

Description	<i>Polymeric Liner Materials for Hot Water Heat Storages</i>
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### Introduction

Hot water heat storages are important components of solar thermal systems. Various polyolefin-based material grades are material candidates to serve as liners in hot water heat storages. In order to fulfil the requirements, characterization of the aging behavior is indispensable for material selection.

### Solar thermal systems and heat storage

Centralized large-scale solar thermal plants for district heating substantially raise the cost effectiveness of solar thermal energy conversion. Using seasonal heat storage, solar fractions of 50 % or more can be achieved for the annual demand in domestic hot water and space heating. Pit and tank storages are the most relevant types of storages, since they do not require specific hydro-geological conditions like borehole or aquifer storages. They use water (pure or mixed with gravel or soil) as storage medium. Since the relative heat losses as well as the relative costs of installation are inversely proportional to the storage capacity, heat storages are most efficient for big storage volumes. The biggest operating storage is the hot water pit heat storage situated in Marstal, Denmark, with a storage capacity of 75000 m<sup>3</sup> of water.



### Polymeric liner materials

To ensure water tightness, hot water storages (tank or pit) are sealed by a water-proof liner. Liners for tank storages are made from stainless steel or polymeric materials, while for pit storages, polymeric liner materials are preferred to stainless steel due to their lower material and installation costs. For example, by using a polymeric liner, the specific installation costs for storages bigger than 50000 m<sup>3</sup> can be kept at approx. € 20 to 30 per m<sup>3</sup>.

Common polymeric liner materials are semicrystalline polyolefin-based polyethylene or polypropylene grades developed for applications with water contact (piping, tunnel and landfill construction, etc.). The relevant material classes are PE-RT for polyethylene-based liners and PP-R and PP-RCT for polypropylene based liners. These polymeric materials exhibit a ductile material behavior in the service temperature range between about 40°C to 95°C, they are waterproof, resistant to hydrolysis and weldable. For applications which require a low water vapour transmissivity, polyolefin-based lining materials are available as multi-layered films containing a vapour barrier.

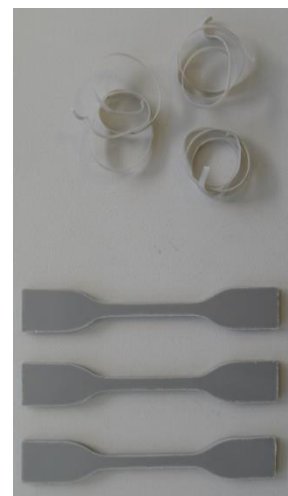
Polyethylene of raised temperature resistance (PE-RT) comprises a material class of medium and high density polyethylenes (PE-MD, PE-HD) that due to their special morphological composition are particularly suitable for applications with hot water contact. Based on the controlled incorporation of octene and hexene comonomers into the growing polyethylene chain during polymerisation, the probability of the formation of tie molecules which are single molecules incorporated into different crystal lamellae, is enhanced. Tie molecules are known to improve material toughness and the resistance to environmental stress cracking as well as the long-term creep properties, the latter of which are particularly relevant for hot water applications.

PP-R (polypropylene-random) and PP-RCT (polypropylene-random with enhanced crystalline structure and improved temperature resistance) are random copolymers of polypropylene and ethylene. For hot water applications, the total amount of ethylene typically does not exceed 5 m%. Similarly to PE-RT type materials, the incorporation of ethylene into the polypropylene molecule enhances tie molecule formation. By increasing the tie molecule fraction, the molecular network in the amorphous PP phase is tightened improving impact toughness and long term creep resistance of PP-R materials. PP-RCT materials are similar to PP-R materials. Due to the introduction of a defined semicrystalline morphology by a special nucleation technique, these materials exhibit even better toughness and creep properties than common PP-R types.

### Development of polymeric liner materials

The objective of work package 05 within the cooperative research project *SolPol-2* ([www.solpol.at](http://www.solpol.at)) was the development of polyolefin-based liner materials for hot water heat storages. For this purpose, more than 10 different polyolefin-based matrix systems were prepared. The compounds were screened regarding the basic requirements for lining applications such as weldability and a sufficiently low modulus around 600 MPa at room temperature providing a certain degree of flexibility during installation. 6 compounds were selected to serve as matrix systems for further investigations.

Prior to aging testing, selected compounds were further modified with additional amounts of various types of stabilizers (sterically hindered phenols, thiosynergists, hindered and aromatic amines) in order to improve the performance of the commercial base stabilization contained within the materials. In total, more than 20 different formulations of polyolefin-based model compounds were characterized as to their aging behavior on specimen level. Specimens were exposed in hot air or water at temperatures between 95°C and 135°C. Aging characterization was performed by Infrared Spectroscopy, Differential Scanning Calorimetry, High Performance Liquid Chromatography and tensile testing. The results revealed significant differences in the thermal stabilities of the formulations depending on the material type as well as the stabilizer system. Based on the results, the first geomembrane explicitly suitable for lining of hot water heat storages was brought to the market by AGRU Kunststofftechnik, Bad Hall, Austria, under the trademark *HTR PE Liner* (HTR: high temperature resistant).



### Summary and conclusions

Polyolefin-based liners are suitable for hot water heat storages and outperform steel liners due to low material and installation costs. However, because of the abundance of polyolefin-based materials on the market and the differences in the thermo-oxidative stability of the various material grades in hot water, careful material selection is a prerequisite to ensure the reliability of the heat storage system. This can be realized by systematic aging characterization of polyolefin-based liner materials. Regarding the material grades, PE-RT, PP-R and PP-RCT grades are considered most suitable to serve as liners in hot water heat storages.

### Recommended literature

Meir, M., Ochs, F., Wilhelms, C., Wallner, G.M. (2012) In: Polymeric Materials for Solar Thermal Applications (Köhl, M. et al., eds), pp. 231-242, Wiley-VCH, Weinheim.

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