Progress in Obstructed Flow Particle Receiver Research

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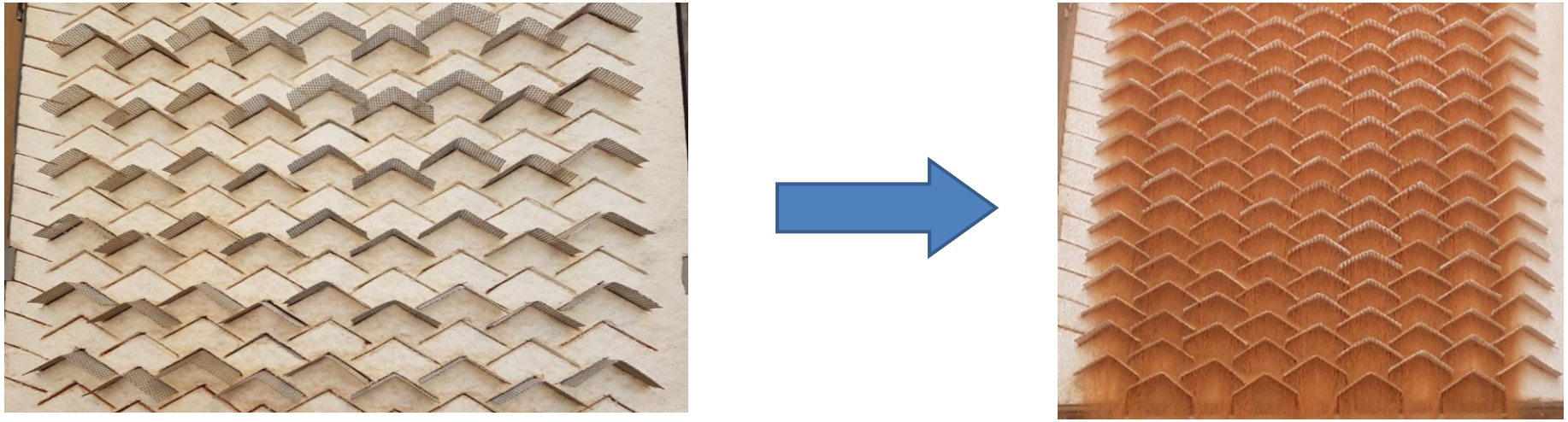
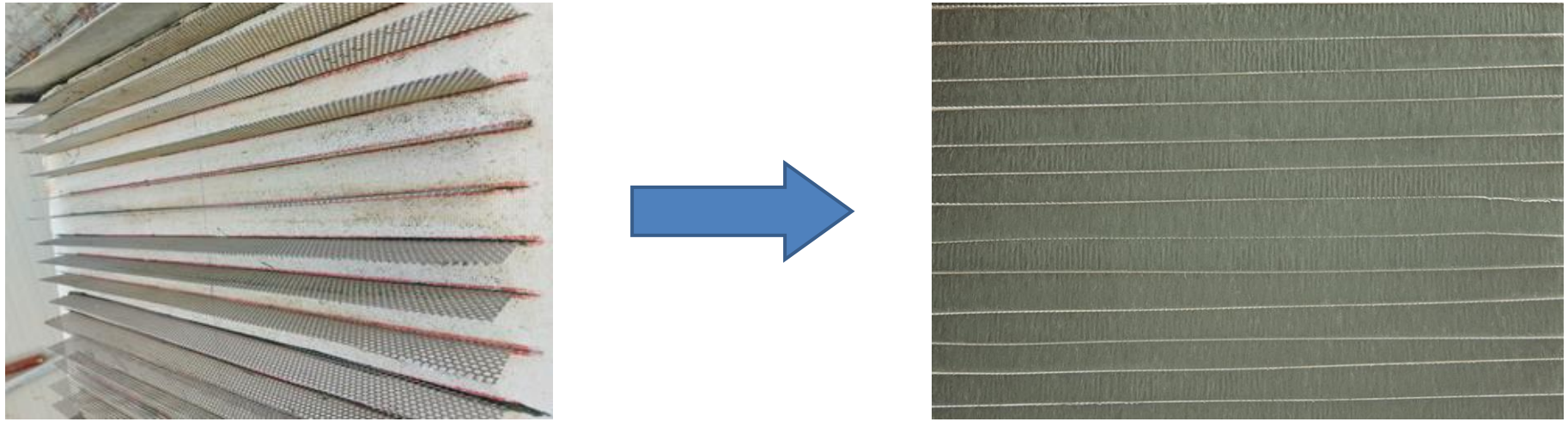
What is an Obstructed Flow Receiver?

- Obstructions at short and regular intervals regulate the flow of particles





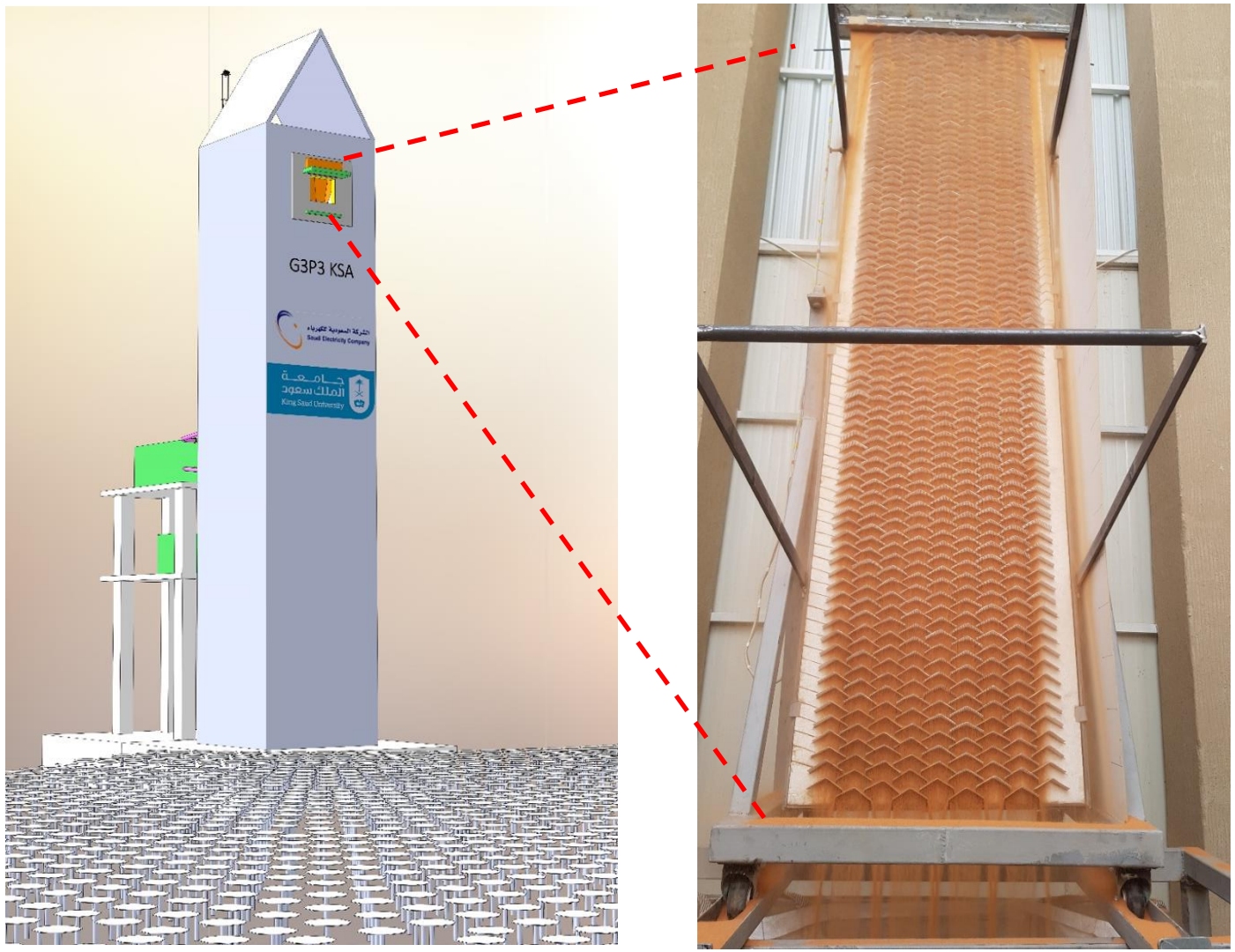
Benefits of Obstructed Flow Receivers

- Tight control of particle speed
  - **Longer residence time**
  - **Larger temperature rise across a small drop height**
- High efficiency due to high opacity
- Dispersed curtain
  - **Good mixing along the way**
  - **Inherently high effective absorptance**

Past Research in Obstructed Flow Receivers

Flow Characterization

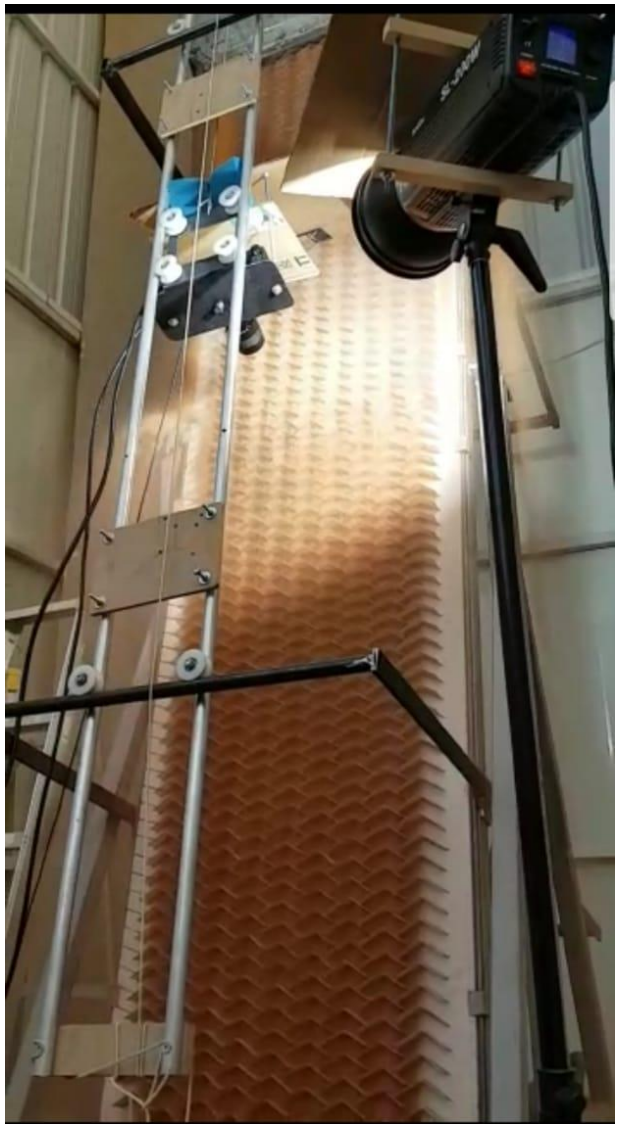
- A full-scale mock-up receiver panel was built
  - **Represents one of five panels to be installed as a part of the Gen3 Particle Pilot Plant (G3P3) project supported by DOE**



Past Research in Obstructed Flow Receivers

Flow Characterization

- Measurements included:
  - **Particle velocity (using PIV techniques)**
  - **Particle retention**
  - **Curtain opacity**

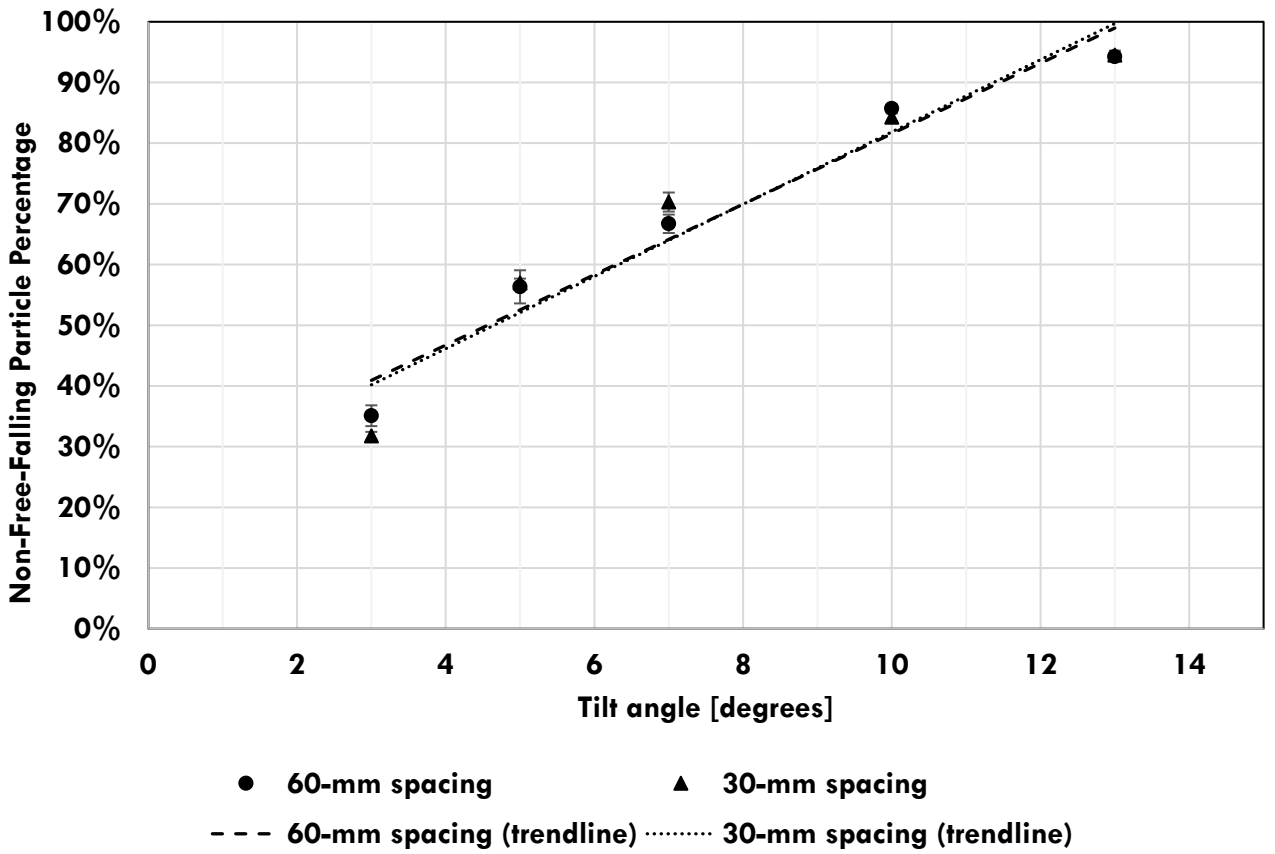


Past Research in Obstructed Flow Receivers

Flow Characterization

- Particle retention near 100% at 15° title angle
- Curtain opacity also near 100%

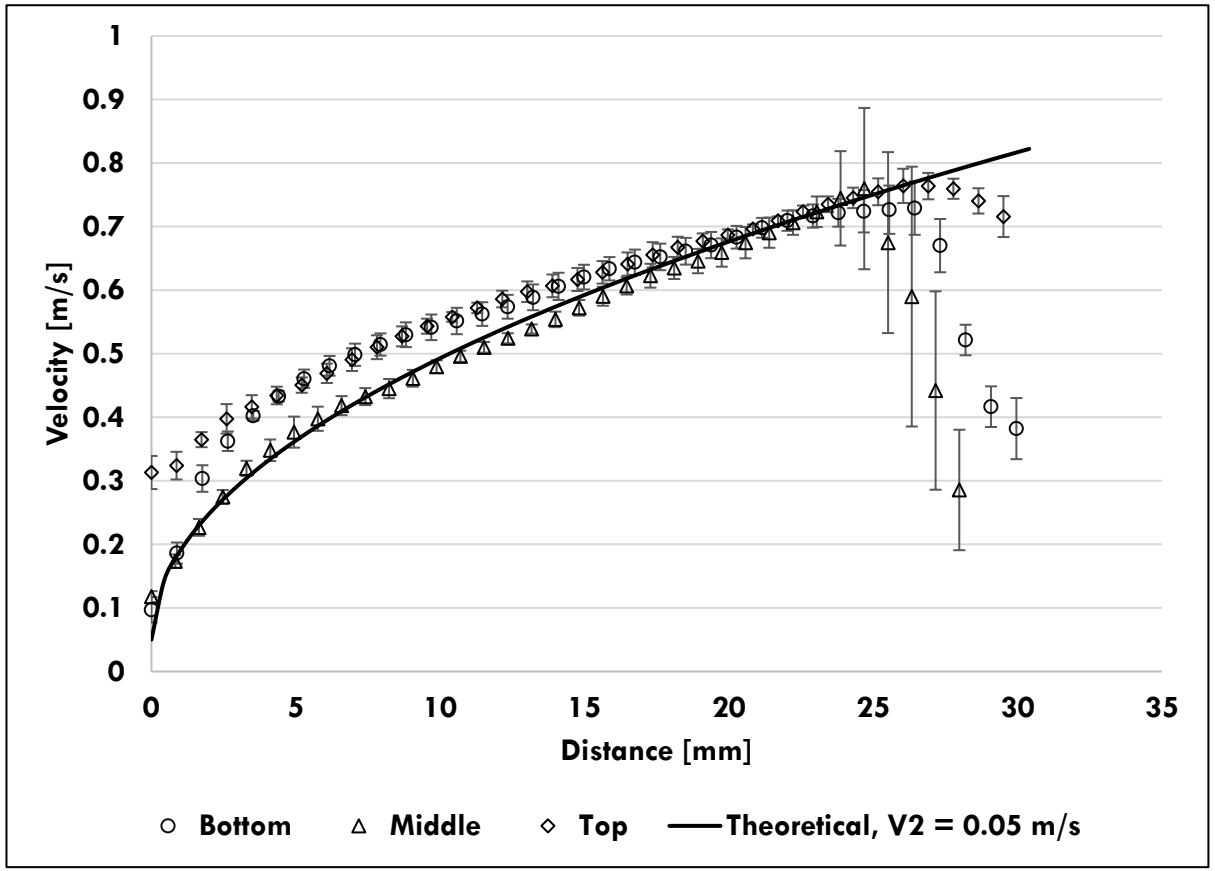
Location	Curtain Opacity
Top	99.90% ± 0.01%
	99.75% ± 0.01%
Bottom	99.74% ± 0.02%
	98.97% ± 0.15%

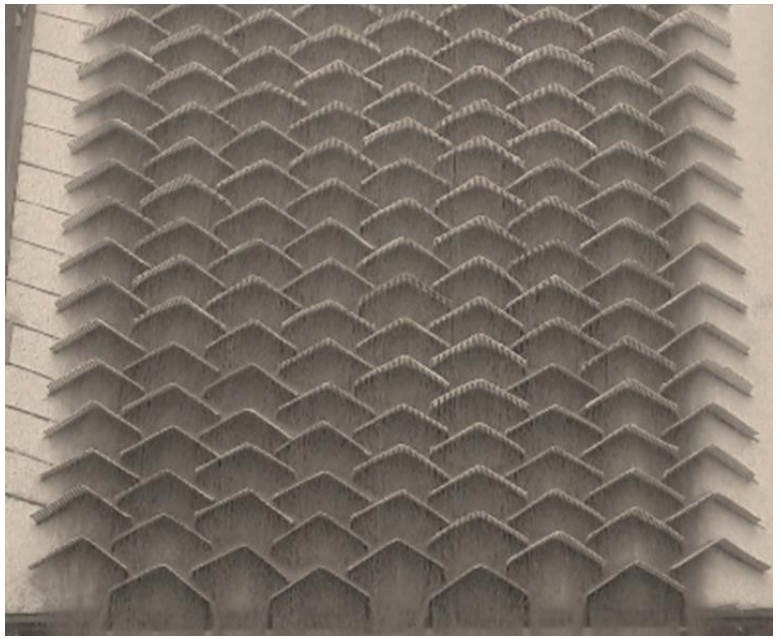


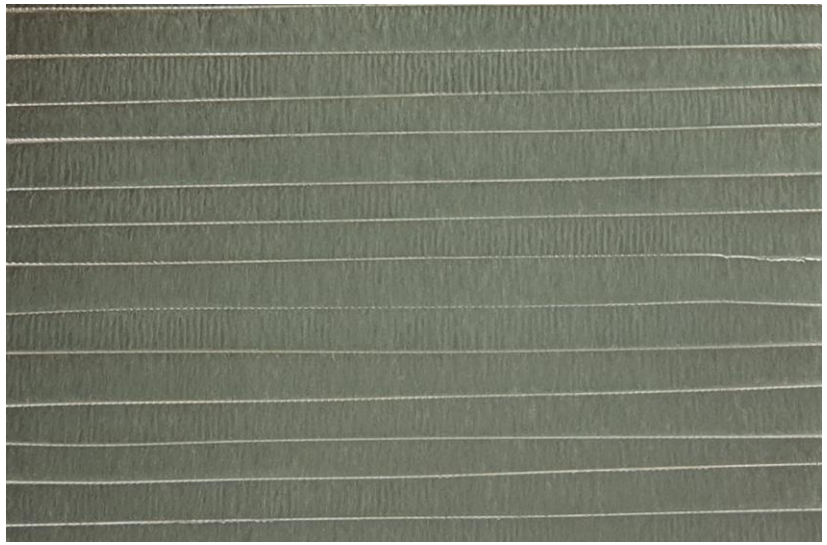
Past Research in Obstructed Flow Receivers

Flow Characterization

- Particle velocity is very well controlled
- Very high flow uniformity



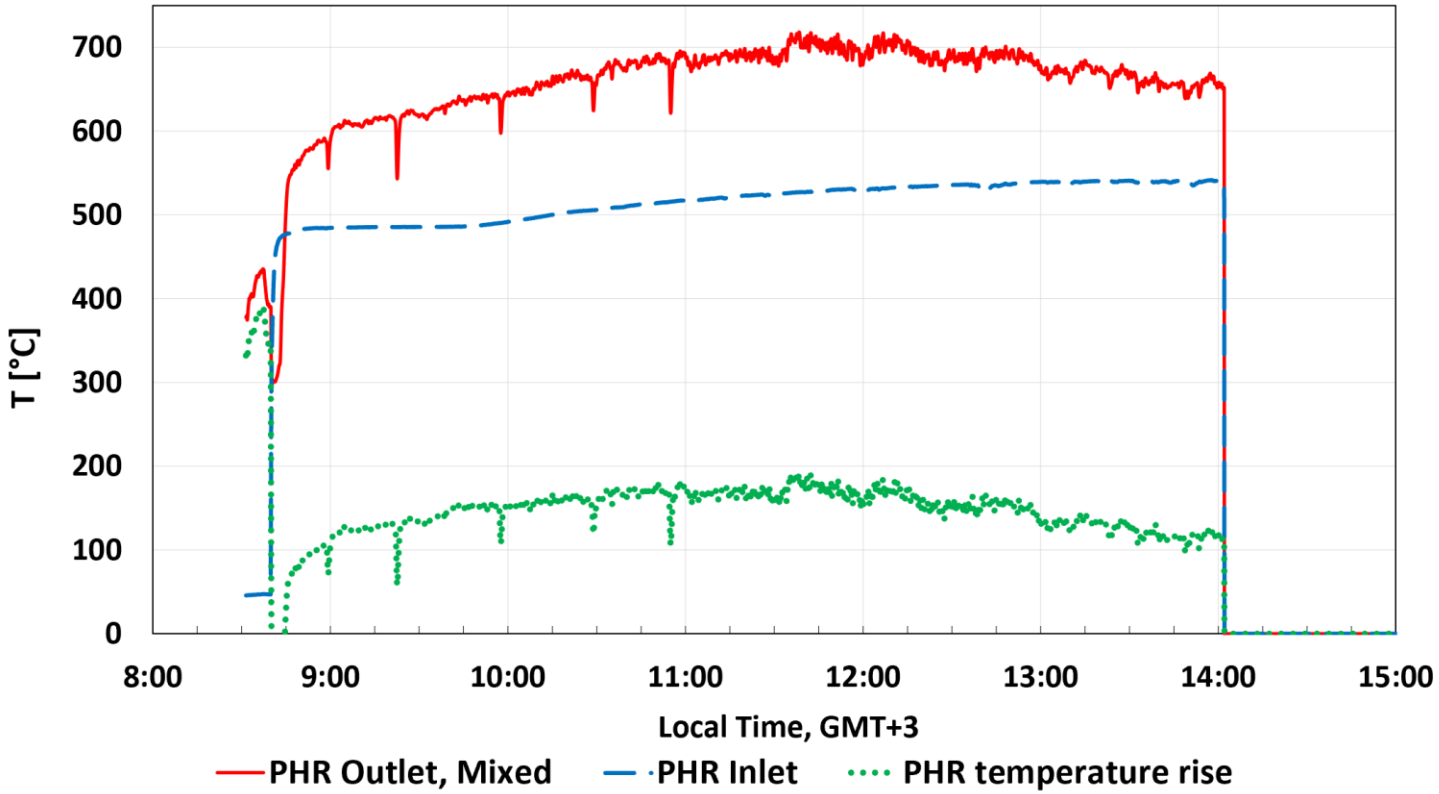




Past Research in Obstructed Flow Receivers

On-Sun Testing

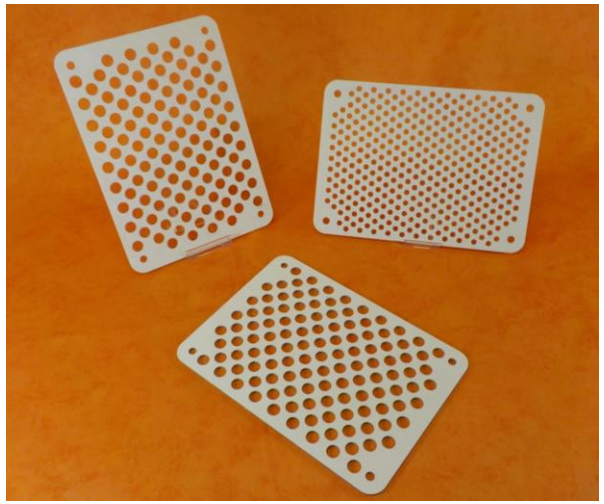
- Temperature rise approaching 200°C within 1 m of drop height
  - **Average flux: ~ 150 kW/m²**
  - **Mass flux: ~ 1 kg/s-m**

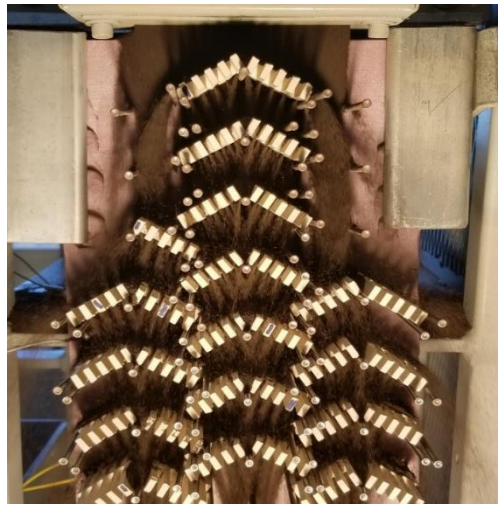


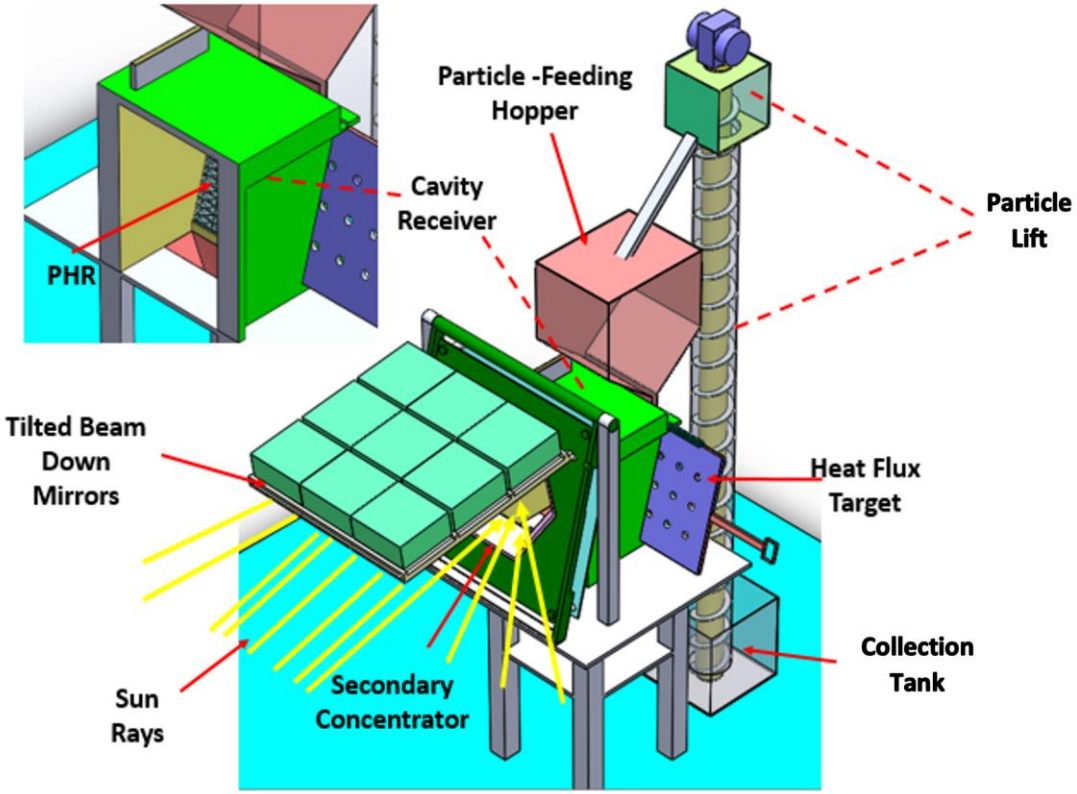
Ongoing Research

Endurance Testing

- Commercial deployment requires robust, highly reliable receiver materials
  - **Target flux: ~ 400 kW/m²**
- Refractory materials are the best candidates
- A high-flux module is being built to test endurance of refractory materials for prolonged periods of time



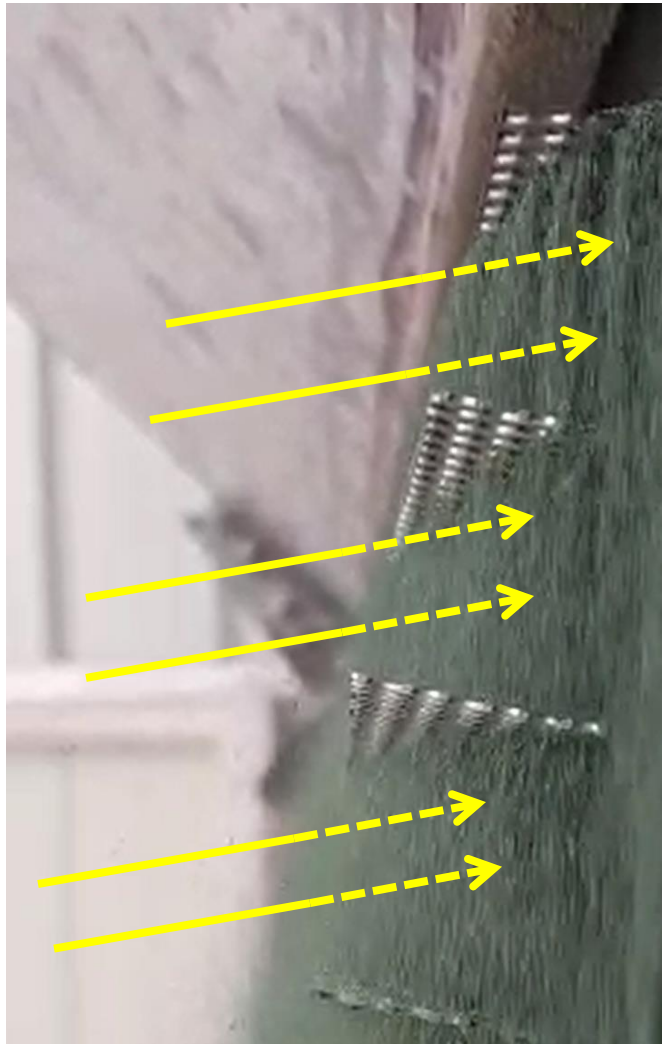




Ongoing Research

Effective Absorptance Testing

- Obstructed flow receivers have dispersed curtains
- Most of sunlight is trapped once it penetrates the curtain
  - **Effective absorptance may be much higher than packed-bed absorptance**
- Opportunity for low-cost natural particulates with low packed-bed absorptance
- The high-flux module will be used for this research as well



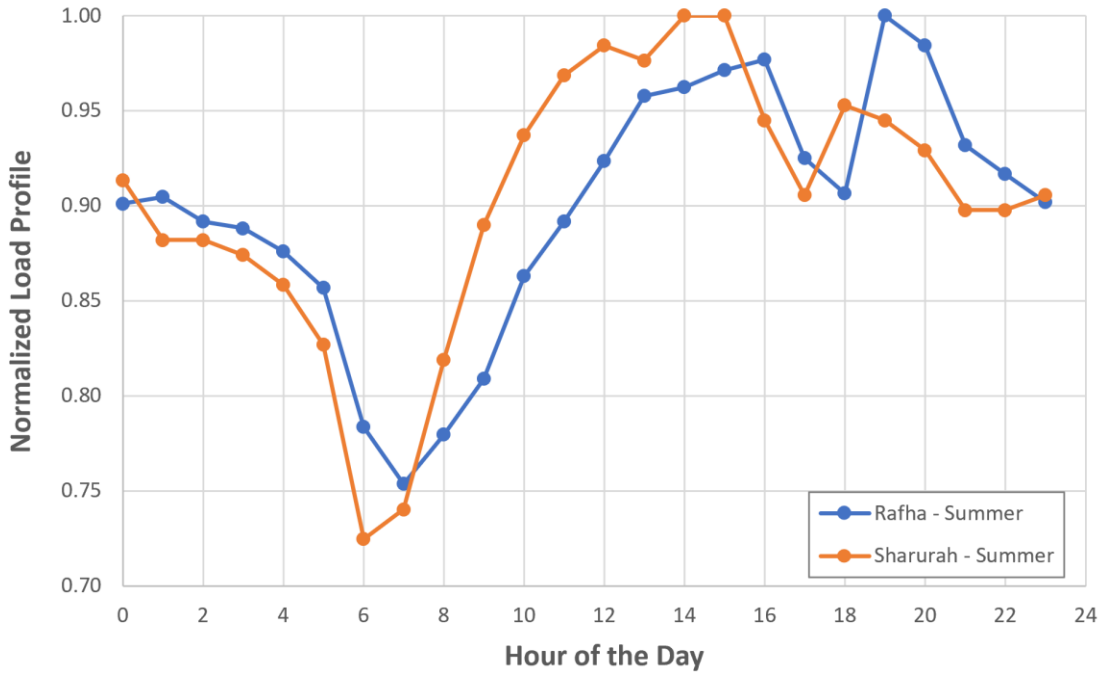
Market for Obstructed Flow Receivers

- Small and medium-scale projects
- Applications with large temperature rises
- These applications require:
  - **Relatively low mass flow rates (1-7 kg/s-m)**
  - **High curtain opacity**
- Obstructed flow receivers are suitable candidates for these applications

Market for Obstructed Flow Receivers

Small and Medium-Scale Projects

- There is a need across the MENA region for off-grid projects
- Long storage hours (high capacity factors) are necessary
  - **Significant peaks in demand well after sunset**
- Example:
  - **Off-grid market size in Saudi Arabia is 470 MW**
  - **Most locations requires less than 5 MWe**

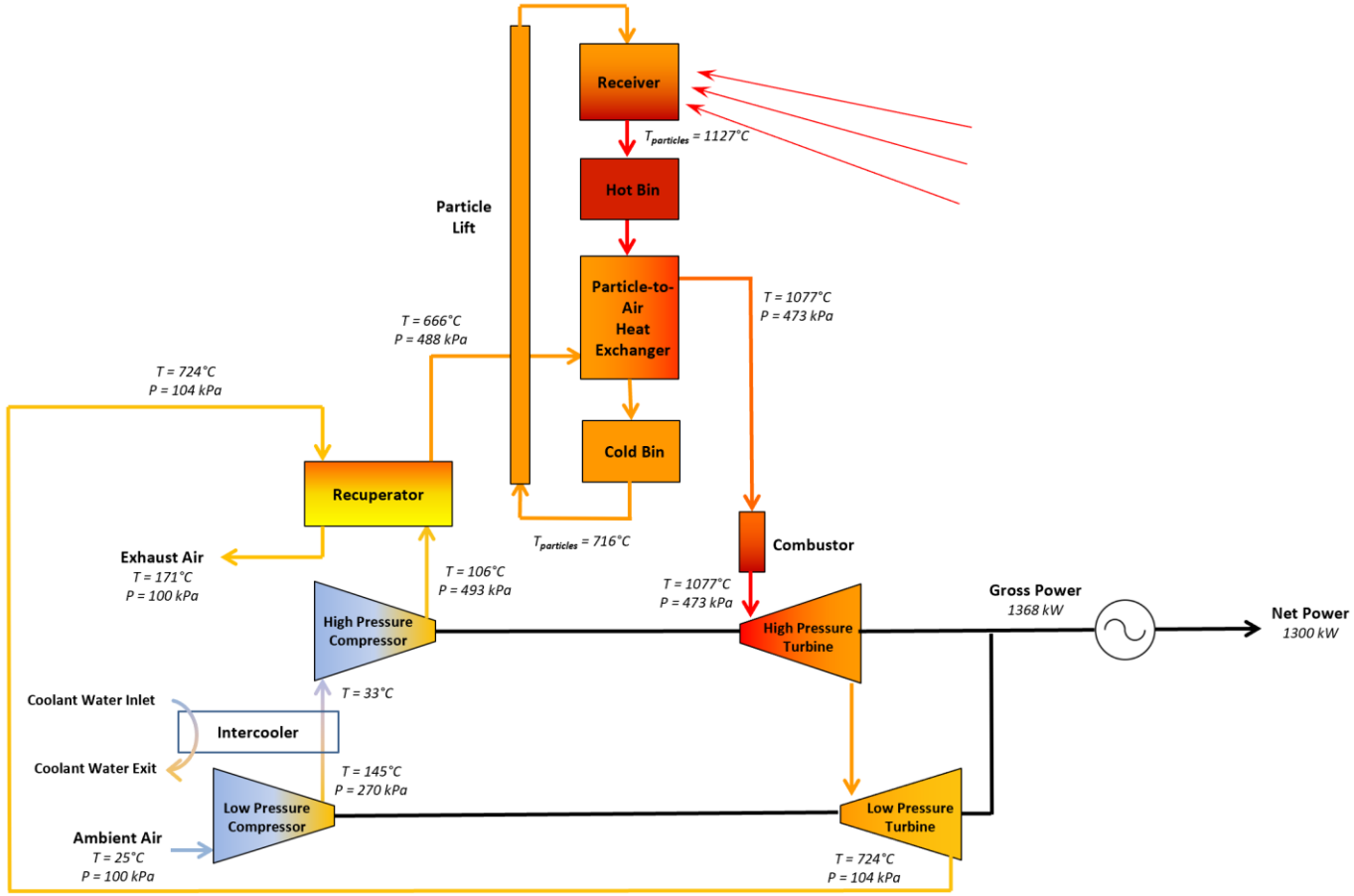


Market for Obstructed Flow Receivers

Large Temperature Rise Applications

Hybrid Solar-Air-Brayton System

- Suitable for the MENA region
  - **Long experience with gas turbines**
- Ready for immediate commercialization
- Requires 400-500°C temperature rise
  - **Mass flow rate will be relatively low**



Energy flow diagram for a 1.3 MWe system

Market for Obstructed Flow Receivers

Large Temperature Rise Applications

Process Heat: Calcination

- Huge demand for process heat applications in MENA and worldwide
- Calcination can take place at temperatures over 800°C
- Heating often starts from ambient temperatures

  → **Temperature rise of more than 700°C!**

- Modular plant design may be preferred (depending on natural resources)
- Mass flow rate will be low

Conclusion

- Extensive research has been done on obstructed flow particle receivers
- The design is becoming mature and close to commercialization
- Robustness needs to be confirmed (G3P3-KSA will do that)
- Measurement of effective absorptance is key to opportunities with low-cost natural particulates with low packed-bed absorptance (testing starts soon)
- Many important applications are in store for this receiver type
- Complements (rather than competes) with other receiver designs

Acknowledgment

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Thank You

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