
STERG
SOLAR THERMAL ENERGY
RESEARCH GROUP

Development of an open volumetric air receiver for a rock-bed thermal energy storage system

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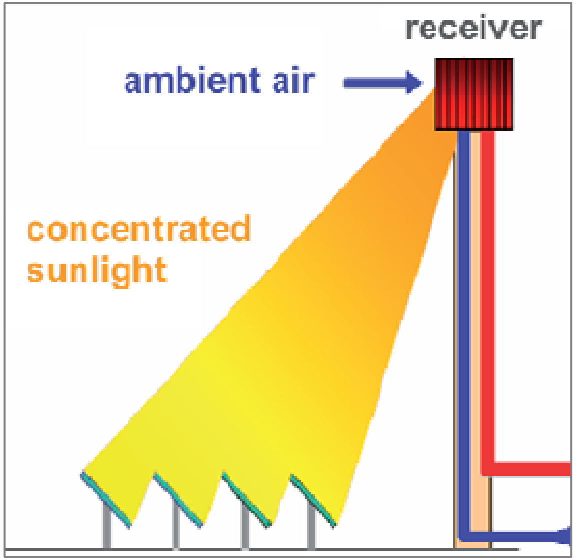
Agenda

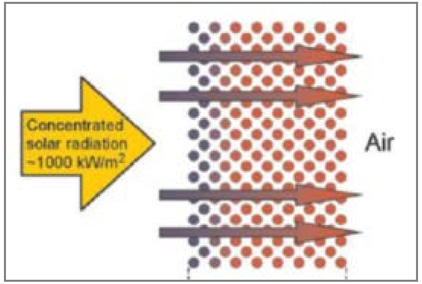
1. Background
2. Project Objective
3. Concept
4. Experimental Setup
5. Results and Discussion
6. Conclusion

1. Background

Open Volumetric Air Receiver (OVAR)

- Highly porous structure absorb concentrated solar radiation
- Ambient air sucked through absorber and heated
- Advantages?
  - Simple design & HTF
- Difficulties?
  - Poor heat transfer characteristics of air



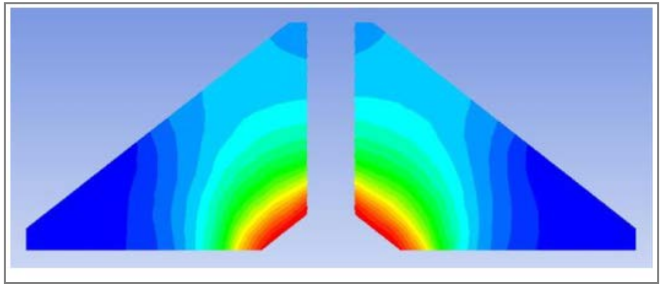


Source: (Fend 2010)

1. Background

Rock-bed thermal energy storage system

- Conical shaped packed bed of rock
- Charging conditions:
  - Ambient air
  - 550 êC – 600 êC
- Currently uses gas-burner to heat up air
- Located at SUNREC where Helio100 is also installed



Source: (Laubscher, 2016)

2. Project Objective

- **Design and develop a prototype of an OVAR to charge the RBS system**

- Key considerations:
  - Simple and cost effective design
  - Use local materials and manufacturing

- First step: Identify suitable absorber material and a scalable receiver design
  - Based on operating conditions – metallic absorber

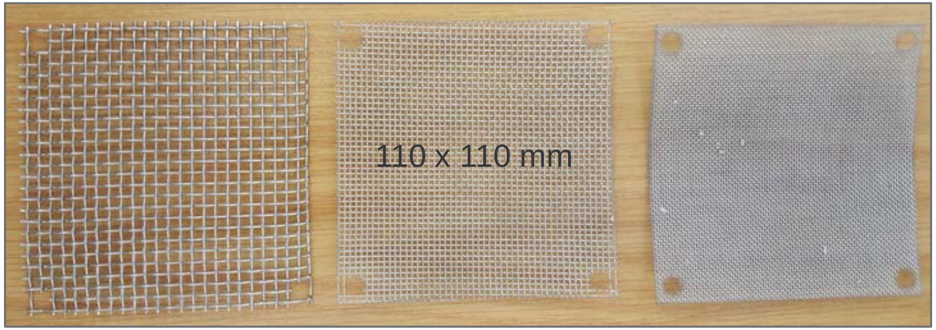
3. Concept

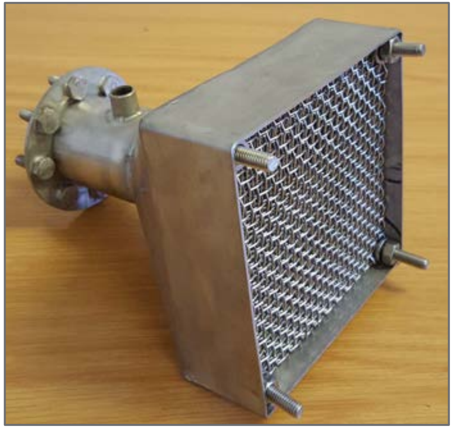
Absorber module

- Gradual porosity wire mesh absorber
- Modular cup based on HiTRec
- Stainless steel 316
- Mesh properties:

	M6	M12	M24
Wire diam [mm]	0.9	0.55	0.37
Aperture [mm]	3.33	1.57	0.69
Open area ratio	0.62	0.55	0.42

M6 M12 M24

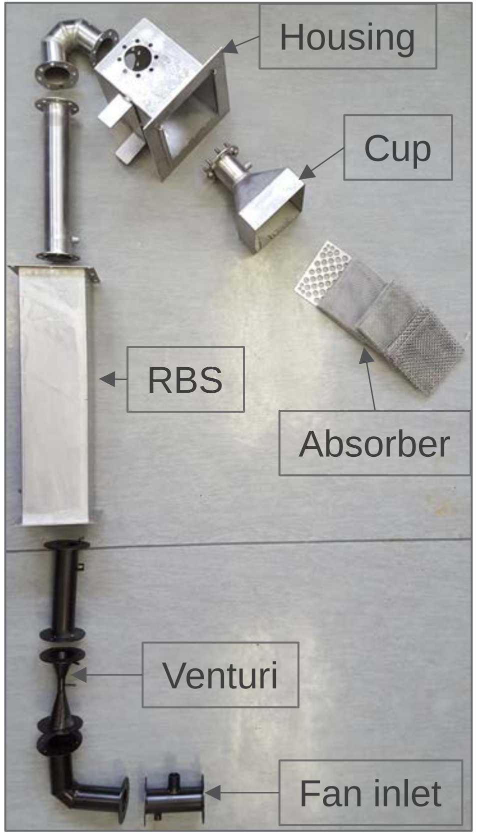




4. Experimental Setup

Test Setup

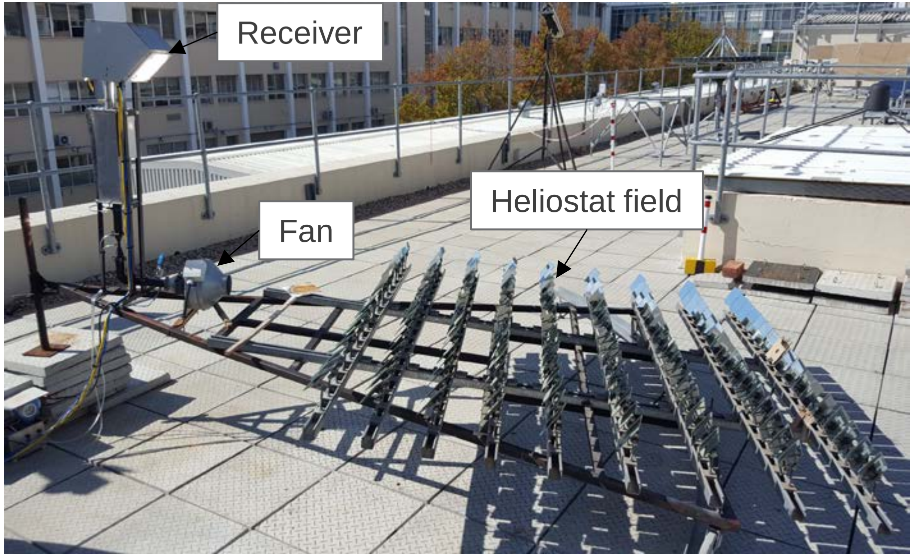
- Component layout based on previous design
- Housing used to simulate adjacent cups and for insulation
- RBS included to cool down air before fan inlet
- Venturi flowmeter used to measure flowrate of air through receiver
- Variable speed fan to control flowrate



4. Experimental Setup

Test Conditions

- Medium flux concentrator
  - 152 mirrors, 100 x 100 mm each
  - Concentration ratio = 71.9
  - PoA = 826 W with DNI = 950 W/m^2
- Different mesh configurations
  - (5/10/10); (5/5/5); (6/4/2) etc.
- Different air flowrates
  - From 0.0010 kg/s to 0.0014 kg/s
- Different weather conditions
  - DNI, wind speed

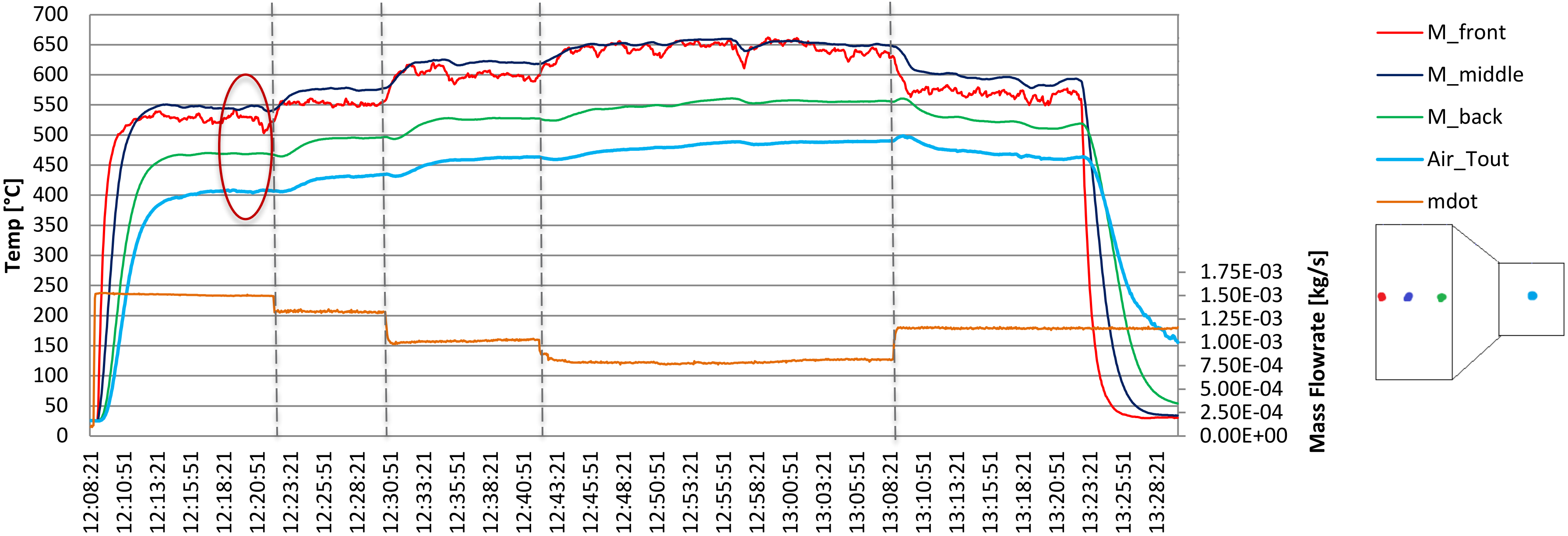


5. Results and Discussion

Date: 6 June 2017
DNI = 775 ë 8 W/m^2
Avg. Temperature = 22 êC
Avg. Wind speed = 3.1m/s

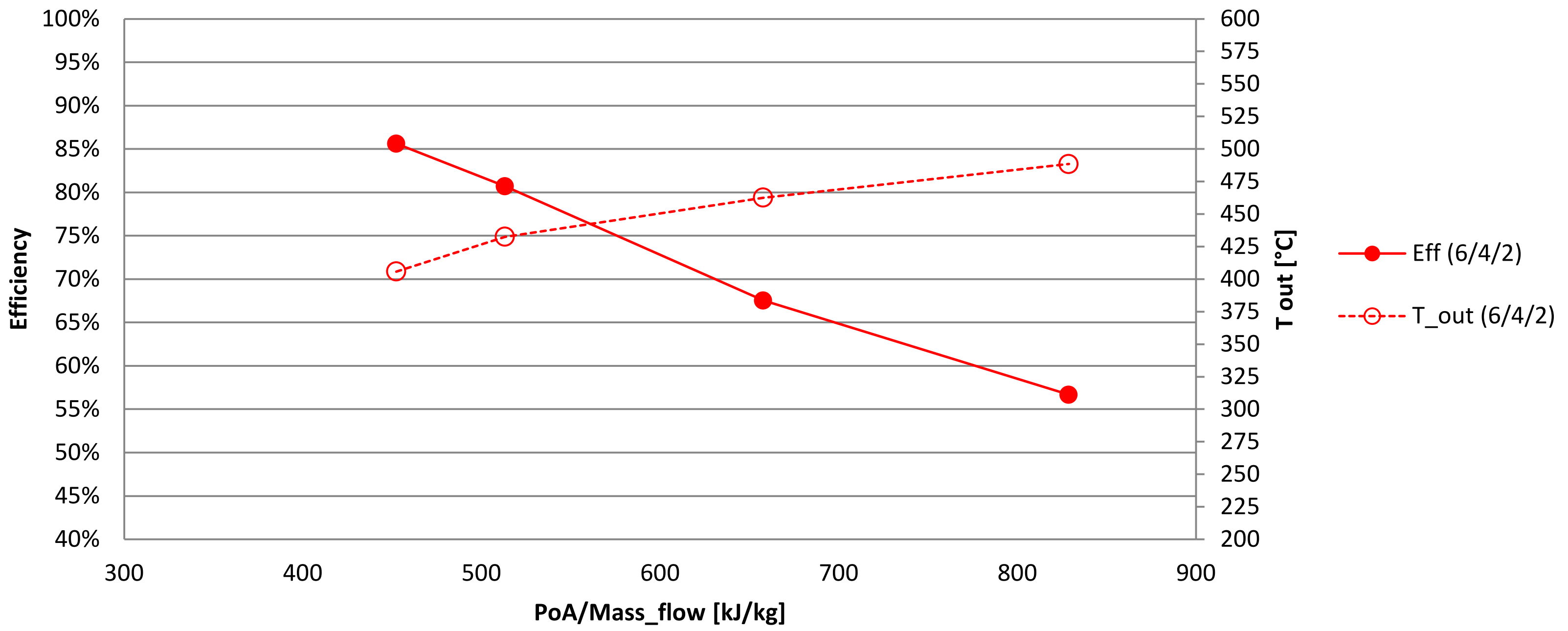
Temperature Measurements

- (6/4/2) mesh configuration



5. Results and Discussion

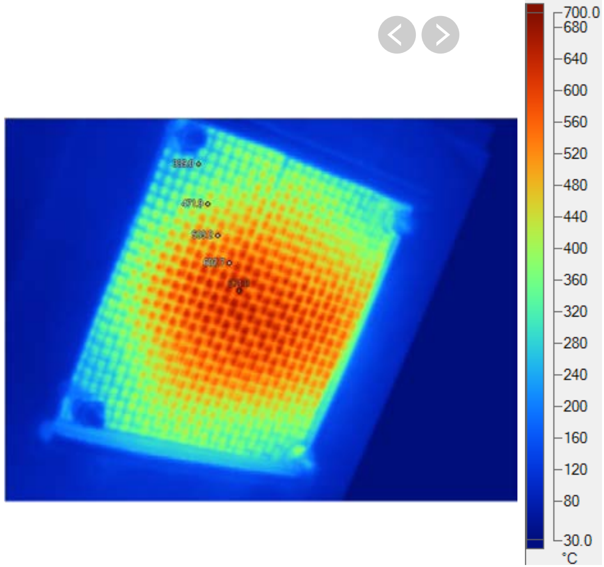
Performance



5. Results and Discussion

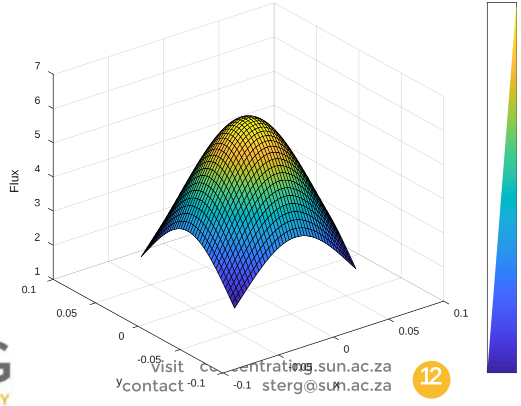
Thermal camera

- Thermal images only used to see temperature distribution over mesh
- Volumetric effect supported
- Gaussian flux distribution visible



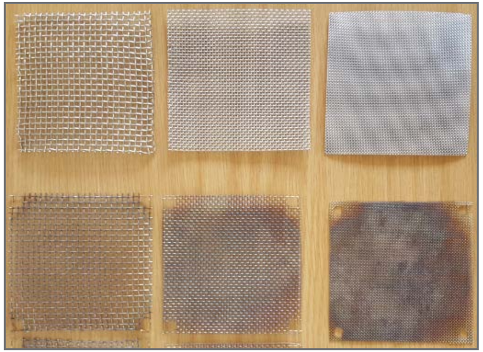
$$I_s(x,y) = F_{peak}\, e^{\left(\frac{-(x^2+y^2)}{2\sigma^2}\right)}$$

$$P_{inc} = \int_{-y}^{y}\int_{-x}^{x} I_s(x,y)\cdot dx \cdot dy$$



5. Results and Discussion

Observations during testing



- Mesh oxidization
  - Darker colour, less reflection
- Environmental influences
  - Wind clearly have major influence on performance
- Test setup design and operation
  - Easy to test different absorbers
  - Allow future optimization ito ARR and other absorber materials

6. Conclusion

- OVAR concept was developed and tested on an experimental setup
- Gradual porosity wire mesh proofed to be a suitable volumetric absorber for the purpose of charging the rock-bed storage
- Modular cup design proofed to have several advantages
- Next step will be to:
  - Test a small receiver which consist of more than one of these cups
  - Further optimize mesh configuration

Thank you for your attention

ACKNOWLEDGEMENTS:

CRSES
STERG

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References

- Fend, T., 2012. Characterization of Advanced Solar Air Receiver Materials. , pp.1–27.

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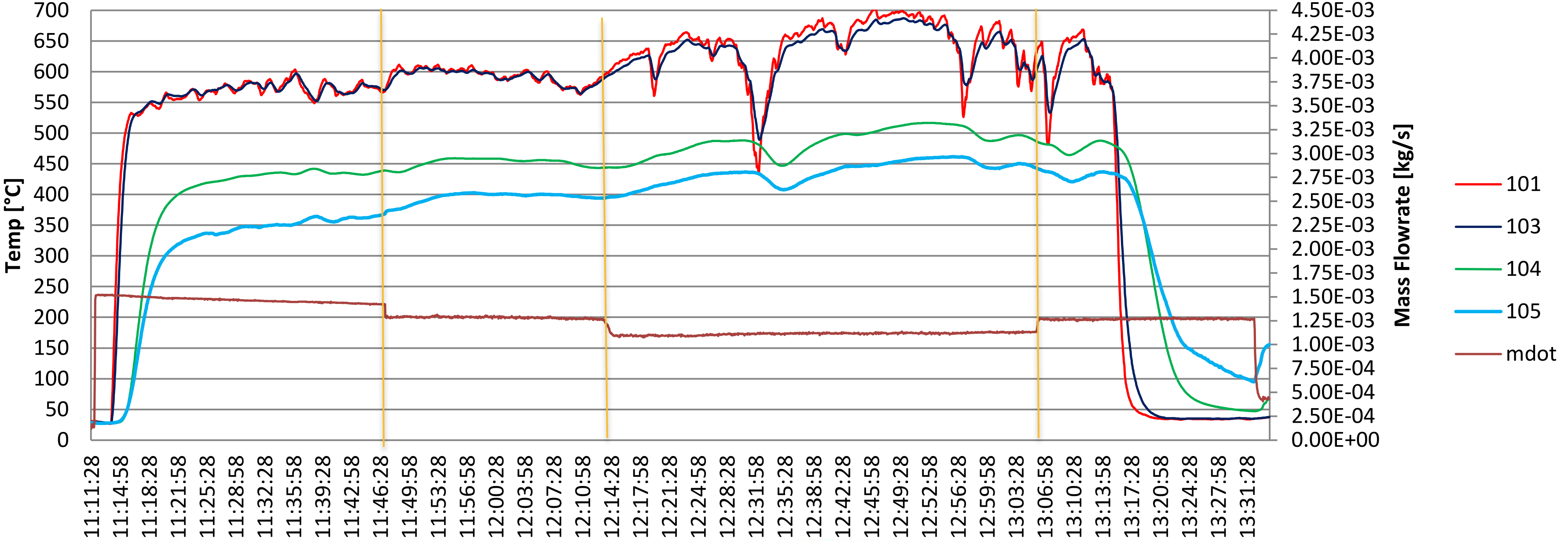
5. Results and Discussion

Date: 28 April 2017
Avg. DNI = 662 W/m² (730 W/m²)
Avg. Temperature = 28 êC
Avg. Wind speed = 2.98 m/s

Temperature Measurements

- (5/10/10) mesh configuration



5. Results and Discussion

Quasi steady state

- (6/ 4/ 2) mesh configuration

				Flowrate 1
Measured	mdot	kg/s	0.001501
	T_out	°C	**405.75**
	T_front	°C	529.80
	T_amb	°C	21.73
	DNI	W/m^2	785.85
Calculated	PoA *	W	678.93
	Q_out	W	582.52
	Efficiency	%	**85.80**
	PoA/mdot	kJ/kg	452.37

$$PoA = DNI \times c \times A_{rec}$$

$$Q_{out} = \dot{m} \cdot c_p \cdot (T_{out} - T_{amb})$$

$$\eta_{th} = {Q_{out}}/{PoA}$$

* PoA = Power on Aperture

4. Experimental Setup

Measurements

- Temperature:
  - Thermocouples
    - 8 Type K (no. 1 - 8)
    - 6 Type T (no. 9 - 12)
  - Thermal camera
- Flow rate:
  - Pressure transducer
- Weather:
  - Sonbesie weather station, roof of M&M