Institute of Engineering
Engineering Thermodynamics

Experimental Results of a Large Scale Single Tank Thermocline

Christian Odenthal, Freerk Klasing and Thomas Bauer

Introduction

For large scale high temperature thermal energy storage, two-tank molten salt systems mark the current state-of-the-art. New fields of application are emerging:

- Chemical sites can mange their energy consumption or even act as an energy supplier (Fig. 1). A presentation on this topic and further reading can be found in [1].
- Conventional power plants could reach lower part load levels.
- Industrial furnaces can shift their energy consumption.

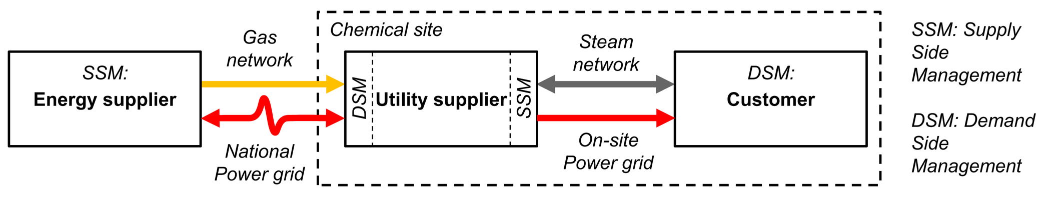

Fig. 1: Load management of a utility supplier on a chemical site [1]

In volatile electricity markets, like in Germany, this increased flexibility enables significant cost reduction potentials.

Molten salt thermocline filler concept

The current two-tank concept comprises potential for further cost reductions: A first step is storing the hot and cold phase inside a single tank. The separation of both phases is achieved by their different density or by a floating barrier. The second step is the thermocline with filler concept, where a large fraction of the salt can be substituted by a low-cost solid material.

TESIS:store facility

The "test facility for thermal energy storage in molten salts" (TESIS:store) has been set up. The facility operates at temperatures up to 560°C and a mass flow up to 4 kg/s. The storage volume is 22 m³, which is equal to 40 t at 300°C. The plant allows the investigation of the thermocline concept with and without filler and gaining widespread operation experience. Fig. 2. shows a picture of the plant and parameters are given in Table 1.

Fig. 2: The TESIS test facility in Cologne

Table 1: Operational parameters TESIS:store

Salt mass	40 + 45 metric tons
Molten salt	nitrate / nitrite salts
Temperature range	150 to 560 °C
Capacity (ΔT=250K)	~ 200 kWh/m³
Heating / cooling power	115+100 / 420 kW
Mass flow rate	max. 4 kg/s

Test set up

Temperatures are measured along the mid axis (z-axis) of the storage tank. The distance between adjacent thermo-couples is generally 20 cm and 10 cm at the inlet regions, since larger temperature gradients are occurring there. To measure radial temperature differences as well (due to trace heating or heat losses), there are two radial axes (f0 and f1). The angle and orientation of the two axes allows to capture a possible asymmetric maldistribution of the flow. Positions of all thermocouples is shown in Fig. 3.

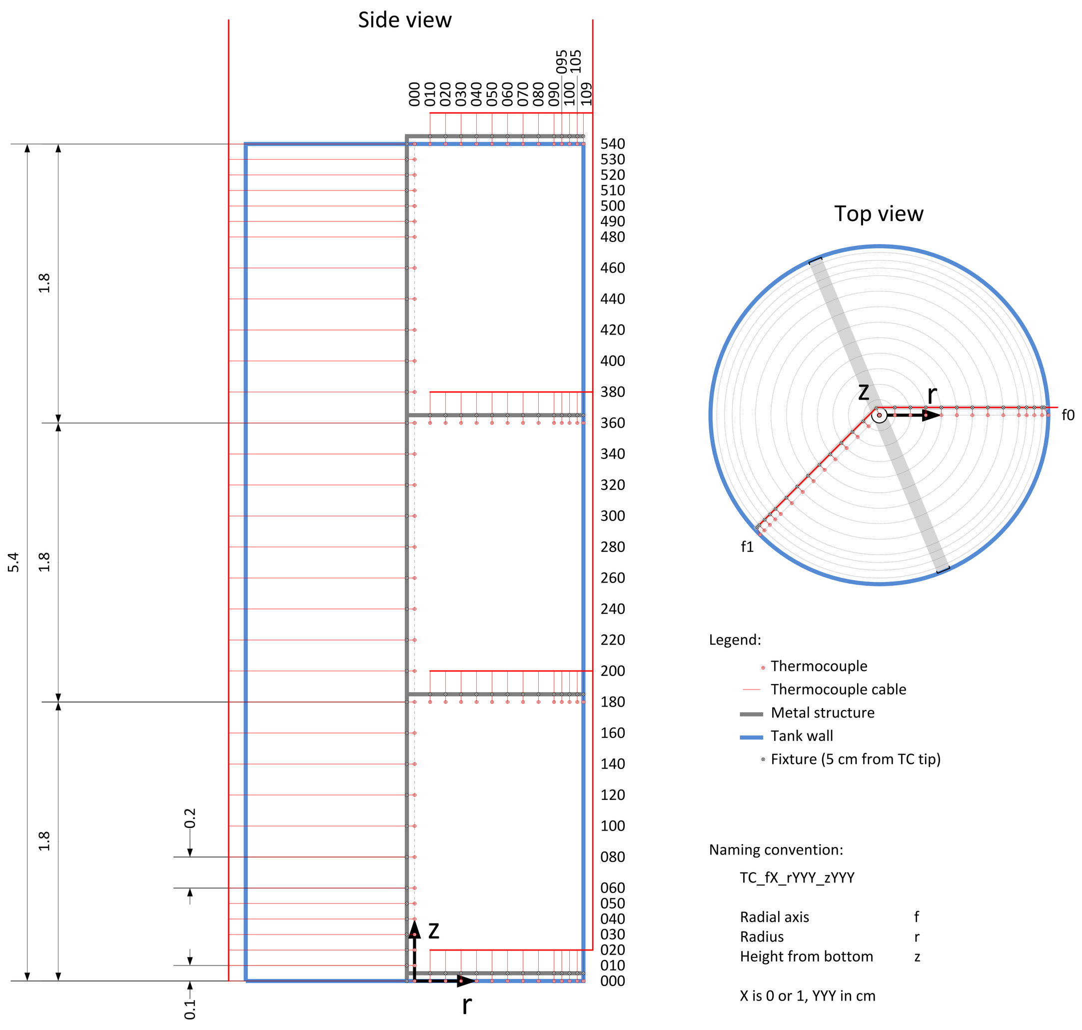

Fig. 3: Thermocouple positions and picture of the thermocouple fixation inside the tank

Results

In this work first experimental results of the thermocline concept without filler are presented. Particular interest lies in achieving a stable thermocline zone where energetically adverse mixing should be minimized.

As HTF, Solar Salt at the maximum temperature and at a mass flow of 3 kg/s is used for several consecutive charging and discharging cycles. The lower temperature is set to 290 °C due to the freezing point of the Solar Salt. The experiments help to understand and improve the molten salt distribution at the inlet regions as well as the development of the thermocline zone. Fig. 4 shows the temperature profiles alongside the middle axis of the tank during discharging.

Some of the data points had to be removed, since the cables of the corresponding thermocouples had been destroyed by too high temperatures.

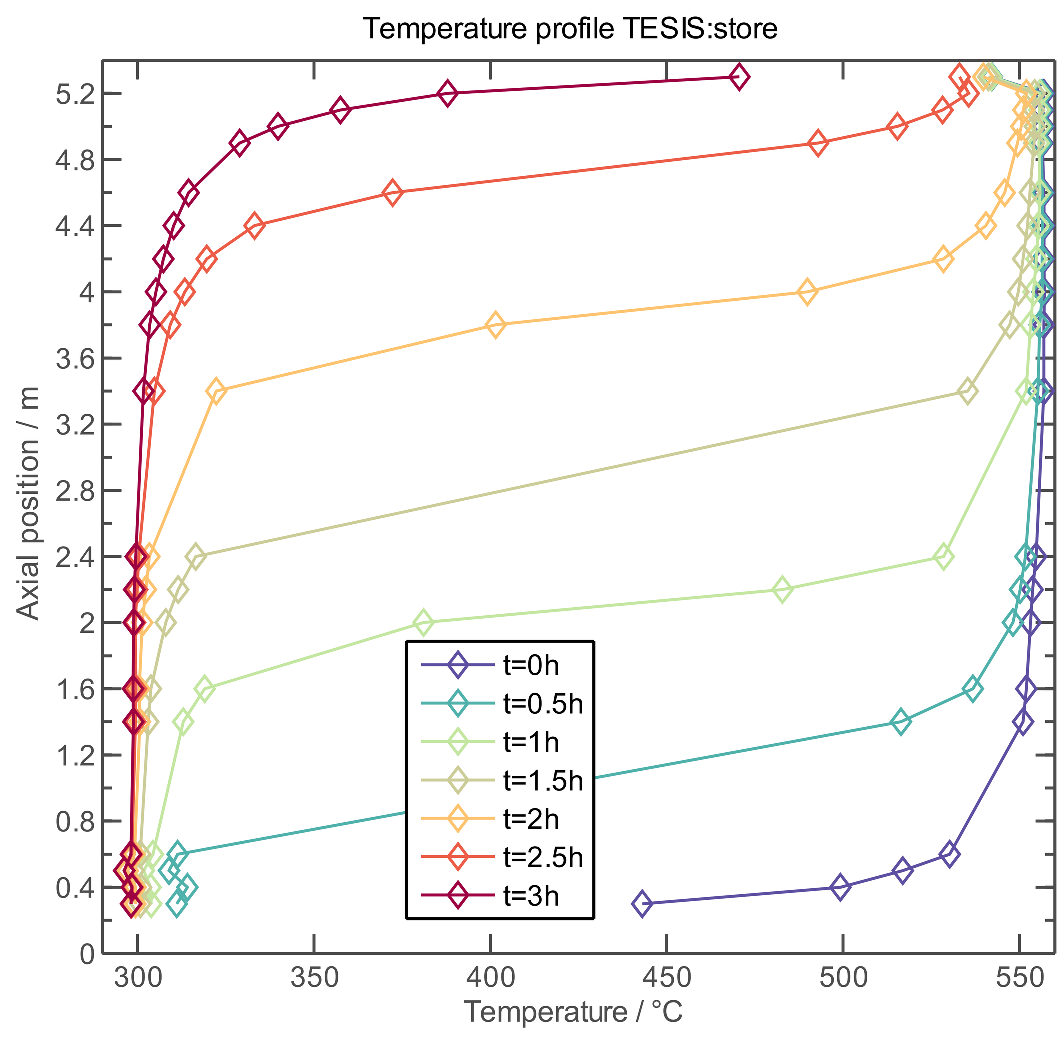

Fig. 4: Temperature profiles alongside the middle axis during a discharging cycle

As can be seen, a stable thermocline profile is developed, which extends over less than one meter. The preceding charge cycle was stopped after the exit temperature reached 360 °C. The reason for the initial profile starting at a higher temperature value is due to the additional capacity of 1 m³ of the tank bottom. The discharging cycle was stopped after the temperature of the salt reached 480 °C at the exit of the storage volume.

Conclusion

- A stable thermocline inside the tank can be established
- Experimental data in a relevant size for model validation has been acquired
- The plant was successfully commissioned

Acknowledgements

The authors thank the German Federal Ministry for Economic Affairs and Energy for the financial support given for this work in the MS-STORE project (Contract No. 0325497 A).

Literature

[1] Klasing et al.: "*Assessment for the Adaptation of Industrial Combined Heat and Power for Chemical Parks towards Renewable Energy Integration using high-temperature TES*"
IRES 2018,
Düsseldorf

Knowledge for Tomorrow

Wissen für Morgen

Deutsches Zentrum
für Luft- und Raumfahrt