Experimental and Numerical Investigation of a 4 MWh Single-Tank Thermocline Storage
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Introduction
For large scale thermal energy storage at temperatures above 300°C, two-tank molten salt systems mark the current state-of-the-art. The two-tank concept offers significant cost reduction potential by storing the salt inside a single tank thermocline (TC), as indicated in Fig. 1. Through this first step, costs for pumps, the unused storage volume and land consumption are reduced. The separation of both phases is achieved by stratification due to density variations. In more advanced concepts (2nd step) a moving barrier (TCMB) could also be applied. Since salt costs can be as high as half of the total costs [1], further potential for cost reductions is given [2]: a large fraction of the molten salt can be substituted by a cheap solid material as in the thermocline with filler concept (TCF).

TESIS:store facility
The "test facility for thermal energy storage in molten salts" (TESIS:store) is located at DLR in Cologne, Germany, see Fig. 2. The plant is ready for testing all of the aforementioned kinds of storage concepts.

Numerical model
An implicit 1D single phase numerical model is implemented in Matlab®. The model divides the storage volume into several layers of uniform temperature $T_i$. The change of inner energy inside the layer is governed by the convective and conductive flux in and out of the layer. The resulting differential equation simplifies to:

$$\frac{\partial T_i}{\partial t} = \frac{1}{\rho c} \frac{\partial}{\partial z} \left( \frac{\partial T_i}{\partial z} \right) + A_i \frac{\partial^2 T_i}{\partial z^2}$$

Experimental results
The radial temperature profiles at the beginning and the end of the charging cycle are shown in Fig. 4. Several thermocouples are damaged due to improper installation. However, all remaining thermocouples show a stable temperature distribution along the radial axis, indicating a uniform flow pattern (plug flow). At the beginning of the charging cycle, the fluid level is at 5.35 m due to the lateral flow). At the beginning of the charging cycle, the fluid level is at 5.35 m due to the lateral

The resulting axial temperature profiles at different times during the charge cycle are shown in Fig. 5. As can be seen, a stable thermocline profile is developed, which extends over less than one meter.

Model comparison
The measured inlet temperature and mass flow were taken as inlet conditions and the actual temperature profile at the beginning as initial condition for the simulations. The model also shows a good overall agreement with the experiments, shown also in Fig. 5. Some discrepancies at the end of the discharge cycle are probably caused by mixing in the inlet region.

Conclusion
- A stable thermocline can be established
- Experimental data in a relevant size for model validation has been acquired
- Good agreement with numerical model

Literature