Technology: Sensible Heat Water Storage

GENERAL DESCRIPTION

Mode of energy intake and output

Heat-to-heat

Summary of the storage process

During charging, heat is supplied to a volume of water, increasing the kinetic energy in its molecules. The heat capacity of water is 4.2 kJ (= 1.17 Wh) per 1 litre of volume and 1 degree of temperature increase. So, for a 300-litre water tank and 70-degree temperature increase (e.g. from 20 to 90 °C), this comes to 24.5 kWh of stored thermal energy at 90 °C.

Since the density of water changes with temperature, its buoyancy forces lead to thermal stratification in the tank. This natural layering should not be disturbed by charging and discharging, as otherwise the storage's mean temperature could drop to a level that necessitates additional heating.

System Design

Small-scale systems are usually integrated into buildings and can hold heating water, domestic hot water, or both. In accordance with its intended use, domestic hot water is usually stored in heat-insulated hygienic tanks made of stainless or enamelled steel. Charging and discharging take place indirectly via an integrated heat exchanger. Storages for domestic heating water are mostly charged and discharged directly, without a heat exchanger. So-called bivalent systems use two heat exchangers, so they can be charged from two different, independent sources, like a boiler and a solar collector (Fig. 1).

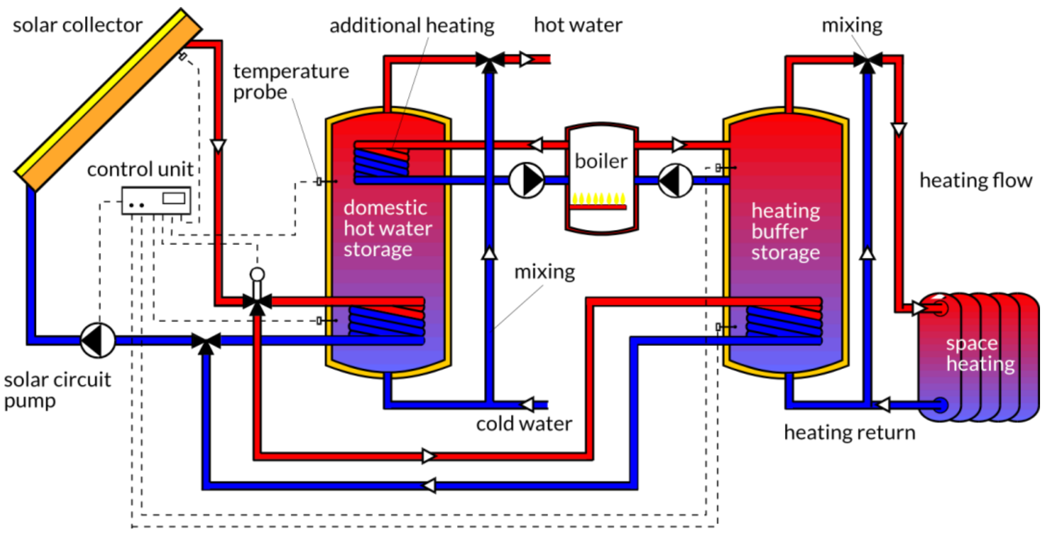

Figure 1: Domestic bivalent sensible double storage system. The domestic hot water tank (typically 200 l) is smaller than the heating buffer storage (typically 1,000 l). Both tanks are charged indirectly via pipe coil heat exchangers. (© ITW, University of Stuttgart).

Common variations of these systems can replace the large domestic hot water tank with smaller components, such as a fresh water station, a combined storage tank (small domestic hot water tank integrated into the heating storage tank), or hygiene coils in the buffer storage tank. So-called stratified charging units ensure the layering of the different temperature levels while reducing mixing to a minimum by reducing the flow velocity inside the storage.

Figure 2: 5,600 m³ hot water storage tank in Bolzano, Italy (© Alperia SpA)

Large-scale systems work on the same basic principles but use much larger storage vessels of various designs. While appropriate for all storage durations, most of them are used seasonally.

Like small-scale systems, they often use tanks for storage, only larger ones (Fig. 2). These are normally cylindrical and always insulated to all sides with a layer of suitable fill material, such as perlite. Due to a better surface-to-volume ratio and consequently lower share of insulation costs in the total price, large tanks generally tend to provide better insulation than small ones. They can be used to supply entire residential quarters with heat over the whole year, but their main use cases are daily and weekly storage in district heating networks. The tanks can be buried partially or fully, to make them less visible and better integrate them into landscape planning (Fig. 3). Pressurised water tanks allow for higher storage temperatures up to about 180 °C (at 10 bar) by avoiding the liquid-gaseous phase transition that water undergoes at 100 °C under ambient conditions.

Figure 3: 6,000 m³ seasonal heat storage tank in Munich during construction and after being completely buried in a hill (© ZAE Bayern)

In spite of being much larger than most storage tanks, pit storages are a very cost-efficient solution. They can store very large amounts of hot water at a very low construction cost, since they are literally just excavated holes in the ground, sealed with a liner, filled with water, and insulated to the top (Fig. 4). Pit storages are an ideal choice for applications like district heating networks, in which they are commonly used for seasonal storage. They do take up a lot of space, however, making them better suited for areas of moderate property pricing than for inner-city development.

Figure 4: Pit heat storage in Dronninglund, Denmark (© PlanEnergi)

Going even deeper into the ground, heat can also be stored in Boreholes or aquifers. Borehole storages use the ground itself as a medium. Charging and discharging take place via borehole heat exchangers, technically similar to the ones used in geothermal systems. Through these, heat is transferred into the ground and tapped from it as required (Fig. 5). Aquifer storage also uses the ground as a storage medium but, moreover, makes use of the water in an aquifer. The basic system consists of two wells sunk into the aquifer with enough distance between them to avoid energetic interaction. One of them is fed with hot water, raising its temperature over time; the other is used to extract ground water at its natural temperature and to feed cooled water from the hot well back into the ground after heat extraction.

Focus on provision of power or energy

Energy

Suitable fields of application

Water temperatures up to 100 °C (180 °C if pressurised)

Technology-Readiness-Level (TRL)

9

State of development/commercial availability

Market-ready products, commercially available

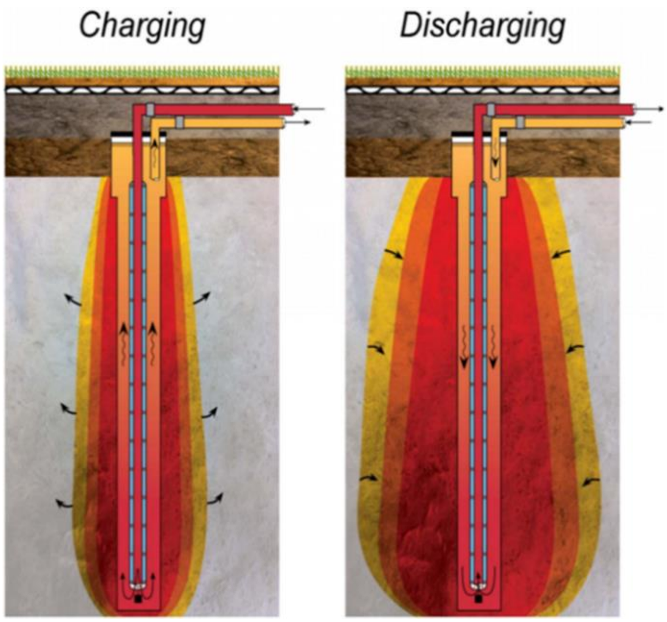

Figure 5: Charging and discharging process of a borehole heat storage (© Ramstad et. Al. 2022)

TECHNICAL SPECIFICATIONS

Specific energy storage density	kWh/m³	kWh/t
	60-100	60-100
Specific power density	kW/m³	kW/t
	30-500	30-500
Typical/feasible storage size	MWh_{out}	MW_{out}
	0.03-1,000	0.015-1
Storage efficiency	50-90 %	
Storage duration	Hours-months	
Response time	Minutes	

Service life (maximum)	Cycles	Years
	20-4,000	n.a.
Loss per time in %	0.5 to 2.5 per day	

Notes on these specifications

The technical specifications depend strongly on the actual application's boundary conditions. Also, due to the very wide volume range of sensitive storage tanks (several litres to 10,000 m³), figures vary widely. The first figure in each given range corresponds to a typical domestic water storage with a volume of 500 l and a discharge pump rated at 500 l/hour. The second figures correspond to a seasonal large-scale storage with a water volume of 10,000 m³ and a discharge pumping capacity of 5 m³/h. 1 cycle per 2 days (domestic) or 1 cycle per year (seasonal) is assumed. Both storages are assumed to be pressureless, therefore their maximum storage temperature is 100 °C, the usable temperature difference about 60-100 K. Losses per time depend on insulation thickness, thermal conductivity, and surface-to-volume ratio. Typically, a domestic storage loses about 2 K/day, a seasonal one about 10 K/month.

ECONOMIC SPECIFICATIONS

Investment cost per kW

1-15 €

Investment cost per kWh

0.4-10 €

Notes on these specifications

Due to the numerous and widely different technical designs of such storage systems and with respect to their different applications' requirements, the cost in relation to output and energy varies greatly. The cheapest sensible heat storages available are currently used for seasonal storage in Denmark. An extremely simple design (outdoor earth pit covered with plastic film) can bring the cost of very large storages down to 0.35 € per kWh of installed capacity.

For further information, see

- ES TCP Task 39: Large Thermal Energy Storages for District Heating