EERA
European Energy Research Alliance
EERA Joint Program on Energy Storage
SP3 on Thermal Energy Storage
August 2018

High-Temperature Sensible Heat Storage

Storage Principle

Sensible high temperature heat storage (SHTHS) raises or lowers the temperature of a liquid or solid storage medium (e.g. sand, pressurized water, molten salts, oil, ceramics, rocks) in order to store and release thermal energy for high-temperature applications (above 100°C). The amount of stored heat is proportional to the density, specific heat, volume, and temperature variation of the storage materials. Basically, specific heat, density and thermal conductivity are the main thermal properties of sensible heat storage materials. Fig. 1 shows the main thermal properties of sensible heat materials.

At higher temperatures the most common liquid storage material is molten salt (Fig. 2). The salt is pumped between a cold and a hot storage tank for (dis-)charging. In direct systems the salt is used as a storage medium and heat transfer fluid at the same time. Indirect systems employ a heat exchanger with an additional thermal oil cycle. Power and capacity of the storage are thus linked to separate units in the system, heat exchanger and storage tanks, respectively. Already highly commercialised, the grid-connected molten salt storage capacity for CSP grew larger than 30 GWh_{th} in 2015.

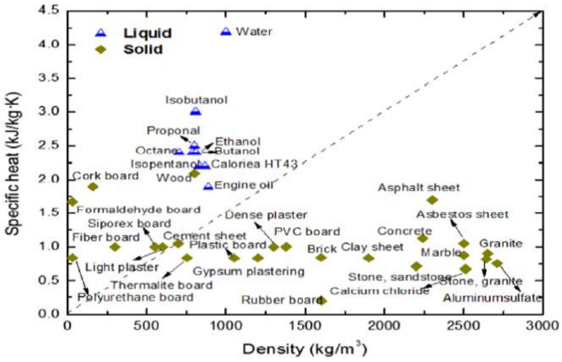

Fig. 1. Thermal properties of sensible heat materials [1].

Fig. 2. Aerial view of Crescent Dunes storage [2].

Technical characteristics

Typical Power Range (MW): up to 300 MW [5]

Feasible size: up to 6 GWh liquid, 0.1 – 4 GWh solid media

Energy density (kWh/m^3):
ΔT=200°C → 138-176 [3]
ΔT=300°C → 207-264 [3]
ΔT=500°C → 345-440 [3]

Response time: Minutes, but depends on heat transfer area (solids) and heat exchanger (liquids) and the storage design and system integration.

Technical lifetime (y): 30 [6]
Temperature range (°C):100-1000°C

Maturity

Installed worldwide:	30 GWh_{th} of molten salt in 2015
Installation costs (€/kWh):	15-40 [2]
Technology readiness level:	4 (solids) - 9 (liquids) [2]

Challenges in development

- Reduce the size by increasing operation temperature window
- Develop single tank for liquids
- Develop packed bed storage
- Identify and qualify new fluids
- Develop salt-based nanofluids

Potential of technology

- Simple application with available materials.
- Long lifetime
- Cost-effective and long storage duration

Barriers

- Limitations arising from material properties
- Pressure losses and temperature decrease at the end of discharge mode (solids)
- Large size and temperature swing.

Common Applications

- Concentrated solar power (CSP)
- Flexible and hybrid conventional thermal power plants
- Industrial waste heat recovery
- Advanced adiabatic compressed air energy storage (AA-CAES)
- Industrial process flexibility and energy efficiency in glass, cement and steel industries, etc.
- Process steam supply from pressurized water storage, a.k.a. Ruths or steam accumulator
- Regenerator (Cowper) storage in the steelmaking and glass manufacturing

Example Applications

1. Solar thermal power plants

SHTES systems increase the percentage of solar energy produced by a power plant, improve operating behaviour, and lead to higher utilization of the power block. Depending on the design of the system, the heat transfer fluid (HTF) may serve as the heat source in an evaporator, creating steam which powers a stream turbine which drives a generator, or the HTF may directly vaporized as it passes through the solar field and then pass straight through the turbine without an intermediate heat exchanger. This excess solar thermal energy is currently stored in tanks filled with molten salt as high temperature sensible heat storage medium as shown in Fig. 3 [7].

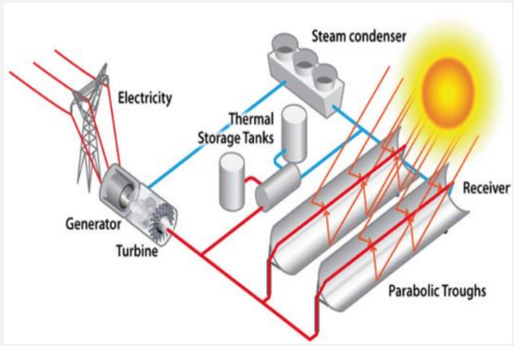

Fig. 3. A direct steam generation concentrating solar power plant with SHTES [7].

2. Waste heat valorisation in industrial processes

The implementation of a SHTES system to store discontinuous waste heat from the exhaust gas of an electric arc steel re-melting furnaces has been studied [4]. Two packed bed sensible heat TES systems were proposed in order to be used at a temperature range from 315 to 1500 °C in both the operational periods, so to time average the widely fluctuating temperature of the energy source, and in the peaking periods, so to hold energy until the demand arises (Fig. 4). The system proposed was expected to save 0.0227 MW per ton of produced steel.

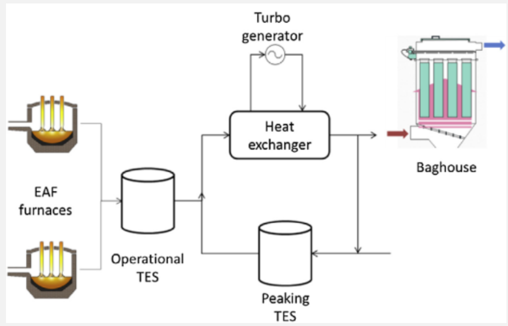

Fig.4. Steel electric arc furnace energy recovery and storage system [4].

4. Advanced adiabatic compressed air energy storage (AA-CAES).

The storage efficiency of an adiabatic CAES plants is reduced by cooling of the air before it enters the cavern, and by reheating the air prior to combustion. In the adiabatic cycle, thermal energy is extracted and stored separately before the compressed air enters the cavern. In such systems (Fig. 6), AA-CAES employs sensible storages to increase the efficiency in the storage of electricity.

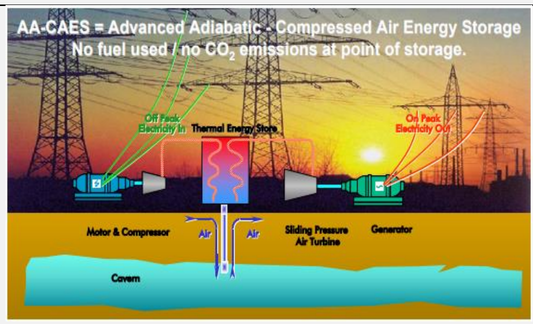

Fig. 6. Adiabatic CAES plant [9].

References

1. G. Li, 2016.
2. EERA/EASE Roadmap, 2017.
3. M. Lui et al., 2016.
4. L. Miro et al., 2016.
5. P. G. Bergan et al., 2014.
6. A.S. Fleischer, 2015.
7. B. Romero, 2013.
8. C. Bullough et al., 2004.
9. S. Zunft et al., 2017.
10. T. Bauer et al., 2012.

Contact

JP Energy Storage
SP3 - Thermal Energy Storage
http://eera-es.eu

European Energy Research Alliance (EERA)
Rue de Namur, 72
1000 Brussels | Belgium