Demonstrating Cost Effective Thermal Energy Storage in Molten Salts: DLR’s TESIS Test Facility

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Advantages of Molten Salt

- Unpressurized (low vapor pressure)
- High heat transfer rates
- Low viscosity
- Operation temperature up to 560 °C
- Most common HTF in solar tower plants
- Trend for future parabolic trough plants

Molten Salt as Heat Transfer Fluid (HTF)

- Unpressurized
- Less expensive than synthetic oil
- No heat exchanger to HTF molten salt
- Nontoxic, nonflammable and no explosive phases
- Spec. heat capacity (liquid phase): about 1.5 kJ/(kgK)
Overview of molten salt storage technology

2-Tank (state of the art)

Thermocline

Thermocline with filler

cold tank

hot tank

single tank

single tank
Research at DLR – TESIS Facility
Test facility for Thermal Energy Storage in Molten Salts

Test section for molten salt energy storage – TESIS:store

- Flexible test section for alternative thermal energy storage concepts
- Long-term / permanent testing possible

Test section for molten salt components – TESIS:com

- Flexible set-up for various components (e.g. valves, receiver tubes or instruments)
- Critical conditions possible
Research at DLR – TESIS Storage Test Section

TESIS:store

Molten salt medium: Nitrate - Nitrite salt mixtures

- Min. operation temperature: 150 °C
- Max. operation temperature: 560 °C
- Max. mass flow rate: 4 kg/s
- Max. mass of filler material: 45 t
- Max. empty tank volume: 22 m³

→ Behavior of storage system, model validation / refinement, molten salt chemistry on large scale
Photo of the TESIS Plant
Potential for Cost-Reduction of Molten Salt Systems

Potential #1:

Cost Reduction Potential for Thermocline Storage
- Foundation (15 %) - 42 %
- Storage Tank (13 %) - 25 %
- Storage Material (52 %) - 72 %
- Piping & Pumps (10 %) - 22 %
- Other Costs (10 %) - 55 %

Potential #2:

General potential:

Limited operational experience
Understanding of corrosion mechanisms
Understanding of molten salt degradation / small ∆T

Source: 100 MWe power plant, DLR inhouse cost calculations
Example for Cost-Reduction: Exergy

Energy Source:
(Solar field)

\[ T_{in} = 290 \, ^\circ C \]

\[ T_{out} = 560 \, ^\circ C \]

Scenario:
- 12 hours charging time
- 2.82 GWh thermal energy

Nominal Exergy:
\(~1.59 \, GWh\)

Regained Exergy:
\(< 1.59 \, GWh\)

Parametric study:
Adapt length of storage volume for
- 12 hours charge time and
- permitted drop of exit temperature
Result of Parametric study

• 100s of possible storage configurations
• Every configuration fits into the scenario
• Difference: Regained exergy vs. molten salt holdup (storage size)

![Diagram showing necessary fluid mass (size of storage) depending on exergy regain. The Pareto Optimum is highlighted.](chart9.png)
## Selected Results of the Parametric Study

<table>
<thead>
<tr>
<th>System</th>
<th>Thermocline, $\varepsilon = 40%$</th>
<th>2-Tank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Permitted change in exit temperature ($\Delta T_e$)</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>Exergy regain ($\Xi$)</td>
<td>99.8</td>
<td>99.8</td>
</tr>
<tr>
<td>Storage volume ($V_{stor}$)</td>
<td>16.7</td>
<td>14.9</td>
</tr>
<tr>
<td>Fluid mass ($m_f$)</td>
<td>12.2</td>
<td>10.9</td>
</tr>
<tr>
<td>Solid mass ($m_s$)</td>
<td>30.0</td>
<td>26.8</td>
</tr>
</tbody>
</table>
Summary

Molten salt thermal energy storage is proven technology with large cost reduction potential

→ DLR has built two test facilities TESIS:store and TESIS:com, which help understanding storage behavior, salt chemistry and testing components for faster market application

Example based on exergy has shown that thermocline storage with filler can achieve

→ high exergetic efficiency and
→ significant reduction of salt inventory (investment cost)
Thank you for your attention

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