Parabolic Trough Receiver Thermal Performance

Parabolic Trough Workshop

Golden, Colorado

March 9, 2007

Sandia National Laboratories

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NREL/PR-550-41422

Parabolic Trough Receiver or Heat Collection Element

- ***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***

Source: Solargenix – APS 1-MW Trough Plant

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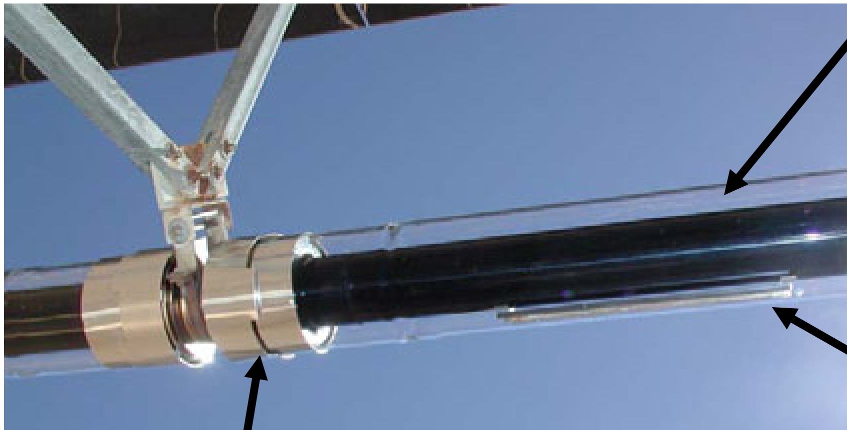
Parabolic Trough Receiver or Heat Collection Element

New Solel UVAC Receiver



Borosilicate Glass Tube
w/ Anti-Reflective Coating

Stainless Steel Tube
w/ Cermet Selective Coating

Getters to Absorb Gases
(Hydrogen)

Protective Shielding for
Glass-to-Metal Seal

Solel UVAC

Bellows &
Glass-to-Metal Seal

New Schott Bellows

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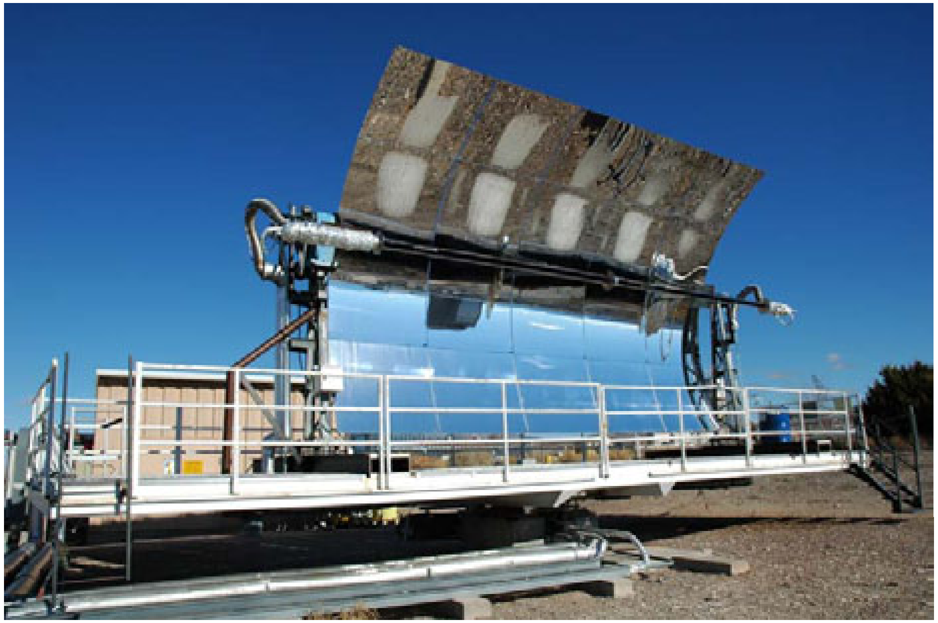
Parabolic Trough Receiver Thermal Testing

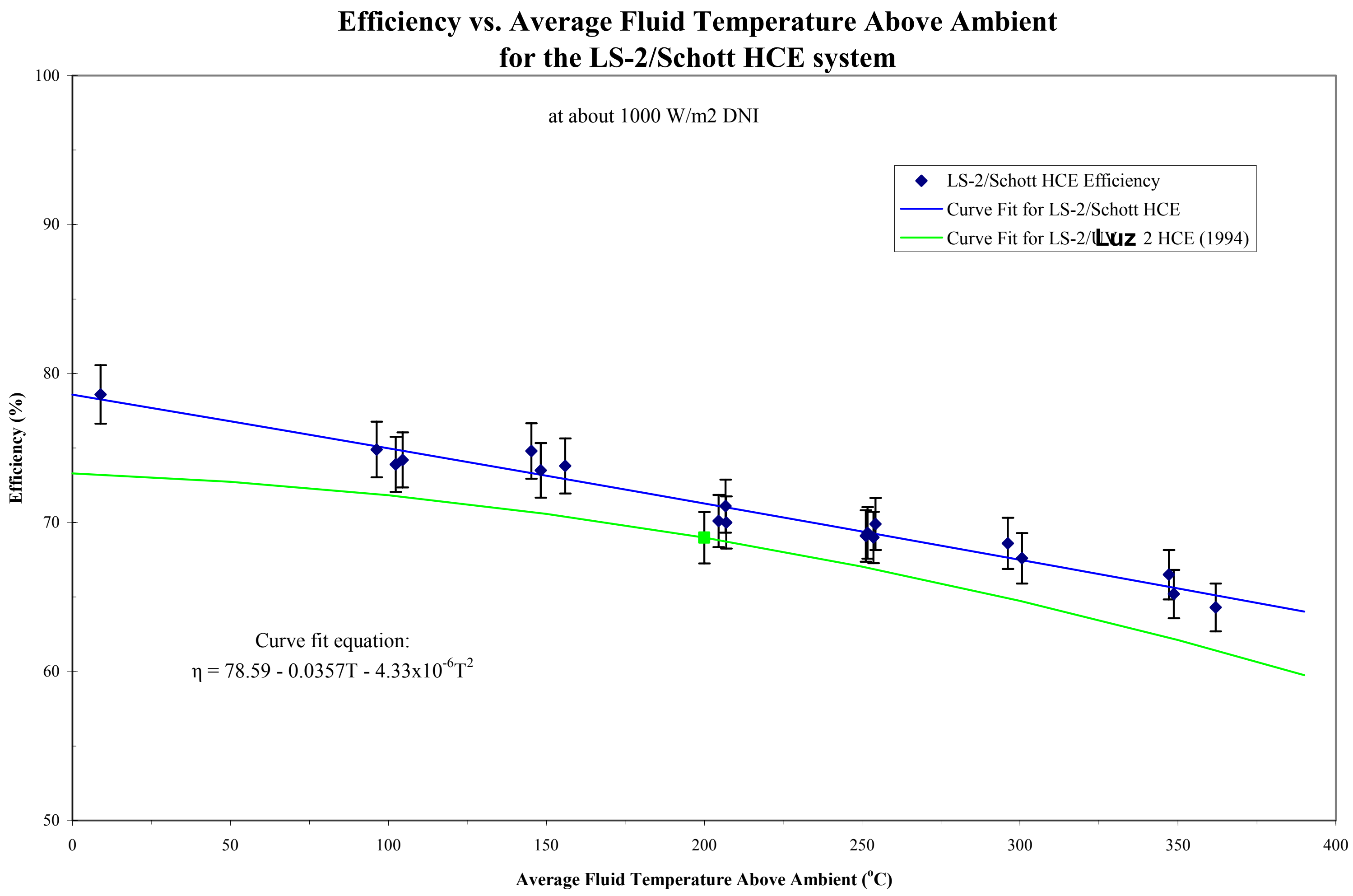
- Outdoor – Thermal Loop Tests
  - Use measurement of flow and temperature difference to calculate energy gained or lost.
  - Sandia Rotating Platform, Plataforma Solar de Almería EuroTrough Collector, SEGS Collector Test Loops
- Indoor
  - Electric resistance heating
    - Heat receiver to steady state temperature
    - Electric power consumed is the thermal loss
  - DLR, Schott, ENEA,NREL

Parabolic Trough Receiver Thermal Testing

- **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



Parabolic Trough Receiver Thermal Testing



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

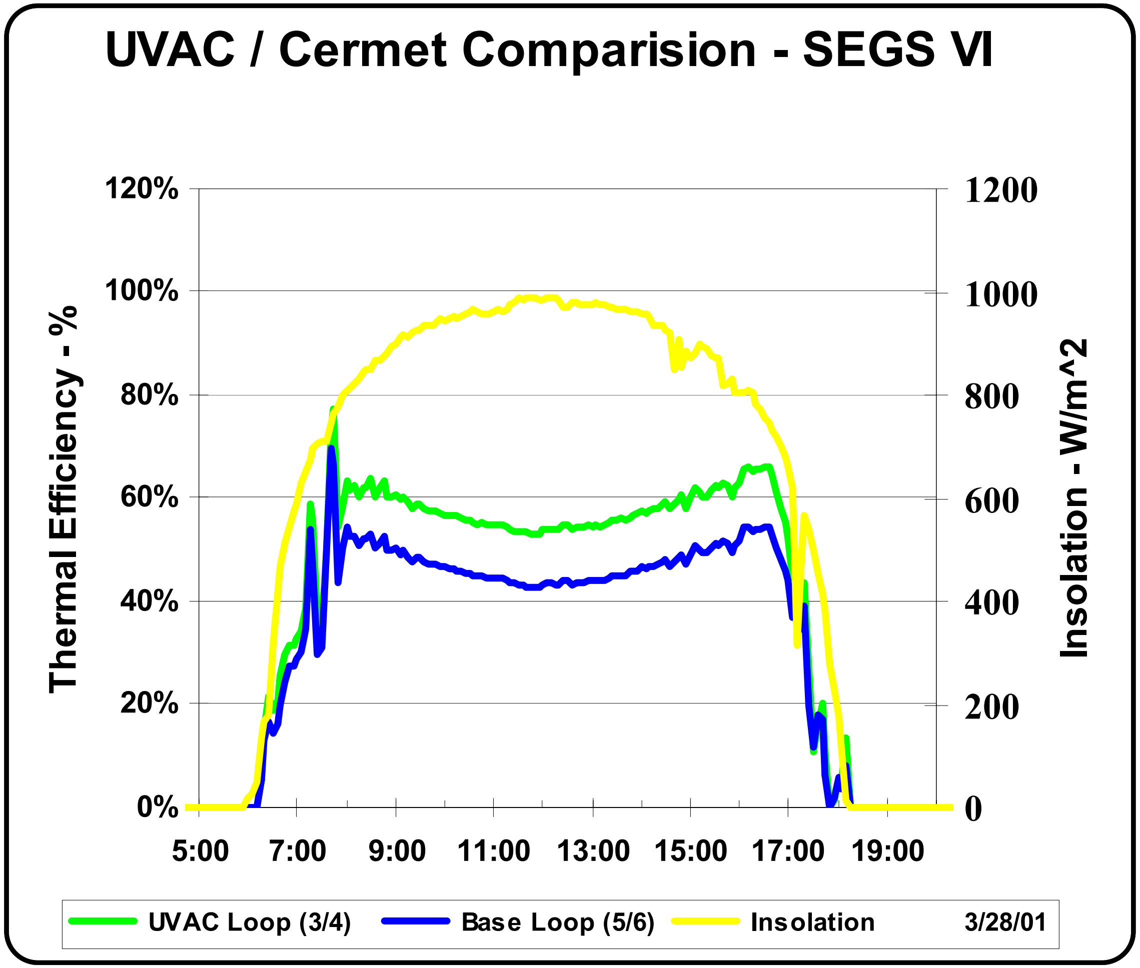
Parabolic Trough Receiver Thermal Testing

- **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



KJC OPERATING COMPANY

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Receiver Thermal Loss
Indoor Test Stand

DLR Receiver Test Lab

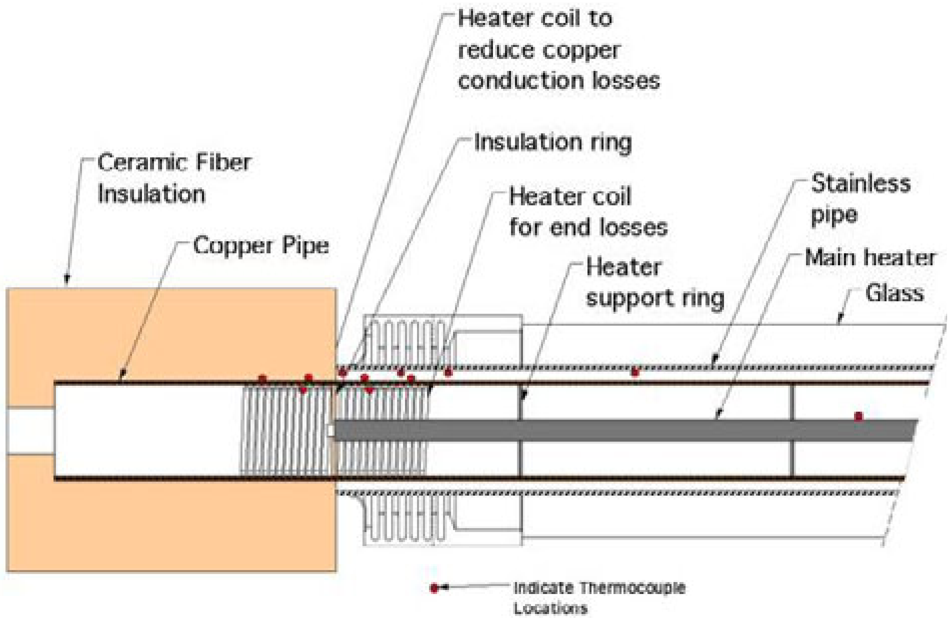
- Electric resistance heating
- At steady state power consumption is equal to thermal losses

Receiver Thermal Loss
Indoor Test Stand

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

NREL Receiver Test Lab

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



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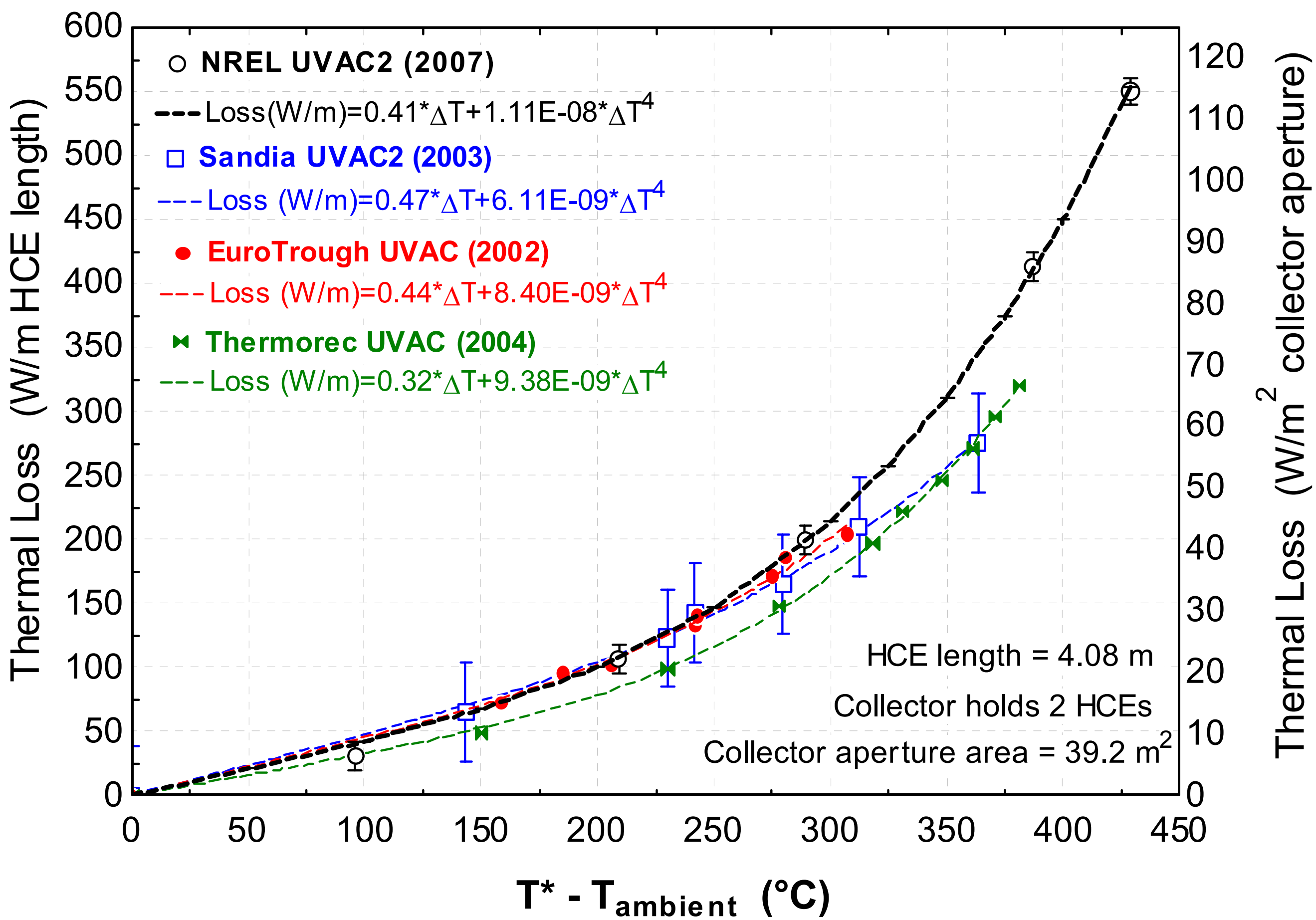
Receiver Test Results
Solel UVAC 2



in liquid cool-down tests, $T^* = T_{fluid}$

in electric resistance testing, $T^* = T_{absorber}$

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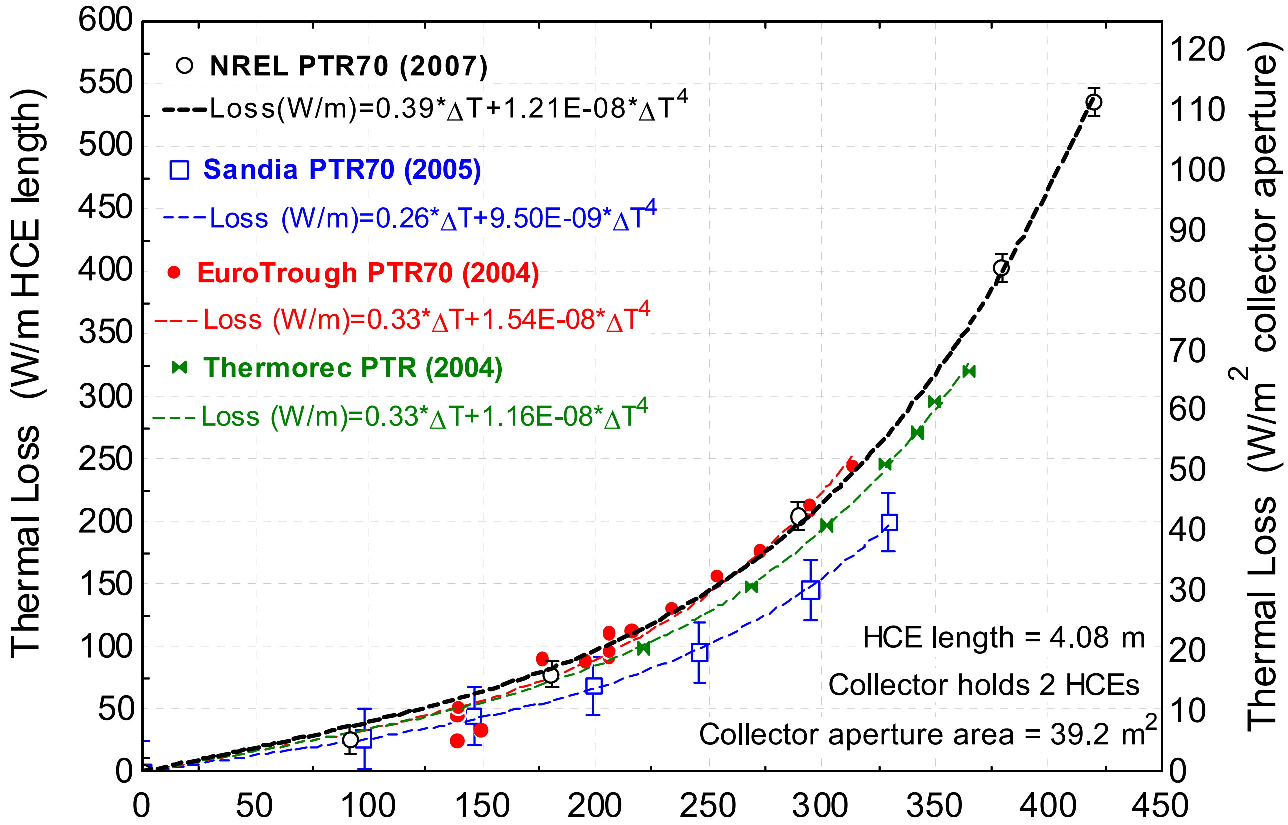


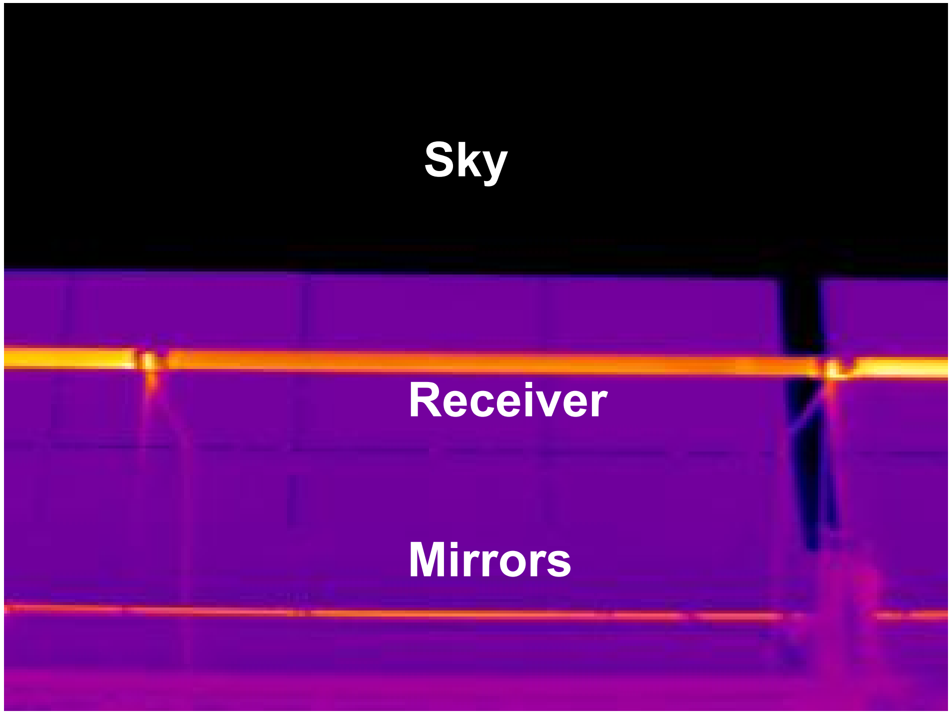
T* - $T_{ambient}$ (°C)

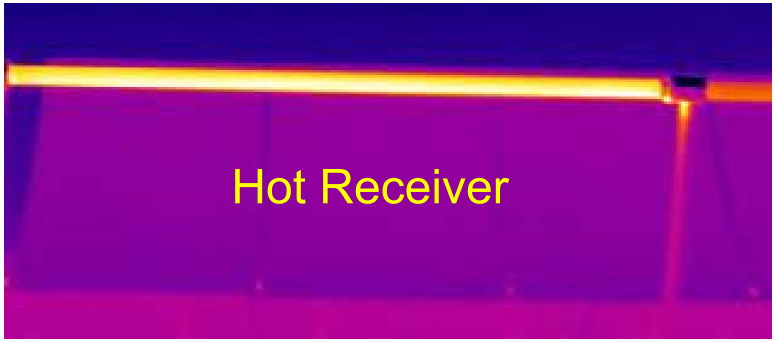
in liquid cool-down tests, T* = T_{fluid}

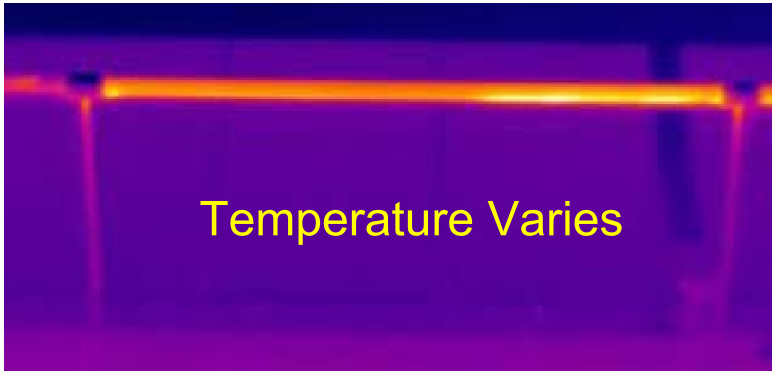
in electric resistance testing, T* = $T_{absorber}$

Receiver Field Survey For FPL Energy

Receiver Field Survey With Infrared Camera







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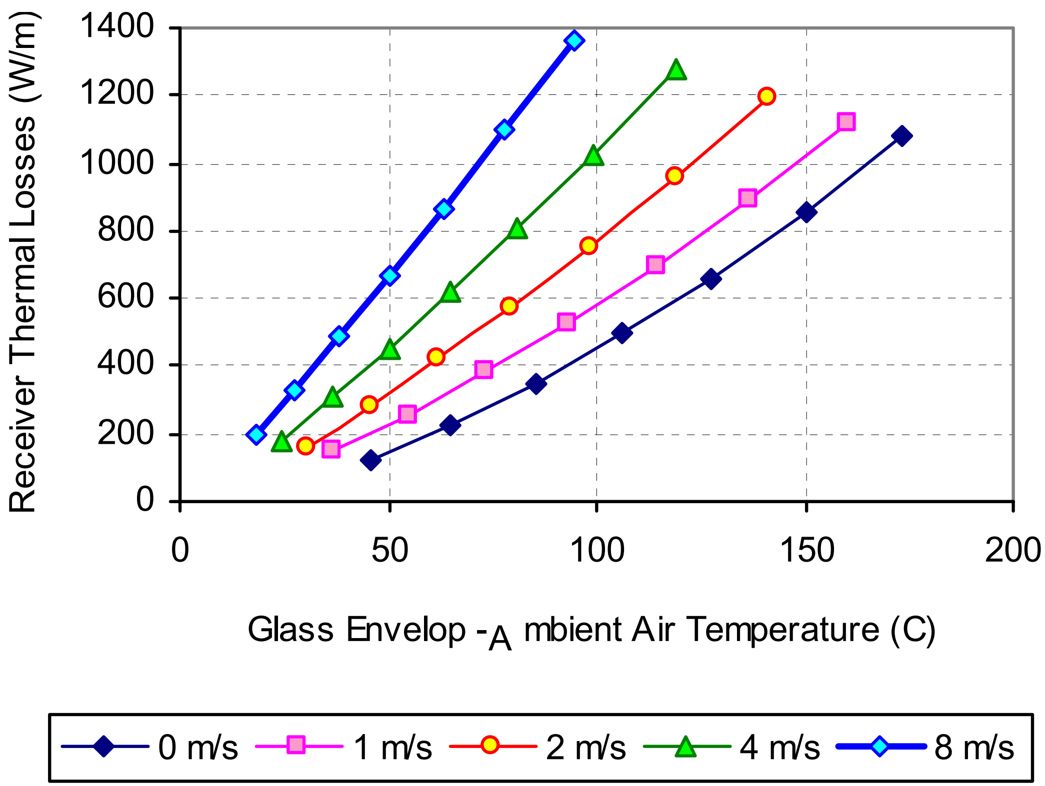
HCE Losses vs. Glass Temperature



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)

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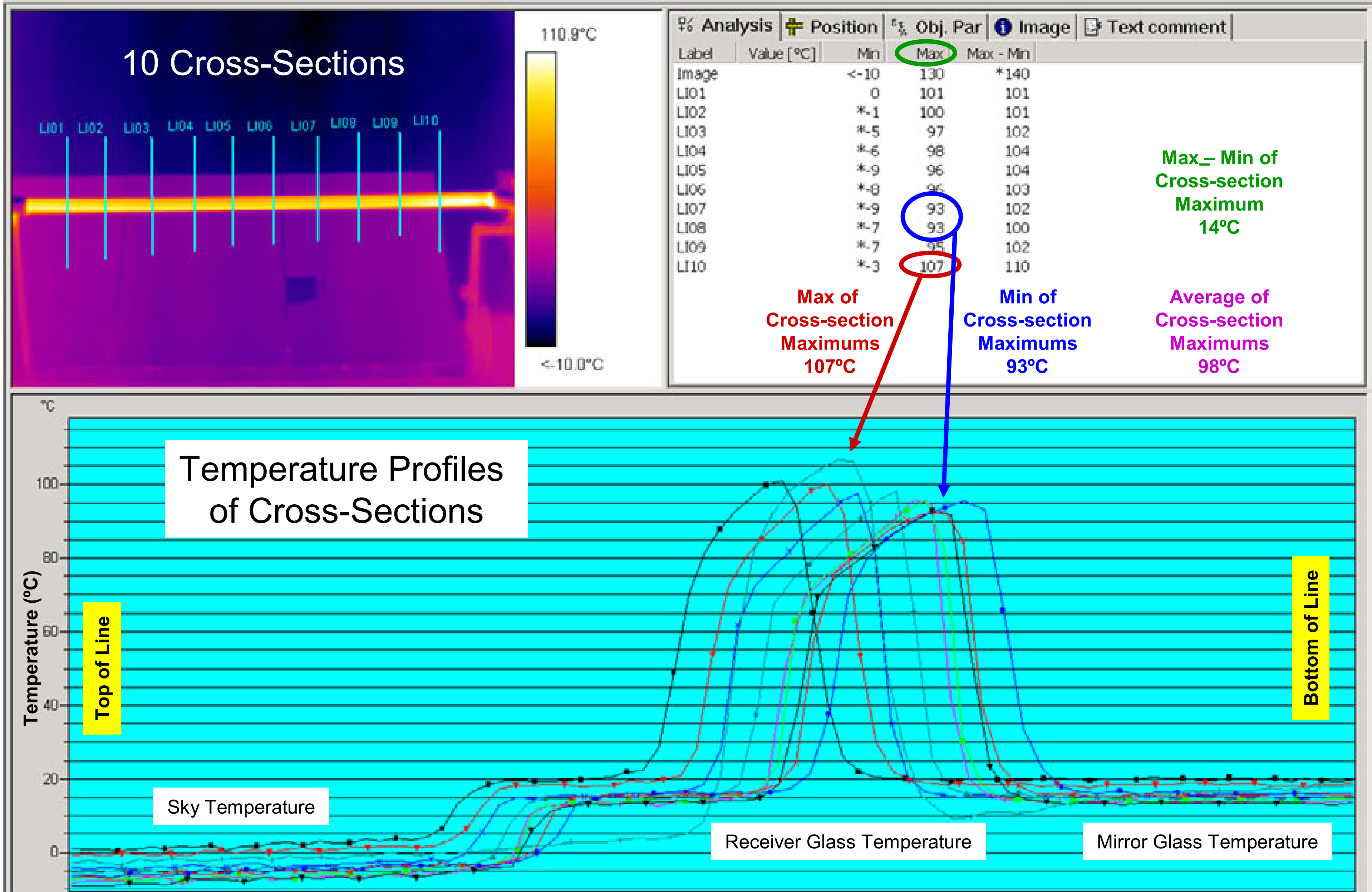
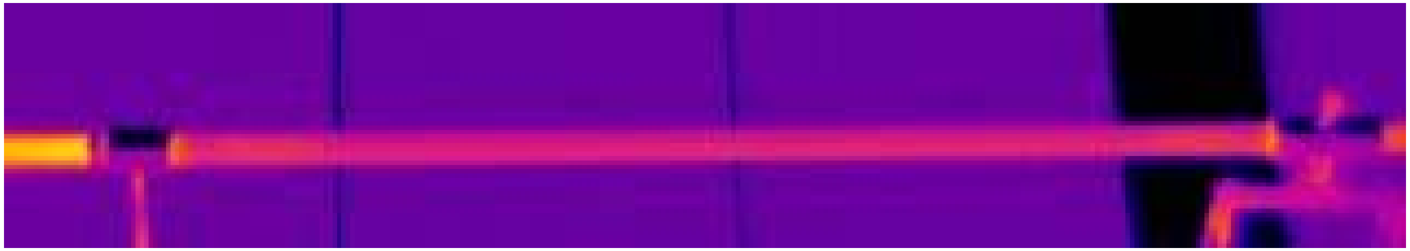
IR Camera Analysis Software



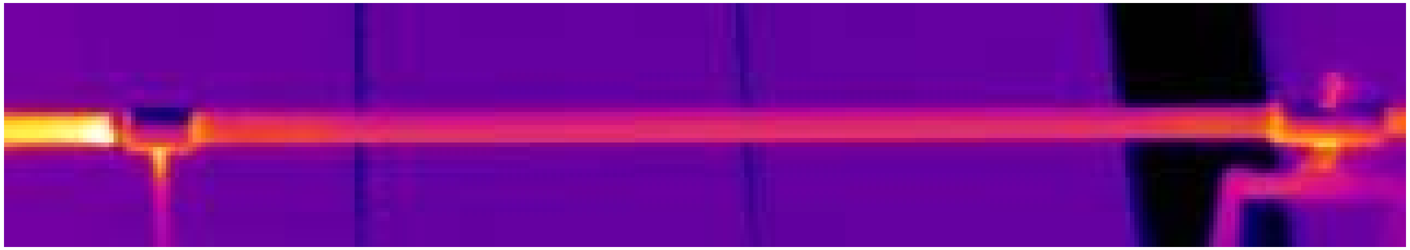
Label	Value [°C]	Min	Max	Max - Min
Image		<-10	130	*140
LI01		0	101	101
LI02		*-1	100	101
LI03		*-5	97	102
LI04		*-6	98	104
LI05		*-9	96	104
LI06		*-8	96	103
LI07		*-9	93	102
LI08		*-7	93	100
LI09		*-7	95	102
LI10		*-3	107	110

Solel UVAC2 (2 years old) with Vacuum

Visible Image of Receiver – Not Tracking



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

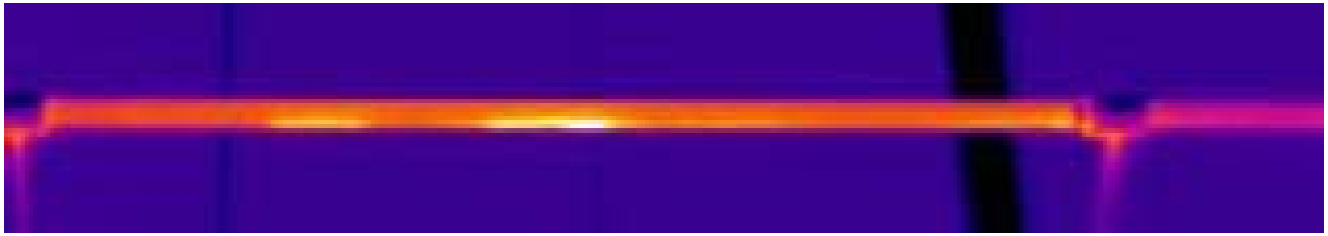


Infrared Image – Tracking (Glass Temp. 68ºC-71ºC)

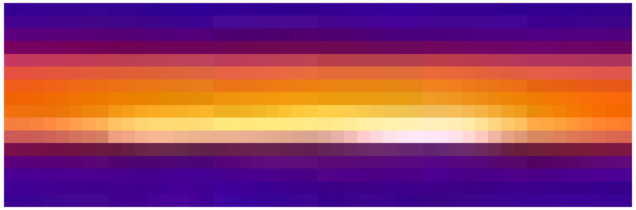
Luz Cermet with Vacuum

Visible Image of Receiver – Not Tracking

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



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



Getter dust is causing hot spots on the glass

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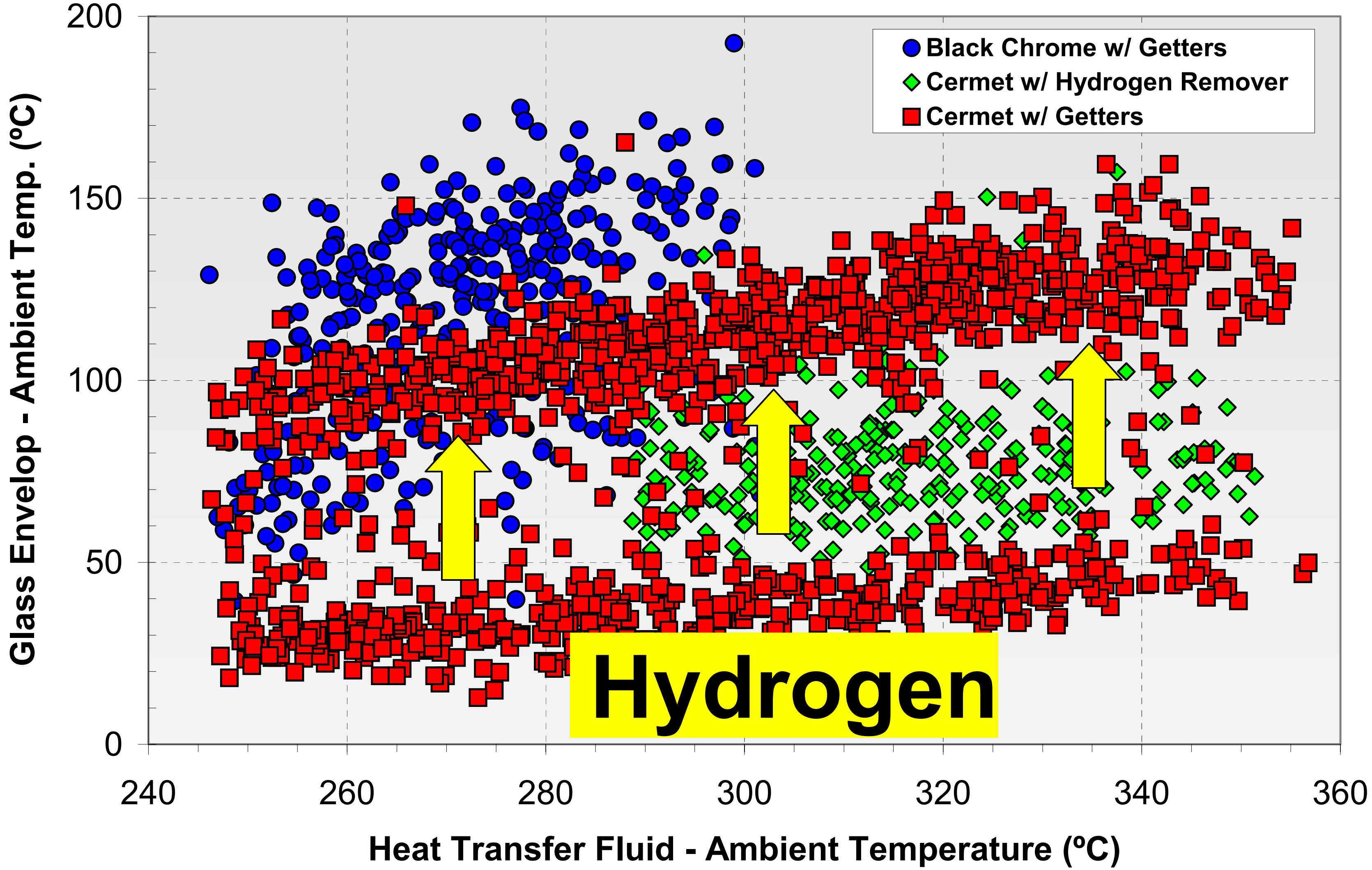
Field Test Results
SEGS VI



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Receiver Field Survey Conclusions

- 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**

IR Camera System Updates

- Improved automation of image acquisition
  - Integration of GPS for automated acquisition of images.

GPS Antenna

GPS Heads-up Display

IR Camera

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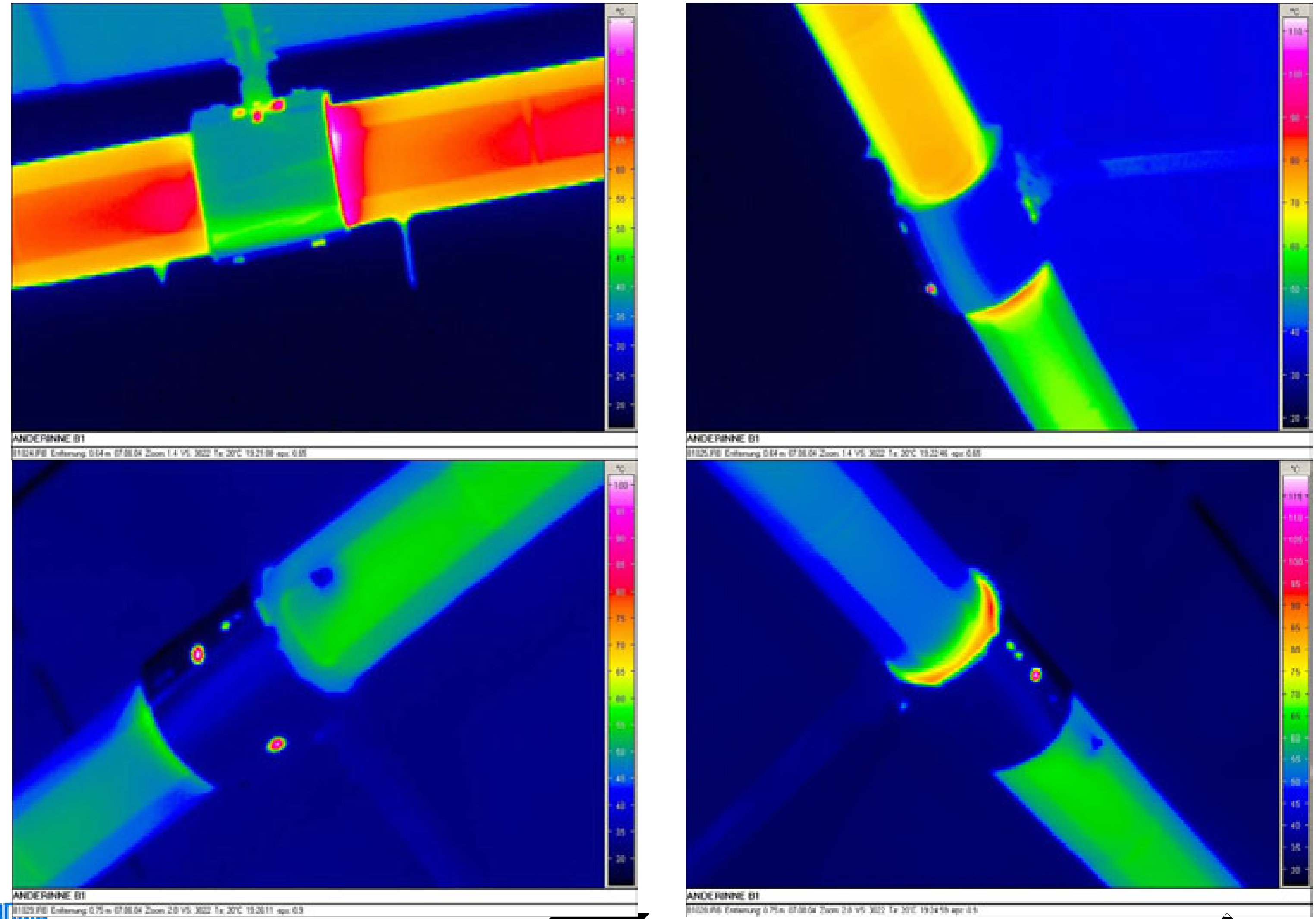
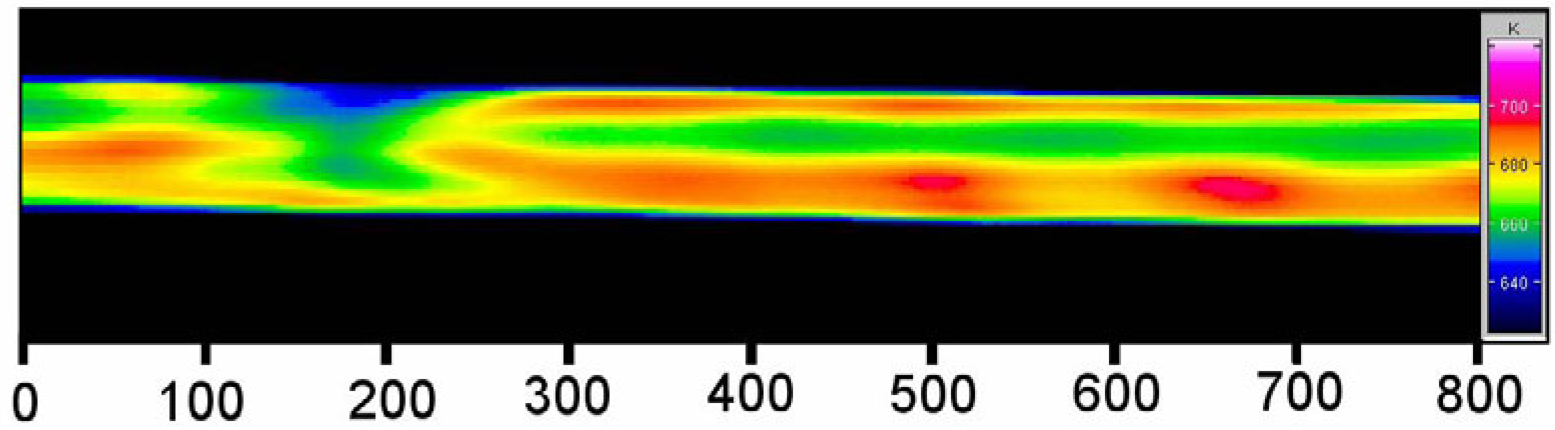
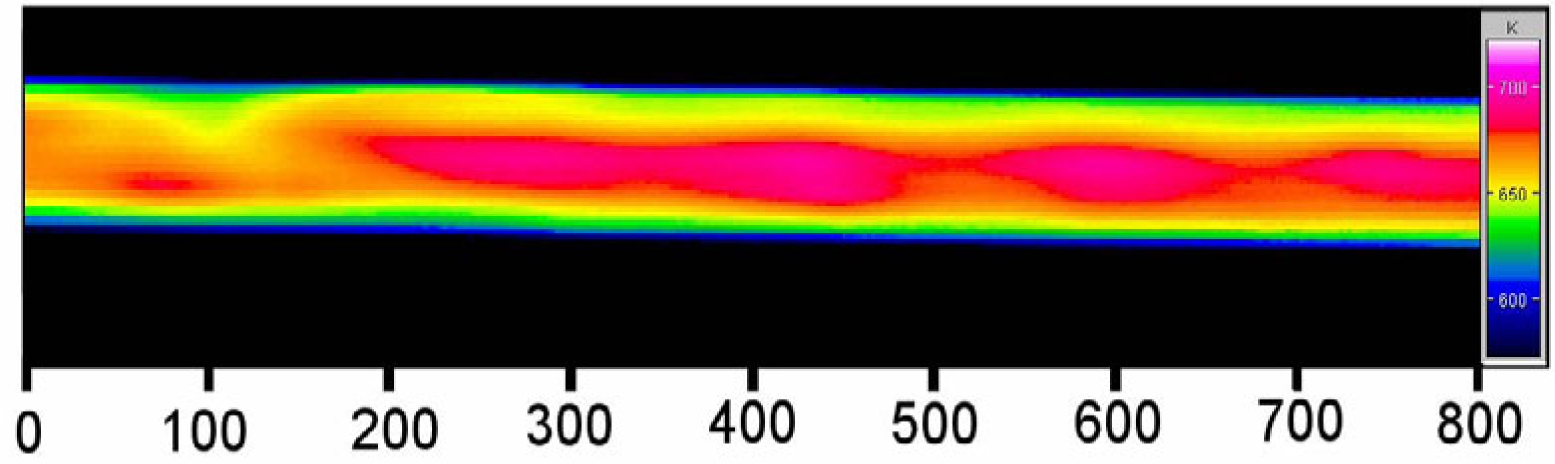
Infrared Camera Measurements through Glass



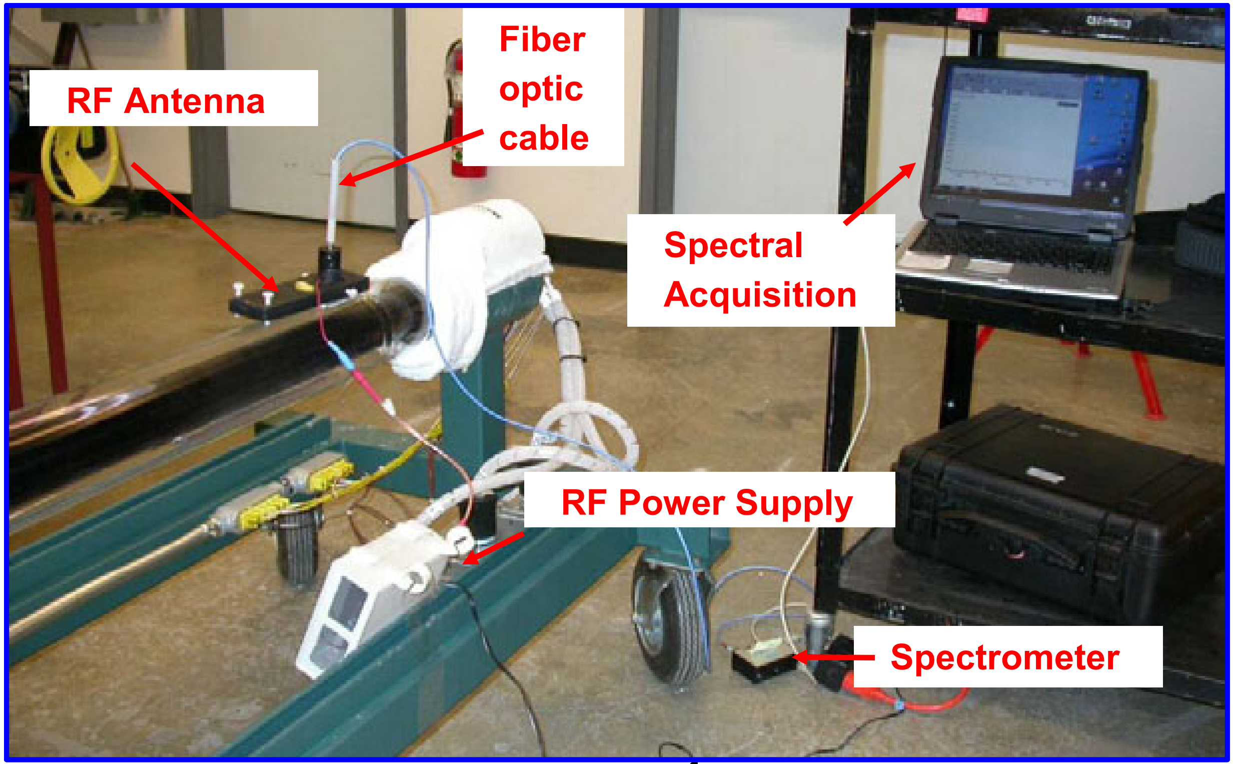
Absorber Surface
Temperature Measurement Results





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.



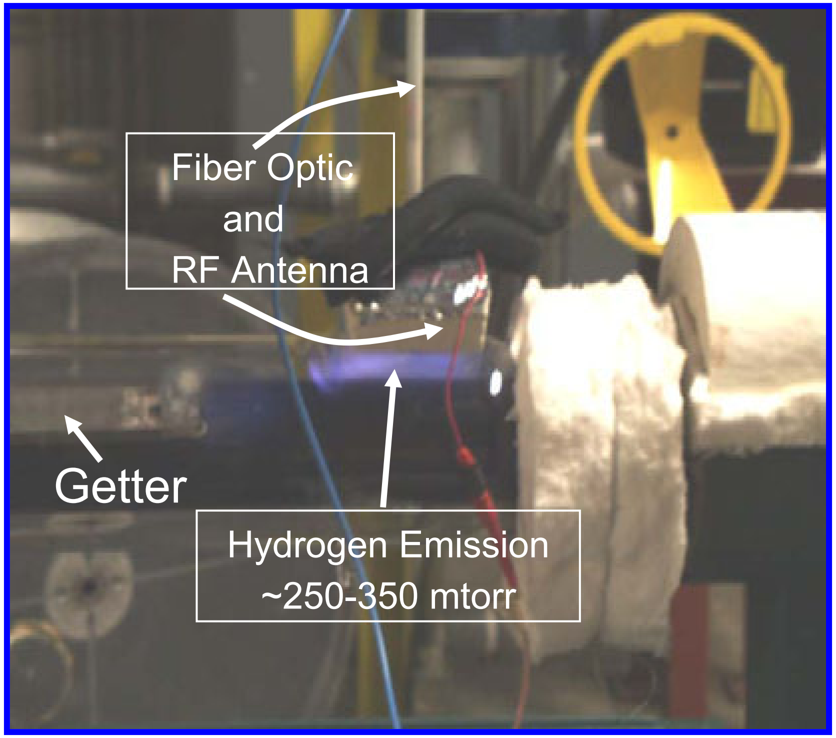
Developed by:

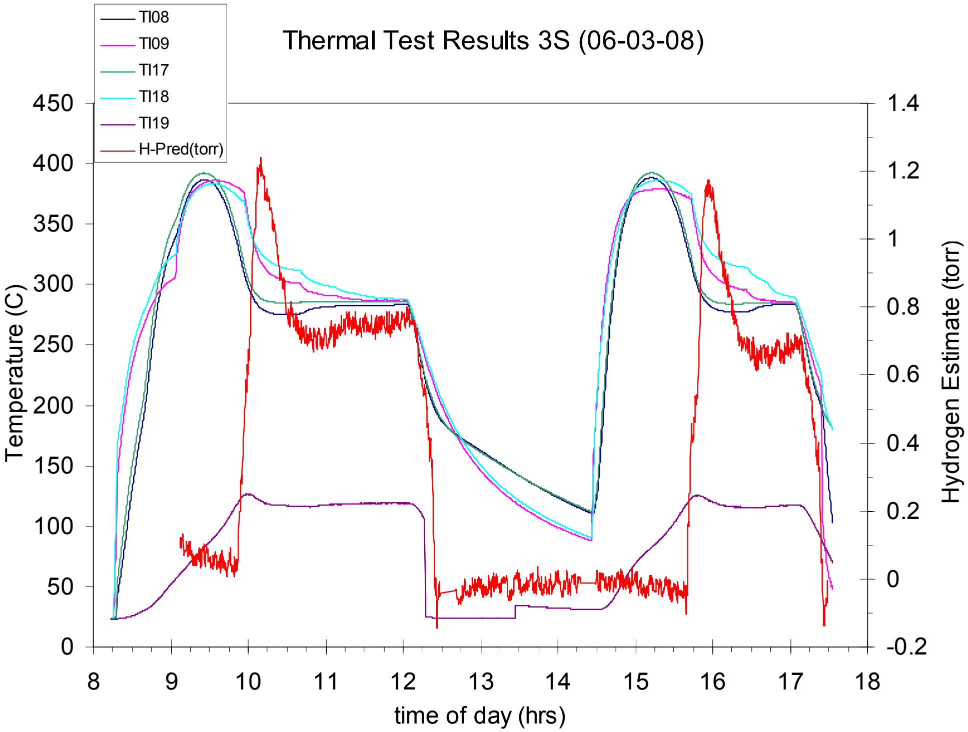
Bob Meglen
Latent Structures
Latent Structures, LLC

&

Ed Wolfrum
NREL

Receiver Test Results
Gas Measurement





- **Hydrogen detected above ~300ºC**
- **Corresponds to Increase in Glass Temperature & Increased Thermal Losses on Hot Receiver**

Latent Structures, LLC

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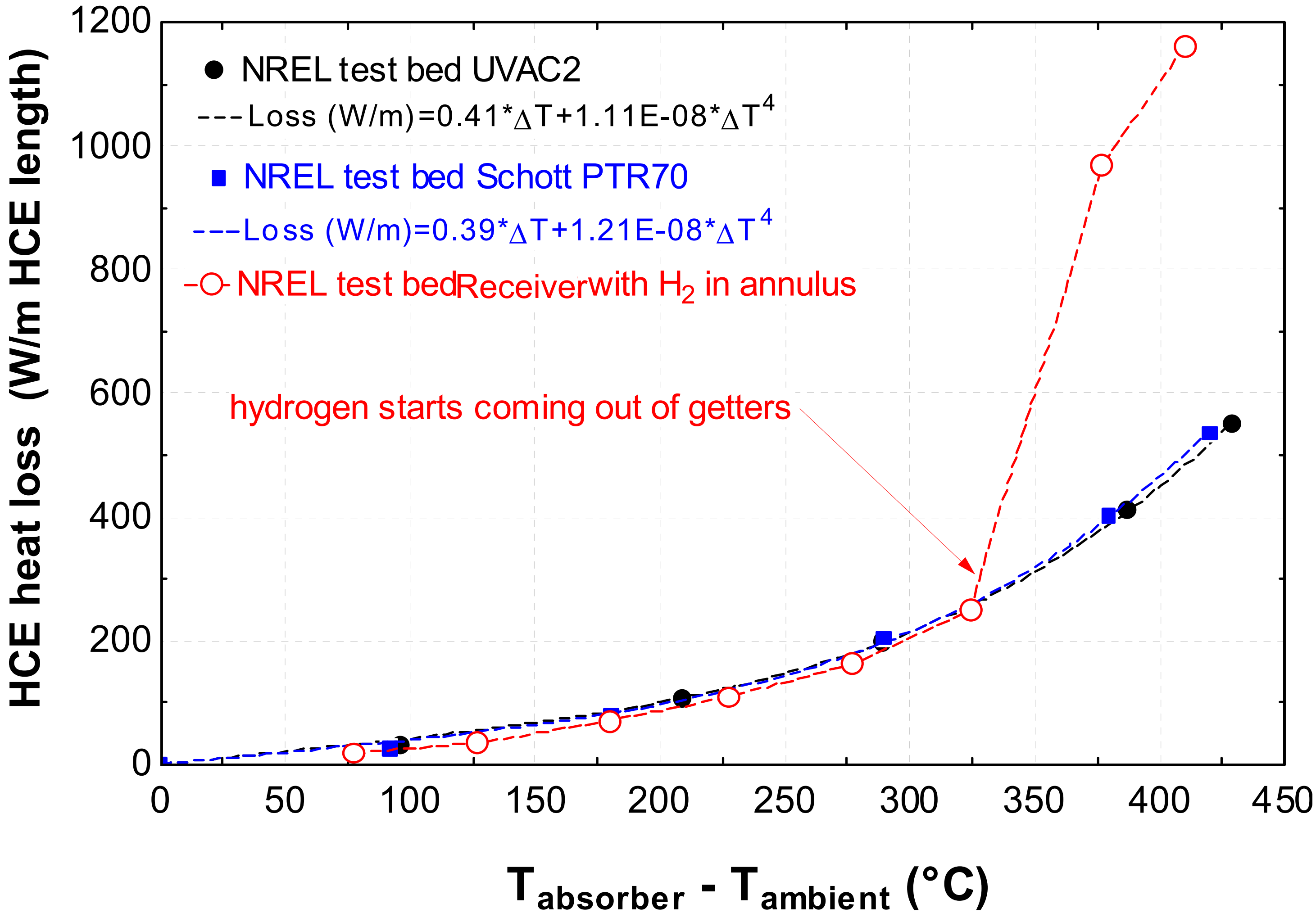
Receiver Test Results

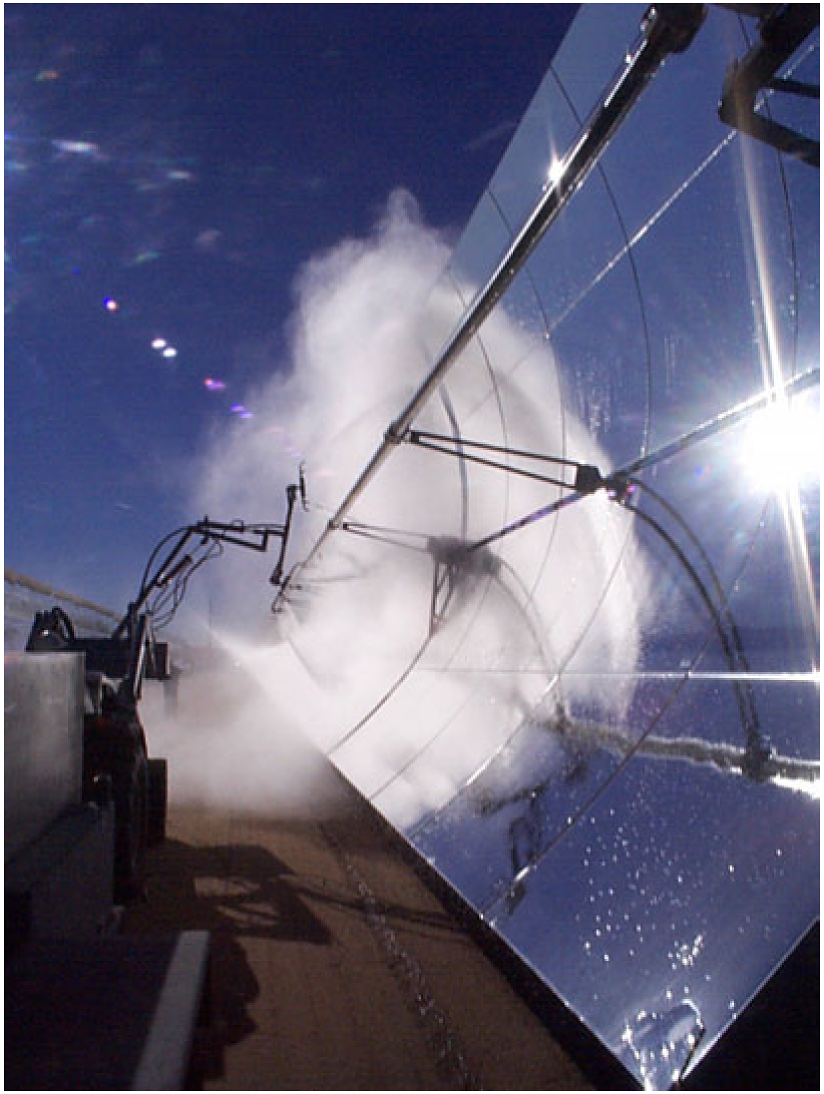


Receiver Test Conclusions
Conclusions

- Outdoor testing
  - 2-axis
  - Single collectors
  - Field Test Loops
- Indoor testing
- Rapid Field Observations

Mirror Washing

High Pressure Spray with Demineralized water



Mirror Washing

Deluge wash with Demineralized water


Thank You