



Sandia
National
Laboratories

SAND2019-13276PE

Heat Exchanger State of the Art

National Lab Perspective



October 31-November 1 2019, Denver, Colorado, USA

Matthew D. Carlson, Sandia National Laboratories



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

SAND2019-XXXXX

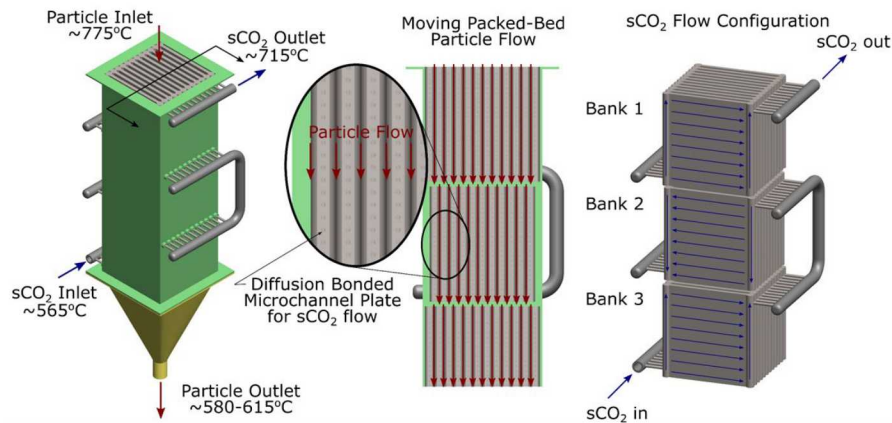
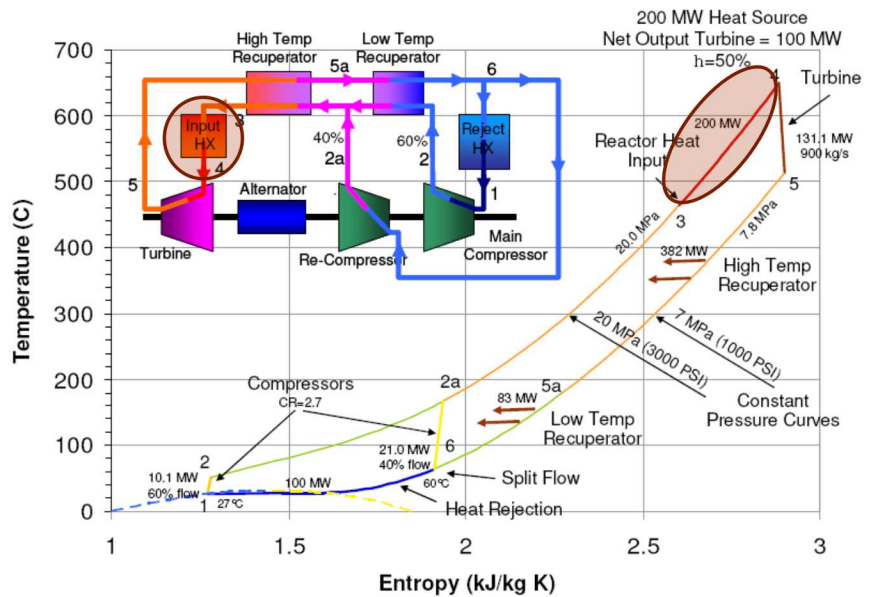


Refining the Scope of Supply



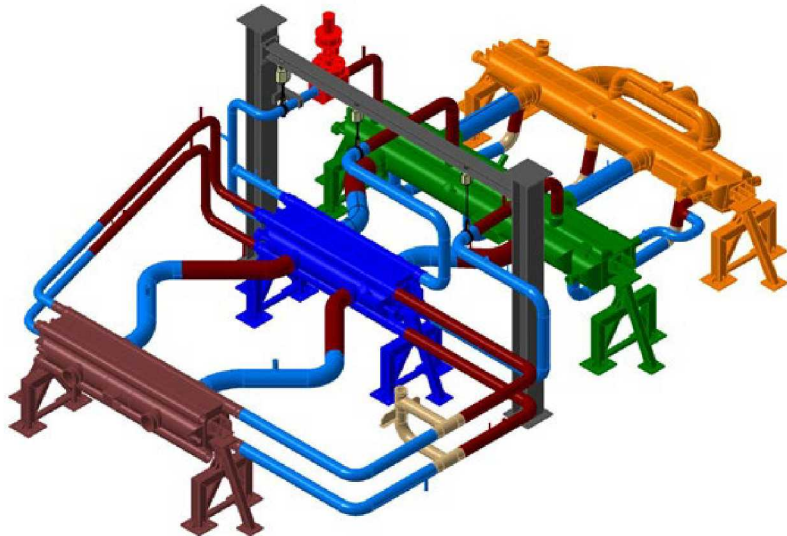
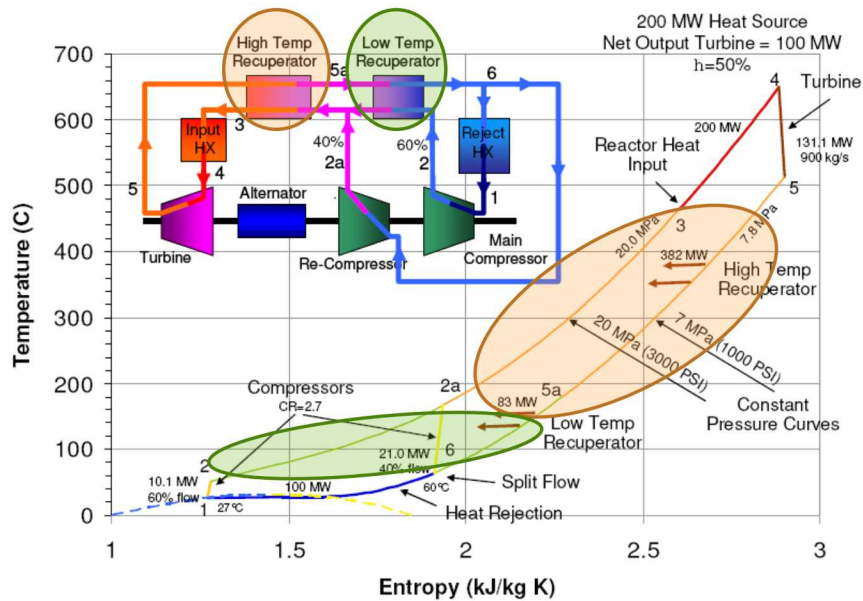
Heat Exchanger State of the Art: National Lab Perspective

Scope of Supply: Primary Heat Exchangers



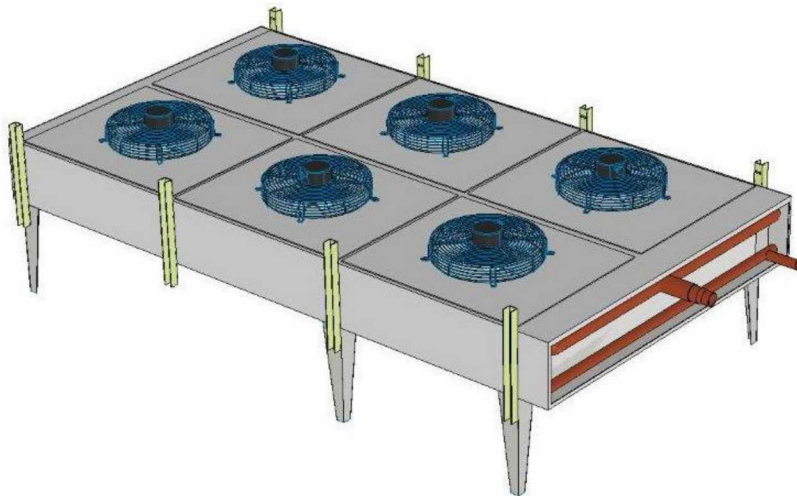
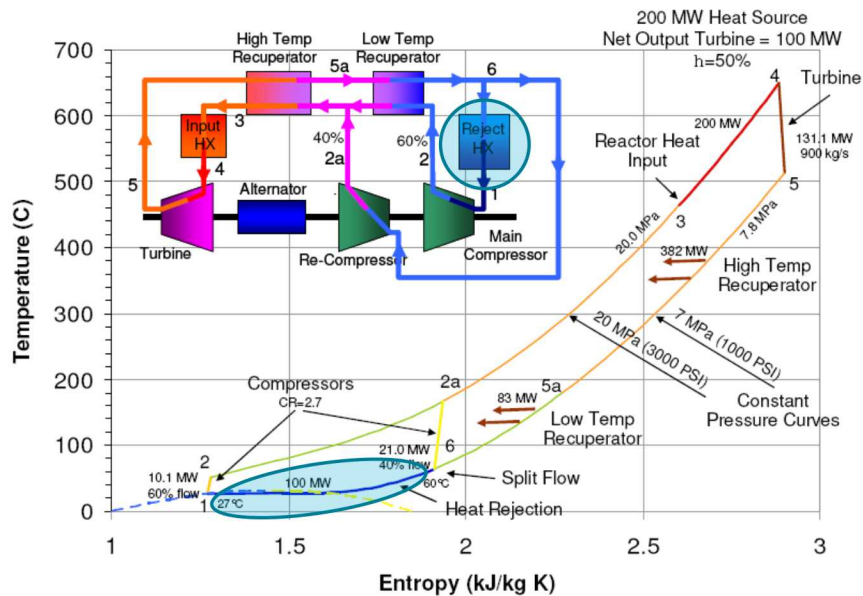
Design Line Item	Hot Side	Cold Side	Comment(s)
Composition	Varies	CO2	Particles, salt, gas
Flow / kg/s-MWth	4 to 5	3 to 6	Trades with ΔT
Inlet Temp / °C	635	~470	Trades off with storage cost
Outlet Temp / °C	~485	620	
Pressure Drop / bar	1	2 to 10	Trades with efficiency
MAWP / bar	1 to 10 250	250	Particles, Salts Gas
MDMT / °C	649	649	Code Case 2577
Flow Direction	Down	Up	For gravity flow/drain
Est. Channel Size	5 mm	1 mm	
End Connections	Clamp	Clamp	Grayloc-style
Materials	S31600/3	S31600/3	Particles
	S34709?	S31600/3	Molten Salt
	S31600/3	S31600/3	Gas

Scope of Supply: Recuperators



Design Line Item	Hot Side	Cold Side	Comment(s)
Composition	CO ₂	CO ₂	
Flow / kg/s-MWth	3 to 6	3 to 6	Trades with ΔT , config
Inlet Temp / °C	~470	>100	Trades off with cycle config/efficiency
Outlet Temp / °C	<150	~470	
Pressure Drop / bar	2.5	2.5	Trades with efficiency
MAWP / bar	>70	250	
MDMT / °C	<550	<550	Code Case 2577
Flow Direction	Any	Any	
Est. Channel Size	1 mm	1 mm	
End Connections	Clamp	Clamp	Grayloc-style
Materials	S31600/3	S31600/3	

Scope of Supply: Direct Air Coolers



Design Line Item	Hot Side	Cold Side	Comment(s)
Composition	CO2	Air	
Flow / kg/s-MWth	3 to 6	100-250	Due to pinch
Inlet Temp / °C	150	~30	Trades off size, pinch
Outlet Temp / °C	55	60	
Pressure Drop / bar	2.5	Varies	Trades with blower
MAWP / bar	250	~1	
MDMT / °C	200	200	
Flow Direction	Any	Any	
Est. Channel Size	1 mm	1 mm	
End Connections	Clamp	Clamp	Grayloc-style
Materials	S31600/3	S31600/3	



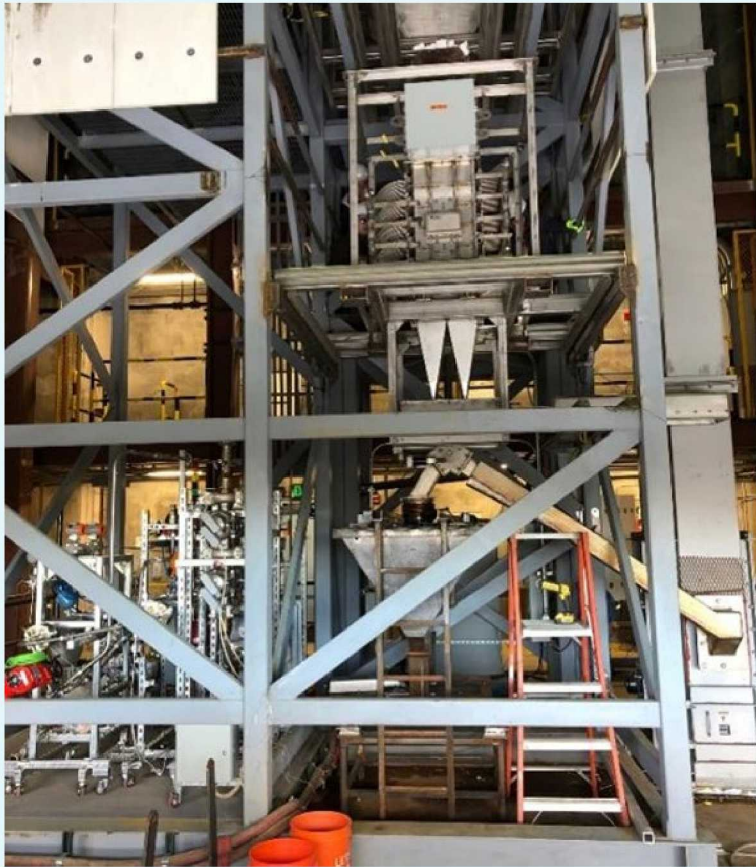
Current Efforts to Improve Performance



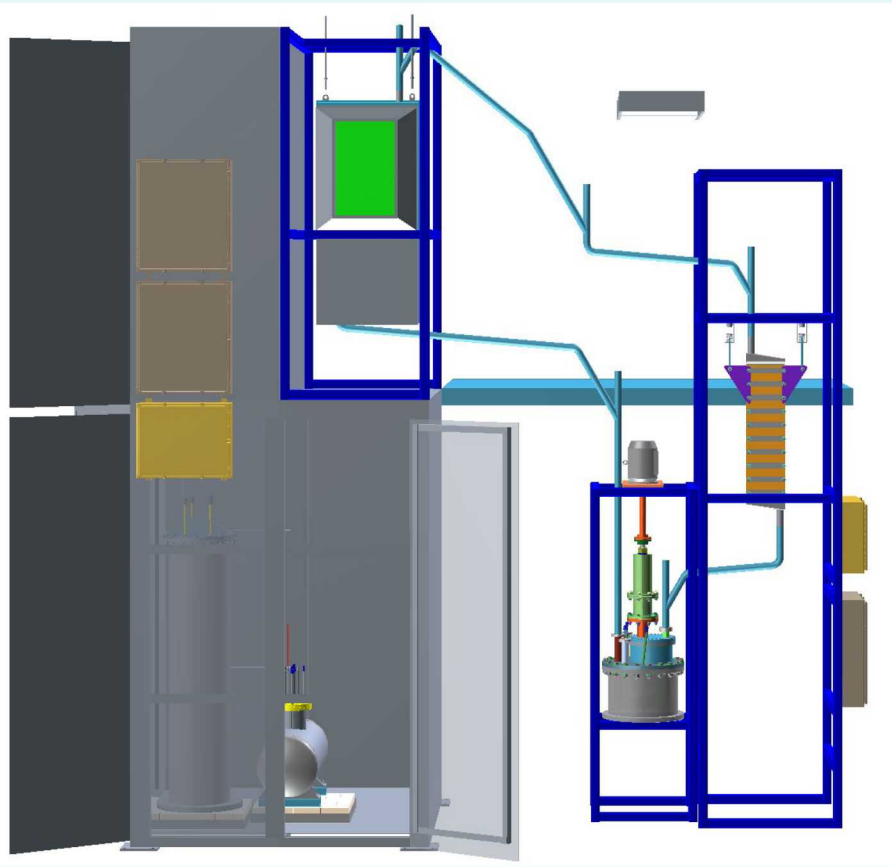
Heat Exchanger State of the Art: National Lab Perspective



DOE-EERE Funded Projects



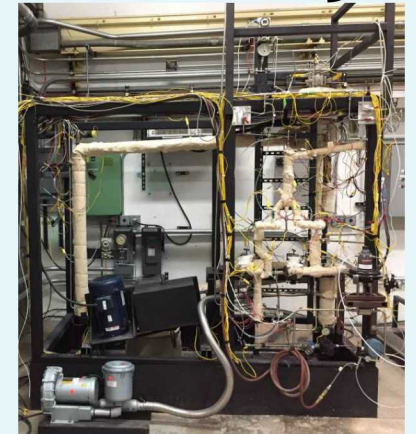
Particle-sCO₂ at Sandia (SuNLaMP)



Chloride Salt-sCO₂ at ORNL (FASTR)

Compact Air Cooler (Not Shown)

DOE-NE Projects



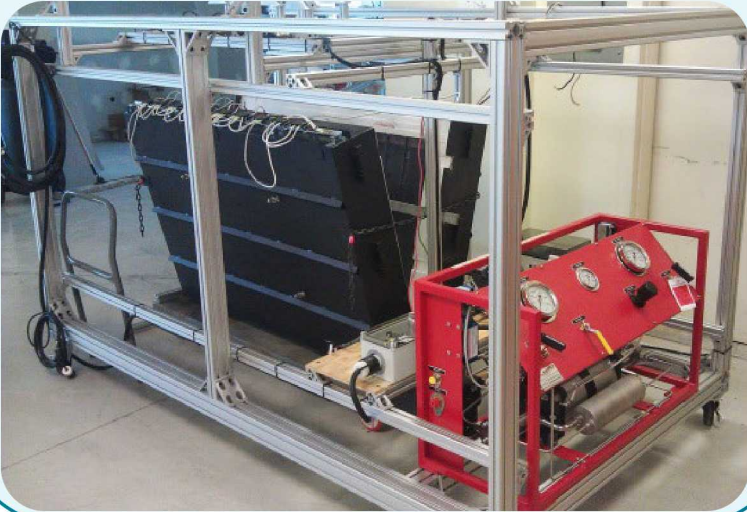
Sodium-sCO₂



Nitrate-sCO₂

Fluoride Salt-sCO₂ (Not Shown)

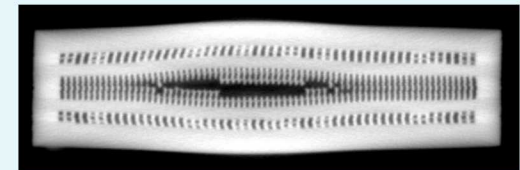
Thermal Fatigue & Creep



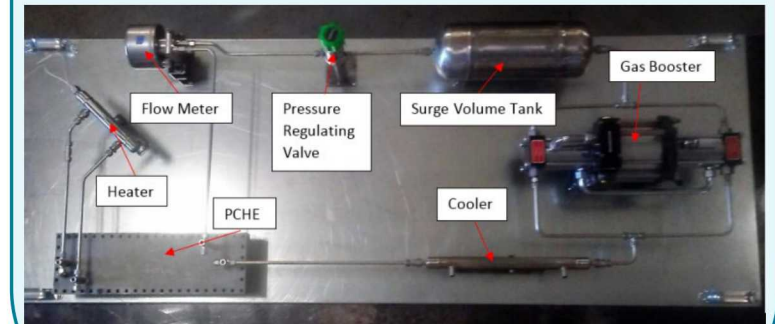
Pressure Fatigue



Universities

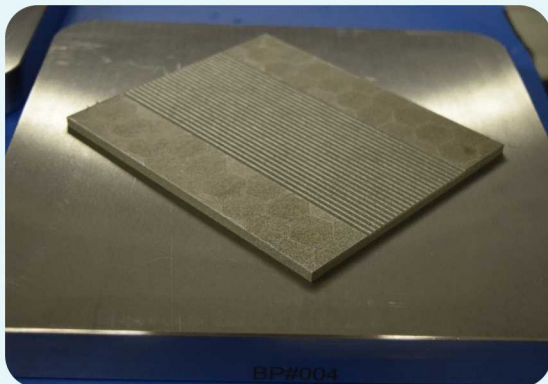


Failure Modes

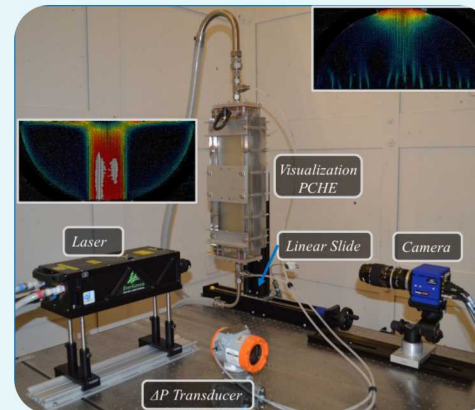


Fouling

Hybrid Additive Shims



Flow Distribution



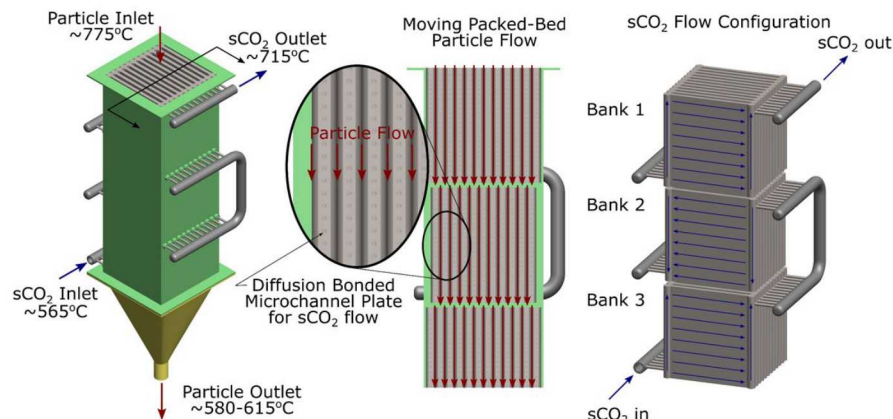
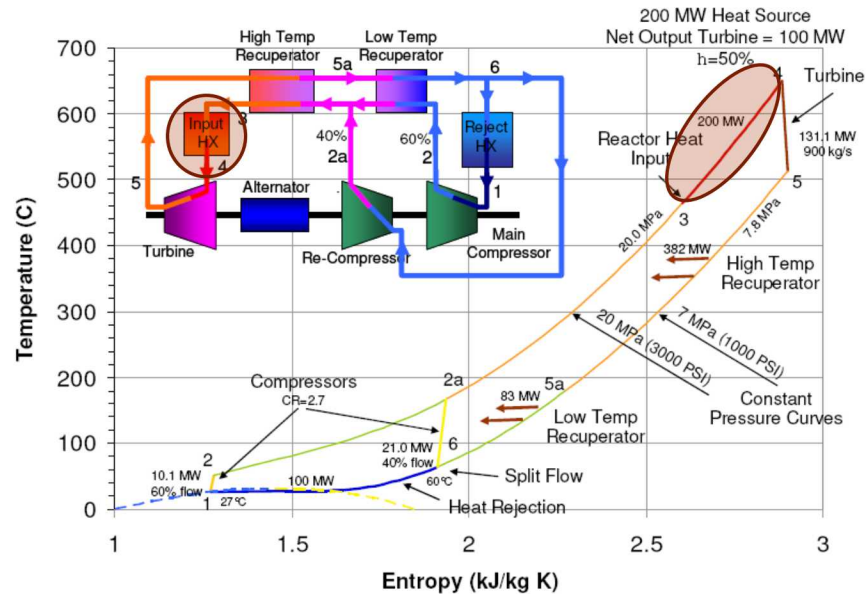


Development Needs & Knowledge Gaps



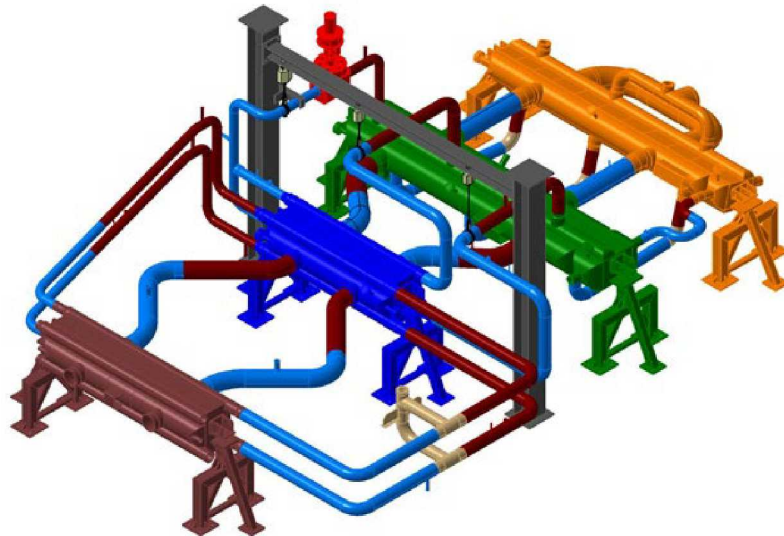
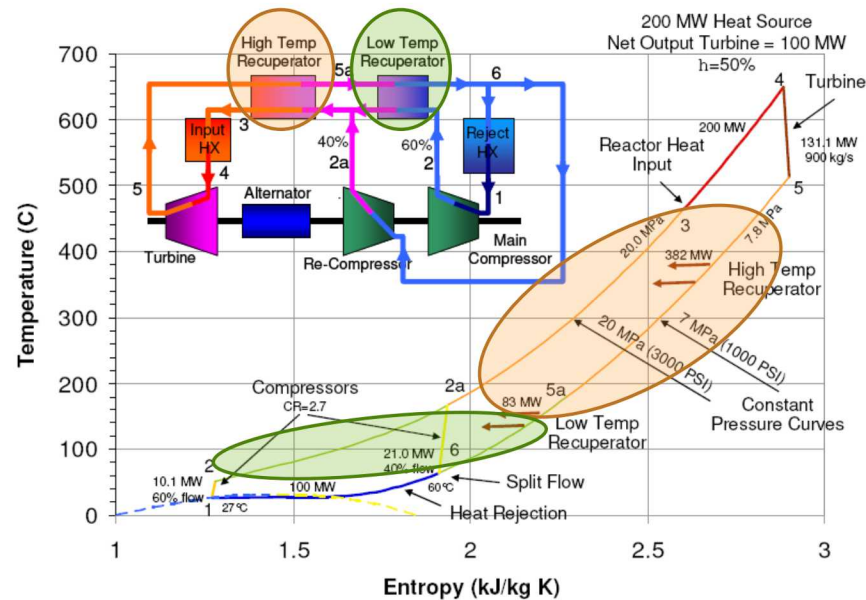
Heat Exchanger State of the Art: National Lab Perspective

Development Needs: Primary Heat Exchangers

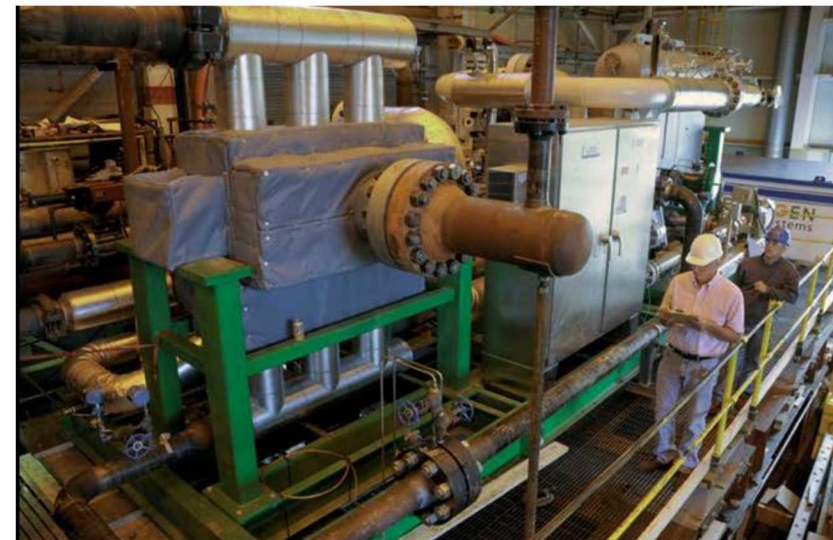


1. Hot-side fluid compatibility
 - Molten chloride salts
 - Liquid sodium
2. Header/manifold arrangements
 - Especially for wider plate spacings
3. Thermal fatigue/creep validation
 - Not required for ASME BPV Code Section VIII but important
4. Demonstration at ≥ 1 MWth scale
5. Faster, cheaper shim fabrication
 - Chemical etching is a major schedule and cost bottleneck

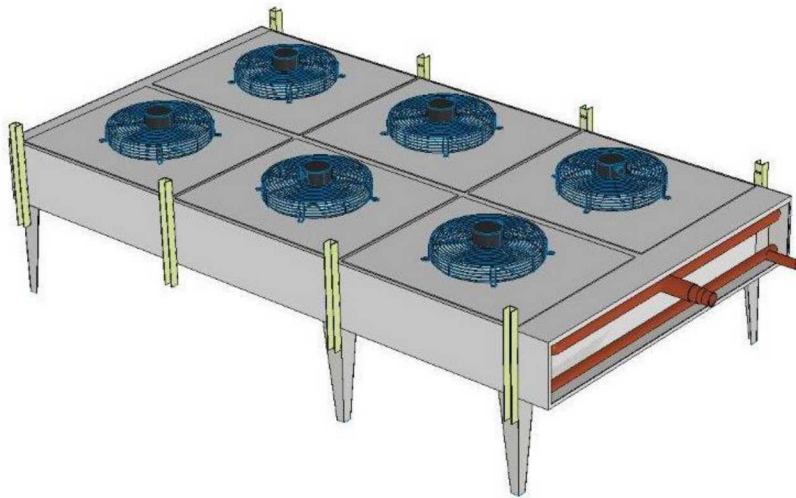
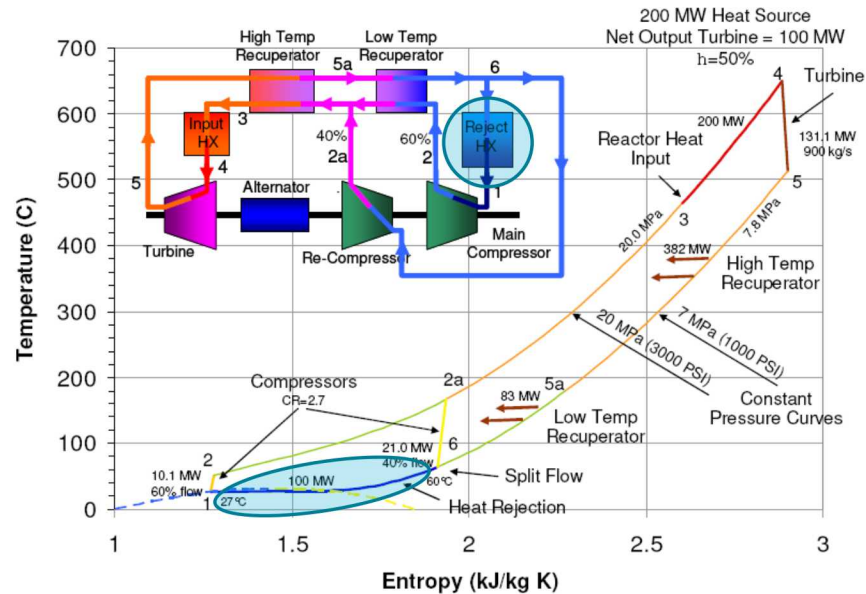
Development Needs: Recuperators



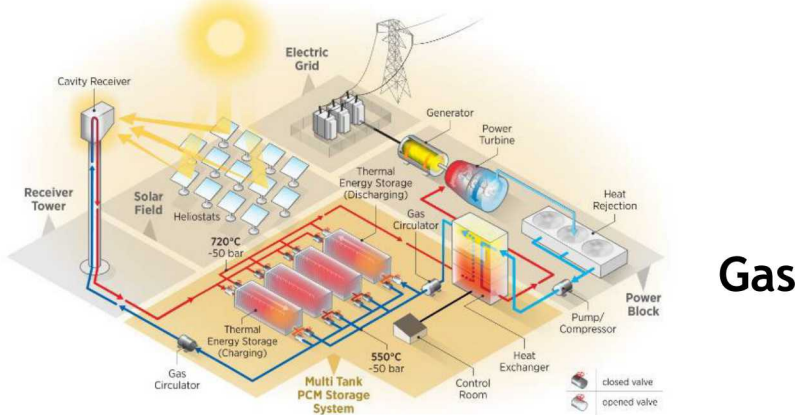
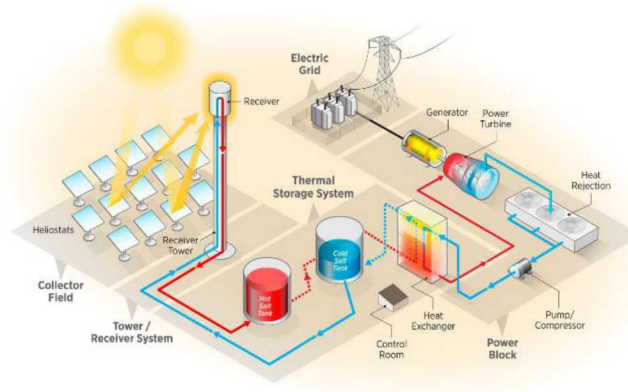
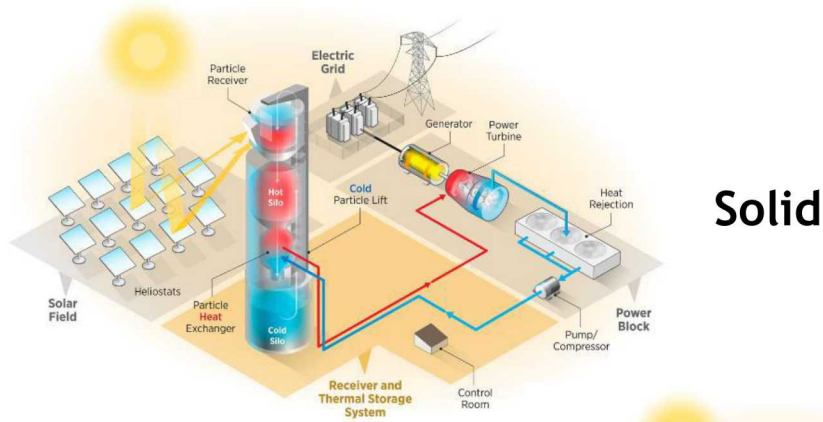
3. Thermal fatigue/creep validation
 - Not required for ASME BPV Code Section VIII but important
5. Faster, cheaper shim fabrication
 - Chemical etching is a major schedule and cost bottleneck



Development Needs: Direct Air Coolers



5. Faster, cheaper shim fabrication
 - Chemical etching is a major schedule and cost bottleneck
6. Balancing compactness and air-side blower size/cost
 - Large air-side heat transfer area
 - Increasing compactness increases blower size, cost, and ducting
 - Intermediate water loop adds considerable operating costs



- Suggested baseline scopes of supply
 - MAWPs and MDMTs
 - Normalized flow and pressure drop
- Can leverage several key activities
 - 10 to 100 kW_{th} Performance Demonstrations
 - Component-level R&D for cost reductions
- Several development needs remain
 1. Hot-side fluid compatibility
 2. Header/manifold arrangements
 3. Thermal fatigue/creep validation
 4. Demonstration at ≥ 1 MW_{th} scale
 5. Faster, cheaper shim fabrication
 6. Balancing compactness and air-side blower size/cost