First Experimental Results of World's Largest High-Temperature Molten Salt Thermocline Storage System with Filler

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In this work the first experimental results of the world's largest molten salt thermocline storage system with filler (TCF) will be presented. The current experimental setup has a thermal capacity of 3.8 MWh and operates in a temperature range from 290 to 560°C.

The molten salt thermocline storage concept is a new concept for storing large amounts of thermal energy at high temperatures of up to 560°C. Instead of storing molten salt in two separate tanks, as in the state-of-art systems, the density difference of hot and cold molten salt is used to maintain stratification inside the single-tank [1]. It has numerous advantages, such as cost saving due to the absence of the second tank, less smaller footprint, allowing higher tank design through shorter pumps, avoiding unused space at the bottom of the tanks and simplification of the gas handling. However, the largest cost reduction potential arises from the application of a low cost filler material, which substitutes a large fraction of the molten salt which presents a major share of the overall storage system cost. Thus, the total costs for the storage system can be reduced significantly. Kelly reported for a two-tank indirect storage system cost reduction of more than 50 % [2].

In the past, several pilot scale plants have been operated. The first and largest one was that attached to the Solar One plant, which had 170 MWh thermal power and used thermal oil with temperatures up to 300°C [3]. Later, another plant was operated by Sandia, this time with molten salt, 2.3 MWh thermal power and up to 400°C temperature [4]. Additionally, lab scale experiments with temperatures up to 400°C have been presented at CEA by Bruch et al. and Rodat et al. [5,6] and at PROMES CNRS by Fasquelle et al. [7] with thermal oil and at Fraunhofer by Seubert et al. [8] with molten salt.

At the DLR experiment, the temperature range is extended one step higher to 560°C. As HTF, Solar Salt at maximum temperature is used for several consecutive charging and discharging cycles. 166 thermocouples measure the temperature distribution along the middle axis and additionally at four planes in two radial directions each. Through the high density of thermocouples the exact thermocline profile can be measured and it is possible to study its development. The radial thermocouples help to understand and improve the molten salt distribution at the inlet regions and to detect asymmetries in molten salt flow. The experimentally determined development of the thermocline zone and its movement speed through the storage volume are compared to a 1D numerical model.

[1] Gil A, Medrano M, Martorell I, Lázaro A, Dolado P, Zalba B, et al. State of the art on high temperature thermal energy storage for power generation. Part 1--Concepts, materials and modellization. Renewable and Sustainable Energy Reviews 2010;14:31–55. doi:10.1016/j.rser.2009.07.035.
[2] Kelly B, Kearney D. Thermal Storage Commercial Plant Design Study for a 2-Tank Indirect Molten Salt System. National Renewable Energy Laboratory (NREL); 2004.
[3] Faas SE, Thorne LR, Fuchs EA, Gilbertsen ND. 10 MWe Solar Thermal Central Receiver Pilot Plant: Thermal Storage Subsystem Evaluation Final report. 1986.
[4] Pacheco JE, Showalter SK, Kolb WJ. Development of a Molten-Salt Thermocline Thermal Storage System for Parabolic Trough Plants. Journal of Solar Energy Engineering 2002;124:153. doi:10.1115/1.1464123.
[5] Bruch A, Fourmigué JF, Couturier R. Experimental and numerical investigation of a pilot-scale thermal oil packed bed thermal storage system for CSP power plant. Solar Energy 2014;105:116–25. doi:10.1016/j.solener.2014.03.019.
[6] Rodat S, Bruch A, Dupassieux N, Mourchid NE. Unique Fresnel Demonstrator Including ORC and Thermocline Direct Thermal Storage: Operating Experience. Energy Procedia 2015;69:1667–75. doi:10.1016/j.egypro.2015.03.127.
[7] Fasquelle T, Falcoz Q, Neveu P, Lecat F, Boullet N, Flamant G. Operating results of a thermocline thermal energy storage included in a parabolic trough mini power plant. AIP Conference Proceedings 2017;1850. doi:10.1063/1.4984431.
[8] Seubert B, Müller R, Willert D, Fluri T. Experimental results from a laboratory-scale molten salt thermocline storage, Abu Dhabi, United Arab Emirates: 2017, p. 080025. doi:10.1063/1.4984446.