Concentrating Solar Power – Trough Technology

Alex marker

SCHOTT North America

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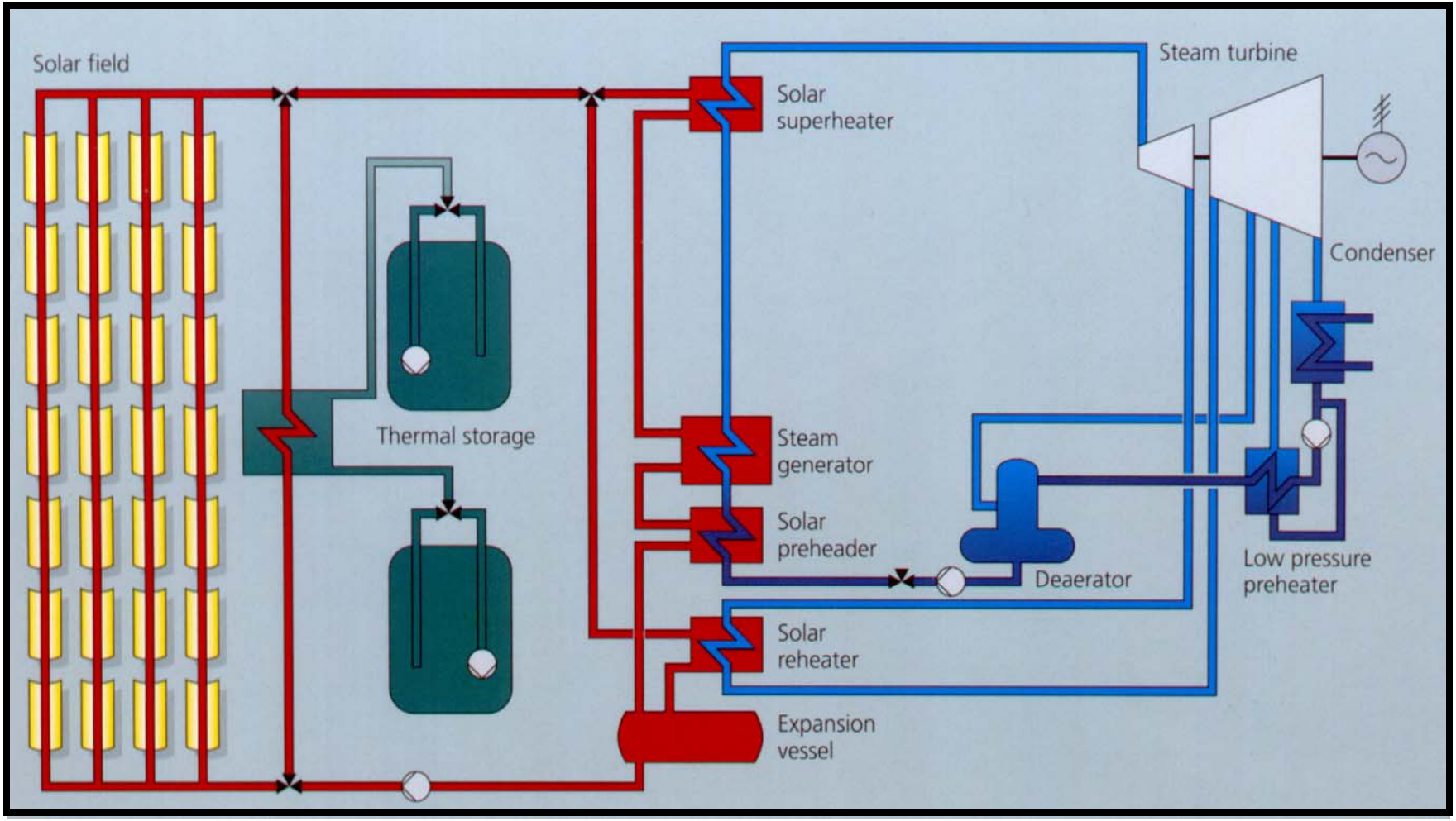

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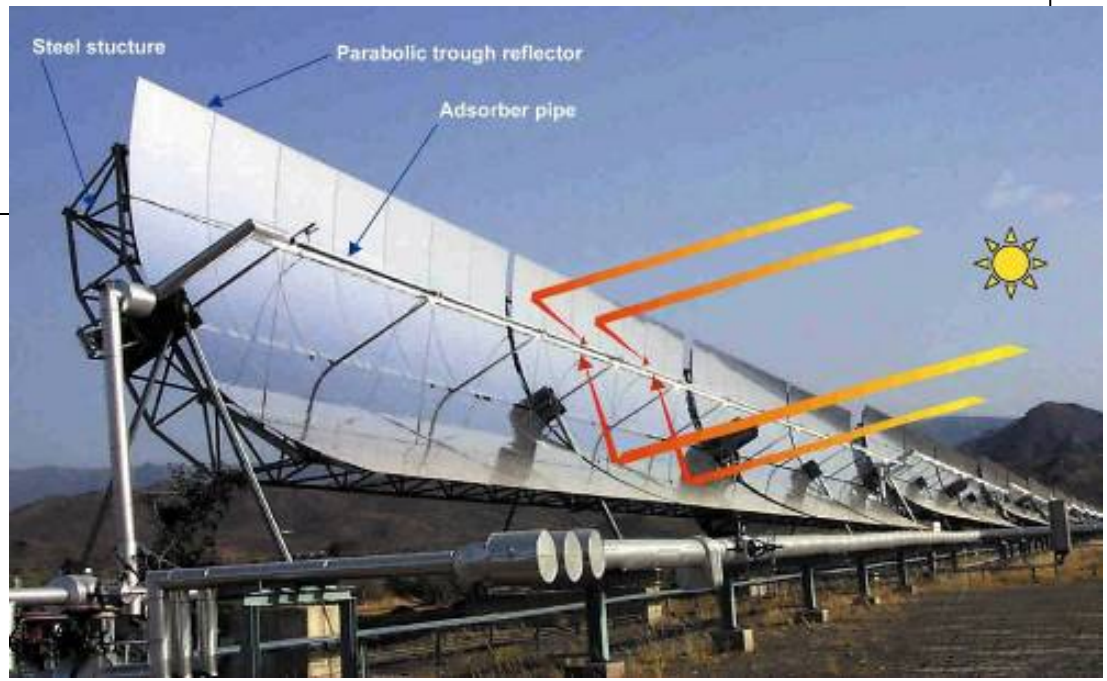
Parabolic Trough Technology



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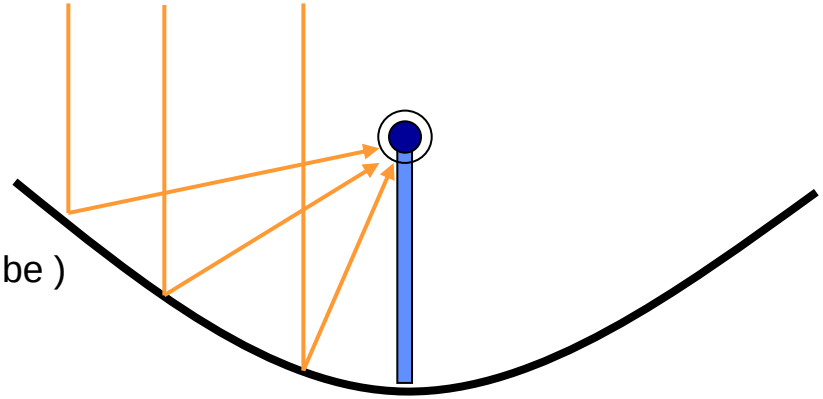
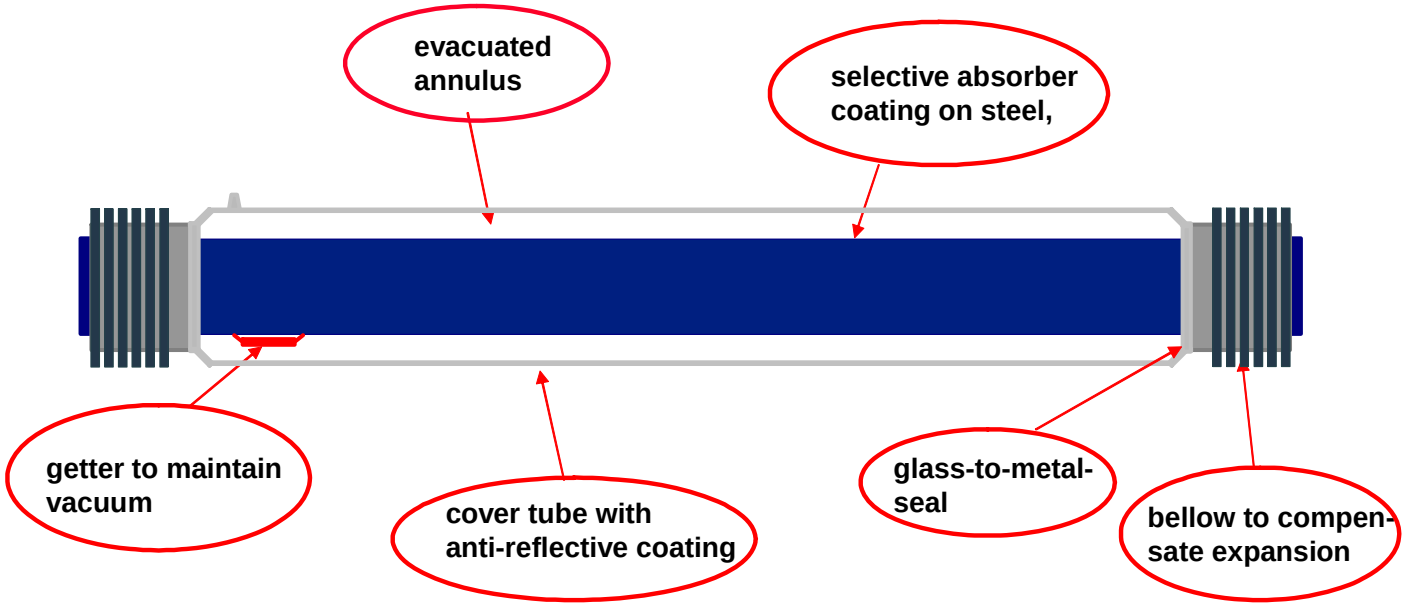
Receiver is the Key Component in Parabolic Trough Collectors

The receiver achieves high efficiency with

- ➔ Low thermal losses
  (→ vacuum, absorber with low thermal emittance)
- ➔ High solar absorptance
  (→ efficient absorber, highly transmitting outer glass tube)
- ➔ Minimum of shading
  (→ short bellows)





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Quality Requirements

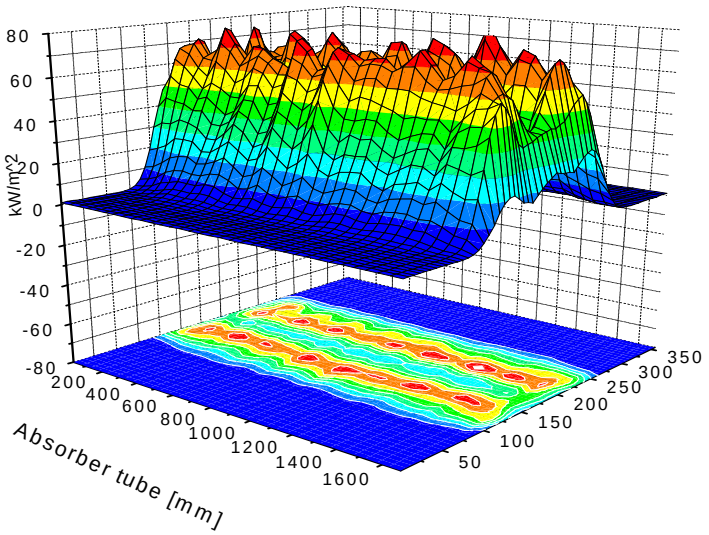
For power plant projects a life span of more than 20 years is required to

- ➔ 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.



Flux density distribution on absorber (DLR, 2007)

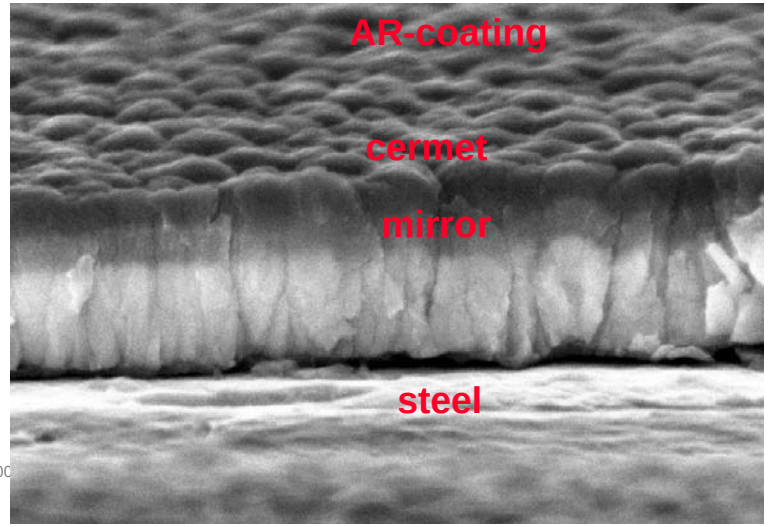
Selective Absorber with Multilayer Cermet for High Temperatures

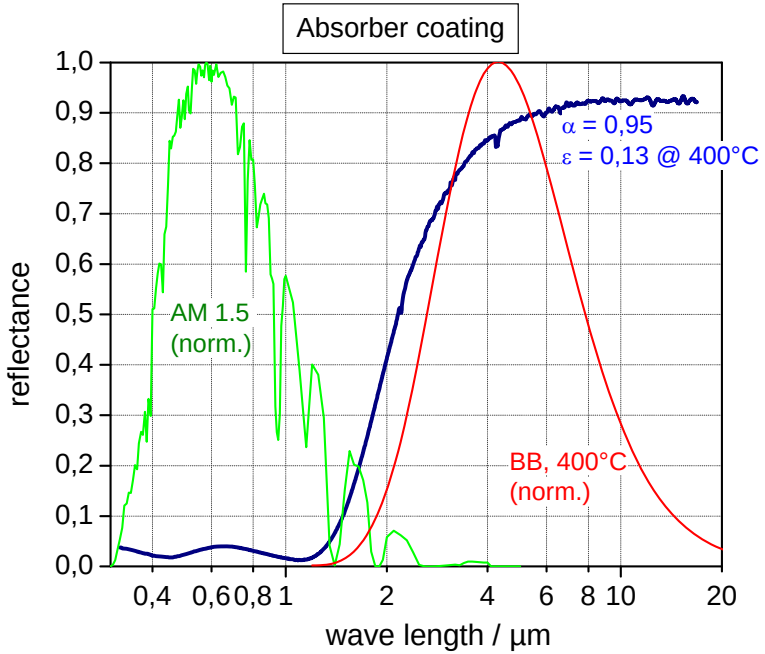
Performance data:

- Temperature stable up to 500 °C
- Solar absorptance >= 95 %
- Thermal emittance <= 14% at 400°C

Material:

- Polished low-carbon steel as substrate material
- Multilayer Cermet coating





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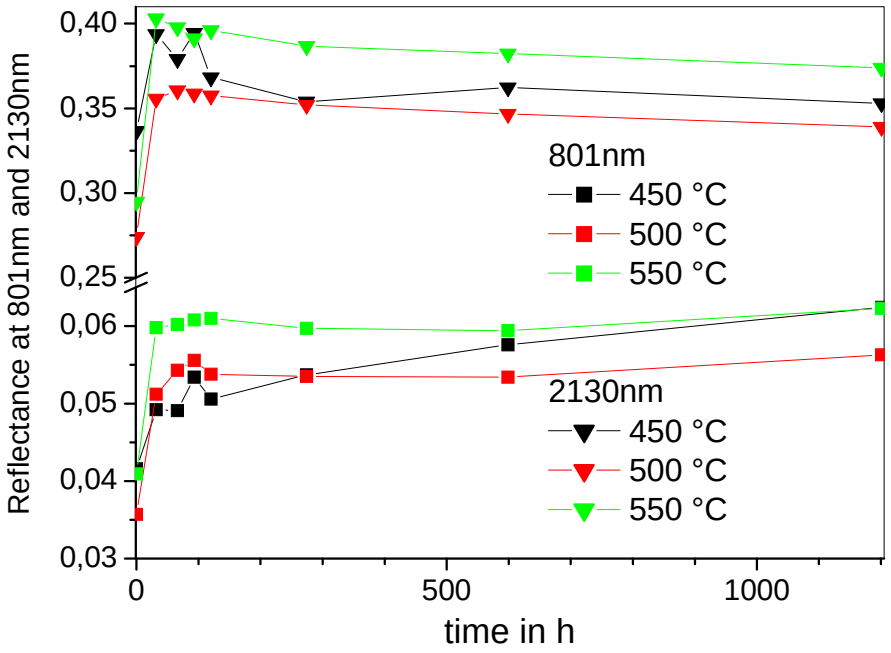
Absorber Coating - Accelerated Aging Test

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

Result:
change in absorptance and emittance < 1%

	Operating Temperature		
Aging Temp.	300°C	350°C	400°C
50 d @ 450°C	680 y	38 y	3,4 y
50 d @ 500°C	4200 y	240 y	22 y
50 d @ 550°C	21000 y	1200 y	104 y



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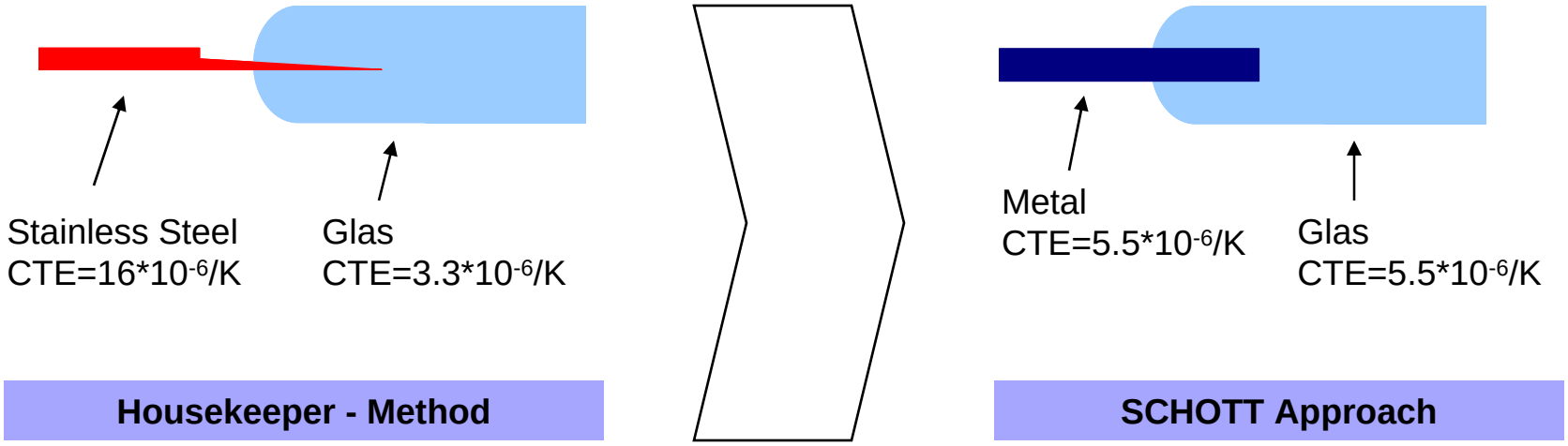
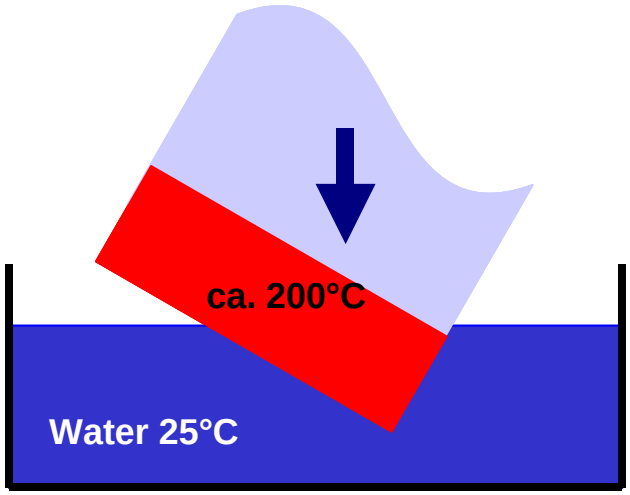
New Glass-to-Metal Seal Improves Strength Properties

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



Glass-to-Metal-Seal (GMS) – Automated Proof Test

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

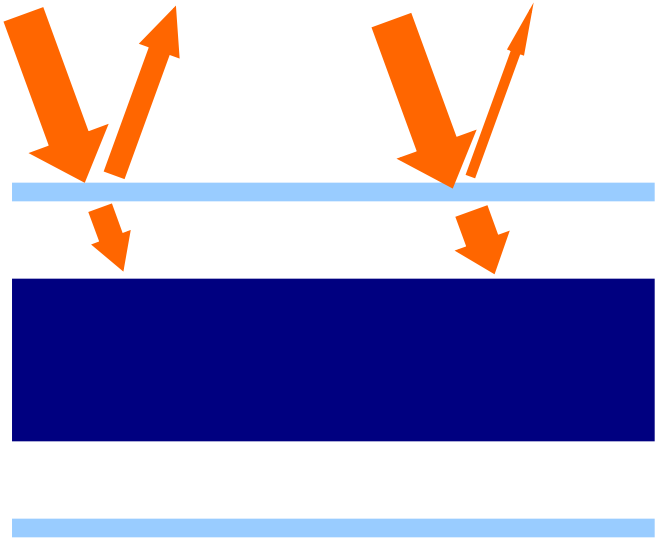


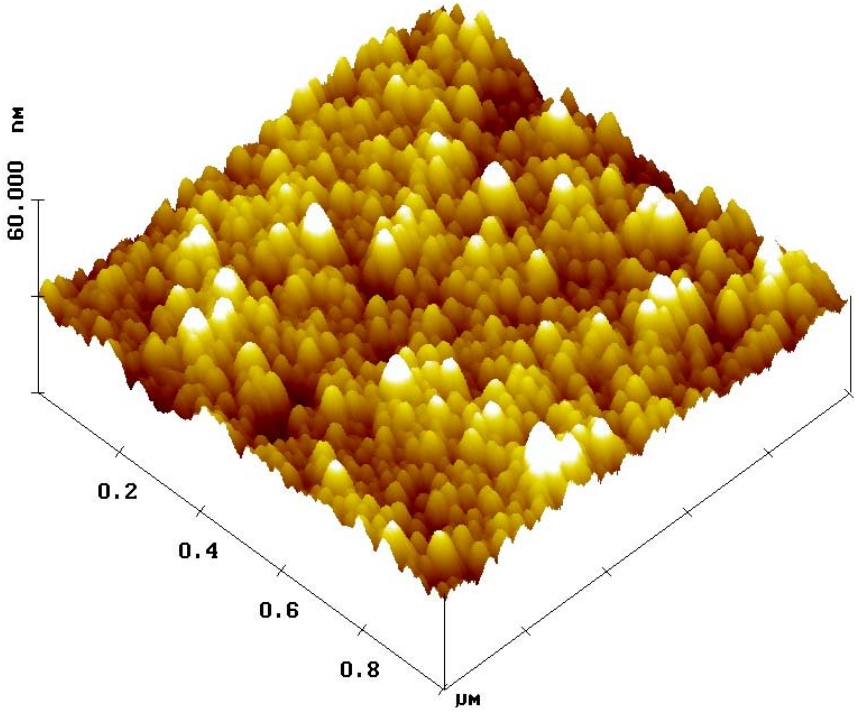
AR Coating with High Solar Transmittance

- Sol-Gel coating for borosilicate glass based on alcoholic dilutions with 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:
τ = 92%

With AR-coating :
τ > 96%





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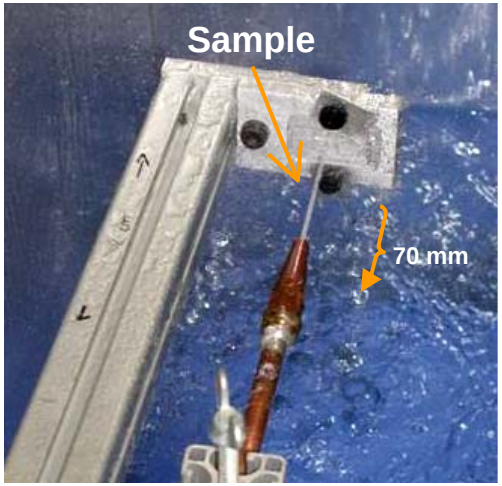
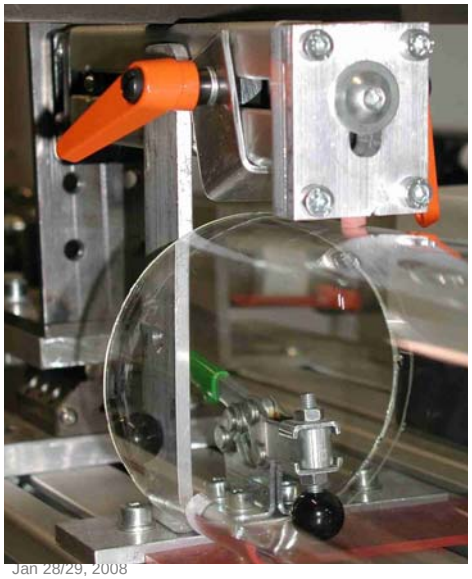
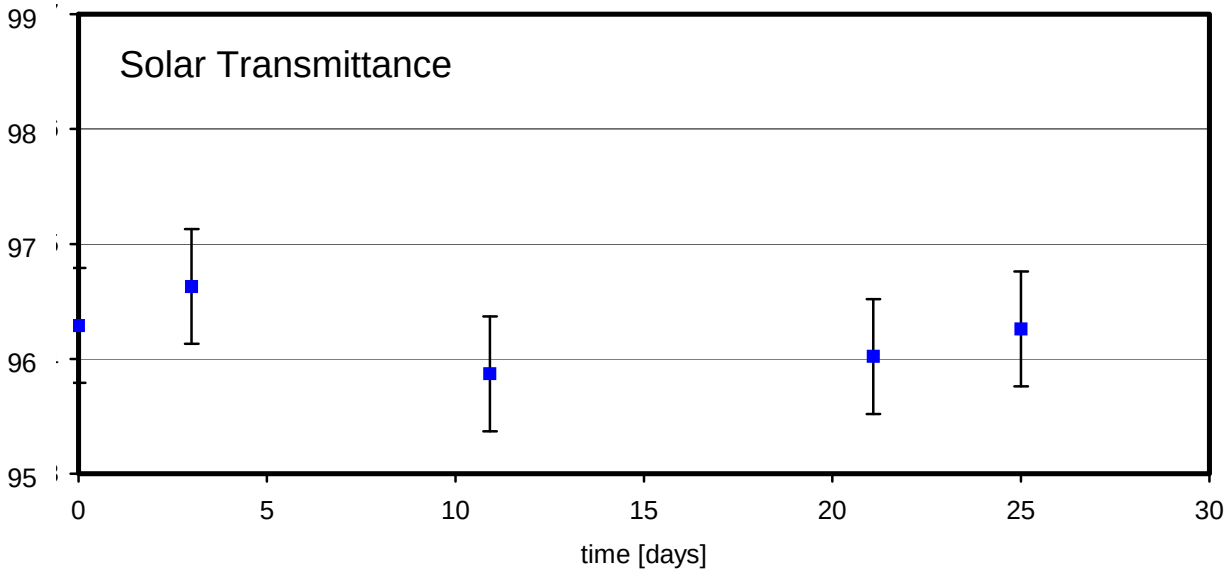
AR Coating – Abrasion Tests







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

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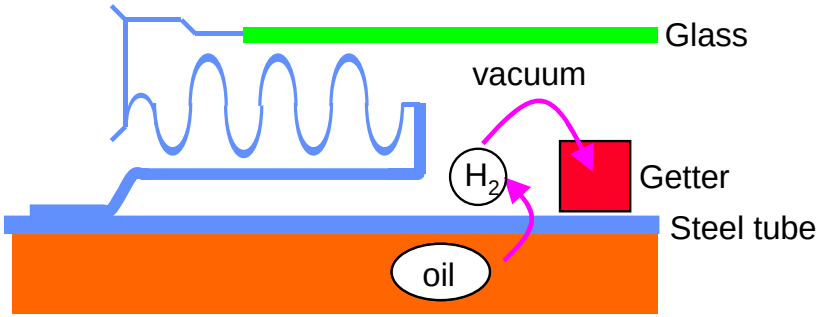
Solutions for Hydrogen Problem

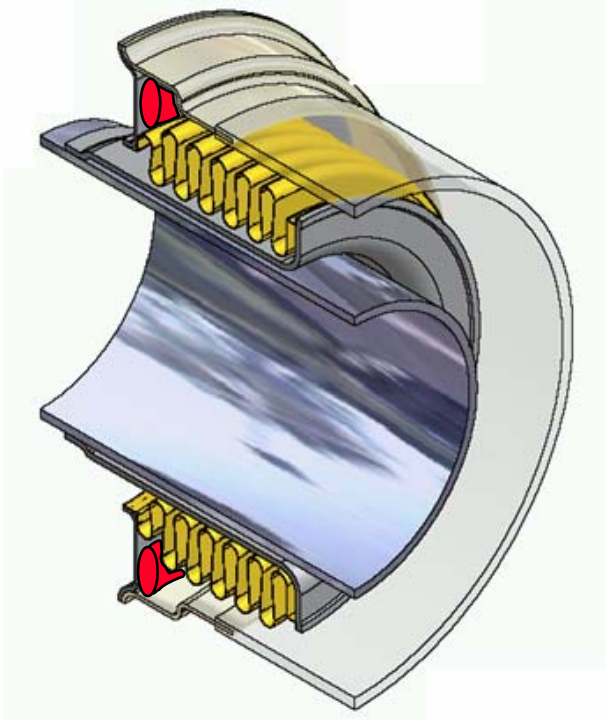
Problem:

- 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:

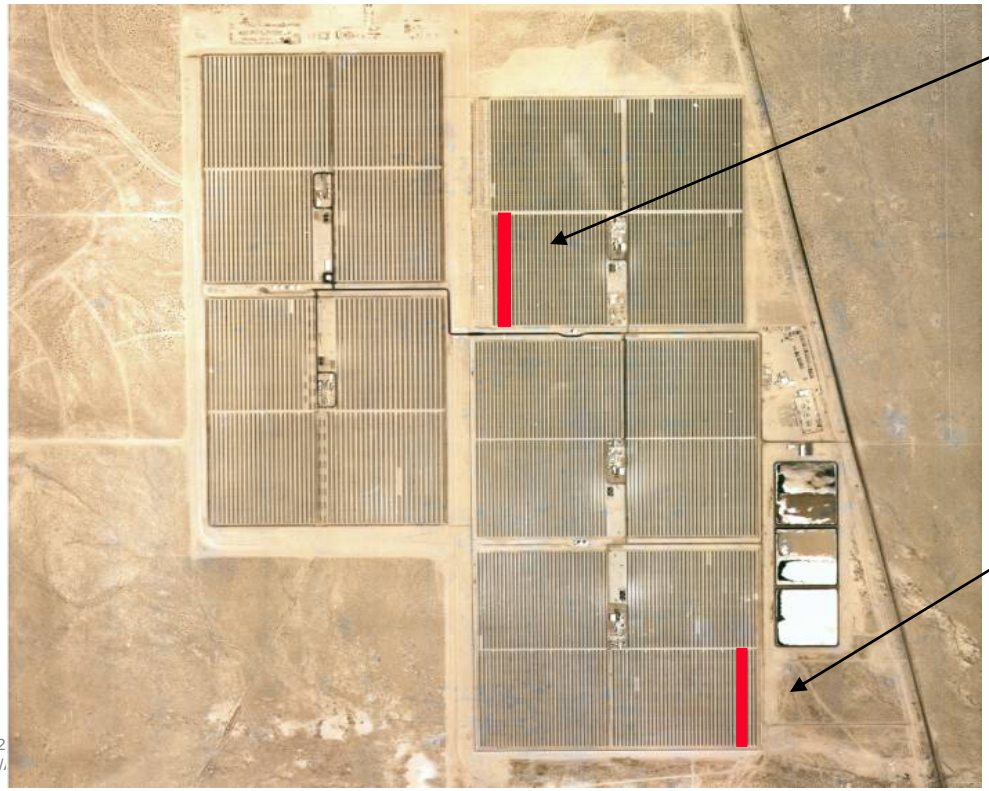
- Barrier coating to reduce permeation rate
- Well designed getter quantity mounted in „cool“ place





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
- About 2% increase in preformance compared to previously installed tubes of competitor (FlagSol)



SKAL-ET test loop

Durability test for GMS

Technical innovations for Receivers

Today:

Thermo-Oil / LS3-design

- 😐 Operation up to 400°C with with steam generator
- 🙂 proven technology
- 😐 Heat storage possible (indirect)
- 😐 over all efficiency 16-17%
- ☹ hydrogen problem

New Heat Transfer Fluid
- higher temperatures
- higher efficiency
- no hydrogen problem

?

Direct steam generation
- temperatures > 500°C
- efficiency >20%
- cheaper HTF

Molten salt
- temperatures > 500°C
- efficiency >20%
- Storage

New Dimensions/Design
- lower system cost
- higher concentration
- higher efficiency

Comparison of HTFs

	Synthetic Oil	**Molten Salt**	**Direct Steam Generation**
Maximum operating temperature	400°C	500-520°C	480-500°C
System pressure	30-40 bar	10 bar	60-100 bar
Corrosion of absorber tubes	no	depends on salt quality	no
Hyrogen problem	yes	unlikely	unlikely
Cost reduction		Getter Steel	Getter
Cost increase			Steel
Main problem	Decomposing fluid	Freezing	High pressure and weight

Conclusions

- Receivers for parabolic troughs are commercially available
- The technology is proven - 20 years of operation, many lessons learned
- Major improvements in efficiency and durability have been implemented
- Synthetic oil is today's heat transfer fluid. Operation temperature is limited to 400°C,
  vacuum maintenance due to hydrogen permeation is important
- Molten salt and direct steam generation are the most promising options to increase
  the system performance, an operating temperature of 500°C seems to be feasible