Detailed information on energy research

Large storage tank developed for small spaces

After successful field tests: Thermal storage tank is to be mass produced with a new manufacturing process

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To heat an apartment building highly efficiently, using a solar power system or combined heat and power plant for example, you need large thermal storage tanks. They often do not fit through standard door openings in existing buildings. Scientists developed a compact storage tank consisting of multiple modules, which is not assembled fully until it reaches the boiler room. Heat losses are lower than with standard cascade models. Individual tanks no longer have to be connected.

The new storage system can be combined with fossil fuel and renewable energy-based heating systems. It is pressure-resistant (3 bar operating pressure) and can be hydraulically integrated directly into the heating system. The pipe connections between the individual modules are in the vessel. This saves space, simplifies installation and reduces heat losses compared with the storage cascades used to date. The individual tanks are insulated separately and connected to one another. The new UniSto storage tank has the same volume but a smaller and fully insulated surface, which reduces heat losses. By way of comparison: The heat loss current of cascades with a volume of 5,300 litres is 430 W, excluding heat losses in the piping. In the new storage model, the loss current for the same volume is 200 W (Fig. 1). These values apply at a temperature difference of 45 K between the storage tank content and ambient air.
The oval individual steel modules of the storage system have a volume of 1,350 litres each. The vessel shell consists of steel plates that absorb the radial pressure. Thin face plates welded to this seal the modules but do not absorb any pressure, instead passing it on to the neighbouring vessel. The individual modules are mounted close to each other on rails during installation and are then pushed together. The charging and discharging pipes run inside the tank. Four connect-

ing rods at both sides link the end modules. These elements, which are externally pressure stable, ensure that longitudinal pressure is absorbed. The storage tank is insulated with EPS (expanded polystyrene) hard shells connected via tongue and groove joints. Vacuum insulation panels (VIP) can be fitted in the corresponding gaps within the hard shells if necessary. All thermal insulation can be retrofitted on installation.

Evenly stratified heat transfer medium

What makes the new concept unusual is the horizontal alignment of the heat tank. "As in conventional storage tanks, the heat is withdrawn from a central point. At 213 cm, the UniSto model is the same height as standard models. Achieving stratification is simple, and there are virtually no temperature differences in this regard between the modules," says scientific project manager Dr Stephan Fischer from the Institute for Thermodynamics and Thermal Engineering at the University of Stuttgart. The interior charging and discharging pipes run the entire length of the vessel and facilitate even thermal stratification. To prevent significant mixing of individual temperature levels during charging or discharging, the researchers located the inlet and outlet slots of the pipes close to the ducts between the modules. The five charging and discharging pipes run through stainless steel sleeves here, which act like baffle plates for the outflowing water. "The flow is deflected and enters the storage tank in a longitudinal direction from the slot gap between the sleeve and pipe. This allows a small slot cross section to be used without the water flowing into the storage tank at high speed and with a lot of turbulence," explains Fischer.

Production goal: Oval instead of cylindrical

To minimise its footprint, the storage tank could not have the standard cylindrical shape. In spite of this, the scientists had to guarantee the requisite pressure resistance. "The challenge was to produce a less common oval casing shape and the double-curved end plates," explains project coordinator Dr Ulrich Leibfried from solar heating system manufacturer Consolar. To achieve this form, the casing is first bent on a programmable roller. The flat face plates must then be welded to the vessel casing with as little warping as possible. To do so, the manufacturer maximised the welding speed and cooling and minimised the welding seam thickness. It achieved an optimal result by welding two additional reinforcing profiles to the inside of the vessel. The work is performed on a newly developed rotating welding table. "It is important that the device ensures a reproducible, even welding speed and rapid heat dissipation," explains Leibfried. After assembly, the storage tank is pressure tested. Trials on the test rig developed in the project and calculations using the FEM (Finite Element Method) revealed that deformation remains within permitted tolerances even at twice the operating pressure.

Field testing in two companies

A Swiss-German energy supply company was the first to install the storage tank, in a nursing home in Rheinfelden. A heat-led, gas-fired combined heat and power plant with an electrical output of 40 kW and 100 kW of thermal output and a gas condensing boiler for peak loads with a thermal output of 400 kW supply the residents of the 74 residential units with all of their heat needs and also covers some of the electricity requirements. The new system replaces two low-temperature gas boilers with 280 kW each. "The UniSto model was interesting for us, as we generally choose slightly oversized buffer storage tanks for our CHP plants. We often do not have enough space for the buffer storage tank and doors are frequently too narrow for installation during refurbishments," explains Klaus Nerz, Head of the Heat and Energy Solutions department at Energiedienst AG. The vessel in the Rheinfelden installation is made up of three modules and has a volume of 4,050 litres. It is hydraulically integrated in the system so that it stores the waste heat from the combined heat and power system and can make it available both for space heating and heating drinking water. The entire installation is run at an operating pressure of 2 bar. The prototype storage tank costs amounted to 5,000 euros. If the storage tank is produced in volume in future, costs will decrease in the long term.
Scientists from the University of Stuttgart assessed how the storage tank proves itself in practice. For this purpose, they recorded the temperatures

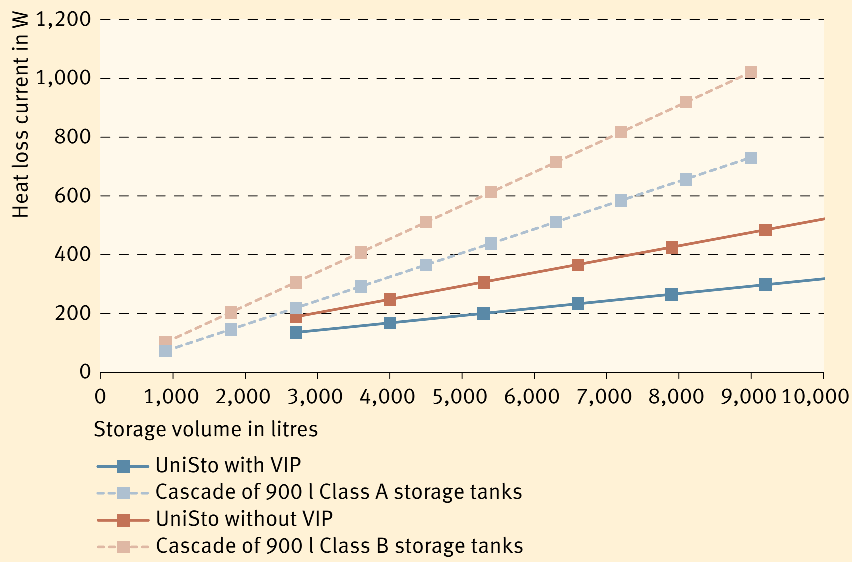

Fig. 1 *Compared with storage cascades, the heat loss currents do not increase as much proportionally to the volume in the new storage system. Unlike storage cascades, UniSto storage tanks have lower heat losses the greater the overall volume is. (VIP = Vacuum Insulation Panel)*

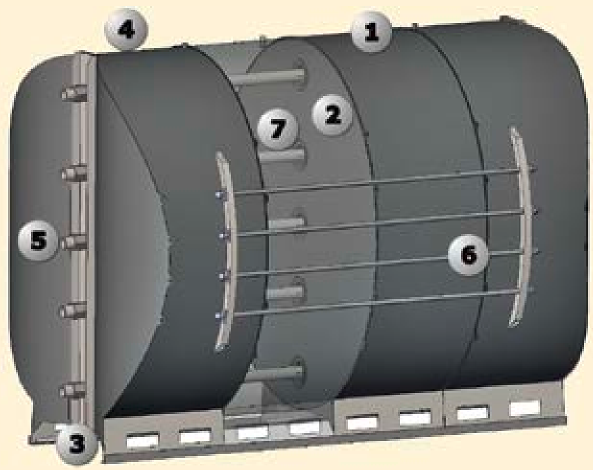

Fig. 2 *This UniSto storage tank consists of four modules. The elements in detail: (1) vessel shell, (2) thin steel plate, (3) rails, (4) pressure resistant end modules, (5) charging and discharging pipes, (6) connecting rods, (7) seal system*

Fig. 3 *Left: Workers carry a storage module through a narrow cellar entrance, Right: UniSto storage tank with thermal insulation made of of silver-grey Neopor® shell plates.*

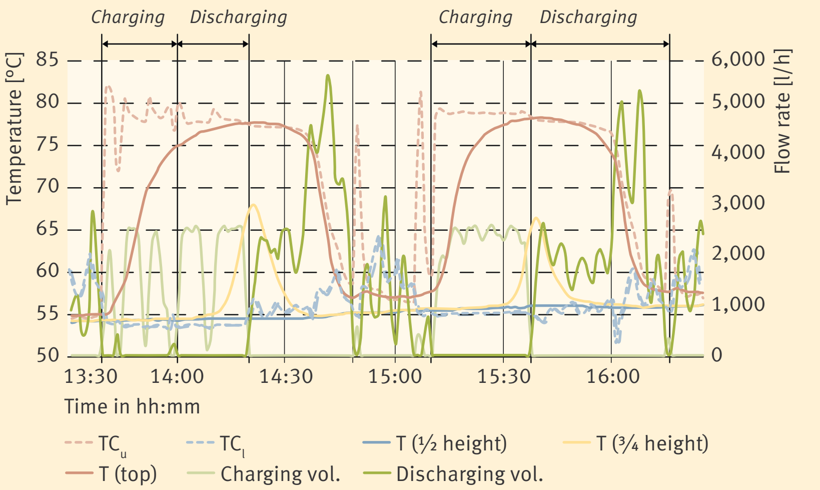

Fig. 4 *Volume flows and storage tank temperatures during operation on 02/01/2016 in the middle storage module of the first demonstration system in Rheinfelden*

in the central module and at the upper and lower connection, as well as the volume flow in the vessel.

They found that the storage tank was virtually always in motion while the system was in operation. This shows how important the thermal storage tank is for supplying the nursing home with heat. The CHP charged the thermal storage tank with a relatively low volume flow of roughly 2,000 l/h, and it was discharged at 3,000 l/h and more. Thermal stratification is good even during shorter and alternating charging and discharging. All investigations made indicate that a good thermal stratification can be expected even at higher volume flows.

The scientists used strain gauges attached at ten different positions on the vessel walls to measure the expansion of the vessel material during operation. The material expansion measured remained significantly below the permitted value of 0.2 % during the entire measurement period.

The storage tank has been working without problems since 2015. Klaus Nerz sums up the results as follows: “We will be building more heating systems with the storage tank this year. Based on the experience gained, we will then decide whether we want to use the model as standard in our installations.”

Energy label for hot water storage tanks

Manufacturers of hot water storage tanks with a maximum volume of 500 litres must display an energy label on their products. Besides the efficiency class, it also states the storage volume and thermal losses of the hot water storage tank. They describe the heat loss rate of a hot water storage tank at a specific water and ambient temperature. For storage tanks with volumes of up to 500 litres, the efficiency class must be indicated on the efficiency label. The efficiency class must be determined for storage tanks with a volume of up to max. 2,000 litres to calculate the overall efficiency of the installation. However, efficiency labels must not be displayed on these larger tanks. The hot water storage tanks currently available are generally in energy efficiency classes C and D. Storage tanks with the best values are in class A.

In addition to this, requirements for environmentally friendly product design are stipulated in the ecodesign requirements. For example, they include stipulations on the product’s energy efficiency or limits for specific emissions. Products that fulfil the minimum requirements receive a CE mark. The energy label and ecodesign requirements are closely linked, but based on different legal foundations.

A second demonstrator in a carpentry shop with two additional residential units in Lörrach also delivered good results. It also features extensive thermal stratification and highly functional hydraulic calibration between the four modules. The storage tank is charged by a 100 kW biomass boiler. A solar energy system with a collector surface area of 10 m^2 also delivered thermal energy. It is connected to a combined storage tank. As in Rheinfelden, there would not have been enough space at the installation location for a conventional heat storage system with the required volume of 5.4 m^3. In April 2016, the individual modules of the new storage system were easy to position and push together on two rails installed on the floor.

In 2017, members of the industry consortium will test the UniSto storage system in other applications. The storage system will then be marketed as a volume product.

Storing thermal energy outside the building

The most suitable storage tank type for the application depends on the respective area and the structural conditions. The UniSto storage tank is available with a maximum required volume of 10,800 litres. For larger capacities, only the connecting pipes and rods must be changed. For very high volumes, it can make sense to use a storage tank type that can be installed outside the building. There must be enough space on the property to install this large vessel, and the associated adverse aesthetic effects must be taken into consideration. Storage tanks installed outside buildings require very good thermal insulation. By contrast to models installed indoors, heat losses cannot be used to help cover heating requirements.

The required storage time also plays a part in determining the most suitable storage tank. In the StoEx project, scientists from the University of Stuttgart developed a series of large storage tanks that can store energy for weeks to months. They are installed outdoors. Innovative insulation increases the thermal capacity compared with conventional products. At the same time, costs are to be reduced. For example, the storage tanks can be integrated in local heating networks or support the heating supply systems for larger buildings like kindergartens, care homes or hospitals.

For insulation, the researchers used vacuum material in a double-walled hot water storage tank. They filled the cavity with a loose fill mix of 70 % (w/w) of coarse expanded perlite and 30 % (w/w) of fumed silica. The volume was then evacuated to a vacuum pressure of between 0.4 and 1 mbar. The insulation mix has a relatively low effective thermal conductivity even at a comparatively high vacuum pressure. The tests showed that the vacuum tightness is sufficient for the operating period of up to 50 years.

It depends on the respective application whether vacuum thermal insulation makes economic sense. Simulations proved that the higher the planned solar coverage is, the more economical this technology is compared with conventional insulation. The advantage of this technology is that the hot water storage tank can be far smaller.

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Links und literature (in German)

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