GENERAL DESCRIPTION

Mode of energy intake and output

Heat-to-heat

Summary of the storage process

Latent heat storages are based on the shift in internal energy that occurs whenever the storage material undergoes a phase change within a narrow temperature interval. Usually, the transition between the solid and liquid state is used.

Figure 1: Latent heat storage module with 700 kW power, storage capacity 1 h, $NaNo_3$ as storage material, phase change at 305 °C

One of the main applications for high-temperature latent heat storages is for heat storage in industrial steam systems, using water vapour as a working medium and condensation or evaporation processes for charging and discharging. The storage material is selected to have its phase change in the same range as the water's evaporation temperature. Depending on the working pressure, storage materials are therefore required to have a melting temperature between 150 and about 330 °C. Due to budgetary considerations, nitrate salts or eutectic mixtures of these are often chosen as latent storage materials for this temperature range, but other material classes, such as dicarboxylic acids, are also suitable. When developing storage systems, the low thermal conductivity of PCMs must be taken into account. Various concepts were considered in this regard to ensure a sufficiently high power density.

While charging, condensing steam flows through the heat exchanger, the temperature of which is 5-10 K above the storage material's melting temperature. The condensation heat melts the storage material. On discharge, the water pressure is lowered to a point where the boiling temperature lies about 5-10 K below the storage material's phase change temperature, the solidification heat is employed for evaporation. During discharge, the solid storage material builds up a steadily growing layer on the heat-transferring surfaces. Due to the low thermal conductivity of the PCMs, heat exchangers with surface-increasing structures or conductivity enhancing fillers are used to ensure sufficient performance of the storage system.

Focus on provision of power or energy

High-temperature latent heat storages are often designed for energy provision. In applications where the storage is to ensure the short-term availability of backup capacity, the focus is placed on providing power.

Suitable fields of application

Latent heat storage systems are suited for integration into subcritical steam cycles. For solar thermal power plants using steam as a heat transfer medium in the absorber system, latent heat storage systems have been developed to allow for temporal decoupling from solar irradiation. In general, latent heat storages can improve the dynamics of steam power plants, reducing partial load and start-up losses. In process manufacturing, latent heat storage systems can increase energy efficiency by improving the exploitation of waste heat. Temporal deviations between the availability of and demand for waste heat can be evened out here, storage units can compensate for fluctuations and thus facilitate the use of waste heat in conversion processes used to generate electricity or cooling.

State of development/commercial availability

Latent heat storages with integrated finned tube heat exchangers were set up and operated with phase change temperatures between 140 °C and 305 °C, the power ranged from 1-700 kW, the capacities were in the hourly range. The technology has reached TRL7.

R & D: After demonstrating the functionality, one focus of the current development work is on the economic optimisation of latent heat storage units. The optimisation of the embedded heat exchanger's geometry in dependence of application-specific boundary conditions is central to this. Alongside this, alternate manufacturing concepts for finned tubes are being considered. Since each PCM has one specific phase change temperature, more materials are also being investigated in terms of suitability as PCMs to allow for better adaptation of the phase change temperature to specific applications.

Active latent heat storage systems form another focus of development. The goal here is the mechanical decoupling of storage material and heat exchanger. In such systems, the heat exchanger size depends solely on the power, not on the capacity. It can deliver a constant power output, adjustable over a wide range. Thermomechanical stress due to volume change is averted, another goal is a cost reduction compared to the current state of the art.

For storage capacities below 1 MWh and phase change temperatures ranging around 500 °C, metallic PCMs such as alloys of aluminium and silicon are also being considered.

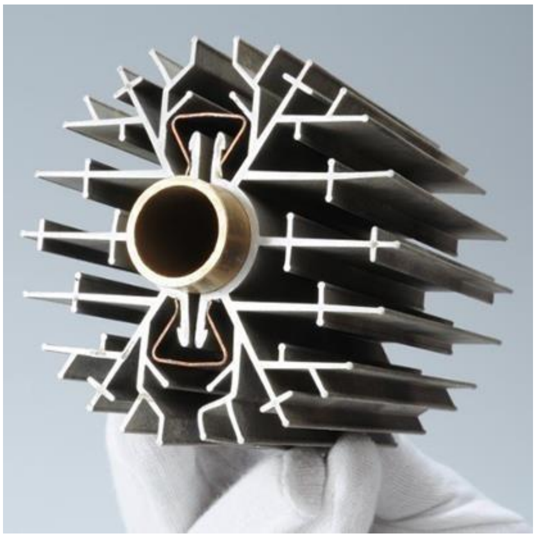

Figure 2: Tube segment with axial cooling fins

Figure 3: 100 kW latent heat storage module, charging with solar-generated steam. Binary nitrate salt mixture as storage material, phase change at 220 °C.

TECHNICAL SPECIFICATIONS

Specific energy storage density	kWh/m³ 95.5	kWh/t 49
Specific power density	kW/m³ 15-80	kW/t 7.5-41
Typical/feasible storage size	kWh_{out} 100-500,000	kW_{out} 100-100,000
Storage efficiency	98 %	
Storage duration	1-8 hours	
Response time	2-8 minutes	
Service life (maximum)	Cycles 10,000	Years n. a.
Loss per time in %	0.5-2.5 per day	

ECONOMIC SPECIFICATIONS

Investment cost per kW
50-100 €

Investment cost per kWh
40-80 €

Operating and maintenance cost (based on investment/kW and kWh)
< 1 % of overall investment

For further information, see
German Aerospace Center (DLR), https://www.dlr.de/EN/