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Detailed information on energy research

Cost-saving erection of large heat storage tanks

A newly developed overground hot water storage tank using segmental construction on the test rig

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Scientists are testing a large overground hot water storage tank with lower production costs than comparable constructions thanks to its construction with prefabricated steel segments. The OBSERW research project is building on the experience gained from a large cool water storage tank that has been tried and tested in the district cooling network of the city of Chemnitz for more than ten years. For the first time, the construction principle, which is flexible in shape and size, could be transferred to hot water storage tanks that have to withstand high temperatures and temperature changes.

Overground cold water storage tanks with enameled and sealed segments can be inexpensively produced and work reliably. This has been shown by the construction and long-term operation of a storage tank for the district cooling network of the city of Chemnitz. In order to make the segmental construction also deployable in heat storage tanks, a consortium from research and industry has further developed the construction principles with a multitude of detail solutions. “We worked through the complex task in a three stage procedure,” explains Prof. Thorsten Urbaneck, who coordinated the joint project. “Starting from small scale material tests to laboratory tests on components, we have finally brought all partial results together and tested them in a pilot storage tank.” The demonstrator was built in Nortorf, Schleswig-Holstein. It holds approx. 100 m³ and can be charged and discharged with an output of up to 230 kW. “Perspectively, we could make storage tanks with storage sizes of between 500 and 6,000 m³,” states Thorsten Urbaneck. Therefore, when combined with the low heat losses and a stable temperature stratification, many possible applications

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for both short-term and longer-term storage cycles open up. In solar and district heating systems, the storage tank can contribute to maintaining the pressure and in this way, it performs ancillary services. The development objectives also included low investment and operation costs.

Overview of structural features

In comparison to the existing flat-bottom tanks and cold water storage tanks, the construction concept was thoroughly revised. The overground storage tank consists of screwed together steel segments. The storage tank is thermally separated from the concrete foundation through the pressure-resilient foamed glass plate. The wall and the floating roof are also insulated in order to avoid loss of heat. The thickness of the thermal insulation layer can be adapted according to requirements. As usual for short-term storage in networks with combined heat and power, the demonstrator is charged and discharged using two radial diffusers according to the principle of displacement. Using a radial channel widening they ensure a reduction of the initially high flow velocities meaning that hot and cold water hardly mix and the temperature stratification in the storage tank is maintained. A special feature is the free-form design of the radial diffusers with very low pressure losses. Therefore, a shortfall in the charger's steam pressure is avoided and it is possible to discharge up to approx. 98 °C. The same construction is also suitable for solar thermal systems with variable or constant supply temperatures. In principle, storage tank volumes of up to 6,000 m³ and charging and discharging capacities of up to 56 MW are possible. It can also be used for long-term storage.

The pressure level in the storage tank's roof area is the equivalent of the ambient pressure. The maximum storage temperature is determined by the boiling point of the water. That means that the storage tank is not designed for classic primary networks with supply temperatures of over 100 °C. However, this limitation is countered by important benefits: pressure vessel constructions with strong steel walls are not necessary; storage volumes with good thermal insulation and a small surface-volume ratio can be inexpensively produced and it reduces external heat losses; and the expense for piping and instrumentation is low.

Particular attention was paid to segments' sealing and the screw connections. The sealant must be able to permanently withstand high water temperatures and changing temperature loads. The control of the steam and oxygen diffusion presented a challenge. Likewise solutions to minimise thermal bridges had to be found.

Sealing, coating and insulating

A central task was to permanently guarantee the impermeability of the segment joints. In the laboratory, the scientists tested various sealants for their thermal-mechanic durability. The best results were found with a condensation crosslinking silicone, which was then also used in the demonstrator.

For the corrosion protection of the steel segments, which at the same time guarantees the water quality, various coatings were tested in the laboratory and then tried out in practice on the demonstrator. Hardly any coatings showed any visible changes after approximately one year of operation with temperature loads of up to 92 °C and are therefore also suitable to be used as corrosion protection.

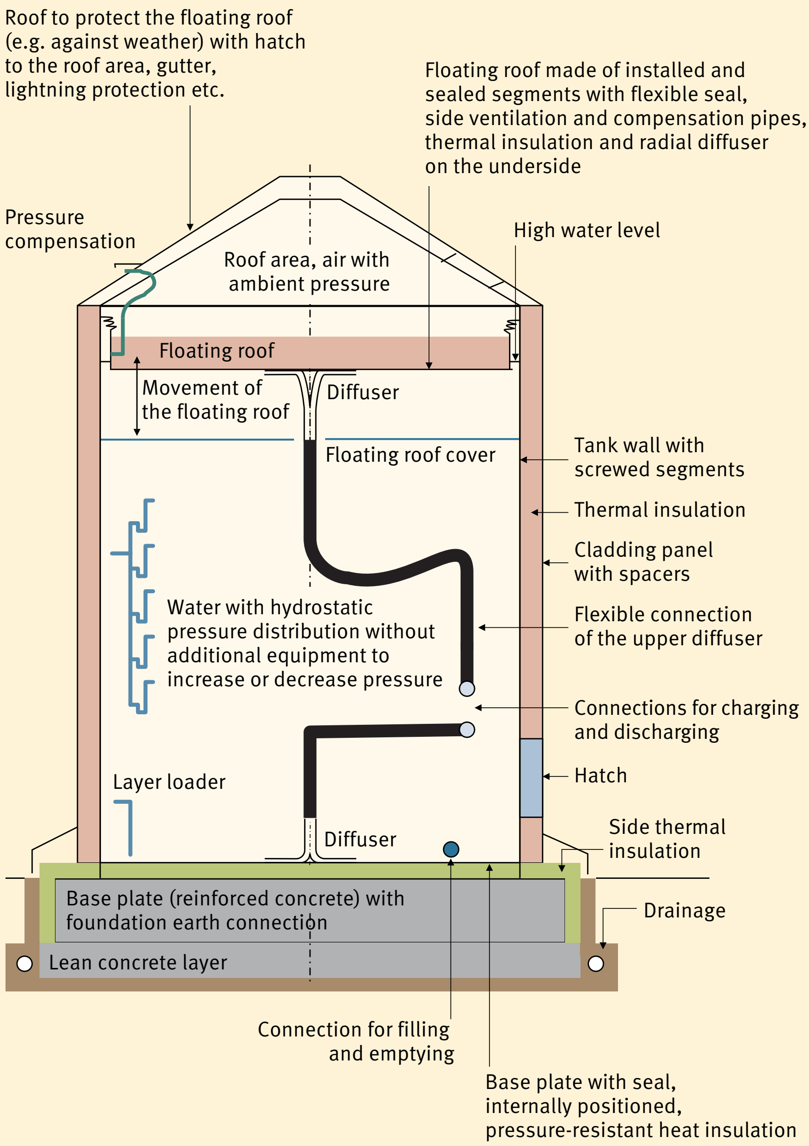

Fig. 1 *Schematic structure of the demonstrator*

At the same time, the project partners tested and compared different insulation materials for the roof and wall insulation. The best choice turned out to be pourable polyurethane particles for technical, economic and ecological reasons. They were provided as recycling material at a comparably low price. The bulk material easily fills the spaces that occur between the cladding panel and the screwed wall. In contrast, the installation of thermal insulation panels would be much more costly because screwing together the segments, the spacers and other structural elements would make installation more difficult. Consequently, the filling technique also reduces the production costs.

Typical problems for insulation fillings have proven to be uncritical in tests under conditions close to those in real application. The starting material showed fluctuations in the product quality, however, in the observed application they did not impact the usability and only negligibly impacted the insulating effect. Fill heights of several meters, e.g. in the wall structure, can be achieved without any change to the properties or the settlement. The hydrophobisation of the particles has proven to be extremely effective. Particles stored under water only absorb very little water, even over months. Particles with contact to the ambient air dry quickly. The scientists were unable to find any significant, moisture-caused degradation processes.

Fig. 2 *Structure of the storage tank wall: The cladding panel is connected to the screwed segments via thermally decoupled stainless steel strips. The spaces in-between are insulated with a polyurethane bulk.*

Fig. 3 *Top left: The floating roof in the roof area is flexibly sealed. For insulation the segments are filled with PU bulk. The outer layer form accessible XPS thermal insulation panels. Bottom left: The upper diffuser is integrated in the floating roof. Its form has been specially optimised. Right: The 100 m³ demonstrator in Nortorf has been extensively tested for more than one year.*

As with most insulation materials, the effective thermal conductivity increases with the temperature. However, in this case the increase is only slight and uncritical. The convection flows are more noteworthy for although they are negligible in slab structures, they could reduce the insulating effect in the vertical layer of the wall structure. However, by using convection breaks (XPS plates) the transport processes were effectively suppressed in the laboratory.

Segmental construction also for the floating roof

The storage tank is different to previous constructions, above all in the roof area. The roof made of folded metal sheets guarantees that the pilot storage tank is protected against environmental factors. For larger storage tanks, the use of raftered roofs is envisaged. In the case of the floating roof, the scientists also consistently adhered to segmental construction. Here they were also able to take advantage of the benefits of the lightweight construction and easy transportation. The roof is formed by individual components screwed together to make a fixed panel, whose stability allows the diffuser to be installed. A single diffuser is sufficient for a storage size of up to 6.000 m³. Since the radial diffuser is located directly on the underside of the floating roof, it allows the usage of the full storage zone. Furthermore, only low mix effects occur between the inflowing charging fluid of lower density and the fluid in the storage tank with a higher density. This is particularly important for high quality thermal stratification.

A film flexibly seals the edge area between the storage tank wall and the floating roof. This film was also selected from various brands after laboratory tests. The tested construction allows a height adjustment from approximately 70 to 100 cm. The height displacement is based on the requirements of bigger storage tanks. Therefore, the storage tank can compensate temperature-related changes in volume very well. Analogous to the wall structure, a particle bulk fill is used as thermal insulation. Hard foam plates laid on the planks of the floating roof make it possible to enter and inspect the roof area.

Structure of the base

The storage tank wall is attached directly to the foundation. Consequently, the load transfer of the storage tank wall occurs directly in the foundation. The thermal insulation made of foam glass plates is installed on the foundation. A stainless steel plate closes off the storage tank on the base and protects the interior insulation against penetration by storage tank water. The seal between the ground plate and the storage tank wall is implemented in the connection area with the same sealant that is used to seal the wall segments. When the temperature rises the complete wall structure expands and it contracts when the temperature falls. Therefore, the seals are particularly exposed to loads. However, no problems occurred in the test operation. Base and wall connection are practically free from thermal bridges and it is only the base plate that separates the thermal insulation layers from the storage medium. Therefore, there are no heating-up losses.

Conclusion and outlook

The project has shown that a new type of storage tank has been created by way of new developments and multi-faceted optimisations. The many tests in the laboratory and the innumerable simulations have not been presented here. On the basis of these tests and simulations the demonstrator was created and then intensively tested. In this regard, complex tests have proven its practicability or rather that the project's objectives have been achieved. After the first presentations of the demonstrator, the project partners have experienced much interest from municipal utilities, planning offices and public institutions.

The researchers see two future fields of activity. Diverse constructional details (e.g. thermal bridges) could be further developed in order to further reduce external heat losses, to allow easier production and to guarantee cost-effective manufacturing. The next large step is then transferring the newly developed construction principles to very large tanks and the adaptation to the higher loads associated with them.

Heat storage tanks in heating networks

In heat supply systems, many benefits can be achieved by using thermal energy storage. Their use often reduces investment in the peak load area, increases efficiency and utilisation rates and reduces operating costs. For example, the connection and disconnection to a generator can be avoided meaning that start-up losses are reduced and operating times increase. The operation at optimal operating points reduces consumption and wear. By way of the temporal decoupling from the excess heat and grid load, the supply system becomes more flexible. CHP plants can sometimes be decoupled from the district heating demand by way of the intermediate storage of heat and can be operated based on the electricity price.

A considerable benefit of thermal storage tanks is that several energy sources, e. g. solar thermal energy, heat from combined heat and power generation and biomass, can also be well integrated. Above all, the option of integrating renewable energy sources improves the primary energy factor of the total heat supply system. With an increasing share of power generation from renewable energies, the significance of heat storage in CHP plants grows.

Due to the versatile use, in recent years numerous heat storage tanks have been installed in district heating systems. In this sector, a demand beyond the requirements of the German Combined Heat and Power Generation Act (KWKG) can be observed. In Germany, the capacity of large heat storage tanks more than doubled between 2012 and 2016 from 8 GWh_{th} to 20 GWh_{th}. A research project (project number 03ET1188A) estimates a potential of approx. 88 GWh_{th} for a Germany-wide expansion of the district heating supply. The researchers investigated the conditions under which investments in the construction of thermal storage and power-to-heat systems are economically viable, and which improvements would result from the environmental policy perspective. The project was carried out at the Technical University of Berlin in cooperation with the University of Applied Sciences and Arts Hanover, Leipzig University and with consultancy provided by industrial partners.

Classic district heating networks are often operated at temperatures of over 100 °C. Here, predominately slimline pressure vessel constructions or so-called two zone storage tanks are used. Many heat suppliers want to achieve lower supply temperatures due to the respective high thermal losses. The OBSERW project considered this tendency because the storage tank is designed for secondary networks. Other trends are the decentralisation of energy generation as well as the integration in the district concept. This type of storage tank can also be used for these purposes.

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