Round Robin Test on the Measurement of the Specific Heat of Solar Salt

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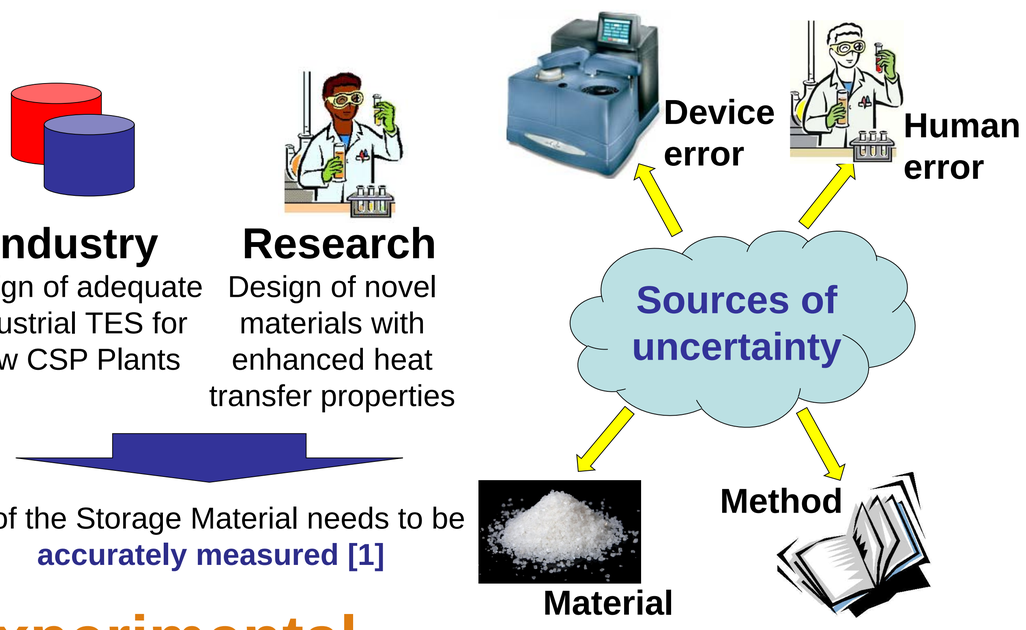
Introduction

Why a Round Robin Test on c_p of Solar Salt?



c_p of the Storage Material needs to be **accurately measured [1]**

Nine partners involved

DLR · University of Birmingham · ENEA · CIC energiGUNE · tecnalia Corporación Tecnológica · Universitat Jaume I · ABENGOA · IK4 TEKNIKER Research Alliance · CEA

Assessment

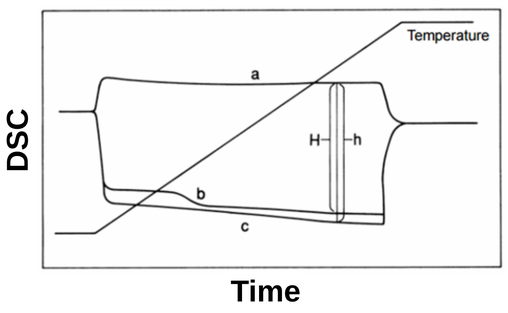
SENER · instituto IMDEA energía

Experimental

General conditions

- All partners start from the same raw material:
  - $NaNO_3$ /KNO_3 (60/40% wt.) mixture melted at 350 ºC – ½ h
- The method of measurement was not imposed
- Three measurement temperatures: 200, 300 & 400 ºC
- The delivered samples were stored under dried argon atmosphere
- Conditioning of samples: 1h at 100ºC prior to measurement

ASTM E1269

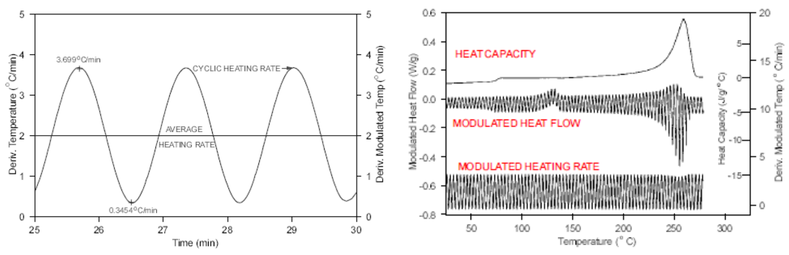


$$c_{ps} = \frac{H}{h}\frac{m_r}{m_s}c_{pr}$$

c_{ps} c_p of sample
c_{pr} c_p of reference material
m_s weight of sample
m_r weight of reference

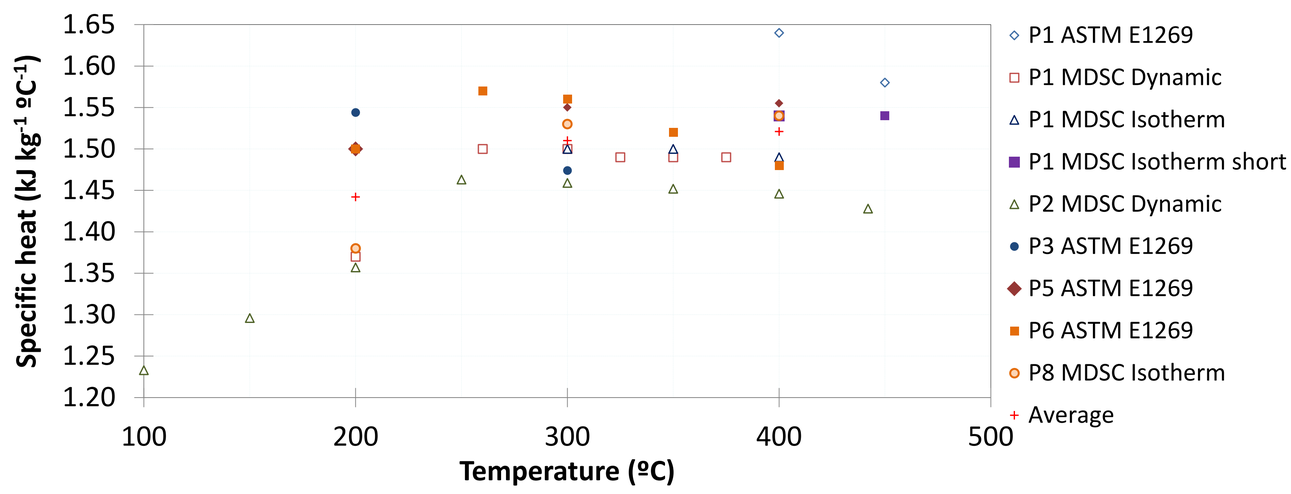
a empty pan. b sample. c sapphire (reference material).
H Difference of sample and empty pan heat flow signal
h Difference of reference material signal and empty pan
Measurement takes place during dynamic segment [2].
Two isothermal segments are required for temperature stabilization

MDSC™ (Dynamic and Isotherm)

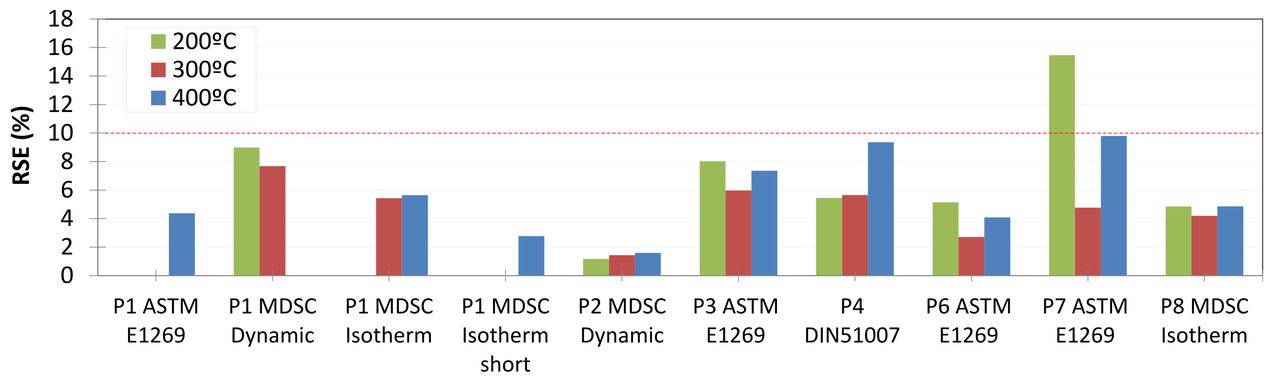


Modulated DSC™ (TA Instruments) [3] measures both heat flow and heat capacity in a single experiment by superimposing a modulated heating rate on top of a linear heating rate.

Results



Results reported by partners. P7 and P4 were removed for high dispersion of results and high deviation from the average respectively



Relative Statistical Error (%) for each partner. RSEs (%) lower than 10% were considered acceptable. RSEs (%) were not calculated for P5, as only 2 measurements were provided [4].

$$CI = \bar{x} \pm \Delta x = \bar{x} \pm t_{\alpha/2} \cdot \frac{SD}{\sqrt{n}} \qquad RSE = \frac{\Delta x}{\bar{x}} \cdot 100$$

Confidence level = 95% [4]

Conclusions

- The normalized method ASTM E1269 and MDSC™ are adequate for the measurement of c_p of SS in the range of temperatures between 200 and 400ºC.
- Comparing the results sent by the partners, a maximum RSE(%) of 5.95% for the measurements of c_p at 200 ºC (solid state) was found.
- The values of c_p at 200 ºC reported by partners using MDSC-based methods were less dispersed than those obtained by the ASTM E1269 method.
- The average results were 1.442 kJ/kg^{-1} ºC^{-1} at 200 ºC (RSE, 5.95%), 1.510 kJ/kg^{-1} ºC^{-1} at 300 ºC (RSE, 2.32%), 1.521 kJ/kg^{-1} ºC^{-1} at 400 ºC (RSE, 3.35%)

Acknowledgements

We would like to thank Workshop SolarPACES Task III for the opportunity to work on this RRT. Personally I, Javier Nieto, want to express my gratitude to my colleague and co-leader of the Material Activity José Gonzalez for his support and advices. Thank you very much, Esther Rojas, for organizing the workshop, and Rocio Bayón to push me a little bit to be the co-leader of the Material Activity. Finally, I would like to thank Izaskun Marañon for the DSC measurements.

References

1. N. Pfleger et al. Beilstein Journal of Nanotechnology 6, 1487–1497 (2015).
2. ASTM E1269-11, Standard Test Method for Determining Specific Heat Capacity by Differential Scanning Calorimetry, ASTM International, West Conshohocken, PA, 2011, www.astm.org
3. http://www.tainstruments.com/pdf/literature/TN34.pdf
4. ASTM E2586-14, Standard Practice for Calculating and Using Basic Statistics, ASTM International, West Conshohocken, PA, 2014, www.astm.org

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