Parabolic Trough Receiver
Thermal Performance

Parabolic Trough Workshop

Golden, Colorado

March 9, 2007
Key to good performance at parabolic trough power plants

- Problems with glass breakage appears to be resolved with new designs and O&M procedures.
- New receivers improve optical and thermal performance
Parabolic Trough Receiver or Heat Collection Element

New Solel UVAC Receiver

- Protective Shielding for Glass-to-Metal Seal
- Borosilicate Glass Tube w/ Anti-Reflective Coating
- Stainless Steel Tube w/ Cermet Selective Coating
- Getters to Absorb Gases (Hydrogen)

Solel UVAC

New Schott Bellows

Bellows & Glass-to-Metal Seal
Parabolic Trough Receiver
Thermal Testing

- Outdoor – Thermal Loop Tests
  - Use measurement of flow and temperature difference to calculate energy gained or lost.
  - Sandia Rotating Platform, Plataforma Solar de Almería EuroTrough Collector, SEGS Collector Test Loops

- Indoor
  - Electric resistance heating
    - Heat receiver to steady state temperature
    - Electric power consumed is the thermal loss
  - DLR, Schott, ENEA, NREL
• Receiver testing on AZTRAK rotating platform @ Sandia
  • Luz Black Chrome (1993)
  • Luz Cermet (1993)
  • Solel UVAC (2003)
  • Schott Cermet (2004)
• Advantages
  • 2-Axis Tracking
  • On-sun or off sun testing
• Disadvantages
  • Only one collector element tested & 2 receivers
  • Low precision on measurements
Efficiency vs. Average Fluid Temperature Above Ambient for the LS-2/Schott HCE system

Curve fit equation:

\[ \eta = 78.59 - 0.0357T - 4.33 \times 10^{-6}T^2 \]
Parabolic Trough Receiver Thermal Testing

- Receiver testing on EuroTrough Prototype @ Plataforma Solar de Almería
  - Solel UVAC
  - Schott Cermet
- Advantages
  - Full collector tested (more receivers)
  - Better precision
- Disadvantages
  - Single E/W axis tracking
  - Reduced test flexibility
• Receiver testing on ENEA Loop
  • Schott Receiver
  • ENEA Receiver (Summer 2007)
• Advantages
  • Molten Salt Test
  • Higher Temperatures
  • Two Collectors
Parabolic Trough Receiver Thermal Testing

- Loop Testing at the SEGS
  - Solel UVAC (SEGS VI)
  - Schott Cermet (SKAL-ET, SEGS V)

- Advantages
  - Field testing in normal operation
  - Full loop tested
  - Comparison to other loops

- Disadvantages
  - Many factors affect results
  - Limited control of test
UVAC Test Loop Results @ SEGS VI
Performance or 192 HCEs

UVAC / Cermet Comparison - SEGS VI

- Thermal Efficiency %
- Insolation - W/m²

UVAC Loop (3/4)  Base Loop (5/6)  Insolation

3/28/01
DLR Receiver Test Lab

- Electric resistance heating
- At steady state power consumption is equal to thermal losses
NREL Receiver Test Lab

- Electric resistance heating
- At steady state power consumption is equal to thermal losses
- Similar to approaches used by DLR & Schott

Calvin Feik, Ray Hansen, Steve Phillips, Al Lewandowski, Carl Bingham, Judy Netter, Chuck Kutscher, Frank Burkholder
Receiver Test Results

Solel UVAC 2

\[ \text{Loss (W/m)} = 0.47 \times \Delta T + 6.11 \times 10^{-9} \times \Delta T^4 \]

in liquid cool-down tests, \( T^* = T_{\text{fluid}} \)

in electric resistance testing, \( T^* = T_{\text{absorber}} \)

HCE length = 4.08 m

Collector holds 2 HCEs

Collector aperture area = 39.2 m²
Receiver Test Results
Schott PTR70

Thermal Loss (W/m HCE length)

T* - T_{ambient} (°C)

in liquid cool-down tests, T* = T_{fluid}
in electric resistance testing, T* = T_{absorber}

0 50 100 150 200 250 300 350 400 450

0 50 100 150 200 250 300 350 400 450

0 10 20 30 40 50 60 70 80 90 100 110 120

HCE length = 4.08 m
Collector holds 2 HCEs
Collector aperture area = 39.2 m²

Loss (W/m) = 0.39\*ΔT + 0.26\*ΔT^4

Loss (W/m) = 0.33\*ΔT + 0.15\*ΔT^4
Receiver Field Survey
With Infrared Camera

Sky
Receiver
Mirrors

Cool Receiver
Hot Receiver
Temperature Varies
For a known wind speed and ambient temperature, ...

- Receiver thermal losses are a function of the glass temperature.
- Receiver condition doesn’t matter (vacuum, lost vacuum, hydrogen)
**10 Cross-Sections**

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**Max of Cross-section Maximums 107°C**

**Max Min of Cross-section Maximum 14°C**

**Average of Cross-section Maximums 98°C**

**Sky Temperature**

**Mirror Glass Temperature**

**Receiver Glass Temperature**

**Temperature Profiles of Cross-Sections**
Solel UVAC2 (2 years old) with Vacuum

Visible Image of Receiver – Not Tracking

Infrared Image – Not Tracking (Glass Temp. 63ºC-66ºC)

Infrared Image – Tracking (Glass Temp. 68ºC-71ºC)
Luz Cermet with Vacuum

Visible Image of Receiver – Not Tracking

Infrared Image – Not Tracking (Glass Temp. 124°C-141°C)

Infrared Image – Tracking (Glass Temp. 138°C-267°C)

Getter dust is causing hot spots on the glass
• IR camera provided a good approach for evaluating condition of a large number of receivers in the solar field.
  – A highly automated approach for imaging receiver and analyzing data developed
  – Good agreement between IR camera and thermocouple measurements
  – Able to take measurement while collectors tracking
  – Approximately 12,000 images of receivers taken (out of ~90,000 receivers)

• Results from testing:
  – Able to evaluate performance of various generations of original and replacement receivers.
  – Getter dust, dirt on glass, or fluorescent coating failure cause increased glass temperatures.
  – Results indicate a potential hydrogen build-up in receivers in solar field
• Improved automation of image acquisition
  – Integration of GPS for automated acquisition of images.
Infrared Camera Measurements through Glass
Absorber Surface
Temperature Measurement Results
Non-Invasive Measurement of Gases in Trough Receiver

- Confined gases under low pressure emit characteristic spectra when a high voltage discharge is allowed to pass through the gases.
- The characteristic emission wavelengths provide the identity of the gas and the intensity of the emissions are proportional to the amount of gas.

Developed by:
Bob Meglen
Latent Structures

&

Ed Wolfrum
NREL
• Hydrogen detected above ~300°C
• Correlates to increase in glass temperature & increased thermal losses on hot receiver
Receiver Test Results

- NREL test bed UVAC2
  \[ \text{Loss (W/m)} = 0.41\Delta T + 1.11 \times 10^{-8}\Delta T^4 \]

- NREL test bed Schott PTR70
  \[ \text{Loss (W/m)} = 0.39\Delta T + 1.21 \times 10^{-8}\Delta T^4 \]

- NREL test bed Receiver with H_2 in annulus

Hydrogen starts coming out of getters.
• Outdoor testing
  – 2-axis
  – Single collectors
  – Field Test Loops
• Indoor testing
• Rapid Field Observations
Mirror Washing

High Pressure Spray with Demineralized water
Deluge wash with Demineralized water
Thank You