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HEAT ACCUMULATOR, USING PCM MATERIALS, IN A SMALLER CENTRAL HEATING SYSTEM

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Abstract: *This article details the design, construction, and modeling of a heat accumulator based on two PCM substances, implemented on a test device in 2024. Intended for a small heating system serving a production plant and a housing estate in the Jizera Mountains, the accumulator offers temperature variability and integrates with cogeneration units via an interconnected CHP-accumulator control system.*

Keywords: CHP, PCM, enthalpy, heat accumulation, cogeneration unit

1. Introduction

At Czech Technical University in Prague (CTU), together with TEDOM a.s, we conducted measurements on Phase Change Materials (PCM) —focusing on operating temperatures, enthalpy, cycling stability, and compatibility with construction materials—resulting in a library suitable for heat/cold supply (Kulish et al., 2023). Based on these findings, project documentation was developed for a thermal accumulator that TEDOM a.s. has integrated into its district heating network in Jablonec nad Nisou. Equipped with an advanced measurement and control system linked to the CHP (combined heat and power) unit, the accumulator is now undergoing real-world testing. This article details the implementation steps and outcomes.

2. External conditions for the heat accumulator in the small district heating system

Designed to optimize CHP operation and manage peak electricity costs, the heat accumulator also stabilizes the grid by enabling rapid CHP activation. It operates within a 60–90°C range for small CHP systems (up to 130°C for boilers), with 70°C common for safe water supply outside the heating season. At the TEDOM a.s. engine plant in Jablonec nad Nisou (since June 2024), CHP water averaged about 75°C, slightly below the usual 85°C. The unit meets standards (e.g., PN16) with atmospheric vessels that allow ±0.5 Bar fluctuations for PCM expansion, while fluid flow is managed by an electronic circulation pump.

3. Placement and connection of the accumulator unit in the system of a smaller heating network

To integrate the accumulator into an existing heating system—its likely future application—the following requirements must be met:

- It should be installed in the existing boiler house near the main heat sources, as placing small accumulators in individual buildings complicates supervision and maintenance.
- It must receive all heat from the CHP for several hours.
- It should allow simultaneous direct supply of some heat from the CHP unit to the district network while storing the rest.
- It must be able to supply heat to the central system for several hours without another heat source.

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- It should accumulate excess network heat during sudden weather changes.
- It must enable the addition of the CHP units' thermal output to the storage's output, for example during morning heating.

Meeting these requirements implies using a circulation pump that operates independently of the heat source and continuously regulates the heat carrier flow—deciding which working vessels to activate and under what conditions. The storage unit's placement in the CHP system is shown in Figure 2.

4. Theoretical foundations for the design and operation of a heat accumulator

While water-based heat storage is well established, latent heat storage is less mature because PCMs' low thermal conductivity slows charging and discharging. Thus, designs must maximize heat transfer surfaces and minimize distances while remaining simple and cost-effective.

We evaluated two strategies—PCM encapsulation (Liu et al., 2015) and a tube-in-shell heat exchanger (Zauner et al., 2016). After investigating both methods (Jancik et al., 2021; Jancik et al., 2022), we chose the tube-in-shell design with fins to achieve an economically and technologically efficient storage solution.

5. Selection of a suitable heat accumulation substance

PCM selection requires achieving the desired phase change temperature, high heat storage density (to justify its cost over water), stability for at least 1000 cycles, material compatibility, and affordability. Based on the system's temperatures, two organic PCMs—A82 (≈82 °C) and A62 (≈62 °C) from PCM Products—were chosen for series-connected storages. Their key properties are summarized in Tab. 1. Laboratory tests confirmed that both PCMs meet the latent heat capacity, stability, and compatibility requirements.

Tab. 1: Properties of A82 and A62 (pcmproducts.net, 2021).

Property (unit)	**A82**	**A62**
Phase change temperature (°C)	82	62
Density (kg.m^{-3})	930	910
Latent heat capacity (kJ.kg^{-1})	240	205
Specific heat capacity (kJ.kg^{-1}.K^{-1})	2.2	2.2
Thermal conductivity (W.m^{-1}.K^{-1})	0.23	0.22
Maximum operating temperature (°C)	250	250

6. Considered structural arrangement of the heat accumulation unit

Figure 1 illustrates the storage vessel assembly design. Two square vessels hold the PCM for latent heat storage, while two cylindrical vessels contain demineralised water for sensible heat storage. Since heat flow in the PCM is about an order of magnitude lower than in water, the water vessels help smooth out short-term energy fluctuations. The figure also depicts the installation density of the storage device.

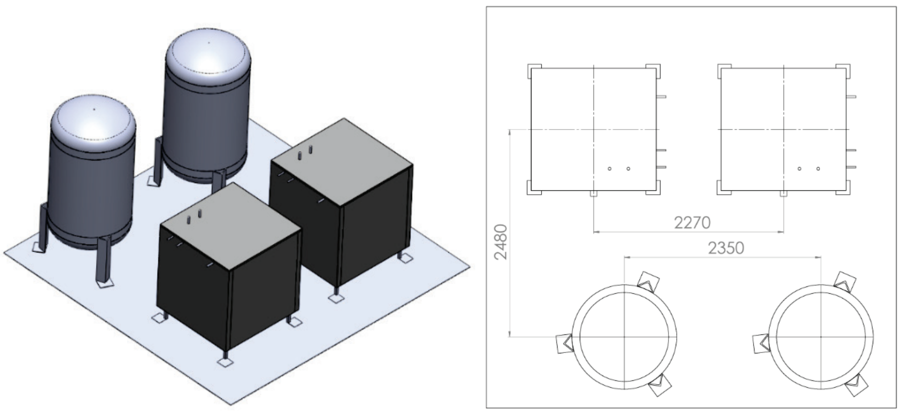

Fig. 1: Geometric concept of heat storage vessels.

7. Design of the structural arrangement of the heat accumulation unit

Figure 2 depicts the energy circuit where two CHP units and a backup gas boiler provide thermal energy for heating and sanitary hot water. A storage unit is connected in parallel to the supply branch, enabling three modes: direct supply from the sources, full supply by the accumulator, or a combined mode that stores surplus energy for later use.

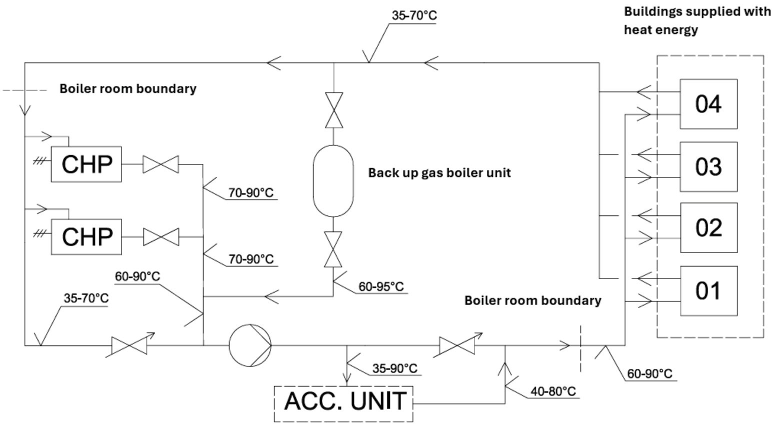

Fig. 2: Example of a connection of heat accumulator into energy circuit

Figure 3 shows a simplified layout of one of the two identical cubic vessels, differing only by PCM type. Each vessel contains a finned-tube system in structural carbon steel with hot-dip galvanized tubes, joined by 2×90° Frabopress bends. The piping is split into four independent circuits connecting to common inlet/outlet manifolds, with PCM filling the gaps. The exterior is insulated with Orstech 45 H plates, and the figure also shows sensor terminals, a pressure relief valve, a bottom drain, and the water circuit connection.

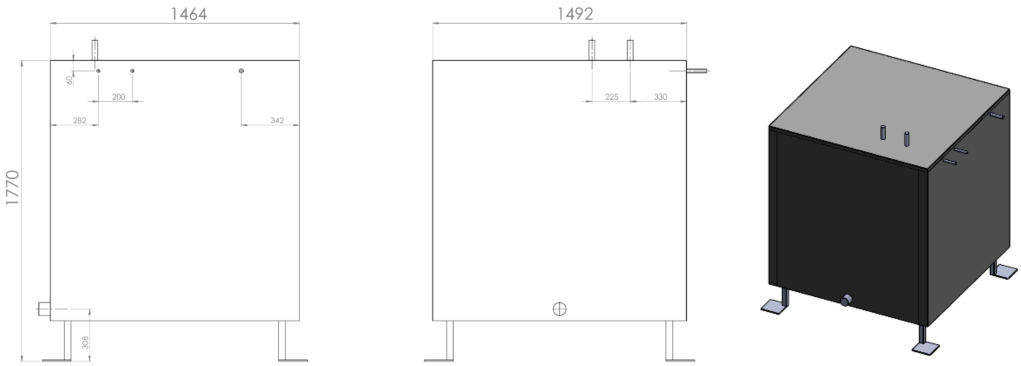

Fig. 3: General arrangement of PCM module

8. Accumulator unit measurement

Heat storage performance was evaluated by measuring the flow rate and inlet/outlet temperatures, enabling calculation of power and total heat exchanged. Using a constant flow of 50 l/min over 3 hours, the A62 module stored 75 kWh during charging (Fig. 4) and released 64 kWh during discharging (Fig. 5), with the difference attributed to initial/final state variations and heat losses.

9. Discussion and summary

The accumulator's evaluation focused on its charging/discharging curves, crucial for cogeneration operators. Figure 4 shows it reaches peak charging power quickly, but Figure 5 indicates a slow discharging rate, potentially limiting its use as a backup heat source. Improving the heat exchange between the fluid and PCM could mitigate this issue.

The research team analyzed PCM properties and designed a two-vessel accumulator—each using a different PCM—for small heating systems with intermittent cogeneration. The unit was built, integrated into the network in late 2024, and is now undergoing testing.

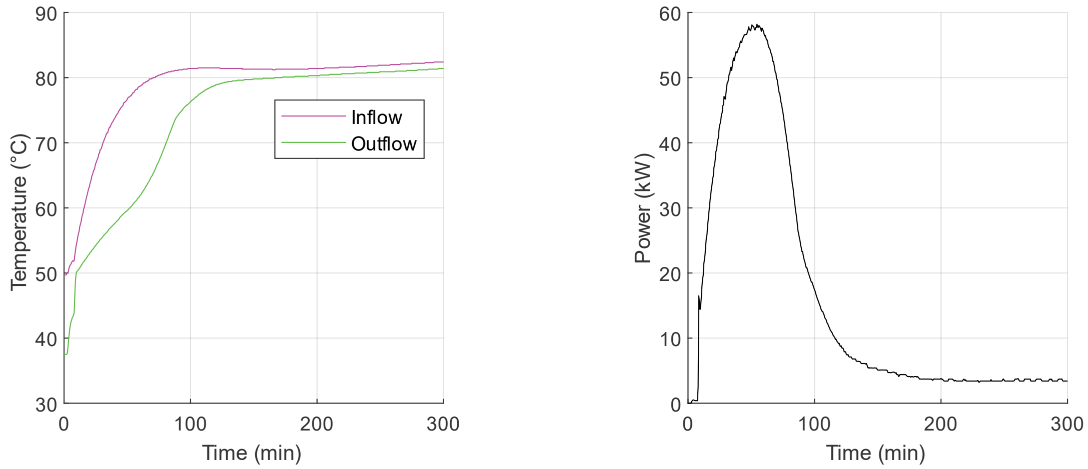

Fig. 4: Inflow and outflow temperature and power during charging of the A62 heat storage.

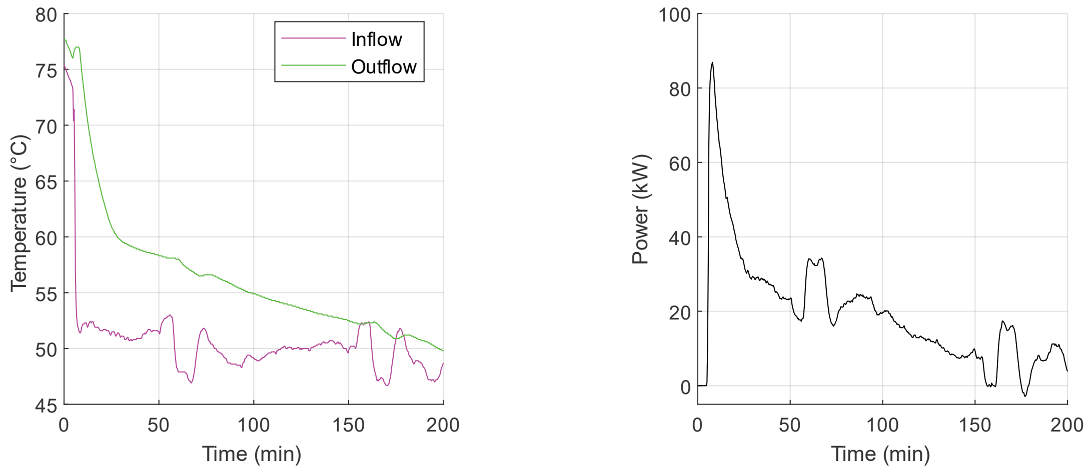

Fig. 5: Inflow and outflow temperature and power during discharging of the A62 heat storage

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