

Description	<ul style="list-style-type: none"> • <i>Black-pigmented PP grades for absorbers</i> • <i>Temperature load profiles for overheating protected flat plat collectors</i> • <i>Aging behavior of PP grades and lifetime modelling</i>
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Introduction

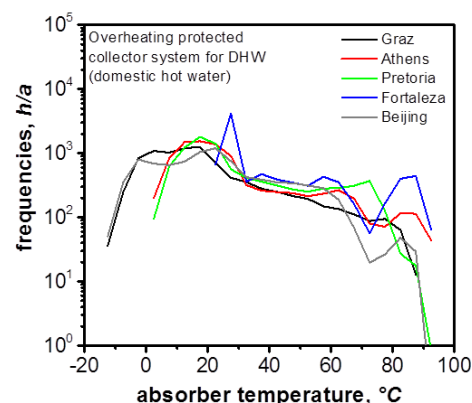
Polypropylene (PP) grades offer a high potential for use in solar thermal absorbers, in particular for flat plate collectors with adequate overheating control. For unglazed swimming pool collectors black-pigmented PP grades are state of the art. PP absorber grades for glazed collectors have to be tailored according to the specific loadings conditions and performance requirements which are significantly dependent on collector and system type. In this info sheet a PP grade widely used for swimming pool absorbers and a novel PP grade investigated within the collaborative research project *SolPol-2* are evaluated as to their applicability for glazed collectors with full overheating protection.

Polypropylene materials (PP)

Polypropylene (PP) is a hydrocarbon based thermoplastic produced in high quantities (~ 50 million metric tons worldwide) and used in a variety of applications. Compared to polyethylene (PE), semi-crystalline PP grades exhibit a higher melting temperature range (maximum at about 165°C), which allows for slightly higher service temperatures. PP grades are tailor-made for specific applications fulfilling rather different property requirements. Besides PP homopolymers (solely based on the propylene monomer) also random copolymers, block copolymers or elastomer modified grades have been developed and commercialized. The most important comonomer is ethylene. Besides the molecular structure also the additive system is varied to adopt the morphology and the property profiles of PP grades.

PP grade for swimming pool absorbers

The market dominating PP grade for swimming pool absorbers with proven long-term durability is based on a black-pigmented PP block copolymer with elastomer modification (also termed PP impact copolymer). Due to the direct light and UV exposure the carbon black content amounts to about 2 m%. The morphology of extruded PP impact copolymer sheets for swimming pool absorbers is characterized by a semi-crystalline structure with spherulite domain sizes up to 100µm. As common for polymeric materials the elastic modulus as a measure for the stiffness of the material is significantly dependent on temperature with a significant decrease from about 1100 MPa at ambient temperature



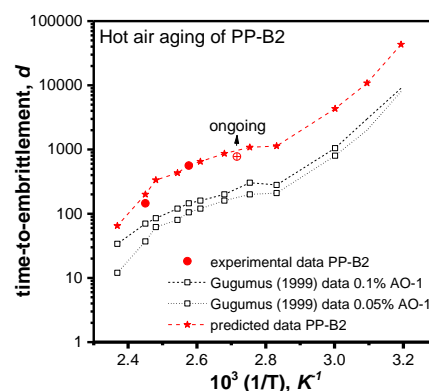
to about 300 MPa at 100°C. The thermal index of the PP impact copolymer for swimming pool collectors, which is an indication for the upper service temperature limit, is about 75°C. Due to the impact modification this grade provides a good low temperature capability down to about -30°C.

Load profiles for overheating protected glazed flat-plate collectors

As described in the info sheet “Collector Overheating Protection with Backcooler” a novel fully overheating protected collector concept was developed and validated in *SolPol-2*. Testing of functional model collectors with extruded swimming pool absorbers based on the above mentioned PP impact copolymer revealed that it is possible to limit the maximum operating and stagnation temperature of a pumped and pressurized flat plate collector with temperature triggered thermosyphon-based backcooling to temperatures below 100°C. For this collector type annual temperature loading profiles were calculated for a pumped hot water system for multifamily houses installed in different climate zones. Depending on the location especially the temperature loads at elevated temperatures are rather different. Higher temperature loads were obtained for e.g., Fortaleza or Athens.

Novel PP grades for absorbers of glazed collectors with overheating protection

In comparison to swimming pool absorber materials, PP grades for glazed collectors have to provide an improved thermo-mechanical stability (higher thermal index), aging behavior in air or water/glycol at elevated temperatures and internal pressure resistance, but less weathering resistance due to the protection with an UV screening transparent cover. Hence, the focus of the material development in *SolPol-2* was on the optimization of the semi-crystalline morphology, the carbon black content and the stabilization system. A comprehensive investigation of a variety of formulations exhibited that a lower carbon black content (0.1 m%) is beneficial to increase the thermo-oxidative stability in hot air. The exposure in hot heat carrier fluid was less critical, which is also related to the stabilizing effect of corrosion inhibitors in glycol. The mechanical properties at elevated temperatures were enhanced by adjusting the crystalline morphology adding a β -nucleating agent. For the novel PP grades a PE80 classification was achieved providing a long-term strength of components for pressure applications. Using a unique aging characterization approach based on micro-sized specimen, a comprehensive set of aging data was established. For the extrapolation of time-to-embrittlement data at enhanced temperatures (115 and 135°C) to service relevant temperatures (< 100°C) theoretical and empirical models were used.



Lifetime modelling of PP absorbers in overheating protected collector systems for DHW

Assuming a model of cumulative damages endurance limits for the commercial swimming pool PP absorber grade (PP-B1) and a representative SolPol-2 grade (PP-B2) were deduced for PP absorbers in overheating protected collector systems for domestic hot water preparation in different climate zones worldwide. Due to the enhanced aging behavior of the novel grade it was possible to increase the expected lifetime by a factor of 2. Ongoing aging investigations are indicating a factor of up to 4 for further improved grades.

Lifetime modelling:

- Extrapolation by Guggenmos approach
- Cumulative damage model (Miner's rule) → failure time (t_f)

$$\frac{1}{t_f} = \sum_{i=1}^{i=n} \left[\left(\frac{t_i}{t_{tot}} \right) / t_{fi}(T_i, \sigma_i) \right]$$

Location	Lifetime PP-B1, y	Lifetime PP-B2, y
Graz	21	32
Athens	15	25
Pretoria	14	24
Fortaleza	8	15
Beijing	23	34

Summary and conclusions

Black pigmented polypropylene grades are suitable also for absorbers of glazed solar thermal collectors. However, the collector design and the material grades have to be adjusted. While Magen EcoEnergy (Israel) has already commercialized an all-polymeric glazed collector with PP absorber, in SolPol-2 further concepts for collector types with significantly improved instantaneous overheating protection and novel PP grades tailored especially for absorber applications have been developed. In further research work, special attention is given to superimposed mechanical and environmental loads.

Recommended literature

Povacz, M. (2014). Black-pigmented polypropylene absorber materials – Aging behavior and lifetime modelling, Dissertation at the Institute of Polymeric materials and Testing at the University of Linz (JKU-IPMT), Austria.