INTRODUCTION AND OBJECTIVES

Different Types of Polymer Collectors

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<th>Unglazed Swimming Pool</th>
<th>Glazed Collector Systems</th>
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<td>Helical Pool Collector, US</td>
<td>Max. temperature ~70°C → PP, PE absorber</td>
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<tr>
<td>SUNLUMO, AUT (ONE WORLD SOLAR COLLECTOR)</td>
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<td>Glazed Collector Systems</td>
<td>Max. temperature ~90°C → PA-GF absorber</td>
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<td>GREENoneTEC, AUT (SOLCRAFTE)</td>
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**COLLECTORS - REQUIREMENTS FOR ABSORBER MATERIALS**

**System type & service requirements**
- Pumped, pressurized hot water
- service life: > 10 years
- region: e.g., Phoenix (USA)

**Key-property requirements for polymer absorber materials**
- solar absorption: 93-95%
- thermal stability: >110°C
- low temperature capability: -30°C
- long-term stability in water/glycol:
  - 75-100°C: > 2,000 h (DHW)
  - 0-75°C: > 85,000 h
- pressure: max. 1.5 bar

**Absorber: Polypropylene (PP)**

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**System type & service requirements**
- Non-pumped, pressurized hot water
- service life: > 5 years
- region: e.g., Athens (GRE)

**Key-property requirements for polymer absorber materials**
- solar absorption: 93-95%
- thermal stability: >110°C
- low temperature capability: 0°C
- long-term stability in (chlorinated) water:
  - 75-100°C: > 800 h (DHW)
  - 0-75°C: > 43,000 h
- pressure: max. 4/6 bar at 90°C/RT

**Absorber: Polyamide glass fiber reinforced (PA-GF)**

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**EXPERIMENTAL AGING CONDITIONS**

**Materials**
- OW-SC: 2 PP grades (100µm specimen)
  - PP-Bα (used for pool absorbers)
  - PP-Bβ (novel pool-grade for absorbers)
- ISC: 1 PA66-GF30 grade (4mm multi-purpose specimen)

**Exposure Conditions**
- Hot Air (PP and PA-GF)
- Heat Carrier Fluid (OW-SC: water + glycol; ISC: water)
  @ Temperatures of 95, 115, 135°C

**Evaluated aging indicators**
- Stabilizer analysis by HPLC-UV/MS (Agilent Technologies 1260 Infinity)
- Oxidation temperature (T_ox) by DTA (PerkinElmer DSC4000)
- Carbonyl Index (C.I.) by FT-IR (PerkinElmer Spectrum 100)
- Embrittlement/failure time by tensile testing (Zwick Roell Z2.5)
**EXPERIMENTAL LIFETIME ASSESSMENT**

Methodology of the solpol-approach

- Temperature loading profiles for different climatic conditions were generated.
- Experimental data were extrapolated to service temperatures (40-90°C).
- Deduction of lifetime by applying a cumulative damage model (Miner’s rule).

**RESULTS – OW-SC LIFETIME-TEMPERATURE LOADING PROFILES**

Loading profiles for OW-SC at different sites

- OW-SC collector system for DHW (domestic hot water) in single family houses.
- Maximum operating temperatures are below 110°C.
- Similar loads in the temperature range from 35 to 65°C for investigated climate zones.
- Highest loads for Phoenix, Mumbai and Antalya; temperatures higher 90°C.
- In Graz and Beijing temperatures below 0°C.
RESULTS – OW-SC
HOT AIR AGING BEHAVIOR

Hot air aging behavior of PP-Bα

- So far no failure in hot heat-carrier fluid!
- Temperature difference of 20°C – acceleration factor for stabilizer loss of about 3
- Antioxidants detection limits agree with critical \( T_{\text{cox}} \) of 240°C
- Significant increase of C.I. and associated embrittlement after 2,500 h at 135°C, 8,000 h at 115°C and 26,500 h at 95°C.

Hot air aging behavior of PP-Bβ (σs - pol)

- So far no failure in hot heat-carrier fluid!
- Faster loss of stabilizer package than PP-Bα
- Faster drop in oxidation temperature levelling of at 220°C
- Better long-time performance of mechanical properties compared to PP-Bα
- Attributable to coarse spherulitic structure of PP-Bα
Experimental data were extrapolated using the Arrhenius and the Gugumus approach

Embrittlement cut-off was defined at 50 years

More critical – Gugumus: Experimental data for PP-H with comparable stabilizer formulation published by Gugumus (1999); vertical shift of Gugumus data to ultimate failure points of PP-grades → synthetic endurance time/temperature curve achieved

Less critical - Arrhenius: Arrhenius-extrapolation shows better material performance at temperatures from 50 to 90°C

Lifetime estimation for PP absorber of OW-SC collector

- Lifetime estimation strongly depends on extrapolation method
- Estimated lifetimes are more than 20 years for both grades
- Lowest lifetime values for hot and humid climate zone (Mumbai, IND)
- $\text{pol}$-grade PP-$\beta$: deduced lifetime years are higher (~ 10-20%) → improved performance
RESULTS – ISC
LIFETIME-TEMPERATURE LOADING PROFILES

Loading profiles for ISC at different sites

- ISC for DHW in single family houses
- Maximum operating temperatures are < 90°C
- Peaks loads are varying between 30 and 40°C
- Highest loads for Fortaleza, Pretoria or Athens
- ISC not recommended for Graz or Beijing

RESULTS – ISC
LIFETIME ESTIMATION

Aging behavior and Lifetime for PA-GF absorber of ISC collector

Aging at elevated temperatures (specimen level)

Extrapolation of aging data

<table>
<thead>
<tr>
<th>Lifetime, years</th>
<th>Graz, AT</th>
<th>Beijing, CHN</th>
<th>Athens, GR</th>
<th>Pretoria, SA</th>
<th>Fortaleza, BRA</th>
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<tbody>
<tr>
<td>PP-GF</td>
<td>48</td>
<td>46</td>
<td>39</td>
<td>37</td>
<td>31</td>
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For < 76°C an endurance time of 50 years is assumed.
SUMMARY AND CONCLUSION

PP absorber for pumped OW SC system

- Hot air exposure is more critical than hot heat carrier fluid (with corrosion inhibitors)
- spherulite-grade PP-Bβ exhibited better long-term performance under service relevant conditions
- More critical: hot and humid climate zone (e.g., Mumbai, Phoenix)
- Lifetimes of 20 years and more were deduced

PA-GF absorber for non-pumped ISC system

- Hot water exposure is more critical (hydrolysis)
- Lifetimes of 30 years and more; lower values for hot climates (e.g., Fortaleza, Pretoria)
- Validation by tests on component level, considering also pressure and chlorinated water to be done