Supplementary Material

Characterizing phase change materials using the T-History method: On the factors influencing the accuracy and precision of the enthalpy-temperature curve

Pepe Tan[a,1,*], Michael Brütting[b], Stephan Vidi[b], Hans-Peter Ebert[b], Pär Johansson[a], Angela Sasic Kalagasidis[a]

[a] *Department of Architecture and Civil Engineering, Division of Building Technology, Chalmers University of Technology, Gothenburg, Sweden*
[b] *Bavarian Center for Applied Energy Research (ZAE Bayern), Würzburg, Germany*

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[*] Corresponding author
Email address: pepe.tan@chalmers.se (Pepe Tan)

Appendix A. Temperature measurements

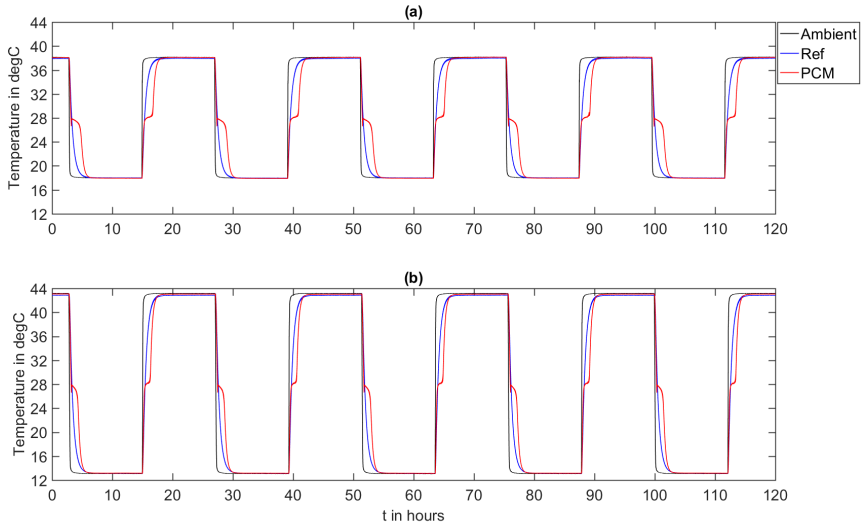

Figure Appendix A.1: T-History measurements of RT28HC for setup A: (a): A-I, (b): A-II (all three sensor positions for reference and PCM are plotted with the same color, respectively)

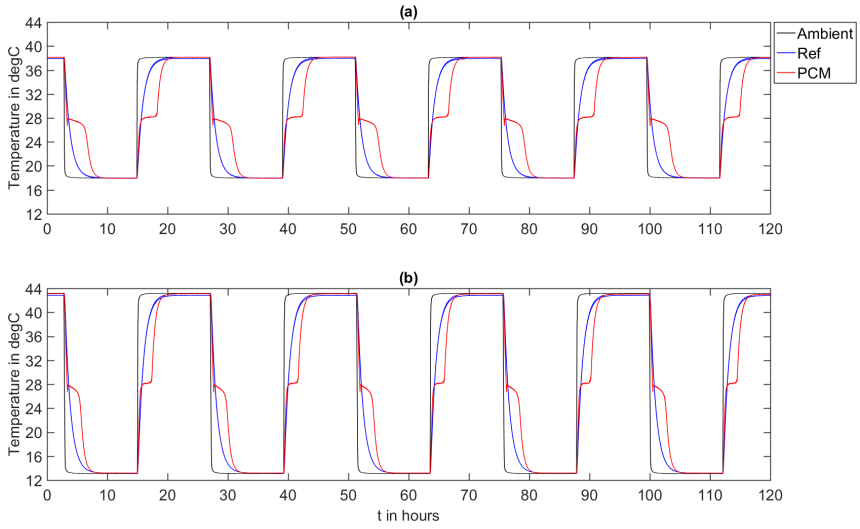

Figure Appendix A.2: T-History measurements of RT28HC for setup B1: (a): B1-I, (b): B1-II (all three sensor positions for reference and PCM are plotted with the same color, respectively)

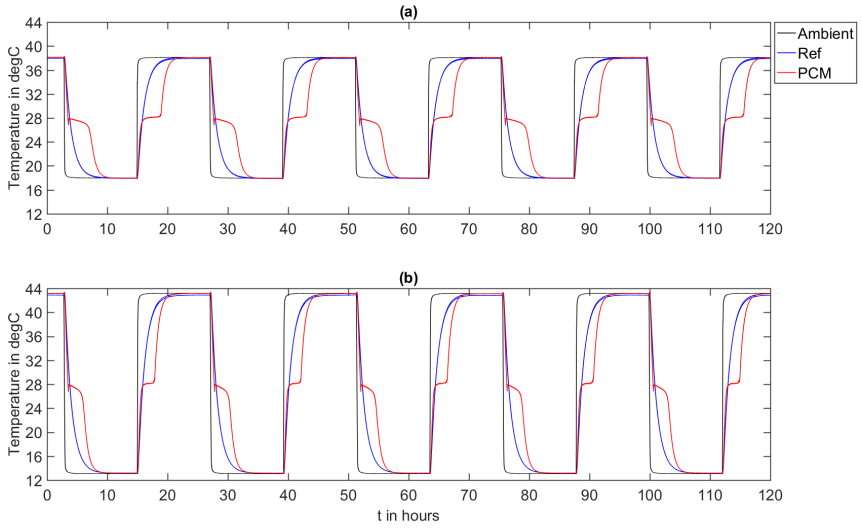

Figure Appendix A.3: T-History measurements of RT28HC for setup B2: (a): B2-I, (b): B2-II (all three sensor positions for reference and PCM are plotted with the same color, respectively)

Appendix B. Enthalpy results

Appendix B.1. Tables

Table B.1: Summary of enthalpy results for Setup A (mean ($\overline{h}$) and standard deviation (σ_h) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Cooling	Heating	
Setup A-I	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (top sensor)	-230.79	-233.33	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (top sensor)	0.58	0.08	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (center sensor)	-235.83	-236.11	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (center sensor)	0.79	0.09	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (bottom sensor)	-234.34	-234.23	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (bottom sensor)	0.23	0.12	$\mathrm{kJ\,kg^{-1}}$
Setup A-II	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (top sensor)	-232.45	-235.72	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (top sensor)	0.18	0.36	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (center sensor)	-237.80	-237.44	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (center sensor)	0.60	0.20	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (bottom sensor)	-236.35	-235.36	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (bottom sensor)	0.49	0.33	$\mathrm{kJ\,kg^{-1}}$

[a] Calculated for a temperature interval of $\Delta T = 33 - 23^{\circ}\mathrm{C}$ with a combined standard uncertainty of $u(T) = 0.1\mathrm{K}$ for the temperature sensors. The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013\mathrm{MPa}$ and $T \approx 20 - 40^{\circ}\mathrm{C}$ for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

Table B.2: Summary of enthalpy results for Setup B1 (mean ($\overline{h}$) and standard deviation (σ_h) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Cooling	Heating	
Setup B1-I	$\overline{h}_{33-23°C}$ (top sensor)	-240.00	-240.99	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (top sensor)	1.05	0.50	$kJ\,kg^{-1}$
	$\overline{h}_{33-23°C}$ (center sensor)	-245.20	-244.74	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (center sensor)	1.25	0.76	$kJ\,kg^{-1}$
	$\overline{h}_{33-23°C}$ (bottom sensor)	-244.79	-243.96	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (bottom sensor)	0.44	0.57	$kJ\,kg^{-1}$
Setup B1-II	$\overline{h}_{33-23°C}$ (top sensor)	-241.52	-243.44	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (top sensor)	0.36	0.39	$kJ\,kg^{-1}$
	$\overline{h}_{33-23°C}$ (center sensor)	-246.68	-246.39	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (center sensor)	0.49	0.07	$kJ\,kg^{-1}$
	$\overline{h}_{33-23°C}$ (bottom sensor)	-246.15	-245.22	$kJ\,kg^{-1}$
	$\sigma_{h_{33-23°C}}$ (bottom sensor)	0.48	0.31	$kJ\,kg^{-1}$

[a] Calculated for a temperature interval of $\Delta T = 33 - 23°C$ with a combined standard uncertainty of $u(T) = 0.1K$ for the temperature sensors. The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013MPa$ and $T \approx 20 - 40°C$ for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

Table B.3: Summary of enthalpy results for Setup B2 (mean ($\overline{h}$) and standard deviation (σ_h) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Cooling	Heating	
Setup B2-I	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (top sensor)	-238.13	-241.28	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (top sensor)	1.06	0.97	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (center sensor)	-243.32	-243.75	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (center sensor)	0.99	0.29	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (bottom sensor)	-243.21	-243.05	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (bottom sensor)	0.96	0.44	$\mathrm{kJ\,kg^{-1}}$
Setup B2-II	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (top sensor)	-240.65	-242.33	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (top sensor)	0.94	0.18	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (center sensor)	-245.95	-244.76	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (center sensor)	0.62	0.49	$\mathrm{kJ\,kg^{-1}}$
	$\overline{h}_{33-23^{\circ}\mathrm{C}}$ (bottom sensor)	-246.00	-243.89	$\mathrm{kJ\,kg^{-1}}$
	$\sigma_{h_{33-23^{\circ}\mathrm{C}}}$ (bottom sensor)	0.63	0.71	$\mathrm{kJ\,kg^{-1}}$

[a] Calculated for a temperature interval of $\Delta T = 33 - 23^{\circ}\mathrm{C}$ with a combined standard uncertainty of $u(T) = 0.1\mathrm{K}$ for the temperature sensors. The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013\mathrm{MPa}$ and $T \approx 20 - 40^{\circ}\mathrm{C}$ for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

Appendix B.2. Figures

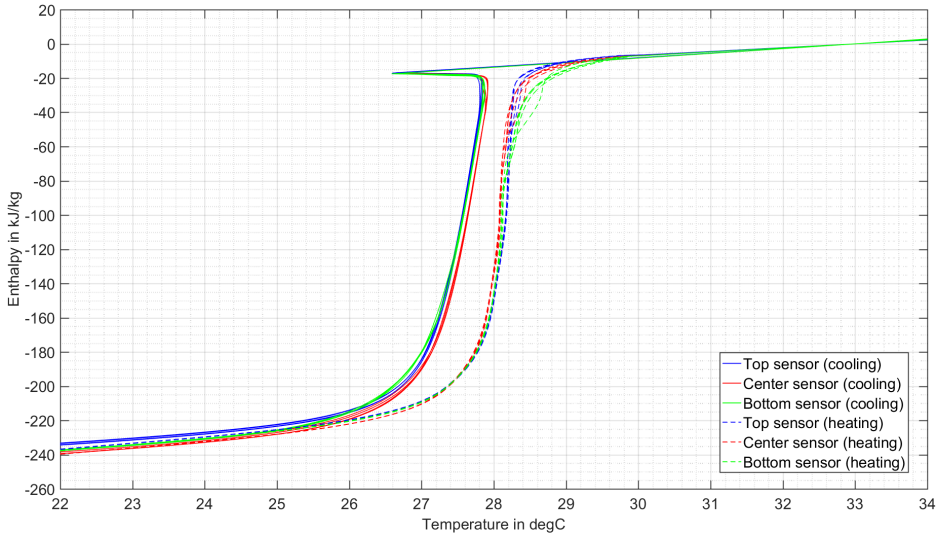

Figure Appendix B.1: h versus T curve for setup A-I using $dT = 0.001°C$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

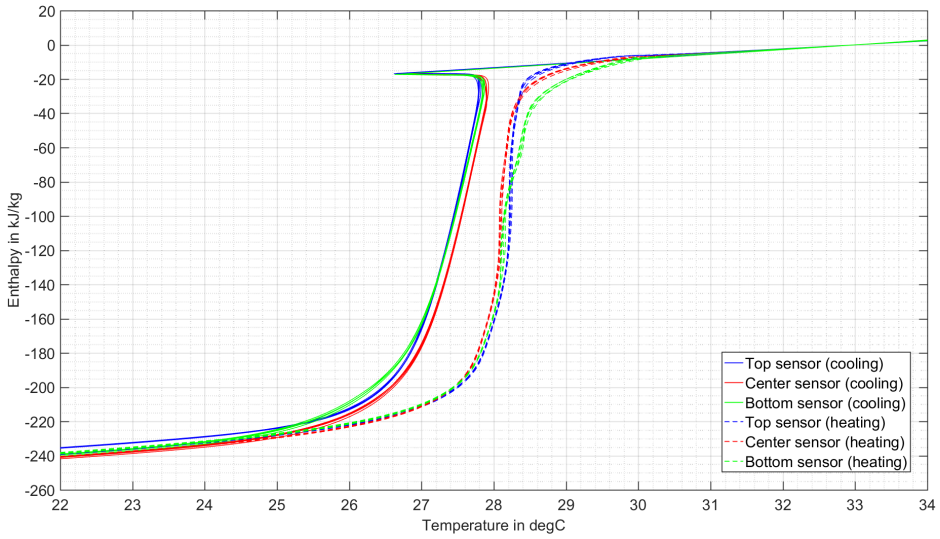

Figure Appendix B.2: h versus T curve for setup A-II using $dT = 0.001°C$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

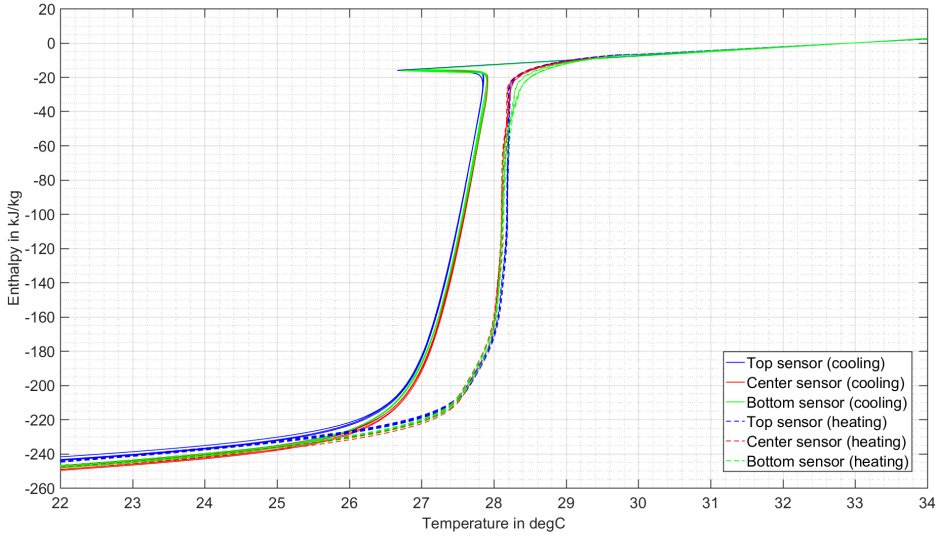

Figure Appendix B.3: h versus T curve for setup B1-I using $dT = 0.001°C$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

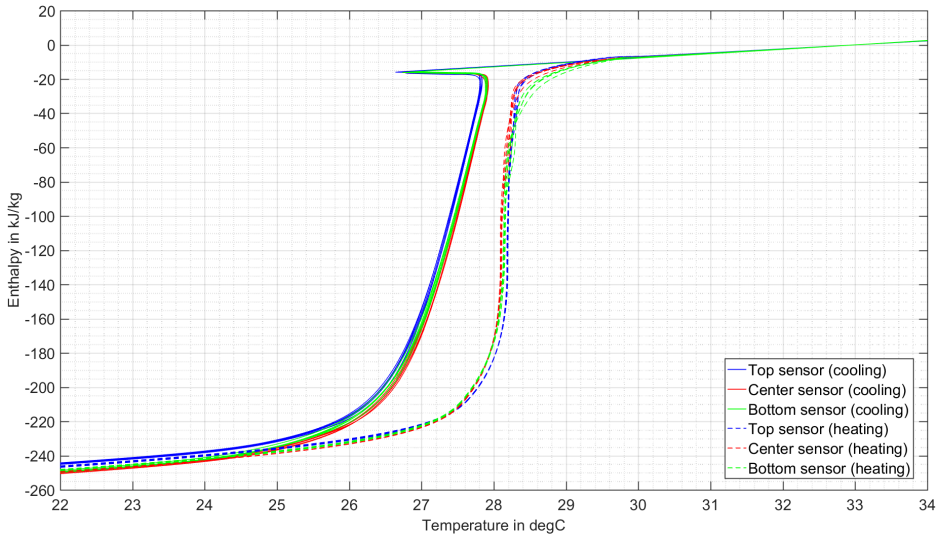

Figure Appendix B.4: h versus T curve for setup B1-II using $dT = 0.001°C$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

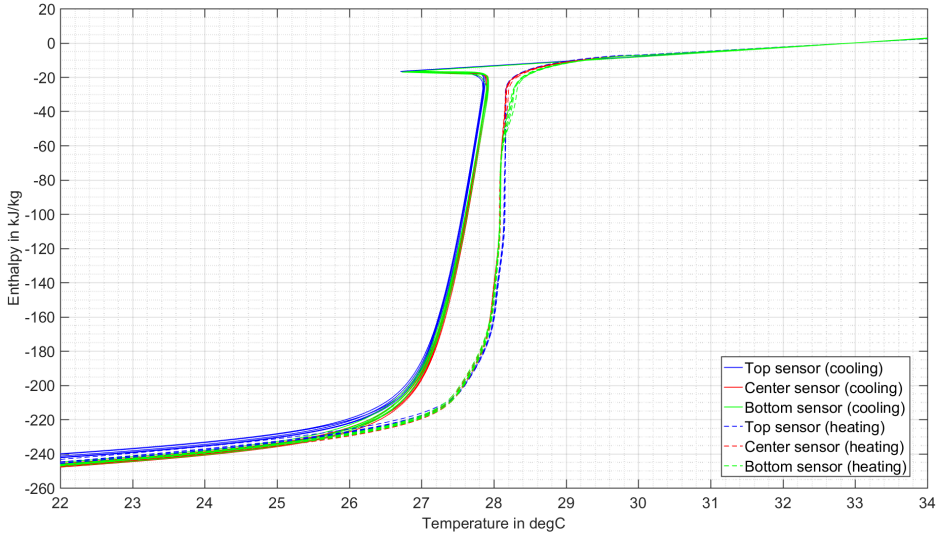

Figure Appendix B.5: h versus T curve for setup B2-I using $dT = 0.001°C$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

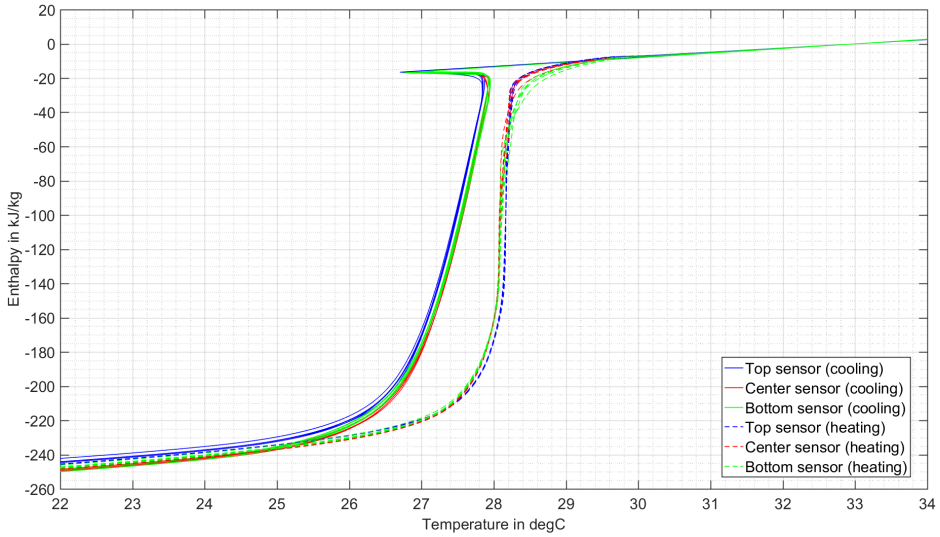

Figure Appendix B.6: h versus T curve for setup B2-II using $dT = 0.001°\text{C}$ (all five cycles are plotted with the same color depending on the sensor position, normalization of h values at 33°C)

Appendix C. Solid and Liquid c_p results

Table C.4: Summary of solid and liquid c_p^{PCM} results for Setup A (mean ($\overline{c}_p$) and standard deviation (σ_{cp}) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Solid[b]	Liquid[c]	
Setup A-I	$\overline{c}_p^{PCM}$ (top sensor)	2.35	2.16	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	8.4×10^{-3}	18.3×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\overline{c}_p^{PCM}$ (center sensor)	2.48	2.35	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	4.5×10^{-3}	12.8×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\overline{c}_p^{PCM}$ (bottom sensor)	2.48	2.35	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	4.9×10^{-3}	12.5×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
Setup A-II	$\overline{c}_p^{PCM}$ (top sensor)	2.53	2.29	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	4.8×10^{-3}	4.6×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\overline{c}_p^{PCM}$ (center sensor)	2.59	2.40	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	4.4×10^{-3}	2.5×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\overline{c}_p^{PCM}$ (bottom sensor)	2.60	2.41	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	4.6×10^{-3}	3.5×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$

[a] The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013$MPa and $T \approx 20 - 40$°C for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

[b] Evaluated between $T = 19.5..21.5$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.

[c] Evaluated between $T = 33..35$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.

Table C.5: Summary of solid and liquid c_p^{PCM} results for Setup B1 (mean ($\bar{c}_p$) and standard deviation (σ_{cp}) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Solid[b]	Liquid[c]	
Setup B1-I	$\bar{c}_p^{PCM}$ (top sensor)	2.44	2.17	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	4.3×10^{-3}	19.3×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (center sensor)	2.52	2.37	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	4.0×10^{-3}	16.3×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (bottom sensor)	2.53	2.37	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	4.1×10^{-3}	17.1×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
Setup B1-II	$\bar{c}_p^{PCM}$ (top sensor)	2.57	2.31	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	7.7×10^{-3}	11.2×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (center sensor)	2.60	2.43	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	7.5×10^{-3}	5.2×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (bottom sensor)	2.61	2.43	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	8.0×10^{-3}	6.5×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$

[a] The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013$MPa and $T \approx 20 - 40$°C for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

[b] Evaluated between $T = 19.5..21.5$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.

[c] Evaluated between $T = 33..35$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.

Table C.6: Summary of solid and liquid c_p^{PCM} results for Setup B2 (mean ($\bar{c}_p$) and standard deviation (σ_{cp}) are calculated over the five cycles for each sensor location).[a]

Setup	Parameter	Solid[b]	Liquid[c]	
Setup B2-I	$\bar{c}_p^{PCM}$ (top sensor)	2.56	2.36	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	9.6×10^{-3}	28.9×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (center sensor)	2.68	2.52	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	7.2×10^{-3}	21.5×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (bottom sensor)	2.69	2.52	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	7.8×10^{-3}	21.9×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
Setup B2-II	$\bar{c}_p^{PCM}$ (top sensor)	2.70	2.44	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (top sensor)	4.3×10^{-3}	7.4×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (center sensor)	2.74	2.56	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (center sensor)	5.0×10^{-3}	7.3×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\bar{c}_p^{PCM}$ (bottom sensor)	2.74	2.56	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$
	$\sigma_{cp_{PCM}}$ (bottom sensor)	4.9×10^{-3}	7.4×10^{-3}	$\mathrm{kJ\,kg^{-1}\,K^{-1}}$

[a] The sample holders were filled at approximately atmospheric pressure $p \approx 0.1013$MPa and $T \approx 20 - 40$°C for reference and PCM respectively, but the exact pressure and $u(p)$ was unknown inside the PCM and reference sample holder for the temperature range of the experiment.

[b] Evaluated between $T = 19.5..21.5$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.

[c] Evaluated between $T = 33..35$°C with a combined standard uncertainty of $u(T) = 0.1$K for the temperature sensors.