Herausforderungen in der Produktion von Receivern für Parabolrinnenkraftwerke

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Receiver is the Key Component in Parabolic Trough Collectors

The receiver achieves high efficiency with:

- low thermal losses
  \(\rightarrow\) vacuum, absorber with low thermal emittance
- high solar absorptance
  \(\rightarrow\) efficient absorber, highly transmittent cover
- minimum of shading
  \(\rightarrow\) short bellows

[Diagram of receiver components: evacuated annulus, selective absorber coating on steel, getter to maintain vacuum, cover tube with anti-reflective coating, glass-to-metal-seal, bellow to compensate expansion]
Production Line for Receivers in Germany

- Production Line in Mitterteich, Germany
- Start: August 2006
- Invest: 15 Mio €
- 80 new jobs in production
- Annual capacity about 110 - 160 MW
Production Line for Receivers in Spain

- 2nd production line in Spain (region Seville)
- production start: spring 2008
- capital expenditure: 22 Mio €
- annual capacity about 110 - 160 MW
### Project Receiver – Time Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>2002</th>
<th>2003</th>
<th>2004</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
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<tbody>
<tr>
<td><strong>Development</strong></td>
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<td>Product and process development</td>
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<tr>
<td>Field test</td>
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<td>Planning Line 1</td>
<td>Set up Line 1</td>
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<td><strong>Production set up</strong></td>
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<tr>
<td>Planning</td>
<td>Set up Line 2</td>
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**Project PARASOL - BMU**

**Project PARFOR – BMU**

**Major partners:**

- DLR
- FLAGSOL
- Fraunhofer Institut Solare Energiesysteme
Quality Requirements

For new power plant projects a life span of more than 20 years is required to
- match the business plans which are based on long pay back periods
- keep maintenance costs low during operation.

During operation receivers are **mechanically** and **thermally** stressed.
Most important issues are:
- Durability of glass-to-metal seal
  (break rate close to zero)
- Stability of vacuum
  (low hydrogen permeation, appropriate getter)
- durability of absorber coating
  (only small degradation of efficiency acceptable)
- abrasion resistance of anti reflective glass coating.
Known Problems

- breakage of glass-to metal-seal (2 - 2.5 %/a)
- shading of radiation shields (> 7% of length)
- degradation of coatings

bellow shields

florescent absorber tubes

Receiver failures at KJC, source: Hank Price, NREL
Selective Absorber with Multilayer Cermet for High Temperatures

Performance data:
- temperature stable up to 500 °C (short term)
- solar absorptance >= 95 %
- thermal emittance <= 14% at 400°C

Material:
- polished low-carbon steel as substrate material
- Multilayer Cermet coating

Absorber coating

\[
\begin{align*}
\alpha &= 0.95 \\
\varepsilon &= 0.13 @ 400°C
\end{align*}
\]
Absorber Coating - Accelerated Aging Test

Aging test of Fraunhofer-ISE:
samples at 450°C - 550°C for 1200 h

Result:
change in absorptance and emittance < 1%

<table>
<thead>
<tr>
<th>Aging Temp.</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 d @ 450°C</td>
<td>300°C 38 a 3,4 a</td>
</tr>
<tr>
<td>50 d @ 500°C</td>
<td>4200 a 240 a 22 a</td>
</tr>
<tr>
<td>50 d @ 550°C</td>
<td>21000 a 1200 a 104 a</td>
</tr>
</tbody>
</table>

Reflectance at 801 nm and 2130 nm over time in h
New Glass-to-Metal Seal Improves Strength Properties

- Breakage of glass-to-metal sealing (Housekeeper) is main cause for damages of receivers in existing power plants.
- Automated production process required to reduce cost and to ensure quality.
- New approach with adapted CTE yields a sealing with low stress.
- Only one glass type necessary.

### Housekeeper - Method
- Stainless Steel
  - CTE = 16 * 10^-6 / K
- Glass
  - CTE = 3.3 * 10^-6 / K

### SCHOTT Approach
- Metal
  - CTE = 5.5 * 10^-6 / K
- Glass
  - CTE = 5.5 * 10^-6 / K
**Glass-to-Metal-Seal (GMS) – Automated Proof Test**

- FEM analysis shows that the main stress is 6 times lower than in common Housekeeper sealing at working temperature.
- An automated proof test (100%) ensures the constant quality of the glass-to-metal seal and avoids defective goods in the consecutive production process.
- Optimization of production yield an minimization of defects during power plant operation.

![Diagram](image-url)

**Diagram Details:**
- Ca. 200°C
- Water 25°C
AR Coating with High Solar Transmittance

- Sol-Gel coating for borosilicate glass based on alcoholic dilutions with \( \text{SiO}_2 \) nano particles for improved abrasion resistance
- solar transmittance of \( > 0.96 \) achieved
- challenges in production:
  - homogenous and stable coating of long glass tubes (✓)
  - automated high precision solar transmittance test for long glass tubes (✓)

Only glass:
\[ \tau = 92\% \]

With AR-coating:
\[ \tau > 96\% \]
AR Coating – Abrasion Tests

Solar Transmittance

AR coating made by SCHOTT | competitive AR coating
---|---
freshly" coated: > 100 strokes | coating of unused receiver: 10 strokes
aged coated envelope: > 100 strokes | aged coated envelope: 2 strokes
Solutions for Hydrogen Problem

Problem:

- Thermo oil decomposes during operation, hydrogen is generated.
- Hydrogen permeation through steel absorber tube leads to vacuum loss and increased heat loss (factor 2-3)

Solution:

- Barrier to reduce permeation rate
- Increased getter quantity mounted in „cool“ place
Vacuum Technology - Challenges in Production

- Test hydrogen capacity of getter material for quality control
- Test of hydrogen permeation rate through stainless steel tubes
- Optimization of evacuation process
Field Test in Power Plant

- 100 Receivers operating in SEGS III, KJC since October 03
- 200 Receivers installed in SKAL-ET test loop at KJC in July and October 2004
- Successful field test, no breakage
- 2.3% increase in performance compared to previously installed tubes of competitor (FlagSol)
Nevada Solar One Power Plant

- Size: 64 MW solar only
- annual capacity: 130 GWh
- mirror area: 357,200 m²
- Project developed by SolarGenix Energy since March 2003
- Under construction since February 2006, on grid since June 07
- 20 years PPA with Nevada Power Company and Sierra Pacific Power Company

Boulder City, NV

(Courtesy of Acciona Solar Power Inc)
ANDASOL Projects in Spain

- Size: 2 x 50 MW with 7.5 h full load storage (> 1 mio m² mirror area)
- first parabolic trough plant in Europe
- Under construction since July 2006 (Plateau of Guadix, east of Granada)
- Andasol 1 on grid in July 2008

(Courtesy of COBRA)
Thank You!

(Courtesy of DLR)