Solar Hot Water Storage with Storage Volumes up to 50 m³

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Abstract

The decentralized long-term storage of thermal energy is challenging the solar energy industry: To maximize solar energy savings for solar assisted heating in Central Europe climates, huge storage volumes are required. To run those systems economically, costs have to be competitive. Within a research project, a modular hot water storage system has been developed. This system can be easily installed in residential buildings and provides a high insulation quality. According to the basic technical functions „water tightness“, „heat insulation“ and „mechanical stability“, individual optimized solutions have been elaborated: A steel frame construction is equipped with sandwich insulation panels and can be installed step by step to build up a cubic container. This approach offers the installation of nearly unlimited storage capacities in buildings. A polymeric liner made of EPDM, butyl rubber or polypropylene seals the container. Requirements to the liner is a long-term stability over 20 years in combination with maximum operation temperatures of up to 95°C. The water vapor diffusion rate through various materials were carried out. It is recommended to implement a vapor barrier when rubber is used as sealing material.

1. STATE OF THE ART

The market success of large-scale solar thermal systems with collector areas of more than 20 m² depends on the possibility to store the yielded solar energy. However, especially in existing buildings a store volume of more than 1 m³ can only be realized with big efforts. Currently, there are four different concepts available on the market that allow the realization of large store volumes:

Interconnection of several small tanks: Although the cascade installation of several small tanks is quite simple, the piping effort can be tremendous. Altogether, cascades are disadvantageous in terms of costs, thermal heat losses and required space in the building, cf. /Wilhelms et al 2008/.

Large monolithic steel tanks: The installation of such large tanks in existing buildings usually requires extensive modifications, resulting in high costs.

On-site-welded steel tanks: These tanks offer a high flexibility concerning the adaptation to the boundary conditions of the building (room size, position of pipes, etc.). They can have a cylindrical or cubical geometry and are usually operated pressureless. Disadvantageous are the large installation effort and the rather poor reliability as well as the lack of a proper heat insulation.

On-site-laminated buffer stores made of fibre reinforced plastics (FRP): This quite new technology allows a simple and fast installation of big solar thermal storages (see /Haase 2009/). But, other than cubical site-welded steel tanks, the cylindrical FRP storages available on the market cannot make optimal use of the available space in the building.

2. MODULAR BUFFER STORAGE CONCEPT

In the frame of a research project financed by the German Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), a new concept for a modular buffer store design has been developed. Due to its optimal use of the available space as well as a simple installation and low production costs it can enhance the market penetration of large-scale solar thermal systems. In the following it is discussed how the three basic technical functions of storing hot water "water tightness", "thermal heat insulation" and "mechanical stability" are realized (see also /Wilhelms 2005/).

2.1. FUNCTION "WATER TIGHTNESS"

Two concepts for the sealing of the modular buffer storage are proposed. Both must fulfill the thermal and functional requirements in long-term use. Basis for the material selection is a maximum temperature of 95°C and a standard operation temperature of 75°C. Both concepts consider polymeric materials as sealing device. In contrast to steel or aluminum, a specific vapor transport through the polymer will occur. Especially the transport of vapor out of the tank through the sealing material is not desired: parts of the insulation might be wetted, corrosion of the outer construction might occur and the water loss might lead to problems during operation of the storage. In the frame of IEA-SHC Task 39, „Polymeric Materials for Solar Thermal Applications" /Köhl 2006/, a test rig has been developed to determine the water vapor transmission and aging behavior of various sealing materials within the testing environment "hot water / air".

The investigations of heat aging of the materials will be finished in 2010. Fig. 1 shows first results of the vapor diffusion measurements. Favored sealing strategies are a vulcanized flexible rubber tank, see fig. 2, and a welded sealing made of polypropylene (PP-H).

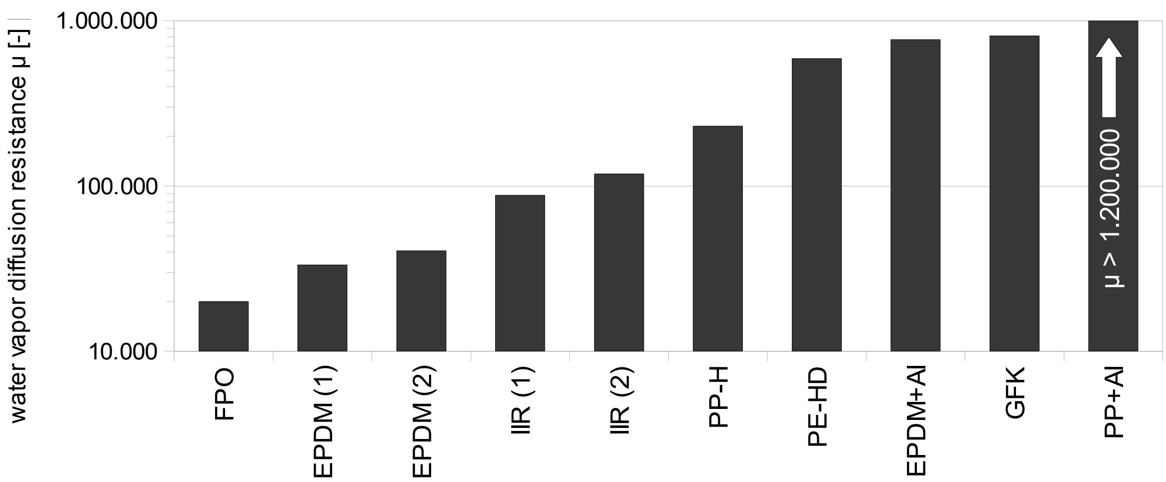

Fig. 1: water vapor diffusion resistance μ of various polymers (own measurements), higher is better

Both systems are well suited for the design of a modular buffer storage and show specific advantages and disadvantages which are shown in Table 1. The main difference of these two sealing techniques is the different installation technique: The flexible tank can be assembled at the production site and is installed in one piece. The PP-H sealing, made of sheets, must be welded on-site.

Fig. 2: Leak tightness test of a flexible rubber tank (left), tank with a storage volume of 5 m³ and in-/outlets (right)

Table 1: Advantages and Disadvantages of the investigated sealing technologies

	rubber (EPDM/IIR)	***PP-H***
Max. long-term operation temperature	90..110°C	90..100°C
Vapor transmission rate	low (without vapor barrier)	very high
Costs (raw material, thickness of 2 mm)	3..7 €/m² (without vapor barrier)	3..5 €/m²
Assembling	Vulcanisation	Extrusion or overlap welding
Leak tightness test	At production site (gas tightness test)	After installation (electrical high frequency test)
Repair options on site	difficult	good
Build-in components inside the storage	difficult	good
Accessibility inside the storage	no	yes

2.2. FUNCTION “THERMAL INSULATION”

The relatively low surface-to-volume ratio of large solar storages reduces the thermal losses through the outer surface. Nevertheless,a high-grade/quality insulation around the storage tank essential especially for long-term storage. Sandwich panels made of polyurethane and steel sheets are used for the discussed concept. The average thermal conductivity of λ = 0,033 W/(mK) is at least 60 % lower than conventional insulation materials like soft foam, EPS or foam glass.

2.3. FUNCTION “MECHANICAL STABILITY”

The flexible tank or the PP-H sealing can theoretically be constructed such that no tensile forces occur in the material. Mainly, the hydrostatic pressure of the stored water induces a pressure load on the sealing. Also, peaks of mechanical stress might occur during installation of the liner or sheet, e.g. in the corners of the tank and at mounting positions. The mechanical stability is realized with a frame made of steel sections. The single frame parts are simply screwed. With an appropriate production management, a frame can be produced such that it fits perfectly in the available room. The sandwich panels are placed inside this frame. After the erection of the storage, peripheral components like pipes, pumps and heat exchanger can be mounted directly at the frame.

Fig. 3: Steel frame construction of the modular storage, partly assembled

3. HYDRAULIC INTEGRATION

The hydraulic integration of a pressureless operated storage can be done with a new-developed charge and discharge unit, see /Zass et al 2009/. External heat exchangers separate the pressureless store from the pressurized fluid in the rest of the heating system. In case of the PPH-sealing, the use of internal heat exchangers is also possible in principle.

4. FIELD TESTS

Within the frame of several field tests, the functionality of the concept and in particular the requirement of an easy assembly has already been proven. Even under unfavorable conditions, the modular store concept could be realized (see example in fig. 4). Another field test unit with a volume of 5 m³ is installed in the new-build construction hall of the Company Wagner & Co. Solartechnik near Kassel. Here, a prototype of the mentioned compact charge and discharge unit as mentioned before connects the store to the heating system (see fig. 5).

Fig. 4: Integration of a storage (4,2 m³) in a residential building: Limited access (left), low room height (middle), installed storage with an optimal use of available room.


Fig. 5: Installed Modular buffer storage (Company Wagner & Co. Solartechnik, Kirchhain, Germany)

5. SUMMARY AND OUTLOOK

A new concept for an inexpensive buffer store was successfully realized. It was shown that the modular design has advantages concerning installation effort, use of available space in the building and system costs. A potential for further cost reductions lies in the improvement of the hydraulic integration into pressurized heating systems as well as in the optimization of the charge and discharge strategies for very large stores.

The store is brought to the market by the company FSAVE Solartechnik GmbH, a spin-off from Kassel University. The series production has been started in March 2009. The price depends on the specific store volume and lies in the range of 350 to 1.200 €/m³ (retail price, VAT excluded).

6. REFERENCES

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