditional windows make a significant contribution to the character and significance of historic buildings. The work carried out at The Engine House demonstrates that the thermal performance of traditional windows can be greatly improved with only minimal impact on their heritage values.

APPENDIX 1

Methodology

The method and analysis outlined below have been developed by Dr. Paul Baker at Glasgow Caledonian University for work previously undertaken for Historic England.

Hukseflux Type HFP01 heat flux meters were used to measure the heat flow through the selected glazing (see figure 1). They are 5mm thick and 80mm in diameter. Two heat flux sensors were used for each window. They were mounted on the panes of glazing in the interior with double sided tape. In addition, surface temperature measurements were taken with type-T thermocouples of the glazing, one on the exterior pane of the window and the other on the heat flux sensor. A third thermocouple was attached to the interior pane of the window as an additional check. The thermocouples were affixed to the glazing with transparent tape.

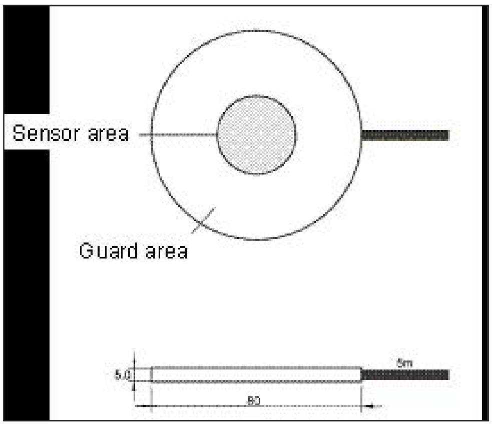
All sensors were logged at 1 minute intervals and stored as 10 minute averages using a Campbell Scientific CR1000 data logger. The dimensions of the logger are approximately 25 x 12 x 4cm. The data logger required a power point for the duration of the monitoring.

Analysis

The U-value or conductive heat loss of each option installed was estimated as follows: A U-value was calculated from the average heat flux meter reading and surface temperature difference between the outer glazing surface and the room facing surface with a correction of the standardised internal and external surface resistances and the thermal resistance of the heat flux meter, using the following equation:

$$U = \frac{1}{\left(\frac{T_{si} - T_{se}}{Q}\right) + 0.17 - 6.25 \times 10^{-3}} \ \mathrm{W/m^2K}$$

where T_{si} and T_{se} are respectively the internal and external surface temperatures and Q is the heat flux. The term 0.17 is the sum of internal and external surface resistances and term 6.25×10^{-3} is the correction for the heat flux meter.



Figures 17 and 18: © Dr Paul Baker, Glasgow Caledonian University.



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