Normandeau School – Passive Solar Greenhouse

ZS2 Wall Sensor Data:

Initial Analysis for Further Discussion

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Modelling Methods

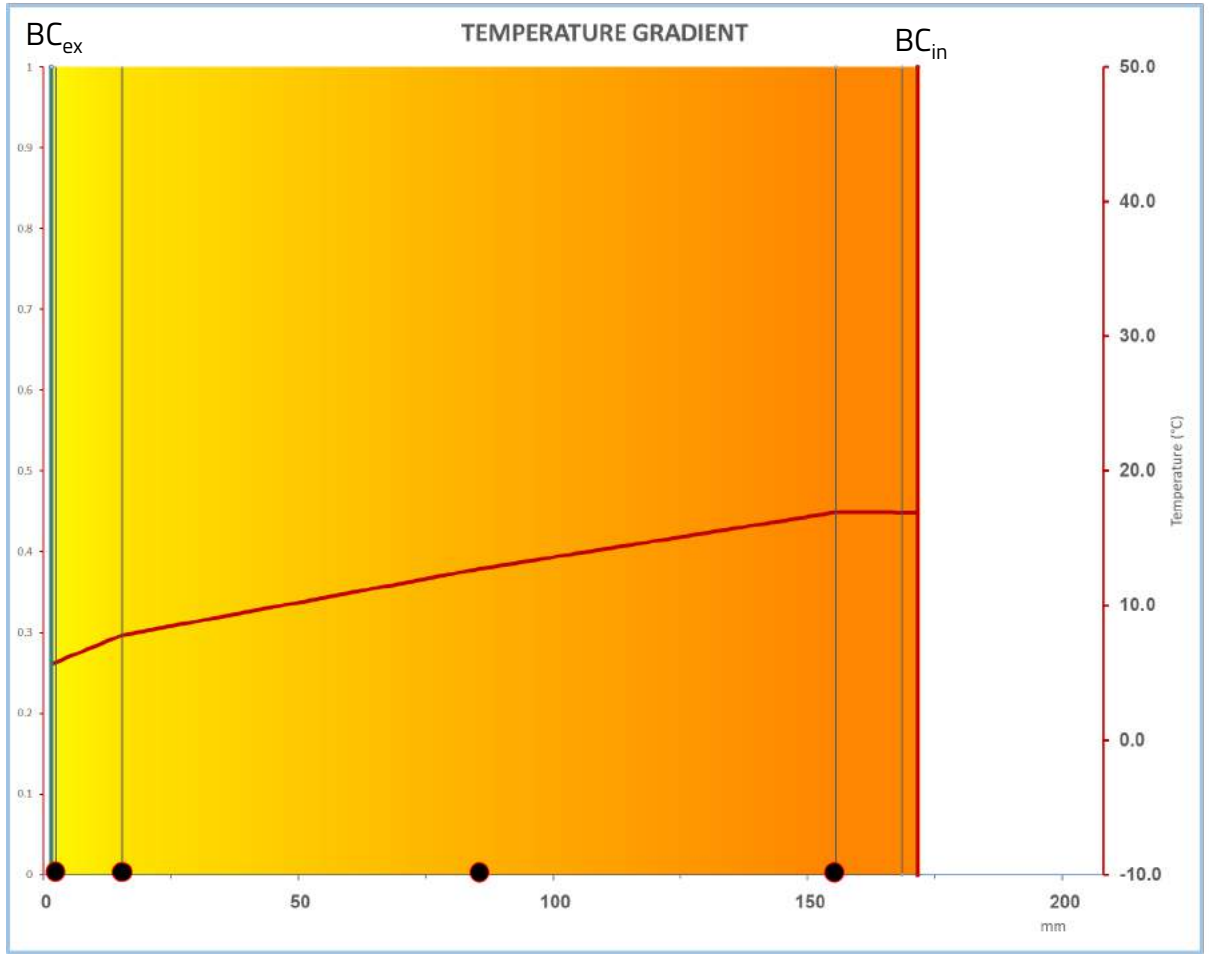
Assumptions

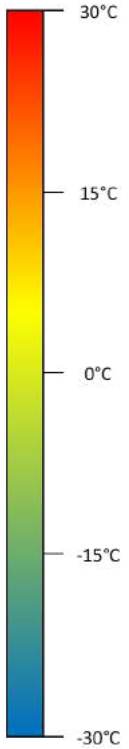
- It is a steady state heat flow model, which is presented under hourly averaged temperature conditions.
- The model illustrates wall performance without humidity corrected thermal conductivity.
- The model only showcases heat transfer behaviour in 1 dimension across the assemblies.
- The experimental heat flux, ϕ_{exp} is measured by the temperature gradient due to a constant theoretical U value of the assembly.
- The experimental R values (Exp. R or R_{exp}) are based on experimental heat flux, ϕ_{exp}, and boundary condition temperature on the surface of the assembly.

Additional Information

- Theoretical R value is obtained by ZS2 specification, which is R27.42.
- RSI*5.678 = Imperial R value
- Theoretical U value, U_{th} = 1/ theoretical RSI
- Experimental Heat Flux, $\phi_{exp} = -U_{th} \times \left(\mathrm{T}(\mathrm{Sensor}\ 5^{*}) - \mathrm{T}(\mathrm{Sensor}\ 1)\right)$
  - The T(sensor 5*) is a calculated temperature based on average room temperature near the interior surface and sensor 4 data. It is assumed as the interior surface temperature of the assembly.
  - The minus sign indicates the instant heat flows against the incremental tendency of temperature gradient.
- $R_{exp} = \phi_{exp}/\Delta T$
  - $\Delta T \equiv T_{in,BC} - T_{ex,BC}$; $T_{in,BC}$ ~ interior boundary condition temperature; $T_{ex,BC}$~ exterior boundary condition temperature.
- This analysis includes the west wall, north wall, and north roof.
  - The east wall contains one dysfunctional sensor, therefore, it is not included in this analysis.

Temperature Gradient Modelling Example





Position of sensors

BC$_{ex}$ = Boundary Condition – Exterior

(at 0 mm)

BC$_{in}$ = Boundary Condition – Interior

(West & North at 170 mm)
(Roof at 238 mm)

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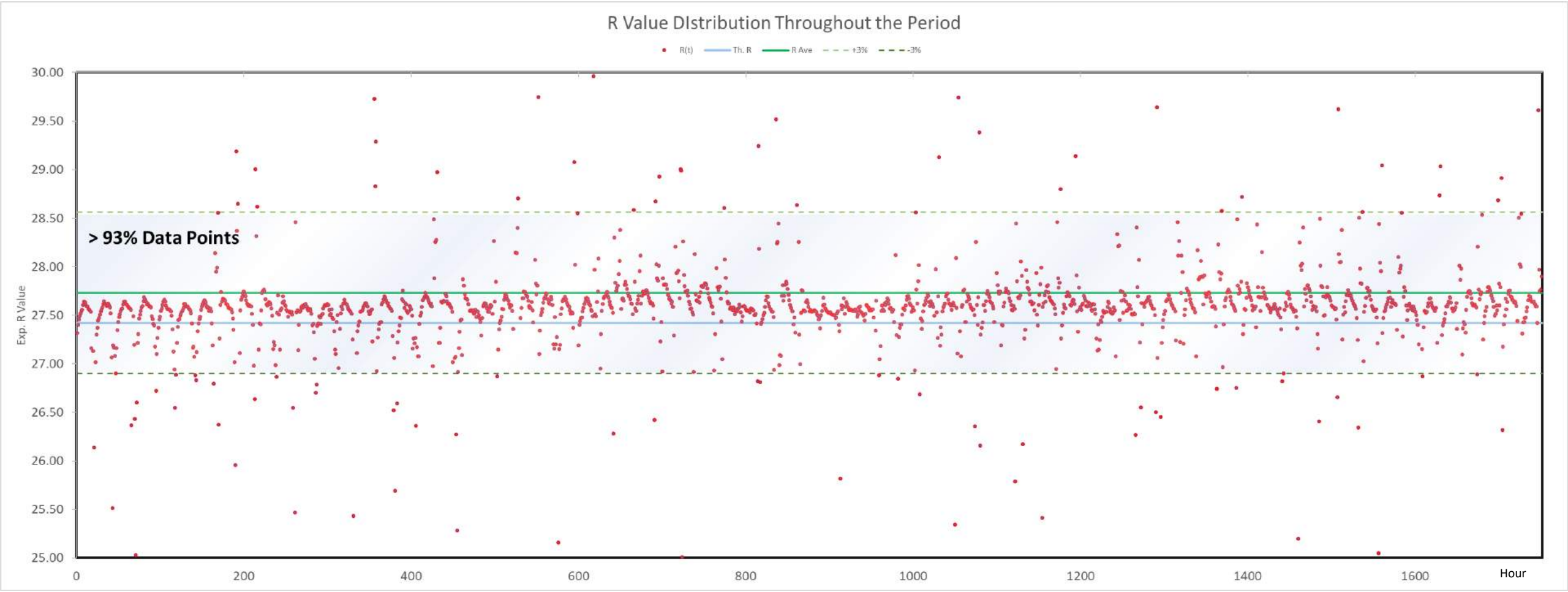
North Wall



1st hour = 2023-05-12 13:00
1752th hour = 2023-07-24 13:00

▲ Measured R values of north wall were varied through the 1,752 hour monitoring period. Based on collected temperature data from the 4 sensors within the assembly, these experimental thermal resistance values can be calculated for each timepoint. More than 93% of them deviate from the averaged value of all data within 3%.

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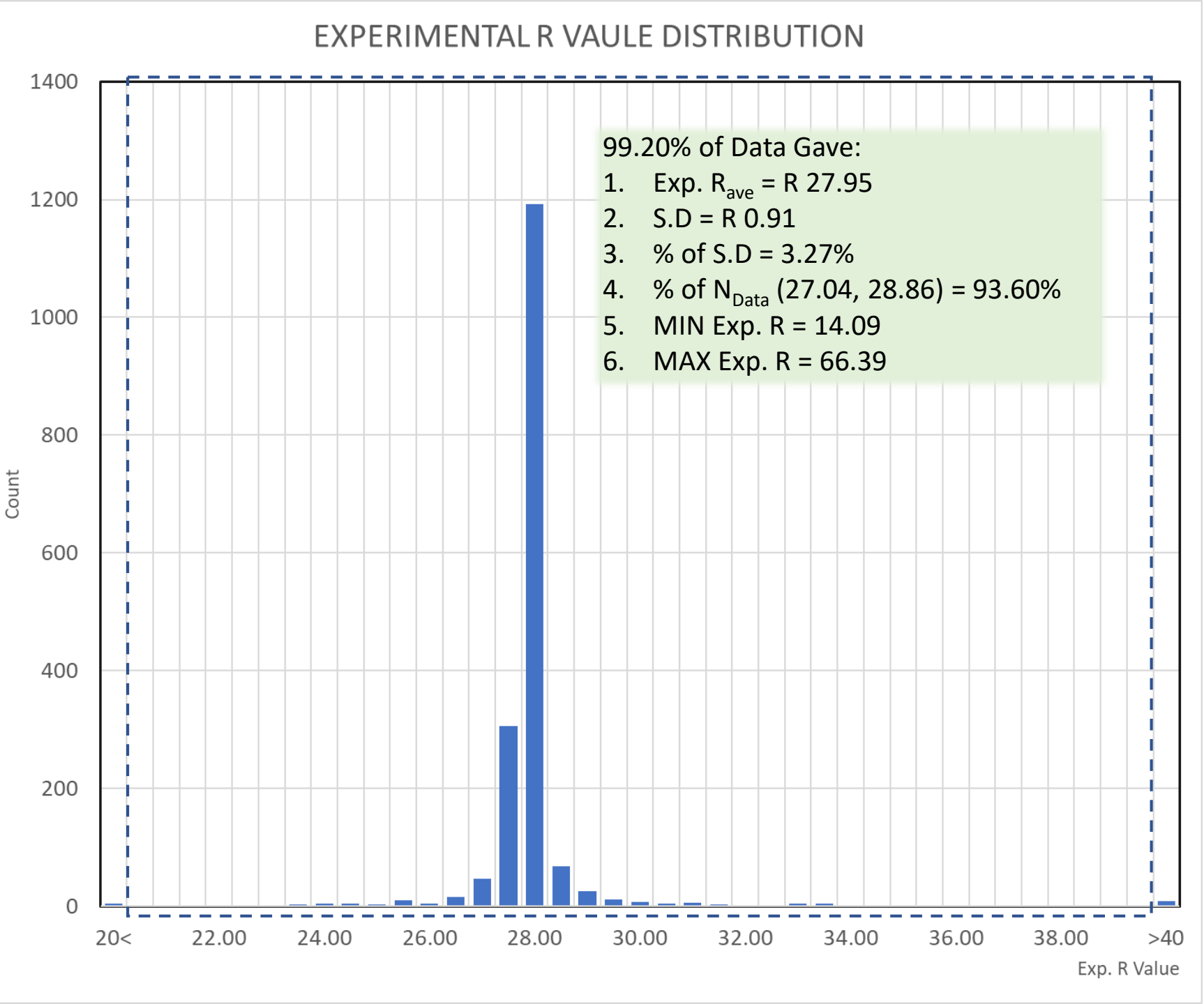
North Wall



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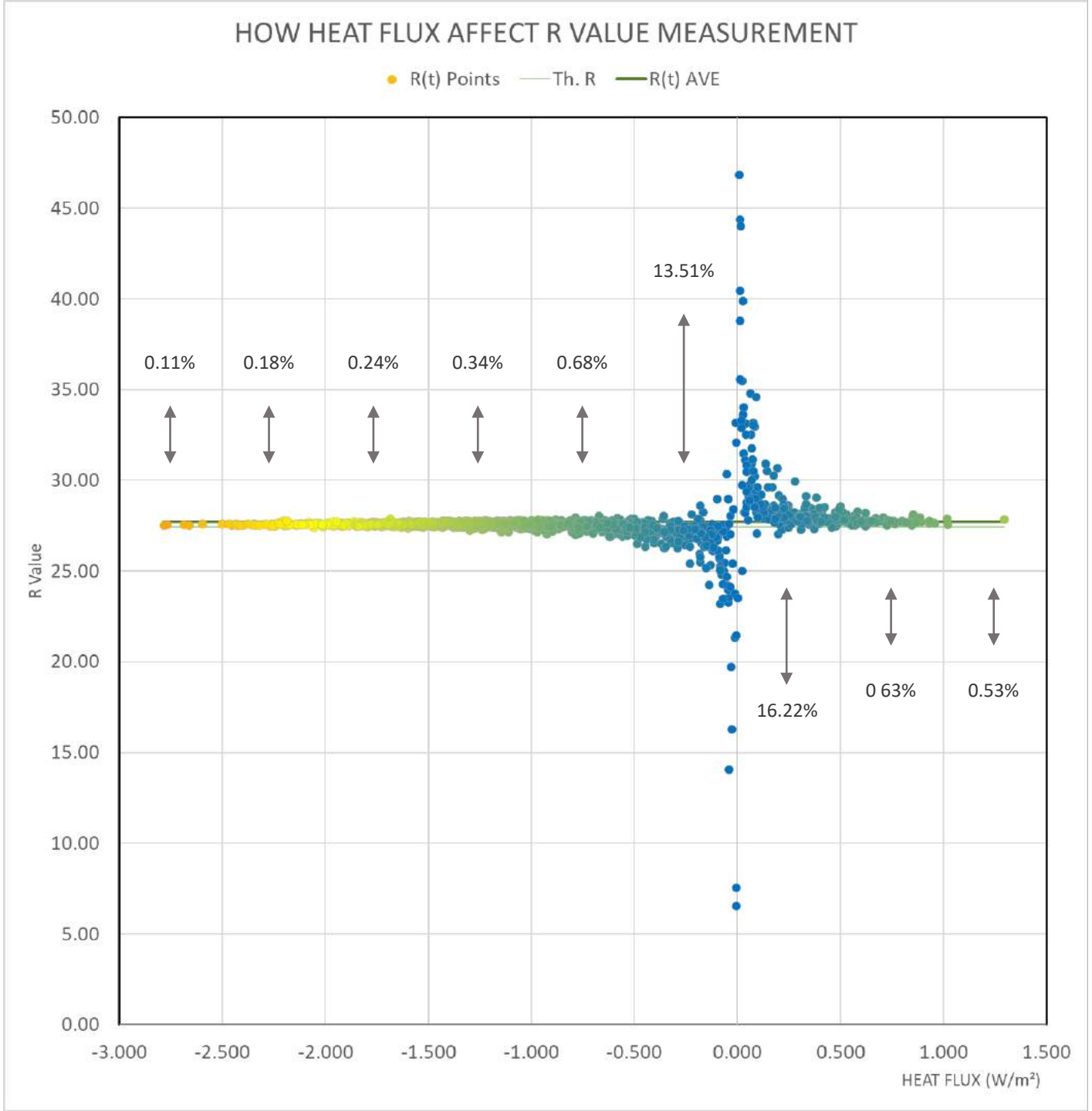
North Wall

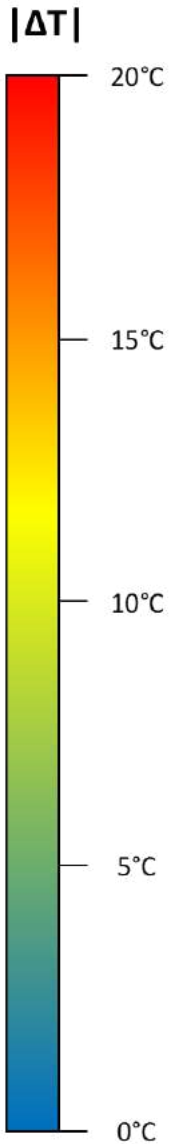
Heat Flux > 0: heat flows from exterior to interior across the wall assembly.

Heat Flux < 0: heat flows from interior to exterior across the wall assembly.

There are **9 data groups** in accordance with the graph's major gridlines. The span between gridlines is 0.5 W/m²

Each dual arrow indicates the degree of scattering within a group from its group mean value.





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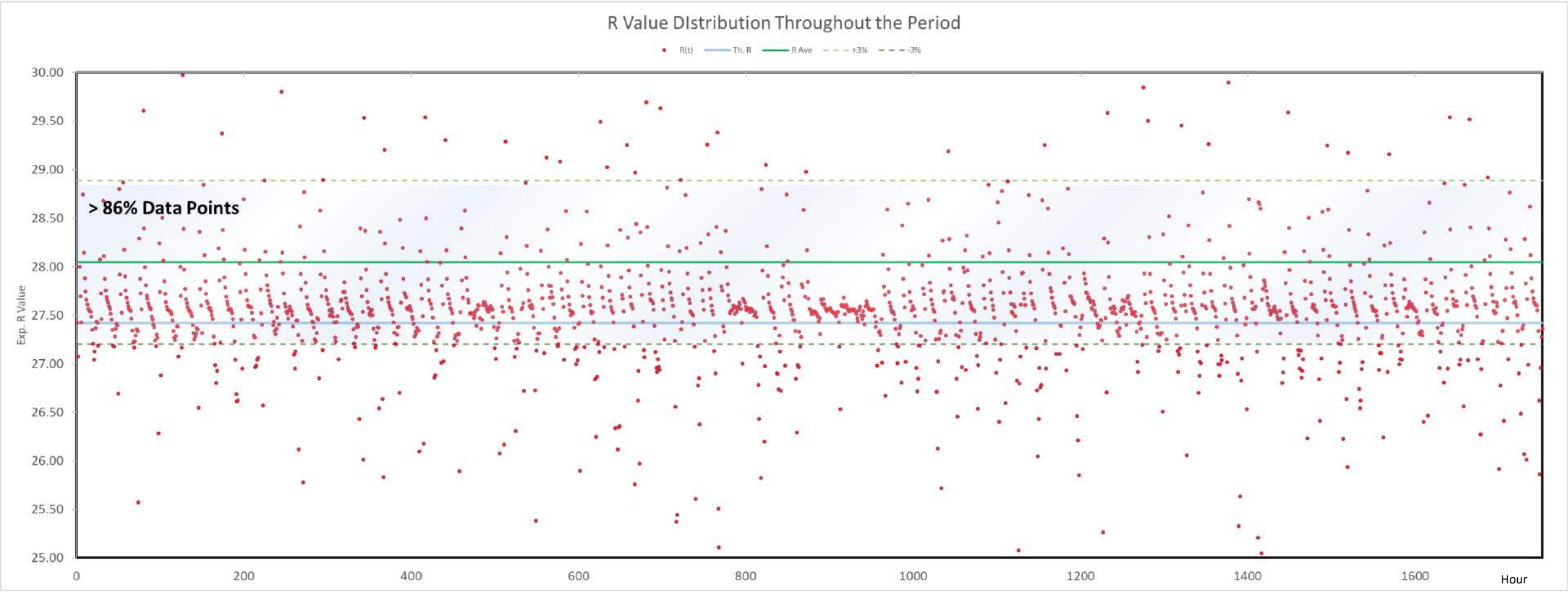
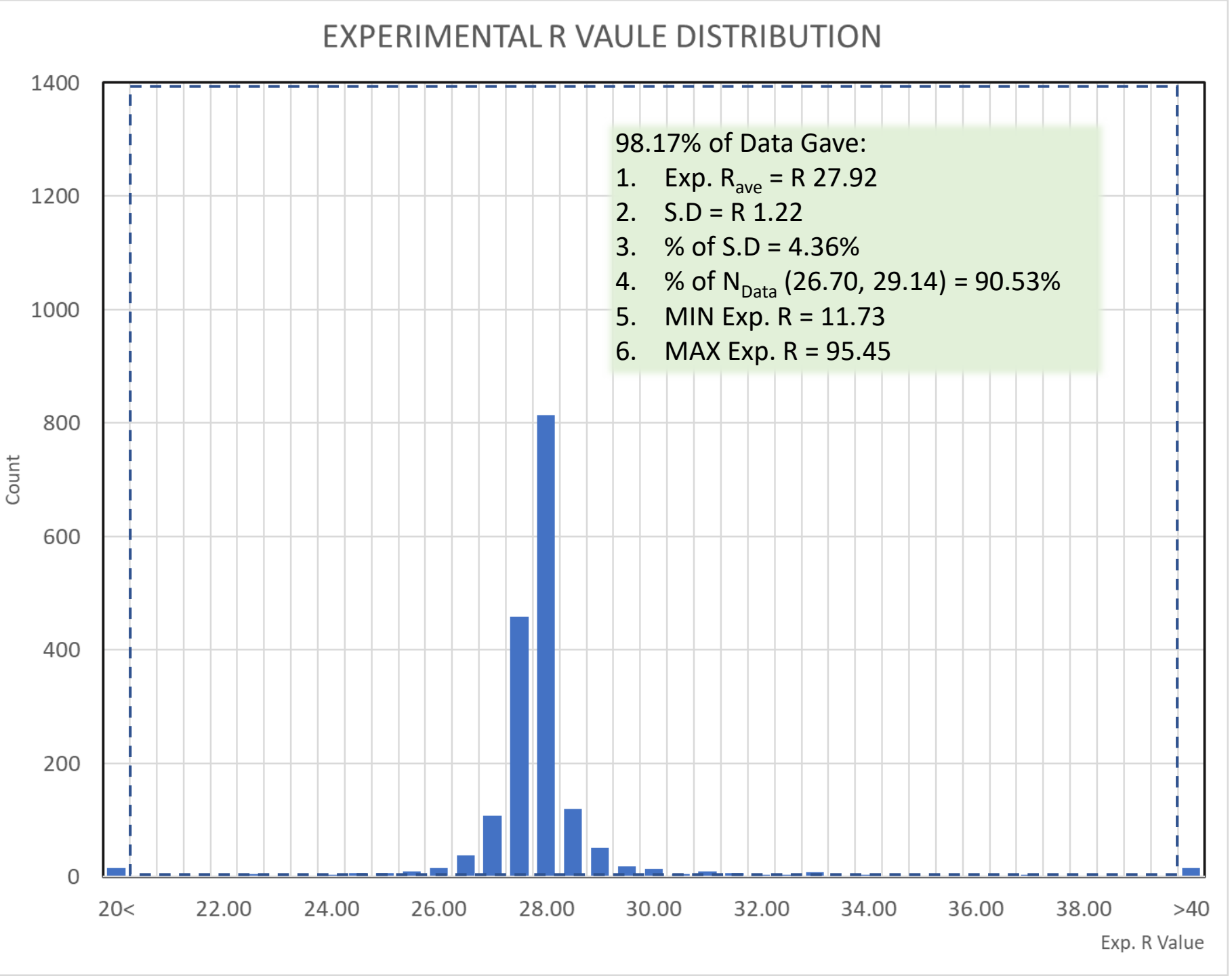
West Wall



1st hour = 2023-05-12 13:00
1752th hour = 2023-07-24 13:00

▲ Measured R values of west wall were varied through the 1,752 hour monitoring period. Based on collected temperature data from the 4 sensors installed within the assembly, these experimental thermal resistance values can be calculated for each timepoint. More than 86% of them deviate from the averaged value of all data within 3%.

West Wall



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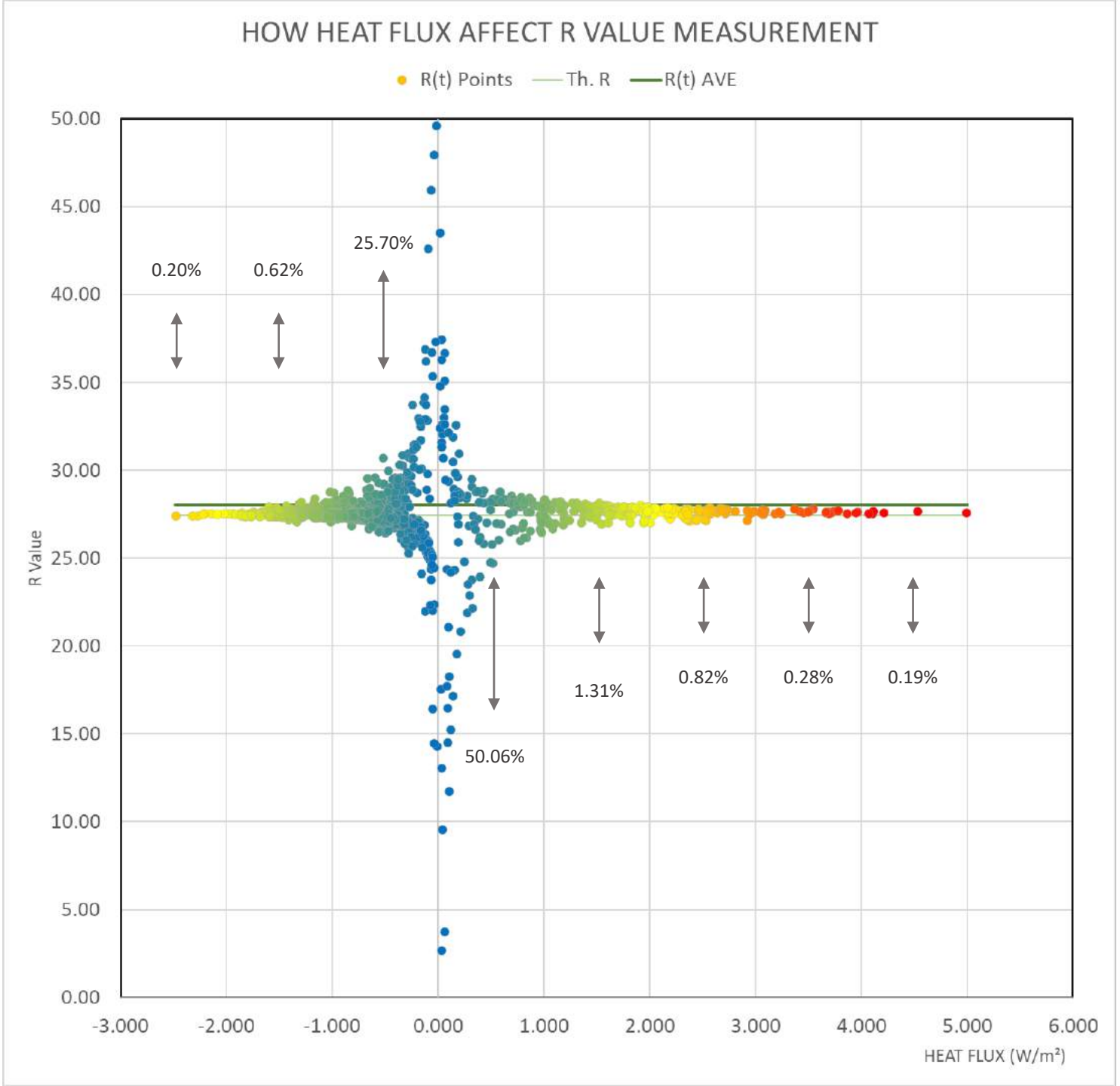
West Wall

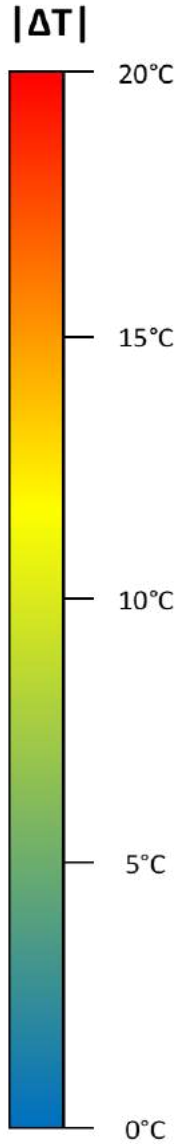
Heat Flux > 0: heat flows from exterior to interior across the wall assembly.

Heat Flux < 0: heat flows from interior to exterior across the wall assembly.

There are **8 data groups** in accordance with the graph's major gridlines. The span between gridlines is 1 W/m²

Each dual arrow indicates the degree of scattering within a group from its group mean value.





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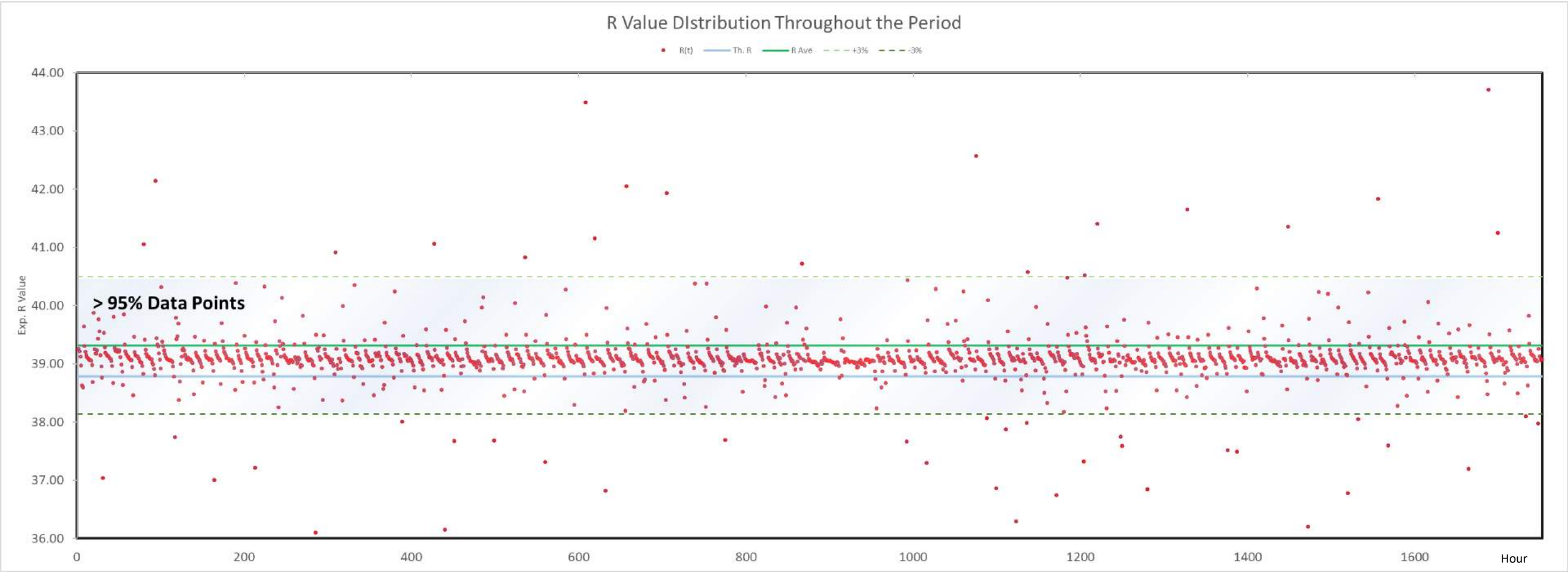
North Roof



1st hour = 2023-05-12 13:00
1752th hour = 2023-07-24 13:00

▲ Measured R values of north roof were varied through the 1,752 hour monitoring period. Based on collected temperature data from the 4 sensors installed within the assembly, these experimental thermal resistance values can be calculated for each timepoint. More than 95% of them deviate from the averaged value of all data within 3%.

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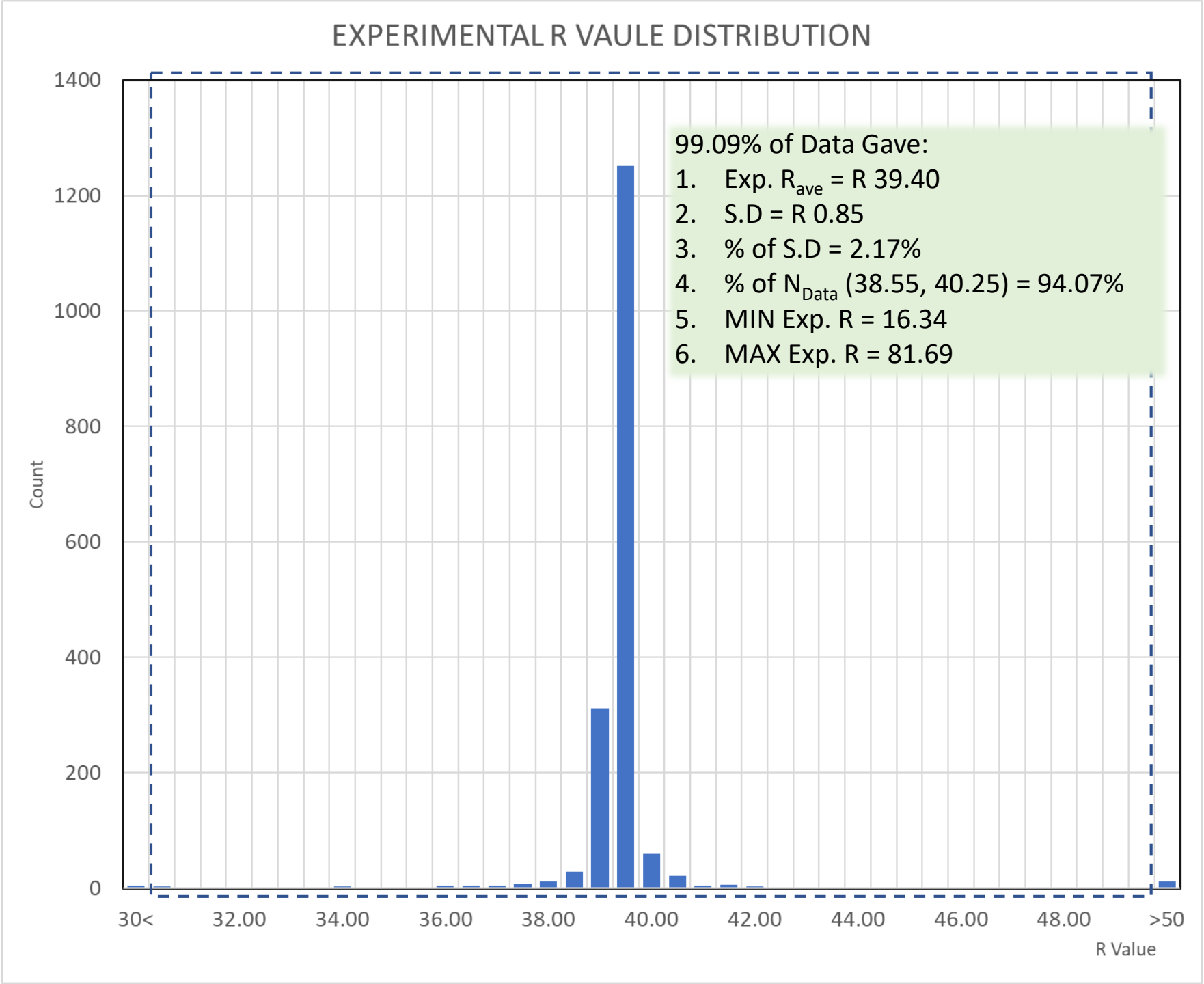
North Roof



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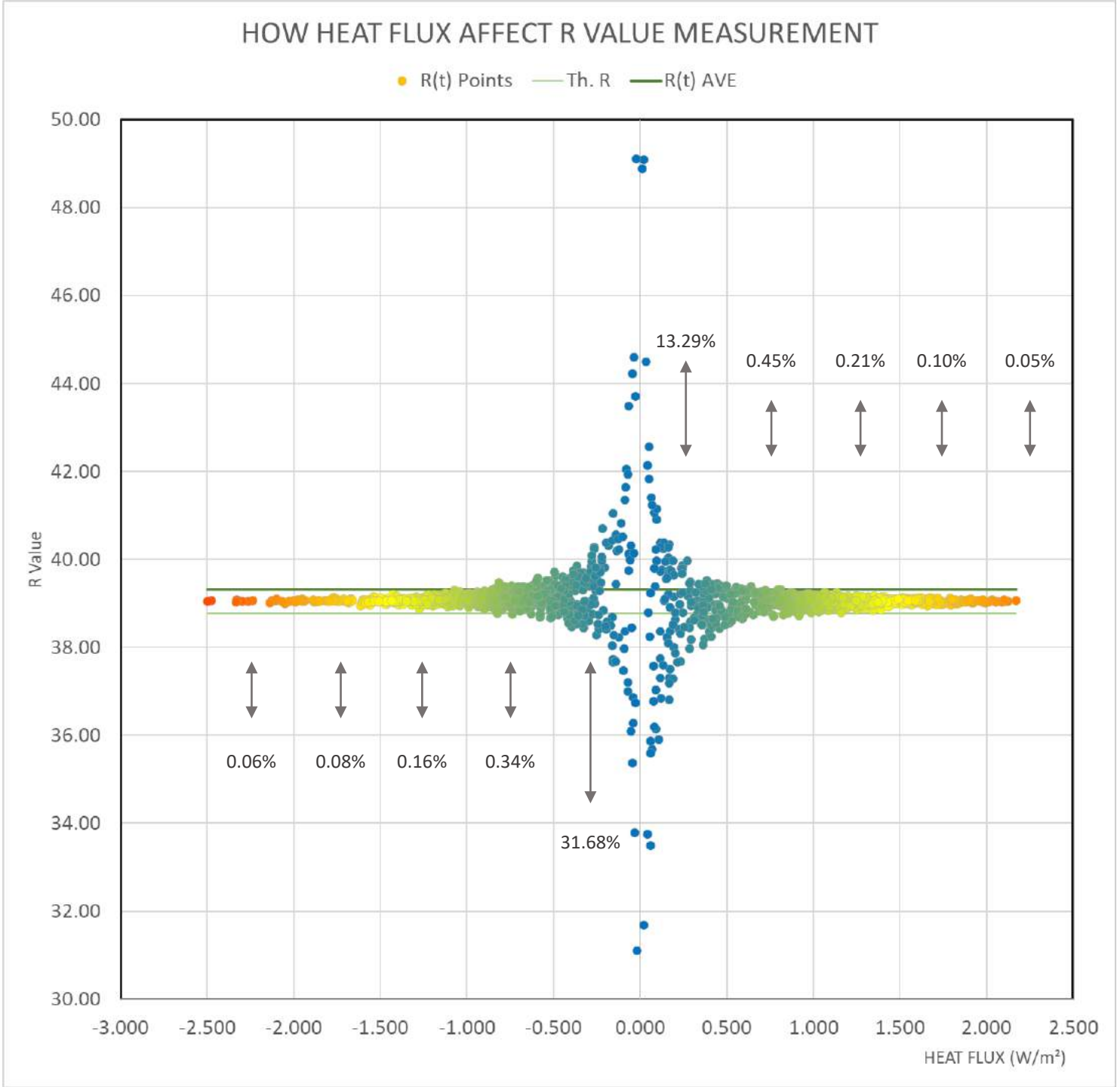
North Roof

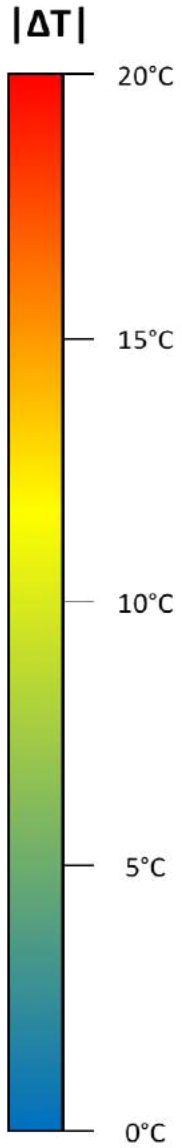
Heat Flux > 0: heat flows from exterior to interior across the wall assembly.

Heat Flux < 0: heat flows from interior to exterior across the wall assembly.

There are **5 data groups** in accordance with the graph's major gridlines. The span between gridlines is 0.5 W/m²

Each dual arrow indicates the degree of scattering within a group from its group mean value.





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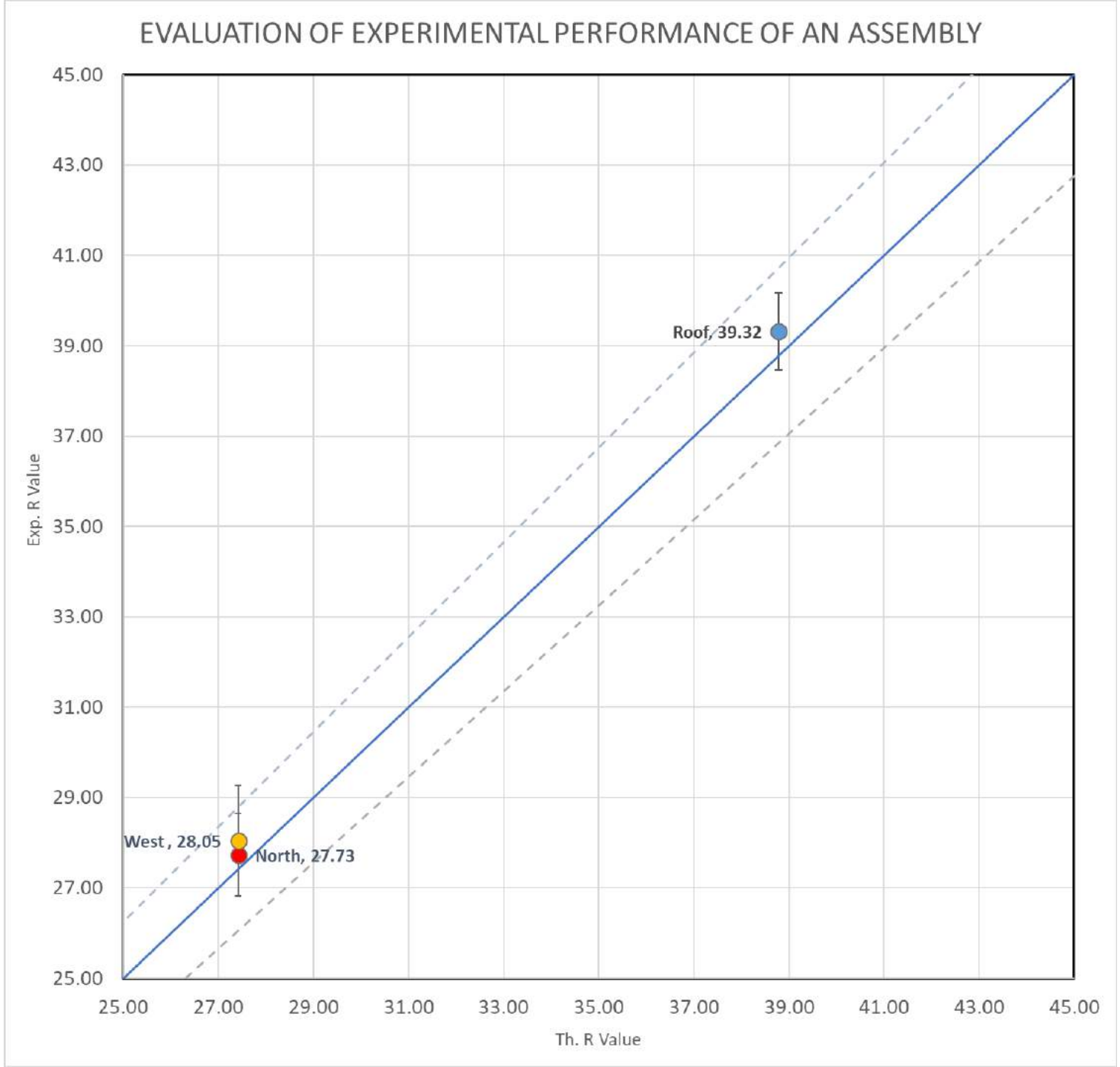

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Summary

- The model only describes the envelope performance in accordance with the changes of temperature within the assembly throughout 1,752 hours during the Spring/ Summer 2023. The data monitoring system was fully commissioned in May 2023
- In general, the actual performance of the envelope might be better than the manufacturer's specification.
- The west wall has more frequent environmental changes when compared to the north wall and north roof. It is assumed to be caused by solar radiation landing more frequently on the west wall.
- The measured R values of the west wall throughout the period has larger deviation within the entire data set comparted to the other two envelopes in this analysis.
- When the heat flux across the envelopes are near zero (lower than 1 W/m², regardless of its direction), the corresponding experimental R values have higher uncertainty to ensure their actual R values. Below 1 W/m², requires additional information to refine the model.

Further Research Target:

- Further analysis will be carried out on data collected during winter 2023/2024, to measure the performance of the envelopes under a larger temperature gradient (which wasn't measured during the Spring / Summer).
- Further refinement to incorporate the effect of humidity within the envelope assemblies for the entire performance analysis of the envelopes.