SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Additively Manufactured Metallic Micro-Pin Array Receivers

SETO Receivers and Reactors Workshop

V. Narayanan, UC Davis

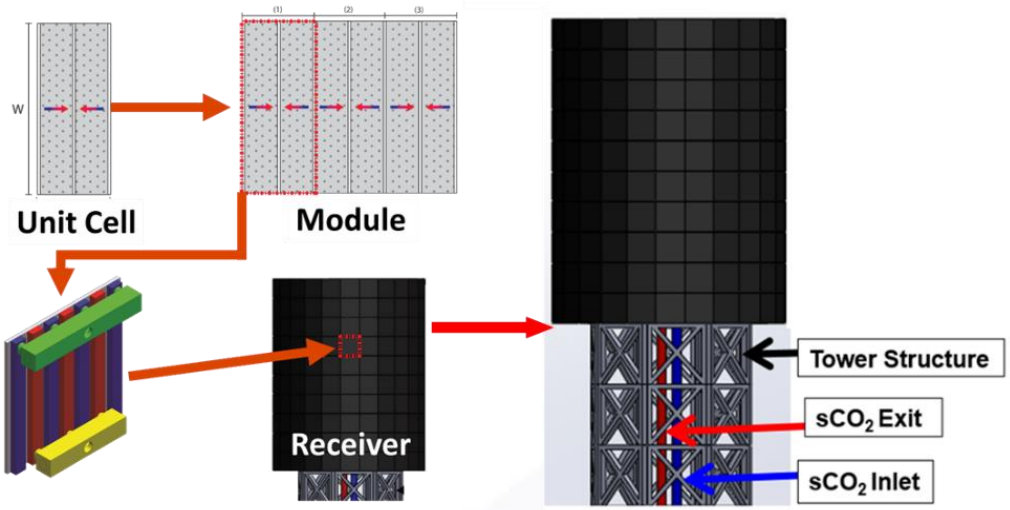
Thursday, February 15th 2024

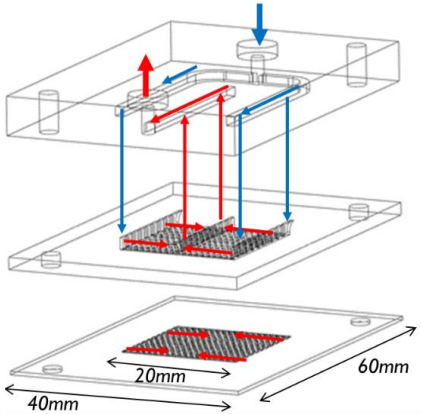
NextManufacturing Carnegie Mellon University
PennState
AMETEK SPECIALTY METAL PRODUCTS
UNIVERSITY OF MICHIGAN
STATE U
MRL MATERIALS RESOURCES, LLC Made in Dayton
SUNVAPOR
UCDAVIS Energy and Efficiency Institute 15 YEARS
Sandia National Laboratories

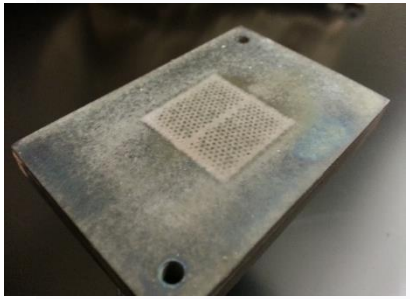
Technical Team

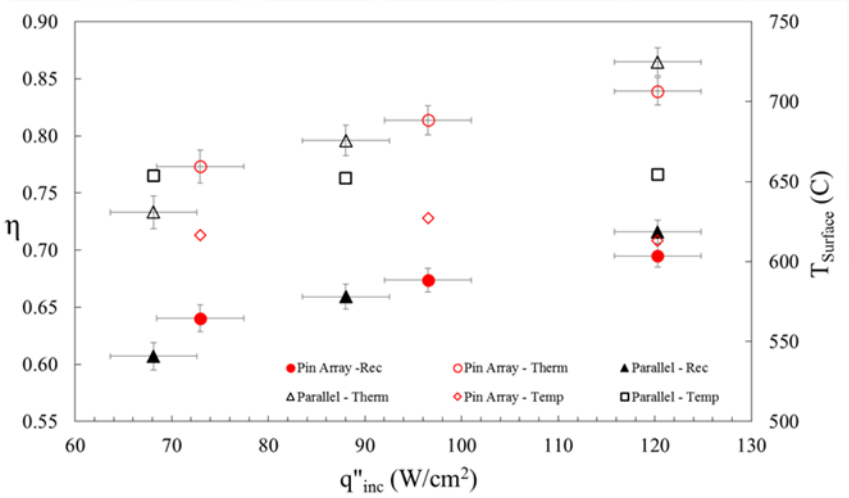
- UCD- Vinod Narayanan, Erfan Rasouli, Jesus Gutierrez Plascencia, Austin Marshall, Aref Aboud, Harsimar Kuller, Nick Gallo
- CMU- Anthony Rollett, Bryan Webler, Junwon Seo
- MRL- Ayman Salem & Dan Satko
- SV- Philip Gleckman, Brandon Hathaway, Sue Gleckman
- SNL- Andrea Ambrosini, Ansel Blumenthal & Aaron Overacker
- PSU- Brian Fronk, Leyli Bahrami & Connor Corso
- UM- Parth Vaishnav & Miki Tsuchiya
- USU- Nadia Kouraytem , Christopher Bettencourt (now at MRL), Farin Khan Raisa, Emily Carroll
- Ametek-cost share partner

Background- Microscale Pin Array Receivers





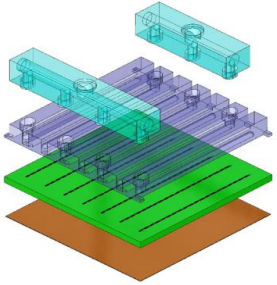


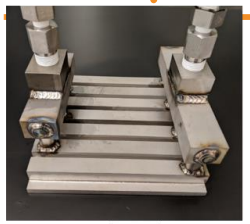


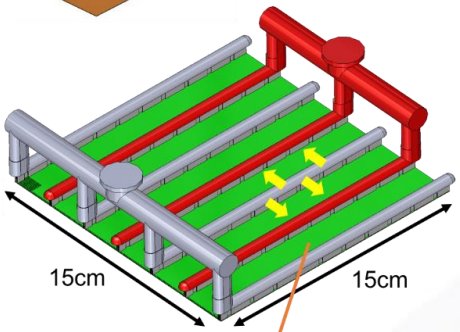
Microscale passages => high heat transfer coefficient; high fluxes for same surface temperature

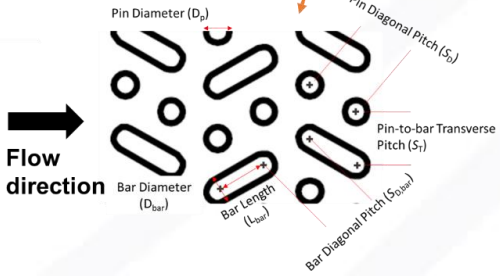
Narayanan, V., Fronk, B., L'Estrange, T., and Rasouli, E., ISEES 2018 Monograph #5 on Advances in Solar Energy, Springer Energy, Environment and Sustainability series., Vol. 5(ch. 11), Springer, pp. 333-355.

Background- µL-PAR- scale up to 15 cm x 15 cm

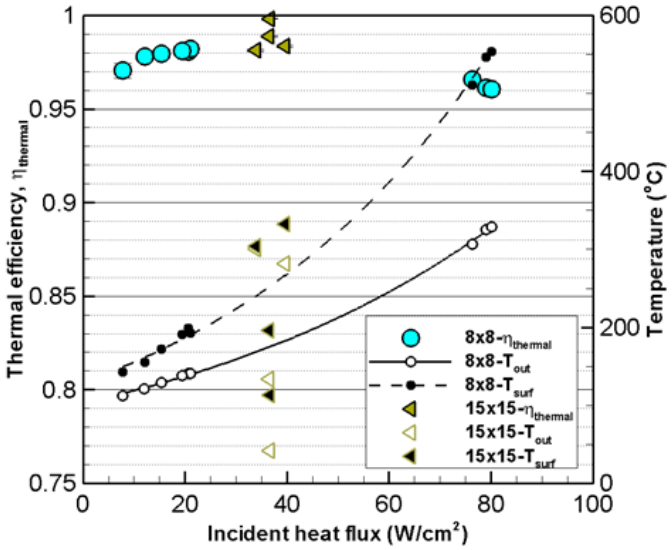




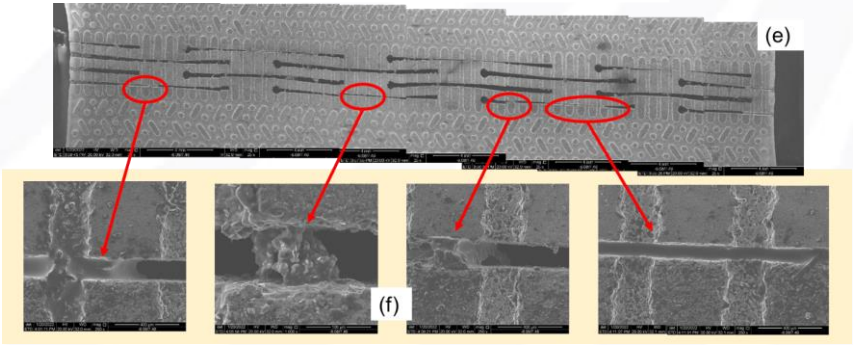




$D_{pin}=D_{bar}=300$ µm; $H_{pin}=150$ µm; $S_T=S_D=L_{bar}=700$ µm

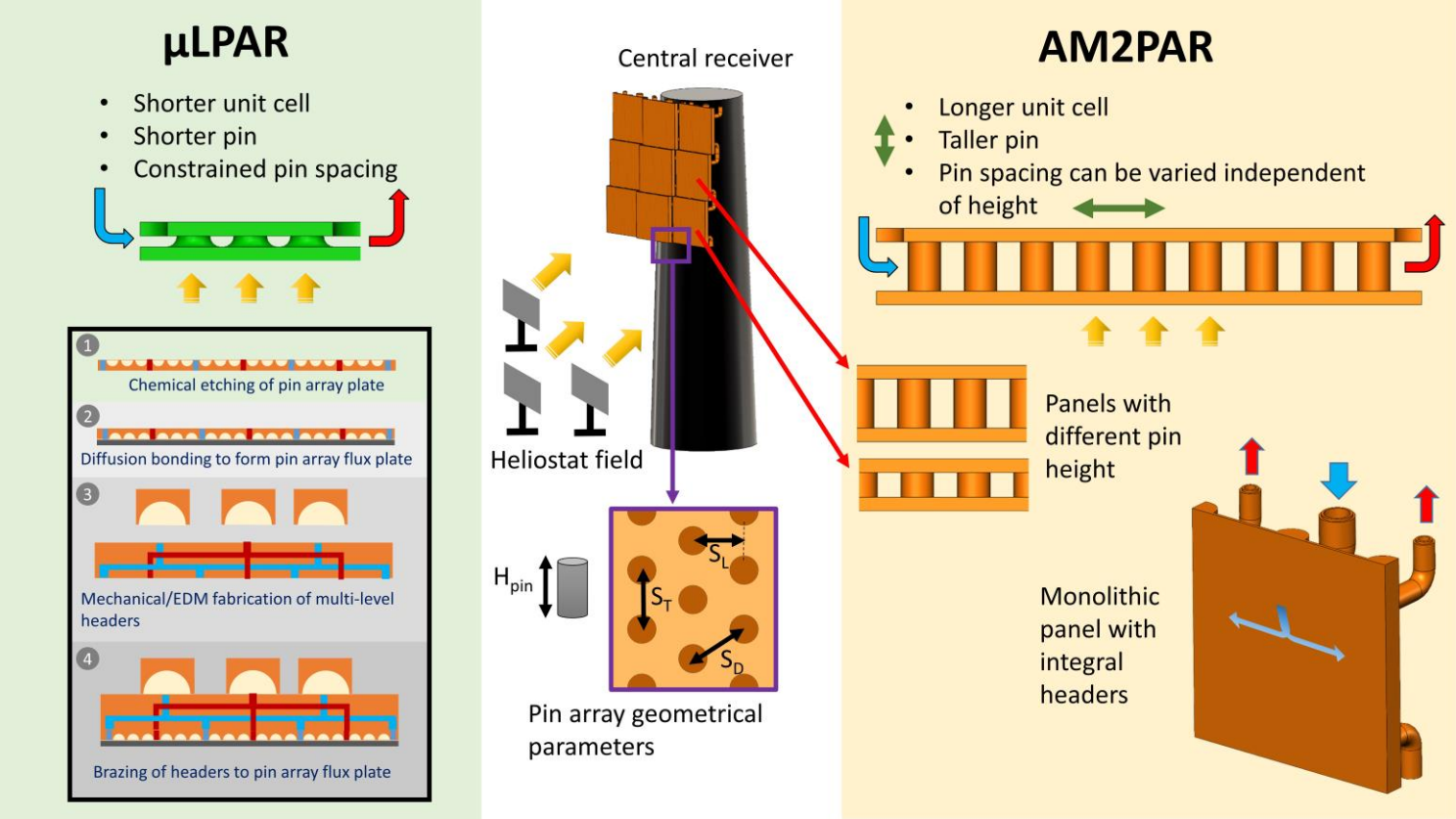


- Fabricated in H230
- Lots of fabrication challenges
- Bulky headers
- Passed pressure test at temperature
- On-sun test showed promise, but resulted in failure
- Post-mortem revealed closed slits at failure location



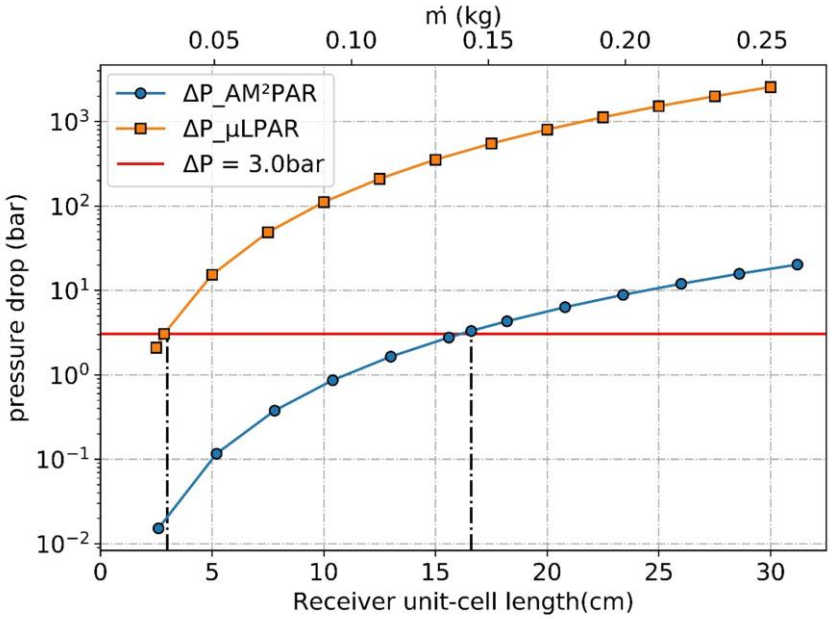
Fronk et al., Journal of Solar Energy, accepted; Rasouli et al., in review

Current work- Additive Manufacturing for PARs

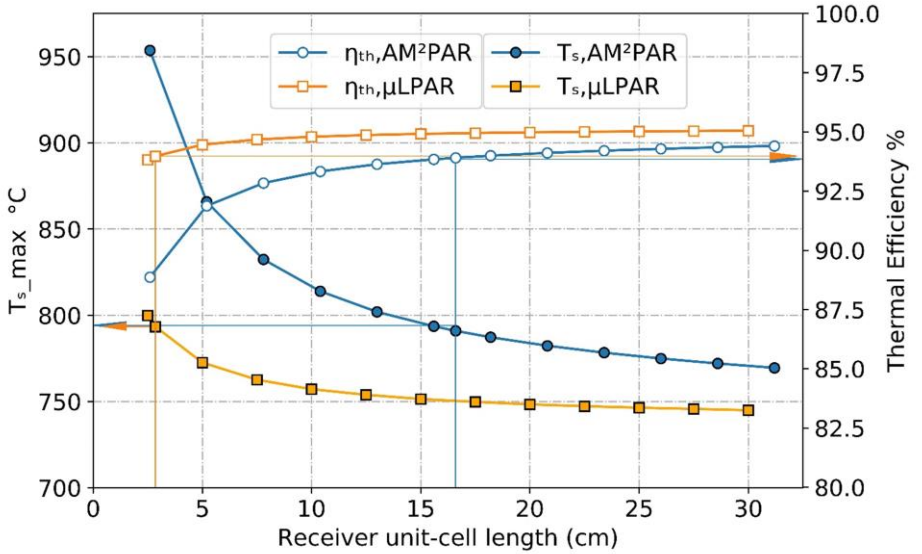


Odele, R. P., Rasouli, E., and Narayanan, V., Journal of Solar Energy, 241: 621-636

Panel Performance Comparison- µL vs AM PAR



(a)



(b)

	H_{pin}(mm)	D (mm)	Sl (mm)	St(mm)	St/D
µLPAR	0.3	0.35	0.7	0.7	2
AM²PAR	1.8	1.2	2.13	2.46	2.05

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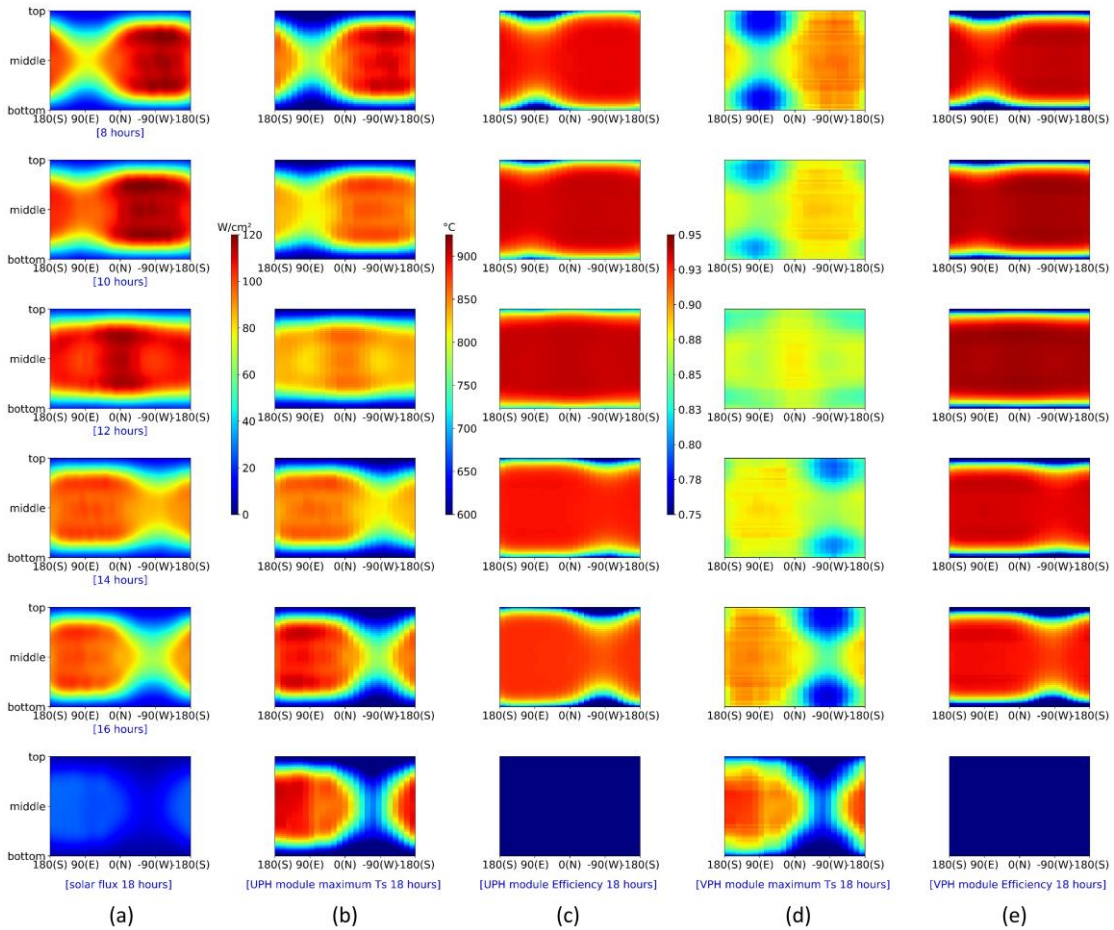
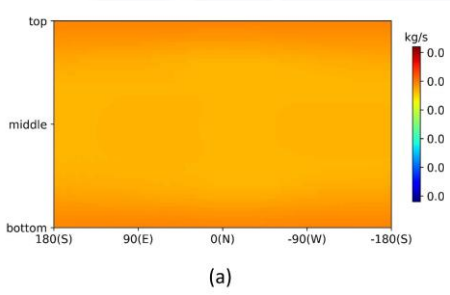
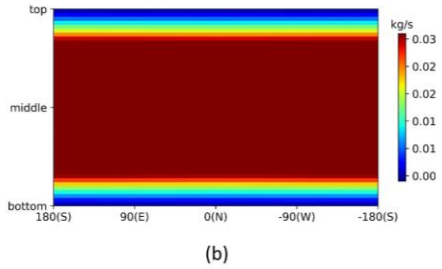
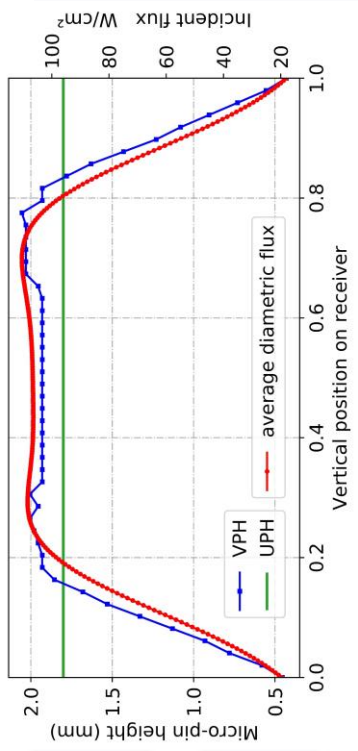
Central receiver performance









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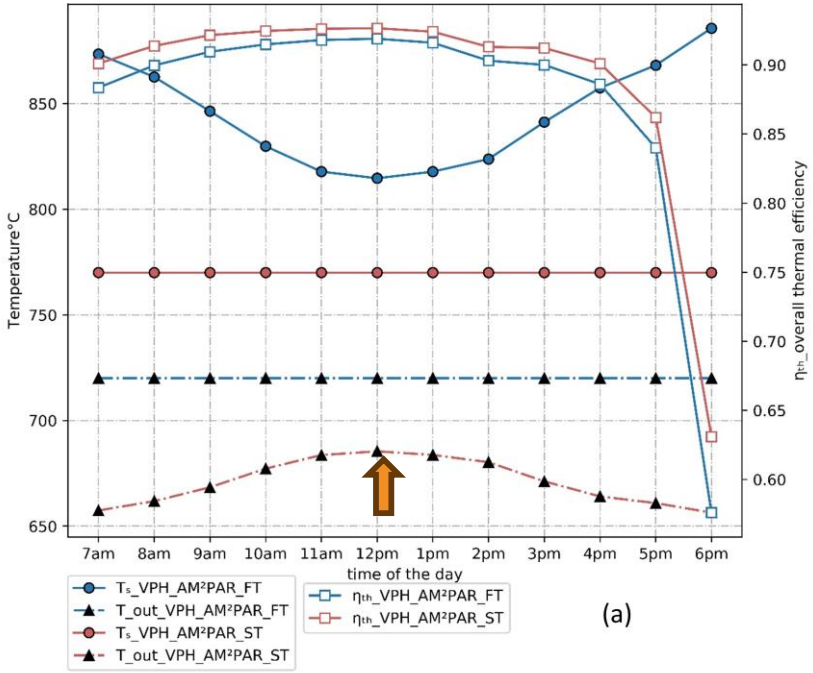
Central receiver performance

Takeaway:

- We are pushing the limits of the material for a T_{exit} of 720 ^{o}C with this pin array design for H282 for sCO_2 power generation
- Lifetime calculation for H282 using LMP approach suggests that the surface temperature needs to be lower than 770 C, and stress less than 105 MPa for 30-year lifetime.



(a)

Odele et al. (2022) determined that for a pin array design such as the one shown, fluid exit temperatures can be in the 660- 680 C range if the maximum surface temperature is limited to 770 C

- Can exit temperature be increased for the same $T_{s,max}$?
- Can stresses be reduced in regions of high $T_{s,max}$?

These questions will be explored in second generation of receiver panel designs

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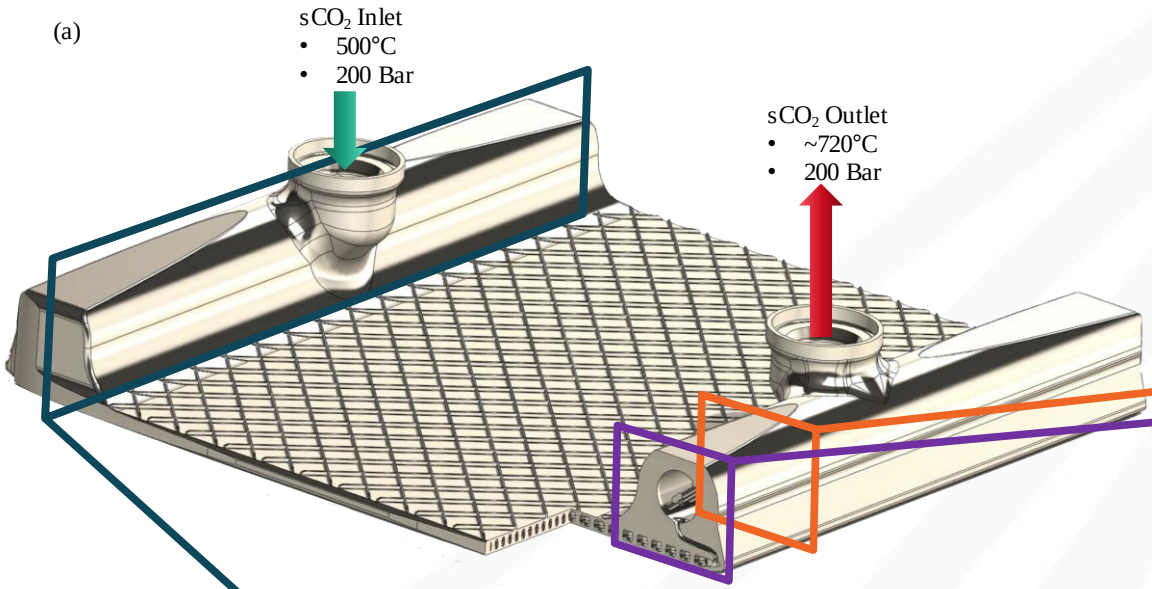
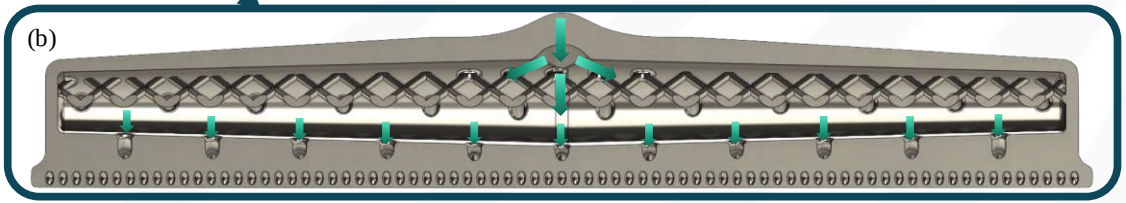
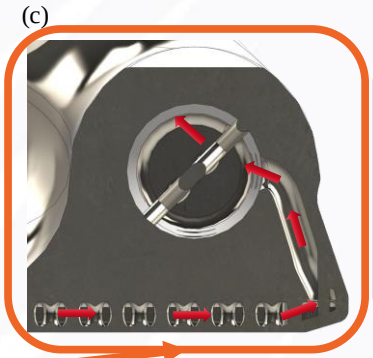
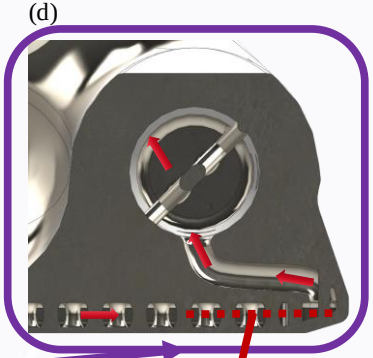
Gen 1 sCO_2 panel design



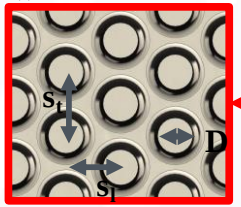


Cross sectional view of header channel where flow disperses through the lattice to the ends of the header channel and into both the high and low angle tubes

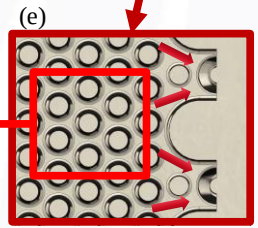




Includes 12 high angle tubes and 11 low angle tubes directing flow from the pin array to the header channel. All ⌀2.25 mm except 2 central high angle tubes are ⌀2.125 mm



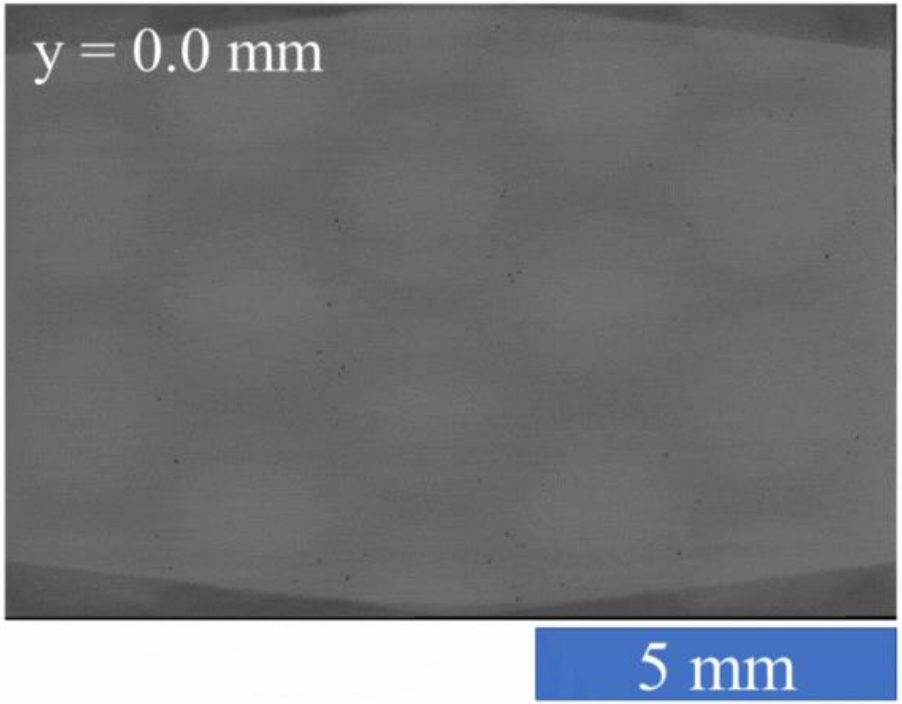
S_t=2.16, S_l=1.87, D=1.2, and H=2.1 mm



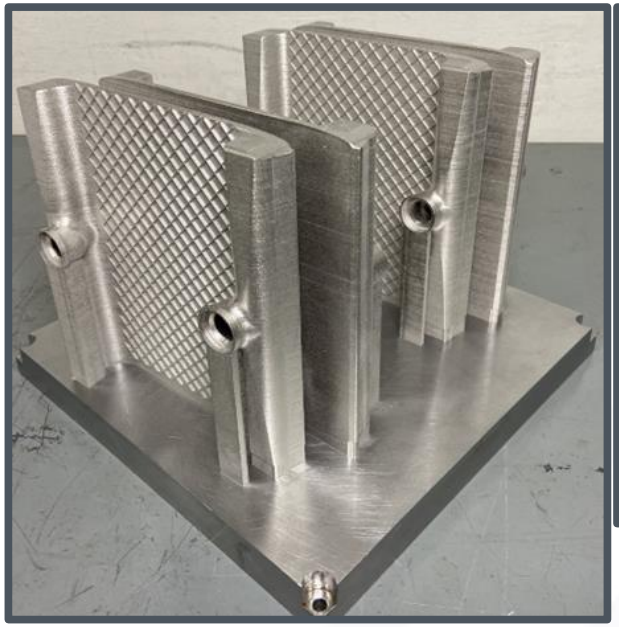
Cross sectional view of the pin array entrance from the header channel tubes

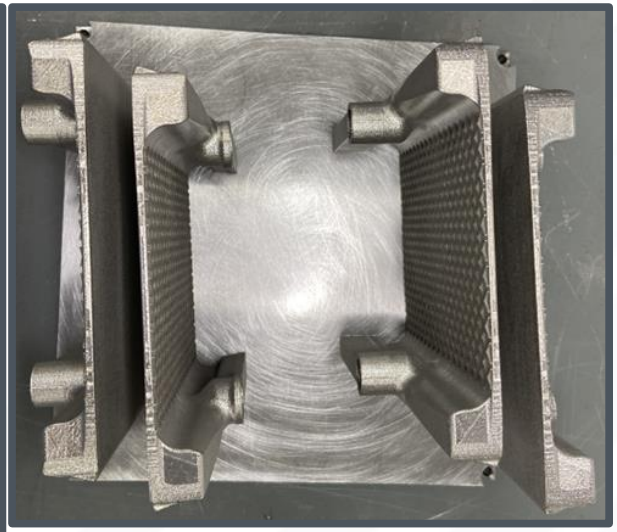
Printing and analyzing sub-scale specimen

The pins are printed so that they are well separated from each other.



L-PBF of Haynes 282 receiver panels

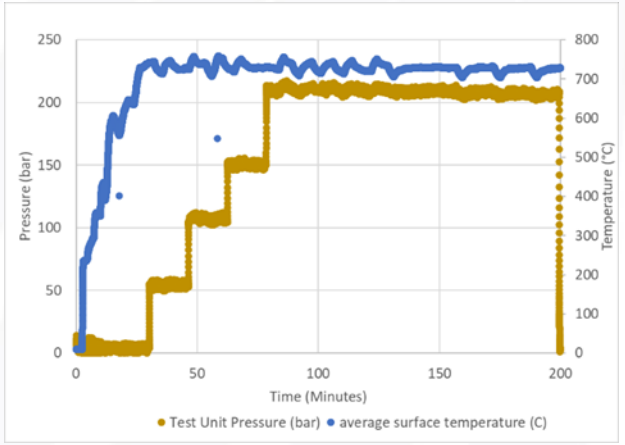




Using similar processing parameters as the one used by CMU; EOS M290 machine

Successfully printed 4 full scale panels on one build plate in MRL's industrial PRox320 machine

- 5 panels successfully passed pressure test at temperature
- On-sun testing scheduled to begin Feb/March



Summary

- Micro pin array receiver can be used for gaseous or liquid working fluids and offers high flux operation potential
- Additive Manufacturing is a potential solution to reduce fabrication risks and develop new designs
- Other ongoing activities include
  - cost modeling,
  - surface modifications for higher solar absorptivity & lower long-range emissions,
  - multimodule assembly and weld integrity,
  - creep and fatigue testing of printed H282 and printed and welded samples,
  - process heat receivers, system, and applications