Innovate UK Future Homes

Blind Screen Window Products Energy House Test

Test Report v1.0

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1 Introduction

This report provides U-value measurements from window blind testing at the University of Salford Energy House 1 test facility. It was undertaken as part of Innovate UK Future Homes Study. The purpose of the testing was to measure under controlled conditions the impact that three products manufactured by Blind Screen have on the heat loss through window glazing.

2 Methodology

2.1 Test facility

The Energy House 1 test facility contains the Energy House, a replica Victorian solid wall end-terrace house constructed within an environmental chamber. The Energy House was built using reclaimed materials and traditional construction methods and can be retrofitted to most fabric thermal performance standards. The chamber can replicate external air temperatures between -12 °C and +30 °C and simulate rainfall, wind, and solar radiation. The Energy House has a conventional hydronic central heating system with radiators in each room that is served by either a domestic gas condensing combination boiler or an air source heat pump. Its building automation control system enables simulation of occupant behaviour, such as window and door opening, lighting and appliance use, and domestic hot water (DHW) draw-offs. The Energy House shares a party wall with an adjoining building, referred to as Pemberton House. Environmental conditions in the chamber and Pemberton House can be controlled and repeated across multiple test periods. This makes it possible to measure the impact of changes building fabric, space heating provision, and occupancy behaviour with greater confidence and speed than houses in the field.

A double-glazed window housed in a uPVC frame in Pemberton House was used for the test. It has 24 mm double glazing panels (4 mm + 16 mm space + 4 mm) with low emissivity coating on the outer surface of the inner pane, the cavity is filled with 90 % argon.

2.2 Centre pane in situ U-value measurements

2.2.1 In situ U-value measurement method

U-Value measurements were made following ISO 9869:1, using a single heat flux plate (HFP) located at the centre of the glazing panel. Each product was tested for a minimum of 72 hours, with the stated U-value being based on the final 24-hour period.

2.2.2 Environmental conditions

The internal temperature was maintained at 20°C using an electric resistance heater connected to a PID temperature controller. Between the heater and glazing, shielding was placed to reduce radiative heat gain incident on the glazing panel and HFPs (Figure 2). For Phase 1 of testing, the chamber HVAC was set to a repeating 24-hour pattern replicating a 'typical' UK day during the heating shoulder season[1] (Figure 1). The pattern was based on the average hourly Chartered Institution of Building Services Engineers (CIBSE) Test Reference Year (TRY) temperatures for Leeds in the between October and May and excludes the period between December and February. For Phase 2 of testing, the HVAC was set to achieve and maintain 5°C throughout the test period to facilitate steady state conditions.

[1] Chamber temperature pattern was a requirement of testing that was taking place simultaneously in the Energy House.

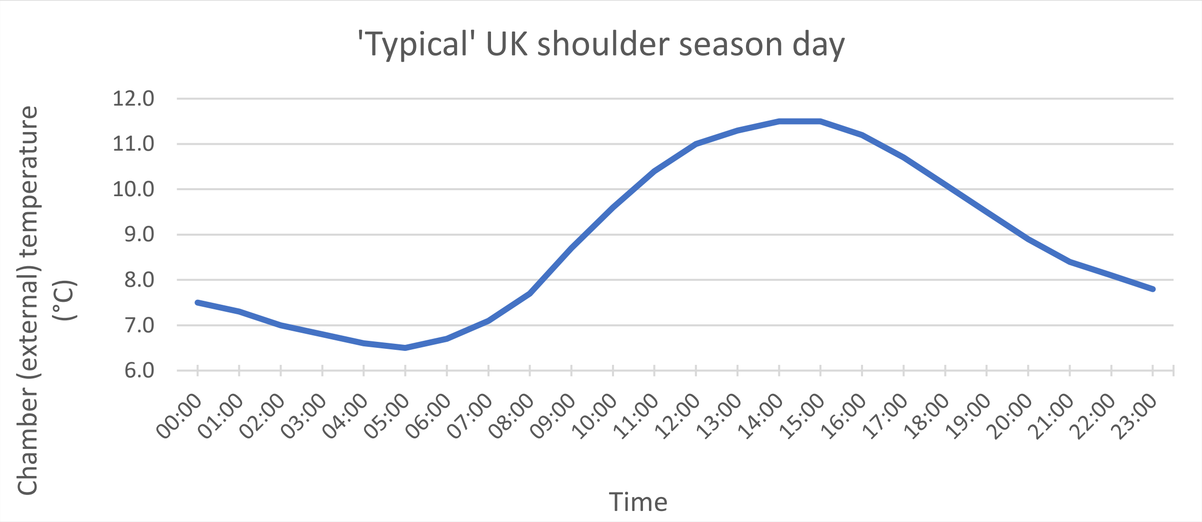


Figure 1 - Chamber temperature profile for a 'typical' UK shoulder season day.

2.2.3 Measurement Equipment

Internal and external temperature measurements were made using Campbell Scientific Hygrovue 10 sensors (±0.1 °C). Heat flux measurements were made using a Hukseflux HFP01 (±3%) in the centre of the main glazing panel. The data was collected at 1-minute interval using a Campbell CR1000X data logger.

Figure 2 – a) Internal test setup, with internal temperature sensor circled in yellow and centre pane HFP denoted by the blue arrow. b) Shows the external temperature sensor highlighted in yellow.

2.3 Products Tested – Phase 1

2.3.1 ZeddFit 01

A vertical blind with light seal fabric and scene set fabric.

Figure 3 - ZeddFit 01 post install experimental set-up.

2.3.2 Double Track 02

A vertical blind with light seal fabric and scene set fabric.

Figure 4 - Double Track 02 post install experimental set-up.

2.4 Products Tested – Phase 2

2.4.1 Blind Screen 02 Dual

A vertical blind with a Light Seal fabric and Breezin net.

Figure 5- Blind Screen 02 Dual post install experimental set-up.

3 Results

The results provided in Table 1 and Figure 6 show that the Phase 1 test of ZeddFit 01 and Double Track 02 resulted in in-situ centre pane U-values of 0.69 (±0.06) W/m^{2}K and 0.68 (±0.05) W/m^{2}K. These measurements represent a centre pane U-value reduction of 49% from the baseline measurement performed with no window covering (1.33 (±0.10) W/m^{2}K). Shown in Table 1 and Figure 7, the Phase 2 test of Blind Screen 02 Dual resulted in an in-situ centre pane U-value of 0.82 (±0.05) W/m^{2}K. This represented a 40% U-value reduction from the Phase 2 baseline of 1.37 (±0.10) W/m^{2}K.

Table 1 - Final 24-hour measured centre pane U-values.

Phase 1 Test	**U-Value [Wm^{-2}K^{-1}]**	**ΔU on baseline [Wm^{-2}K^{-1}]**	**U % Change on Baseline[1]**
Glazing Only (Baseline)	1.33 (±0.10)	-	-
ZeddFit 01	0.69 (±0.06)	-0.65 (±0.12)	-49% (±9%)
Double Track 02	0.68 (±0.05)	-0.65 (±0.11)	-49% (±8%)
Phase 2 Test	**U-Value [Wm^{-2}K^{-1}]**	**ΔU on baseline [Wm^{-2}K^{-1}]**	**U % Change on Baseline[1]**
Glazing Only (Baseline)	1.37 (±0.09)	-	-
Blind Screen 02 Dual	0.82 (±0.05)	-0.54 (±0.11)	-40% (±8%)

[1]*percentages apply to the combination of covering and glazing tested.*

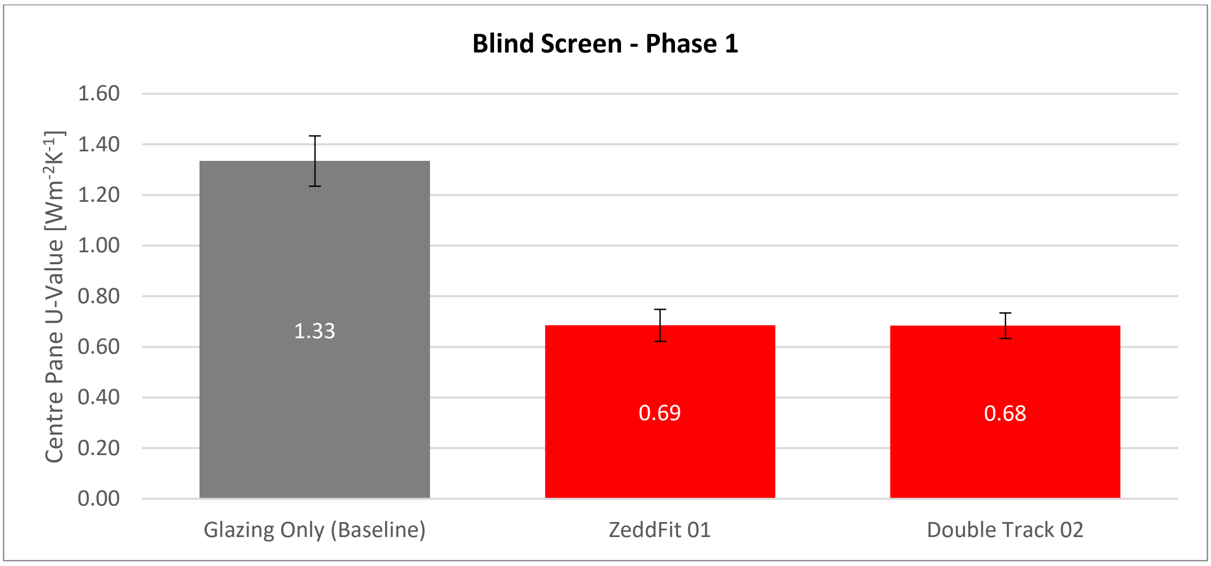


Figure 6 – Phase 1 centre pane U-value measurements.

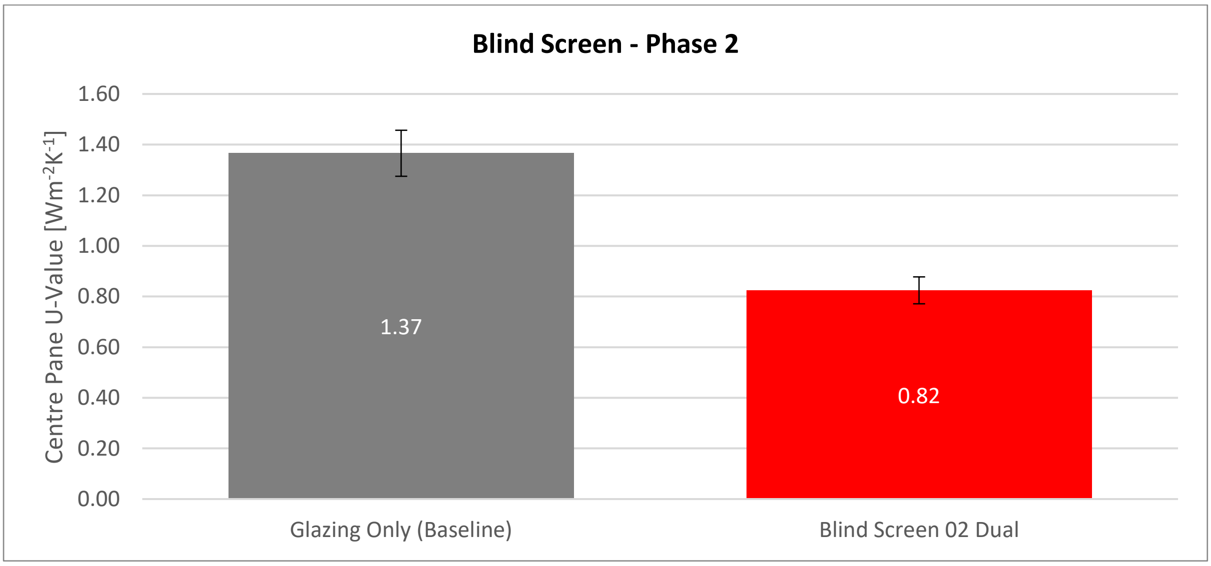


Figure 7 - Phase 2 centre pane U-value measurements.

Results presented comply with ISO 9869 measurements and are based on the final 24-hour measurement period. Appendix A shows the full 72h U-value period for each system, and Appendix B shows the raw heat flux and temperature measurements.

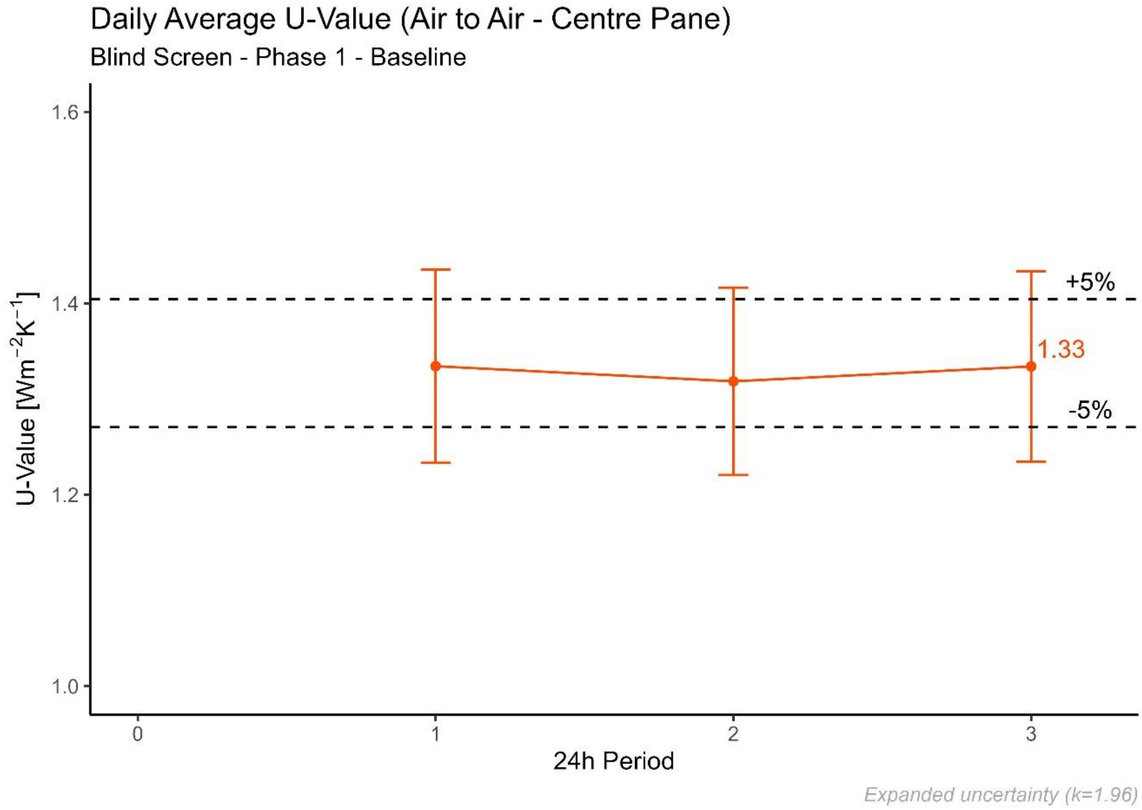
ISO 9869:1 U-value uncertainty is typically between 14-28%. However, as measurements at the Energy House were conducted under steady state conditions, the uncertainty can be further reduced, and has been stated for each measurement. The methodology followed for the uncertainty calculations can be found in Appendix C.

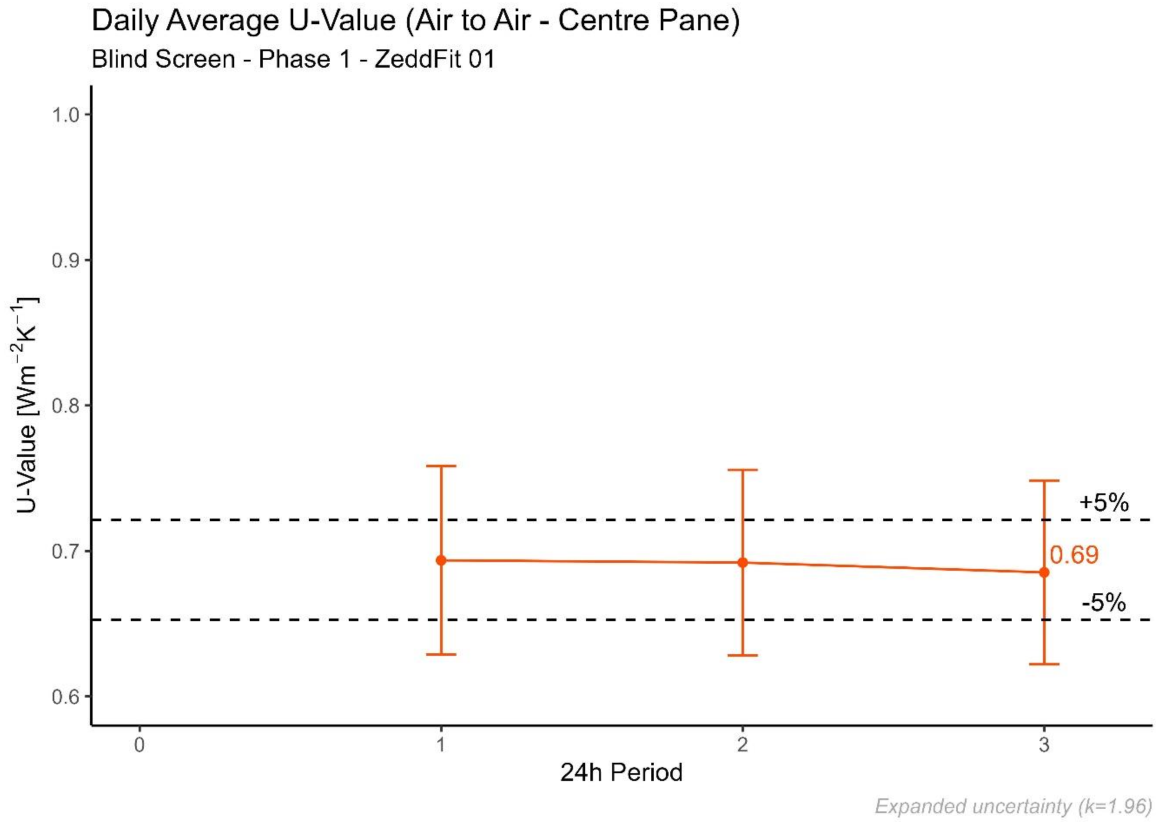
4 Summary

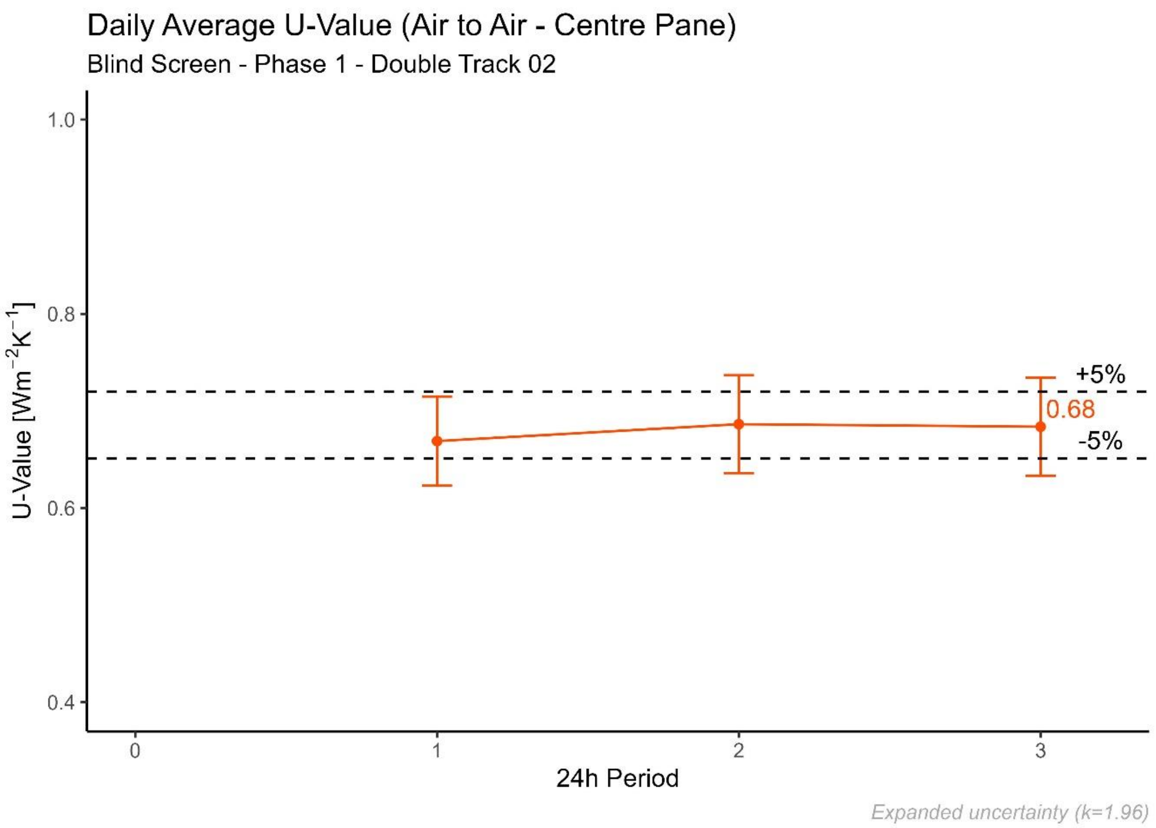
In situ centre pane U-value measurements under controlled conditions found that, during the Phase 1 test, compared to the Phase 1 baseline (glazing only), ZeddFit 01 and Double Track 02 both resulted in a reduction in centre pane U-value of 49%. Phase 2 test results showed that when compared to the Phase 2 baseline (glazing only), the Blind Screen 02 Dual provided a 40% U-value reduction. The reduction in heat loss measured is representative of the centre of the glazing and not the whole window and only applicable to periods in which they are in-use. The reduction in heat loss may vary according to the type of window on which they are fitted.

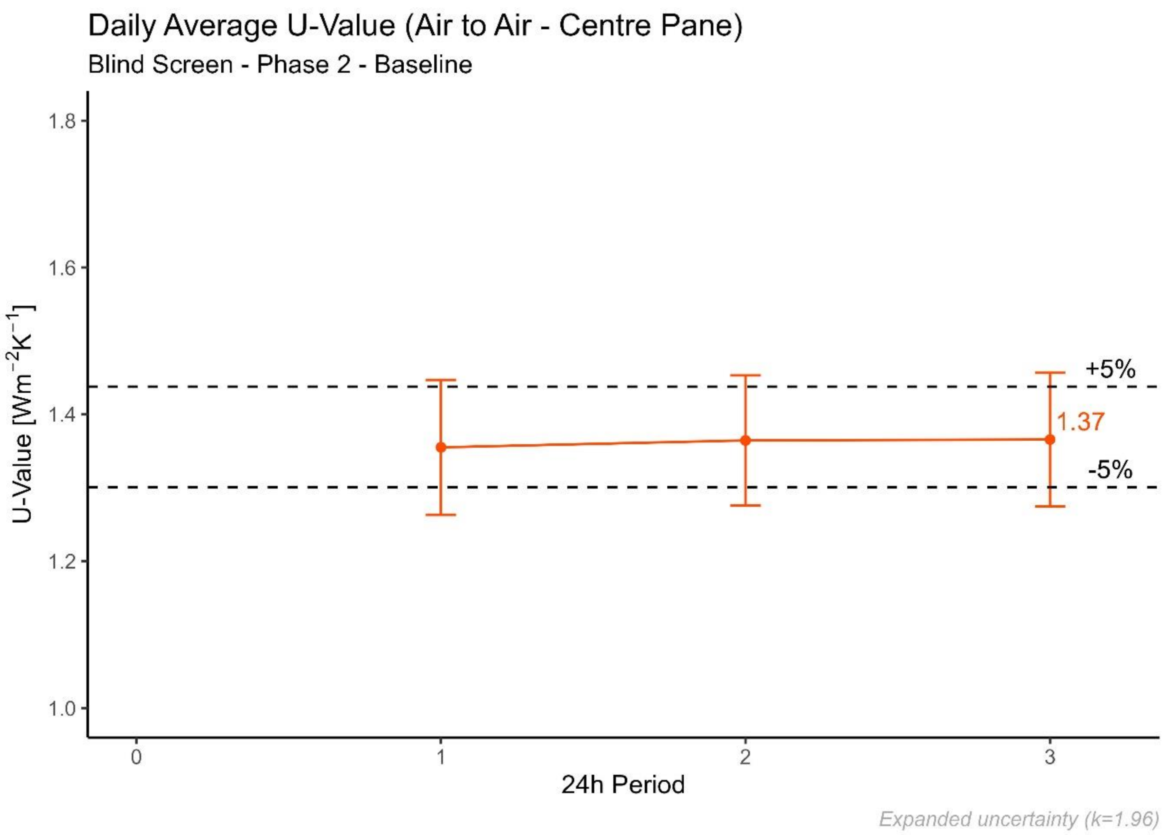
Appendix A - 24-hour Average Centre Pane U-Value

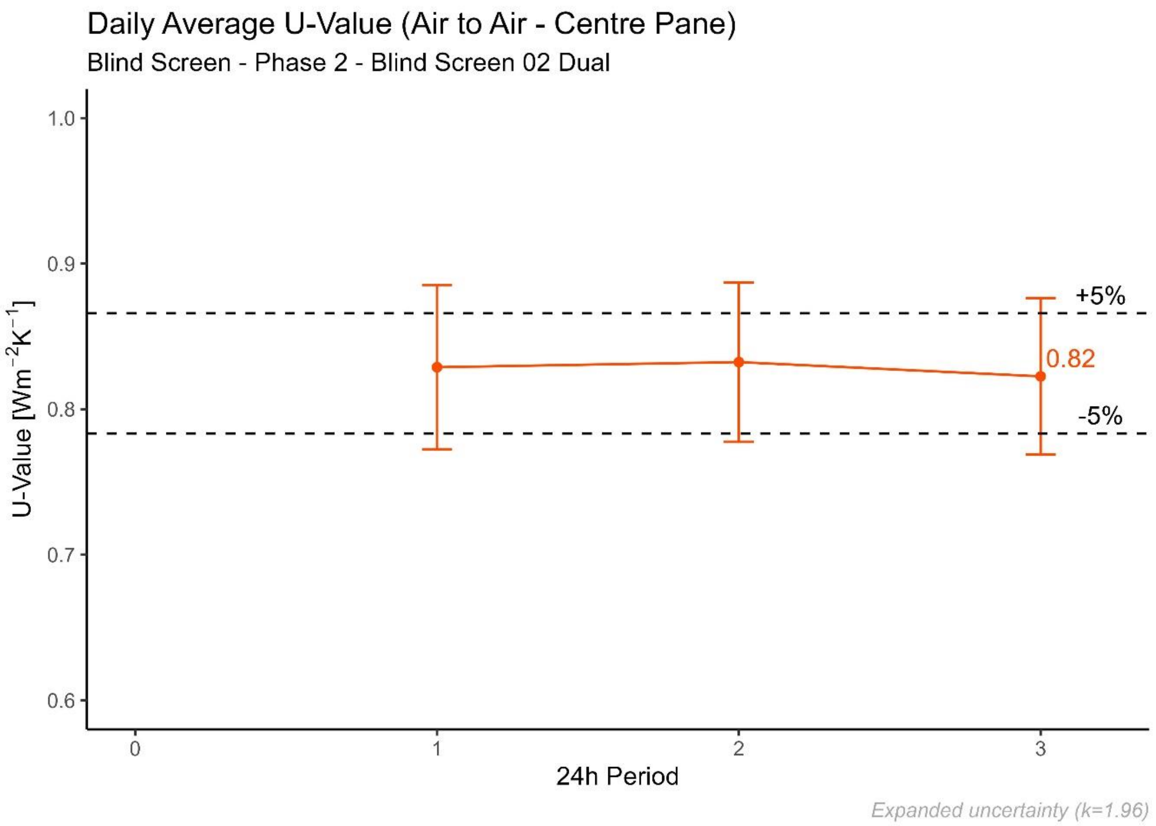
±5% lines are to show conformity to part of the criteria stated in ISO9869:1.





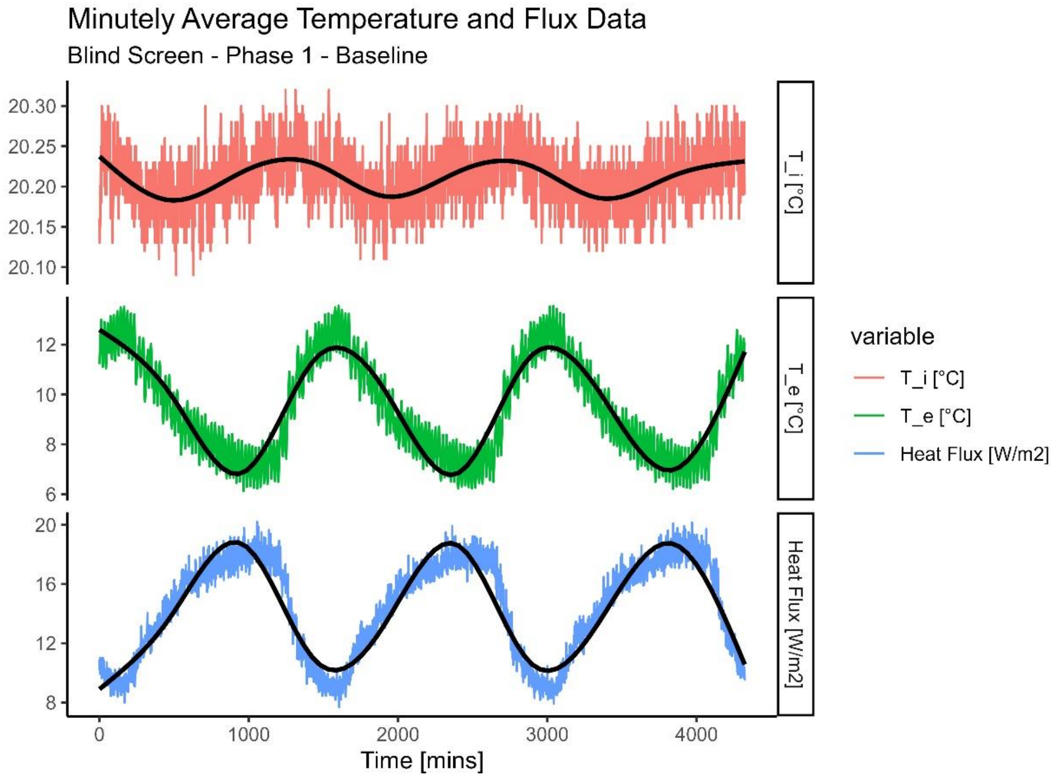

Daily Average U-Value (Air to Air - Centre Pane)
Blind Screen - Phase 1 - Double Track 02
1.0
0.8
0.6
0.4
U-Value [Wm⁻²K⁻¹]
+5%
0.68
-5%
0
1
2
3
24h Period
Expanded uncertainty (k=1.96)

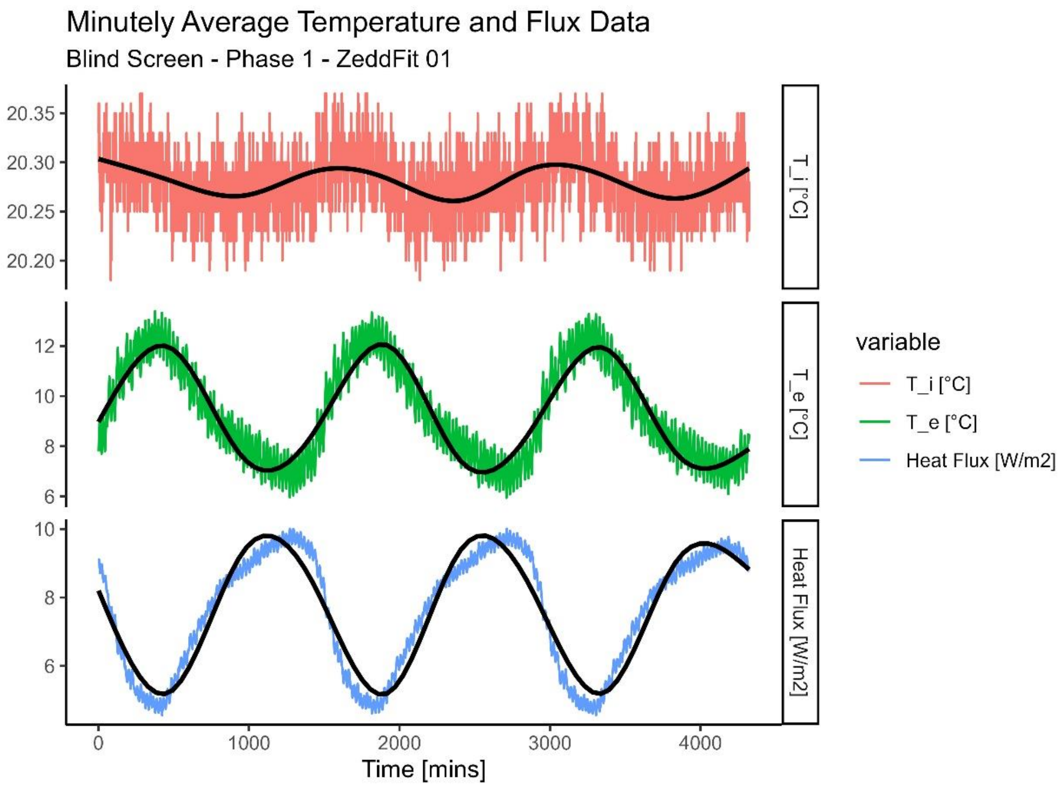

Daily Average U-Value (Air to Air - Centre Pane)
Blind Screen - Phase 2 - Baseline
U-Value [Wm^-2K^-1]
1.8
1.6
1.4
1.2
1.0
+5%
1.37
-5%
0
1
2
3
24h Period
Expanded uncertainty (k=1.96)

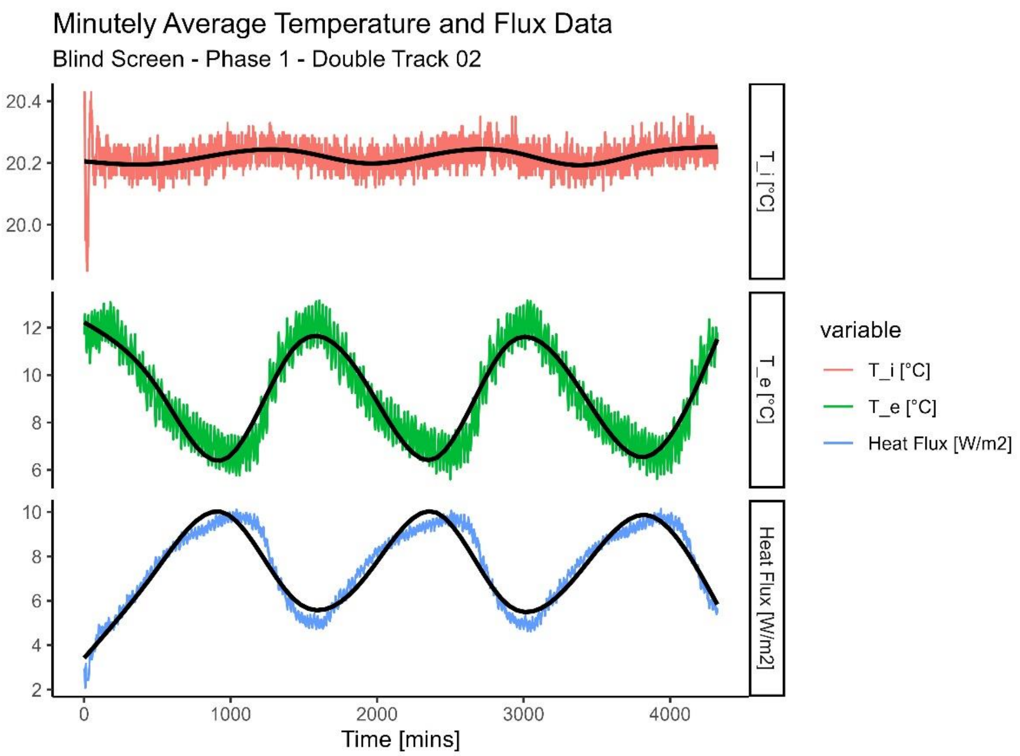

Daily Average U-Value (Air to Air - Centre Pane)
Blind Screen - Phase 2 - Blind Screen 02 Dual
U-Value [Wm^-2K^-1]
1.0
0.9
0.8
0.7
0.6
+5%
0.82
-5%
0
1
2
3
24h Period
Expanded uncertainty (k=1.96)

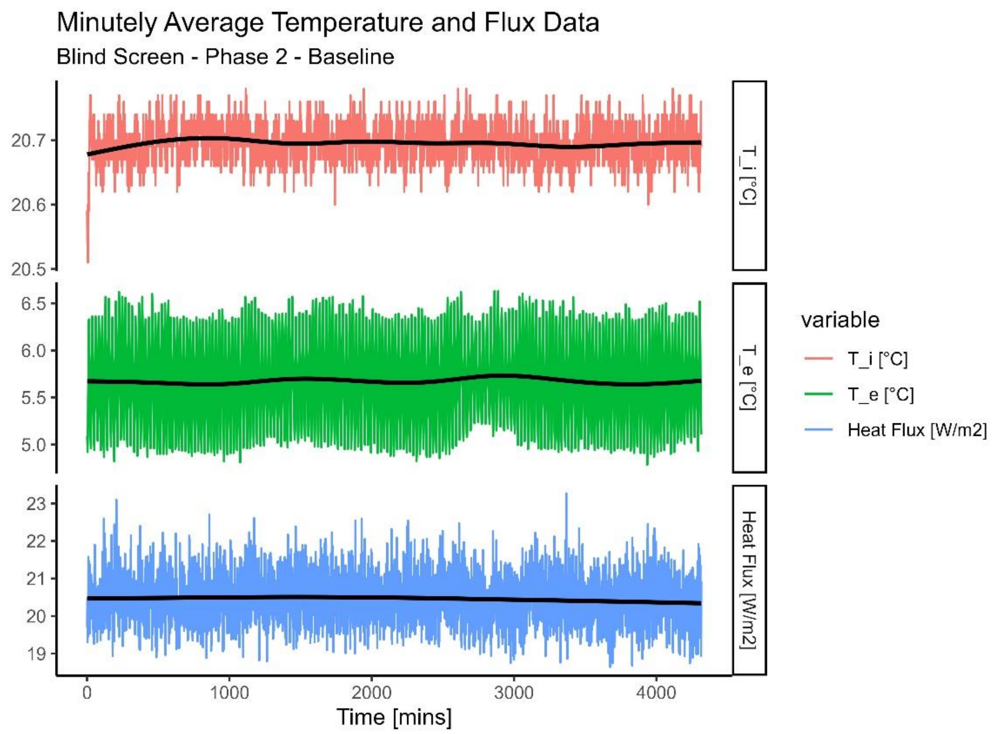
Appendix B - 72h Temperature and Heat Flux Plots

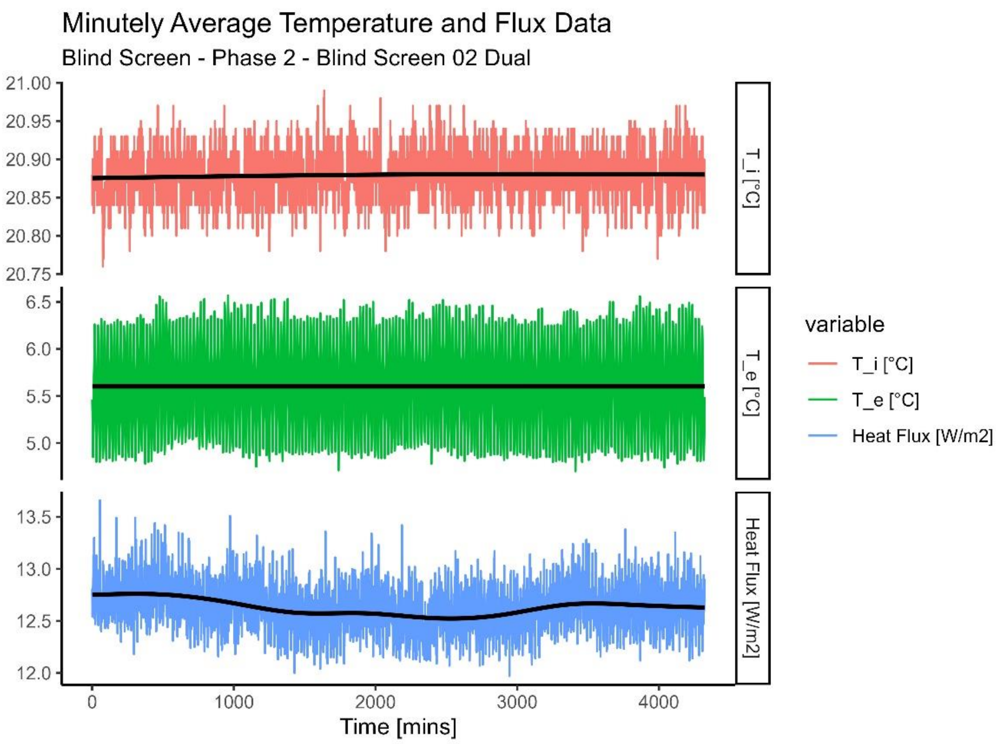
All heat flux measurements relate to centre pane only.






Minutely Average Temperature and Flux Data
Blind Screen - Phase 1 - Double Track 02
20.4
20.2
20.0
T_i [°C]
12
10
8
6
T_e [°C]
10
8
6
4
2
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]


Minutely Average Temperature and Flux Data
Blind Screen - Phase 2 - Baseline
20.7
20.6
20.5
6.5
6.0
5.5
5.0
23
22
21
20
19
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]


Minutely Average Temperature and Flux Data
Blind Screen - Phase 2 - Blind Screen 02 Dual
21.00
20.95
20.90
20.85
20.80
20.75
6.5
6.0
5.5
5.0
13.5
13.0
12.5
12.0
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
variable
T_i [°C]
T_e [°C]
Heat Flux [W/m2]
0
1000
2000
3000
4000
Time [mins]

Appendix C – In-situ U-value measurement method

In-situ U-value measurements of each thermal element were undertaken in accordance with ISO 9869-1. The thermal transmittance of a building element (U-value) is defined in ISO 7345[2] as the *"Heat flow rate in the steady state divided by area and by the temperature difference between the surroundings on each side of a system"*. To account for thermal storage and release, ISO 9869-1 uses a cumulative moving average of the heat flow rate and ΔT to calculate in-situ U-values. However, steady state conditions at the Energy House allows in-situ U-values to be calculated as defined by ISO 7345 using the following equation.

$$U = \frac{q}{\Delta T}$$

Where:

U = in-situ U-value (W/m^{2}K)

q = 24-hour mean heat flow rate (W/m^2)

ΔT = 24-hour mean internal to external air temperature difference (K)

The heat flow rate was measured using Hukseflux HFP-01 heat flux plates (HFPs). The HFPs were affixed to centre of glazing panels using adhesive tape and thermal contact paste. Care was taken to ensure that HFPs were not unduly influenced by excessive air movement by positioning air circulation fans in such a way that air was not blown directly on to the HFPs.

The ΔT for each in-situ U-value measurement was calculated using the internal and external air temperature differential measured in the vicinity of each HFP.

In-situ U-value uncertainty

ISO 9869 applies an uncertainty value of 14-28% to in-situ U-value measurements. However, this uncertainty is based on measurements undertaken in the field without control of external conditions. The ISO 9869 uncertainty calculation was modified for the controlled environment and to include type A and type B uncertainties.

Type A uncertainty

Type A uncertainties consider the statistical variation in the recorded data.

Heat Flux (q)

To reduce noise caused by the operation of electric resistance heaters and fans. the "sma()" function from the "smooth" R programming language package is used to create a simple moving average of the heat flux data. This package optimises moving average by varying the averaging period.

The standard deviation of the smoothed data is calculated and taken as the type A heat flux uncertainty.

[2] ISO (1987) ISO 7345: Thermal insulation –Physical quantities and definitions. Geneva, Switzerland, International Organization for Standardisation.

T_i and T_e

All U-Value measurements considered a single local internal temperature sensor and a single local external temperature sensor. The standard deviation over a 24-hour period for each sensor was calculated and taken as the type A uncertainty.

Type B uncertainty

Type B uncertainties are based on the sources of uncertainty listed in ISO 9869. Table F1 lists the measurement uncertainties provided by ISO 9869 and modifications that were made for DEEP based on the apparatus and test environment. It must be noted that many of the assumptions regarding sources of uncertainty contained within ISO 9869 are not accompanied with background information as to how they have been derived.

Table F1: Measurement uncertainties provided by ISO 9869 and modifications made for DEEP

ISO 9869 consideration	Notes	% error	Absolute error
Apparatus - Logger	Based on logger accuracy and offset value and DEEP steady state ΔT and heat flux for a U-value of 0.09[3] W/m²K	0.3	
Apparatus - HFP	Hukesflux HFP01 datasheet	2	
Apparatus - I. C. temperature sensor	Based on steady state ΔT of 15.3 °C	0.9	0.1
HFP contact	ISO 9869 - unadjusted	0	
Isotherm modification	ISO 9869 - unadjusted	2	
Variation in temp & heat flow	ISO 9869 ~10%. Removed as steady state measurement reported. **Captured in type A uncertainty**	0	
Variation in air (T_i) & radiant (T_r) temperature differences	ISO 9869 suggests 5%. Value halved as air circulation fans increase homogeneity & typical 1-2 °C between T_r and T_a at most locations	2.5	
type B uncertainty	**Quadrature sum**	**3.9**	

[3] U-value of 0.09 W/m²K is the lowest U-value reported in DEEP and associated with a logger uncertainty of 0.3%. As U-value increases logger uncertainty decreases, therefore the maximum logger uncertainty has been applied to all U-value measurements.

Combined Uncertainty

The Type A and Type B uncertainty attributed to each measurement are combined through the RSS method prior to error propagation in the HTC calculation.

$$u_{combined} = \sqrt{u_A^2 + u_B^2}$$

Expanded Uncertainty

All prior uncertainties have been given as k=1. When stating the uncertainty on plots, the expanded uncertainty (k=1.96) is stated, such that:

$$U = k \cdot u$$

Such a coverage factor should result in a 95% confidence interval.