# Experimental study on the Suitability of Acrylic and Copper Globe Thermometer for Diurnal Outdoor Use

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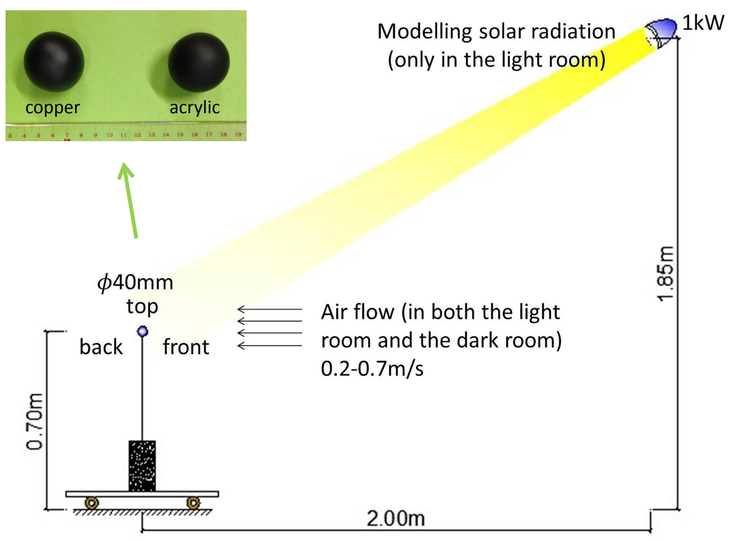
## Introduction

- The 40 mm acrylic globe thermometer is widely used for outdoor measurements of the mean radiant temperature ($t_{mrt}$).
- Its result is found mostly inconsistent with that of the three-dimensional integral method.
- A series of experiments were conducted to investigate the discrepancy in $t_{mrt}$ measured from copper and acrylic globes thermometers.
- Our results shed light on why the acrylic globe thermometer is not suitable for use outdoors.

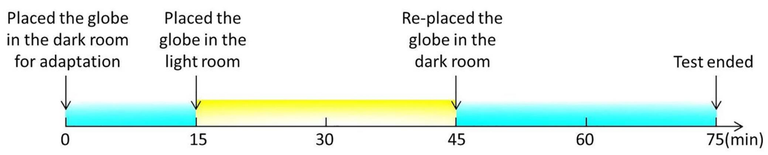
## Methodology

Static indoor experiments and dynamic outdoor experiments were conducted to compare the thermal response of a copper and an acrylic globe thermometer.

### Indoor modelled configuration




Experiment procedure:




Two combinations of indoor settings:

| Parameters | Test Condition DL1 | | Test Condition DL2 | |
|---|---|---|---|---|
| | Dark Room | Light Room | Dark Room | Light Room |
| $ta$ [°C] | 23.0 | 23.2 | 24.9 | 24.7 |
| $K$ [W/m$^2$] | 1.6 | 354.2 | 3.4 | 304.7 |
| $L$ [W/m$^2$] | 436.6 | 449.4 | 451.7 | 458.9 |
| $\bar{V}$ [m/s] | 0.42 | 0.34 | 0.58 | 0.53 |

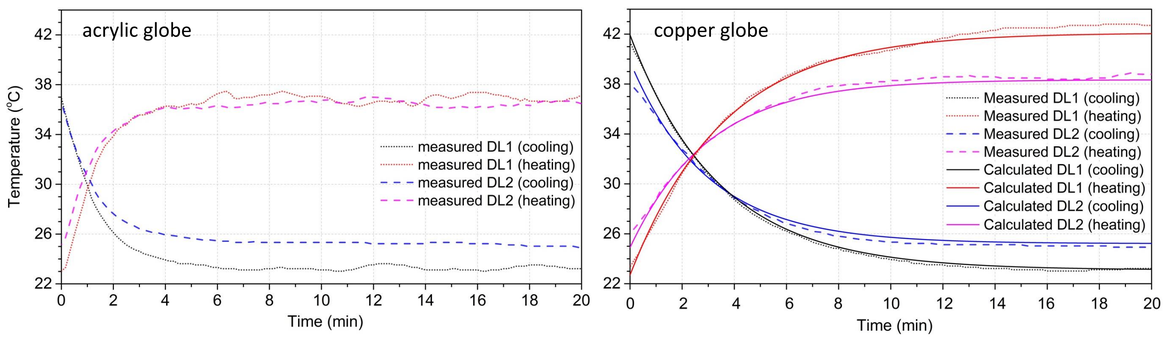
### Outdoor apparatus

Two globe thermometers were tested for successive 10 hours from sunrise to sunset on a semi-clear day of July, 2014.

## Result of static indoor experiments

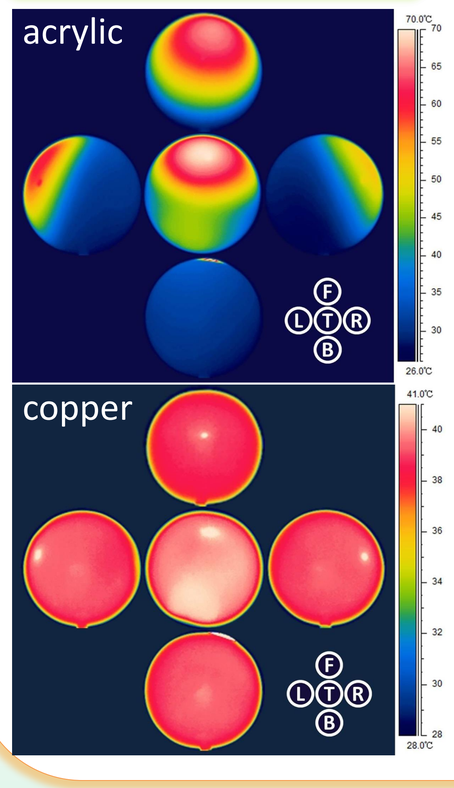
### Heating and cooling curves measured at two combinations of indoor settings

Solving $\left[K\varepsilon_K + L\varepsilon_L\varepsilon_E - \sigma(tg+273.15)^4\varepsilon_L + h(ta-tg) = \frac{C}{A}\frac{dtg}{d\tau}\right]$ by RK4 provides theoretical predictions of globe thermal response.

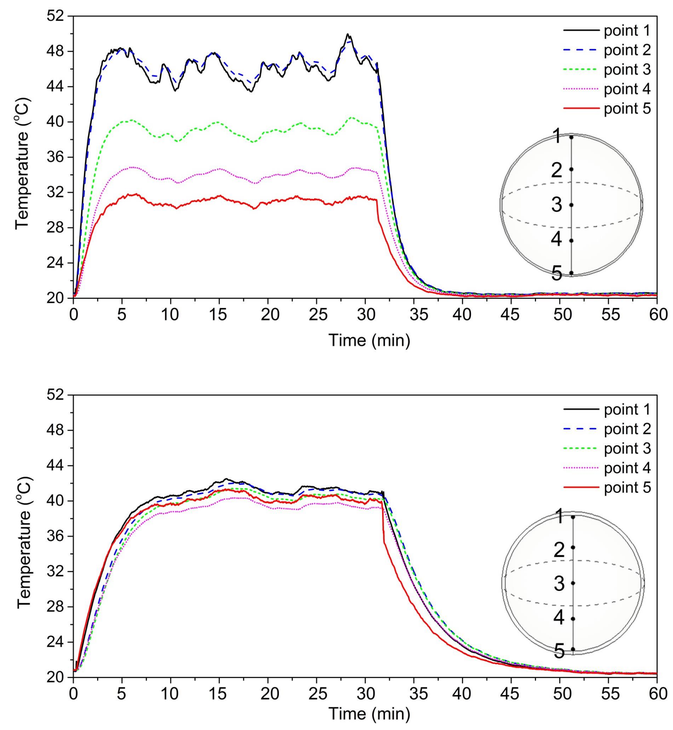



- No reasonable combination of shortwave and longwave emissivity was found for the acrylic globe thermometer.
- Theoretical estimations and measurements of the copper globe thermometer were in good agreement.

### Surface temperature




### Inside temperature profile




**For acrylic globe:**

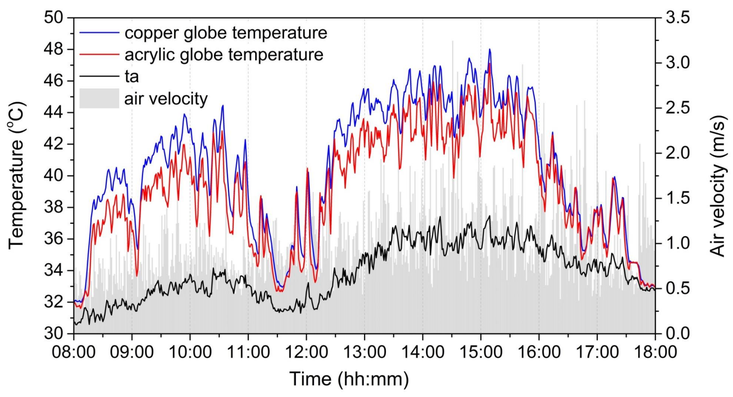
- Temperature variation on the surface is significant.
- Obvious discrepancy is found in the inside temperature profile.
- Centre temperature is too low to represent the whole.

**For copper globe:**

- Surface temperature varies within a narrow range.
- Inside temperature profile is uniform.
- The centre temperature provides a good average of the radiation reaching the globe from all directions.

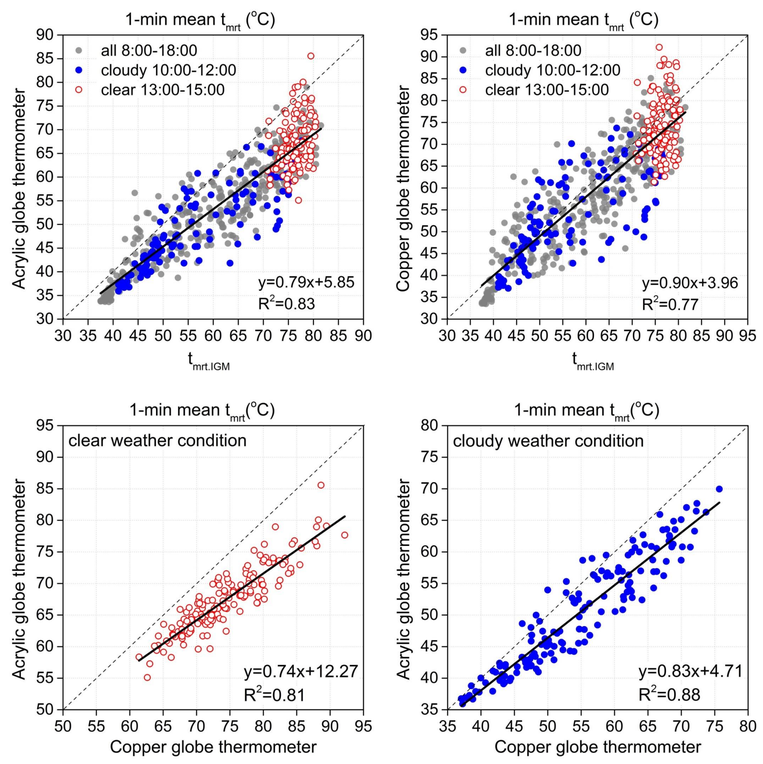
## Results of outdoor on-site observations

### Difference in globe temperatures




- The copper globe is always warmer than the acrylic globe by daylight.
- The acrylic globe thermometer obviously underestimates $t_{mrt}$ compared to the copper globe under both cloudy and clear weather conditions.
- The underestimation is more significant when the solar radiation is strong.

### Mean radiant temperature




## Conclusion

Full paper has been published recently:
Wang, S., & Li, Y. (2015). Suitability of Acrylic and Copper Globe Thermometers for Diurnal Outdoor Settings. *Building and Environment, 89*(0), 279-294.

- Comparing with copper globe, the fatal weakness that prevents an acrylic globe to be used as an outdoor globe thermometer is its low heat conductivity.
- A secondary factor is that solar light can penetrate the shell of the acrylic globe and directly influence the temperature of the thermocouple at the centre.
- Though the acrylic globe thermometer has an advantage in terms of a short response time, it should not be recommended for outdoor use.