Heat Exchanger State of the Art

National Lab Perspective

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SAND2019-13276 PE

Refining the Scope of Supply

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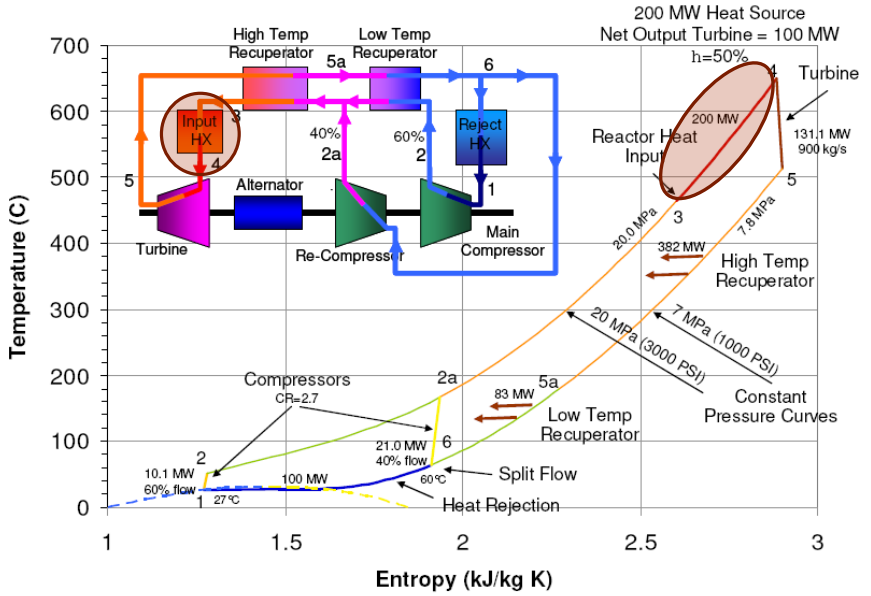
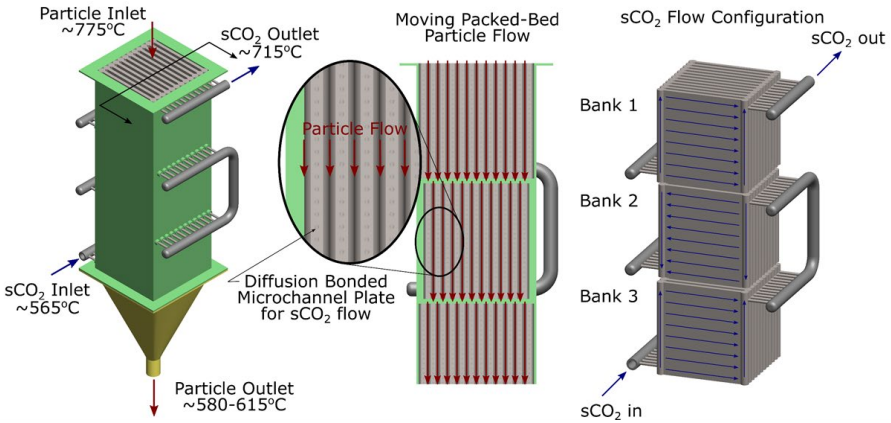
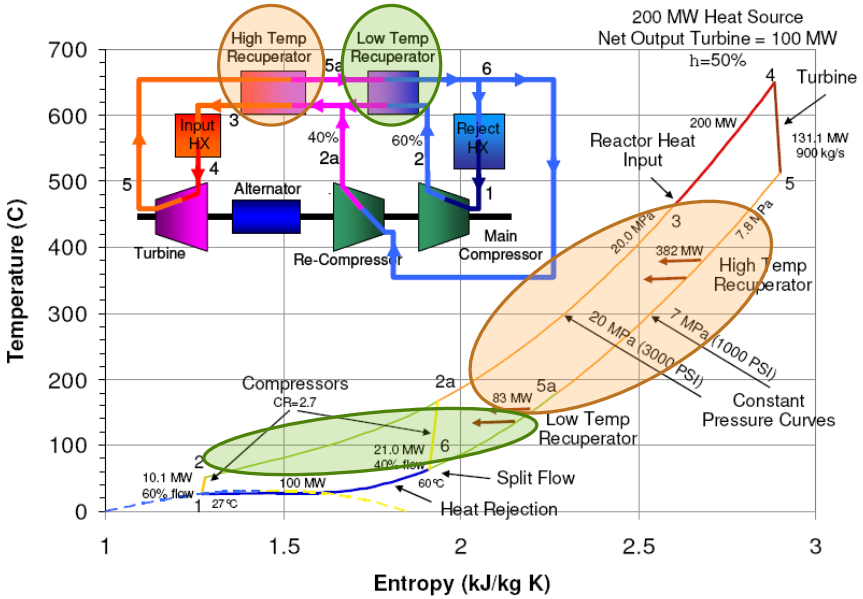
Scope of Supply: Primary Heat Exchangers

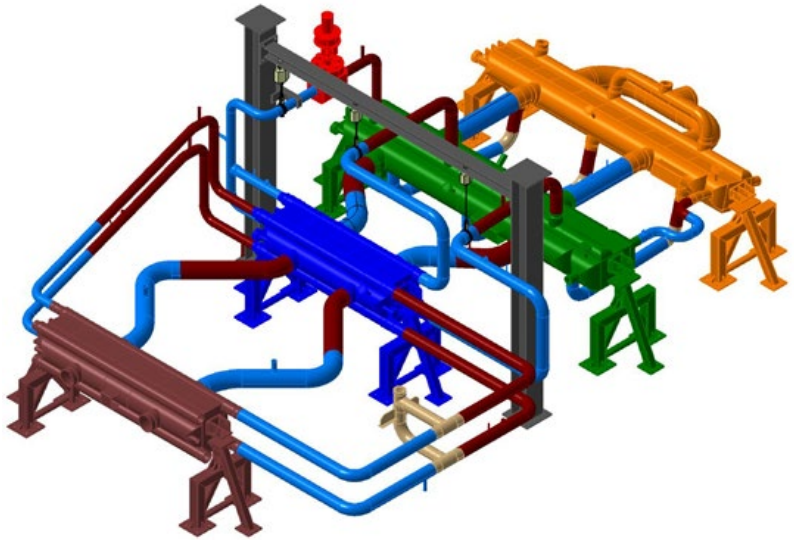




Design Line Item	Hot Side	Cold Side	Comment(s)
Composition	Varies	CO2	Particles, salt, gas
Flow / kg/s-MWth	4 to 5	3 to 6	Trades with ΔT
Inlet Temp / °C	635	~470	Trades off with storage cost
Outlet Temp / °C	~485	620	
Pressure Drop / bar	1	2 to 10	Trades with efficiency
MAWP / bar	1 to 10 250	250	Particles, 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

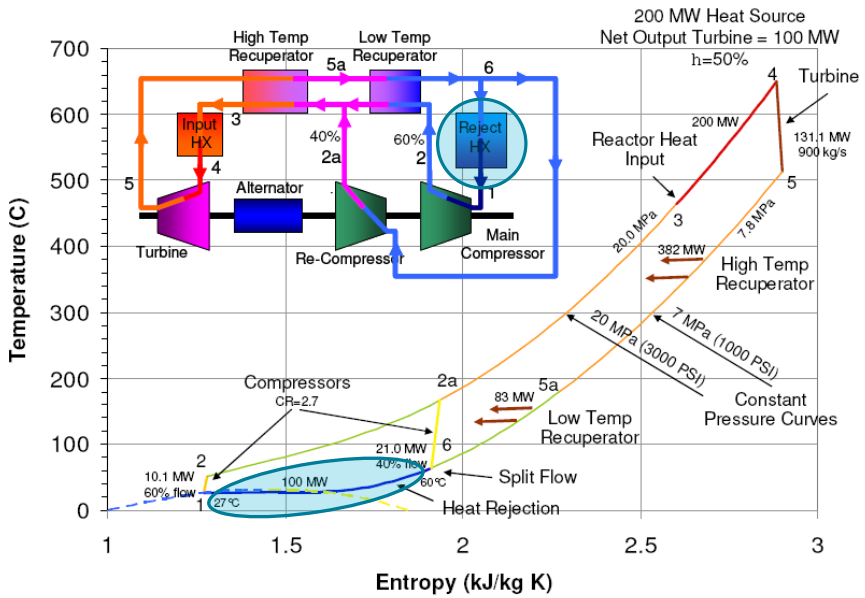
Scope of Supply: Recuperators

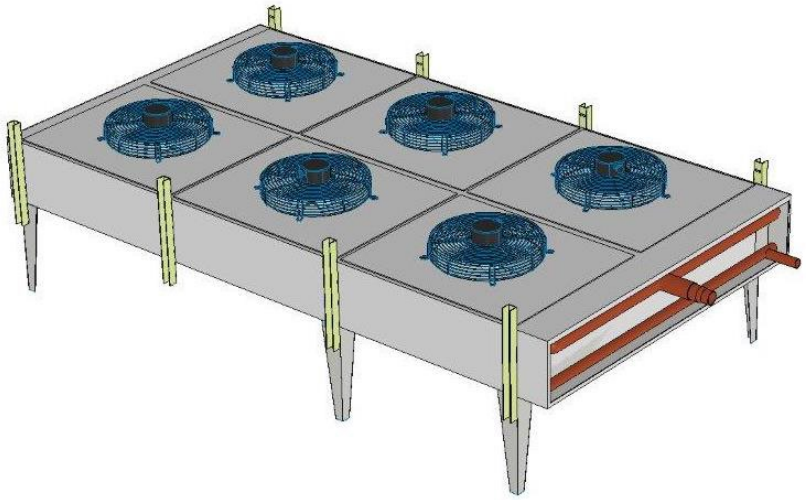




Design Line Item	Hot Side	Cold Side	Comment(s)
Composition	CO2	CO2	
Flow / kg/s-MWth	3 to 6	3 to 6	Trades with ΔT, config
Inlet Temp / °C	~470	>100	Trades off with cycle config/efficiency
Outlet Temp / °C	<150	~470	
Pressure Drop / bar	2.5	2.5	Trades with efficiency
MAWP / bar	>70	250	
MDMT / °C	<550	<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

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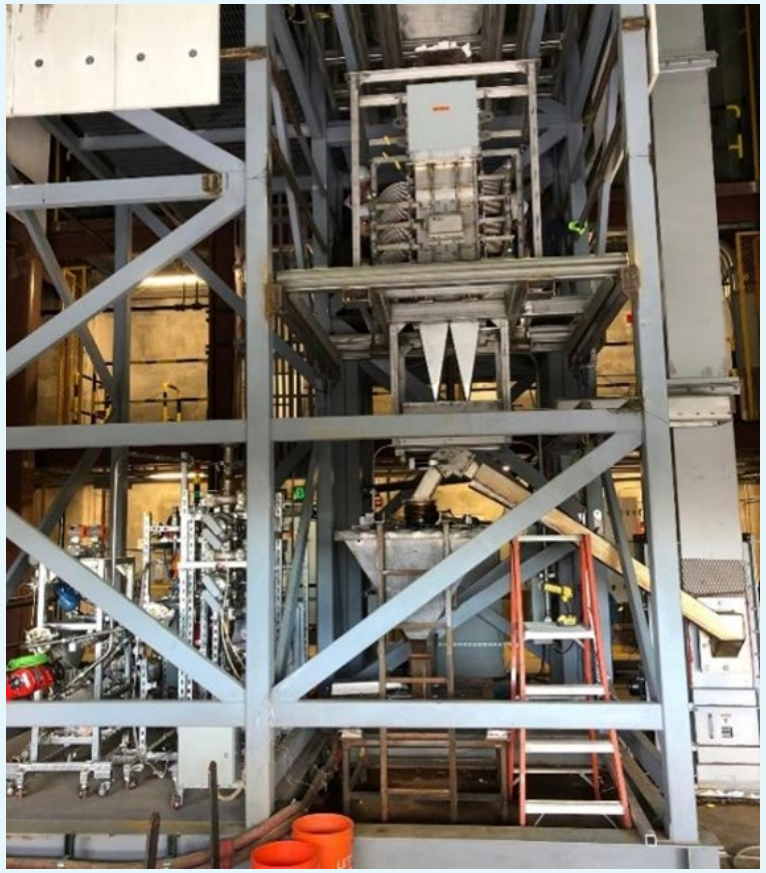
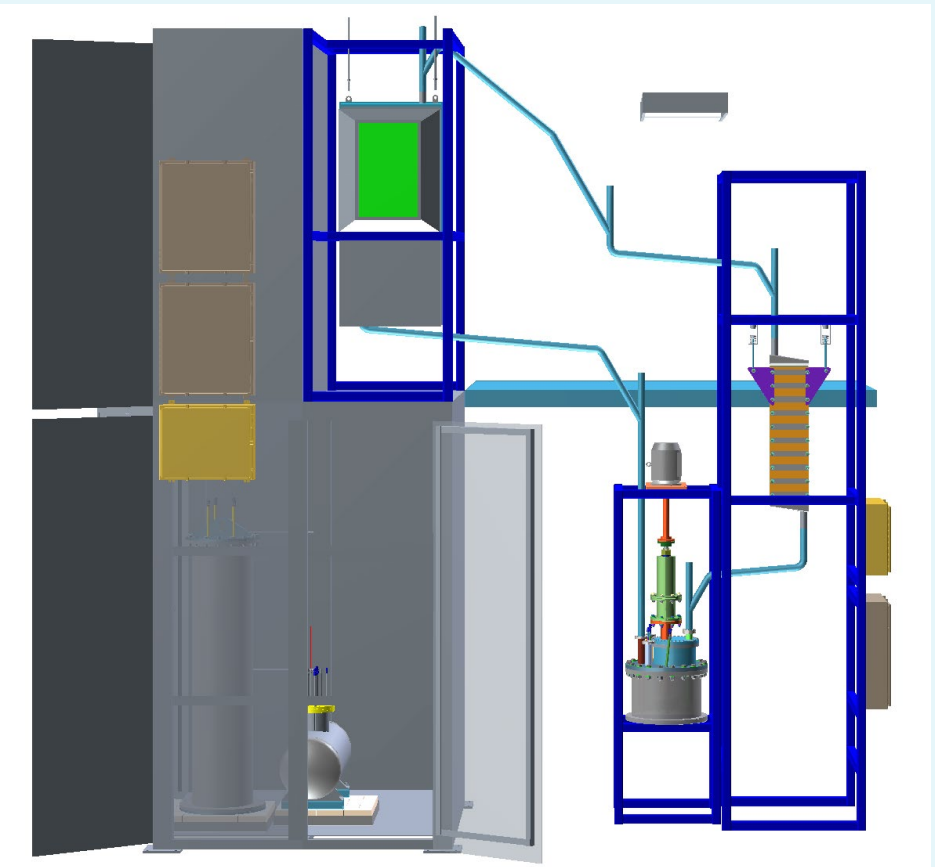
Performance Validation

DOE-EERE Funded Projects



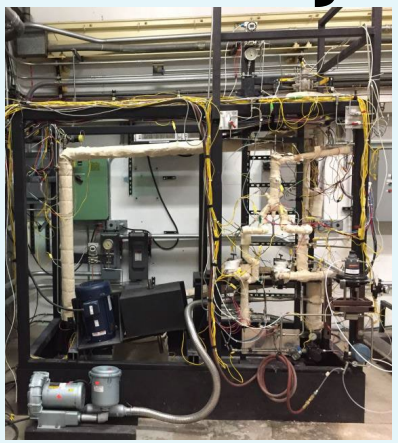
Particle-sCO2 at Sandia (SuNLaMP)



Chloride Salt-sCO2 at ORNL (FASTR)

Compact Air Cooler (Not Shown)

DOE-NE Projects



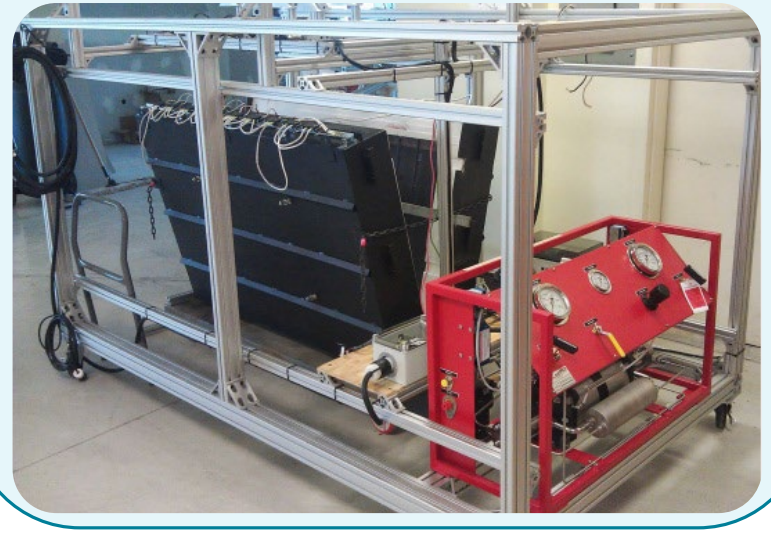
Sodium-sCO2

Nitrate-sCO2

Fluoride Salt-sCO2 (Not Shown)

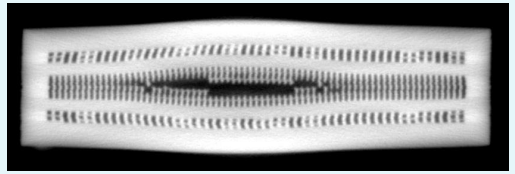
Recuperators: Cost Reduction

Thermal Fatigue & Creep

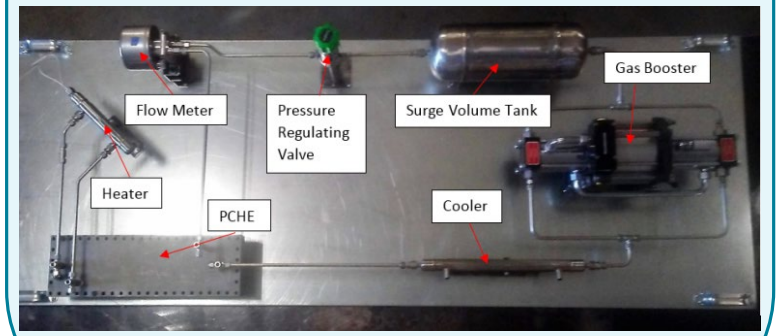


Pressure Fatigue

Universities

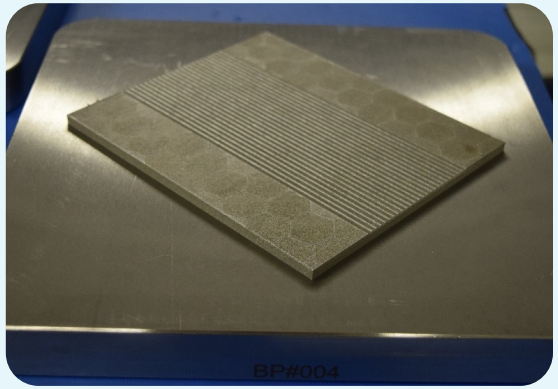


Failure Modes

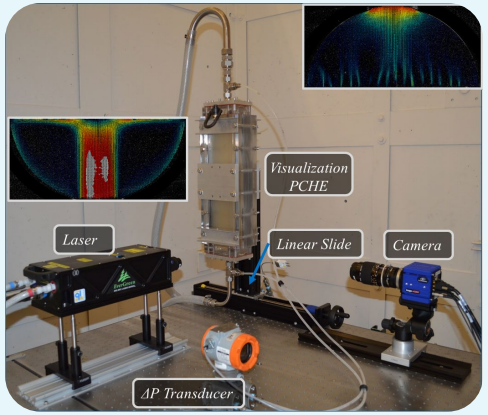


Fouling

Hybrid Additive Shims



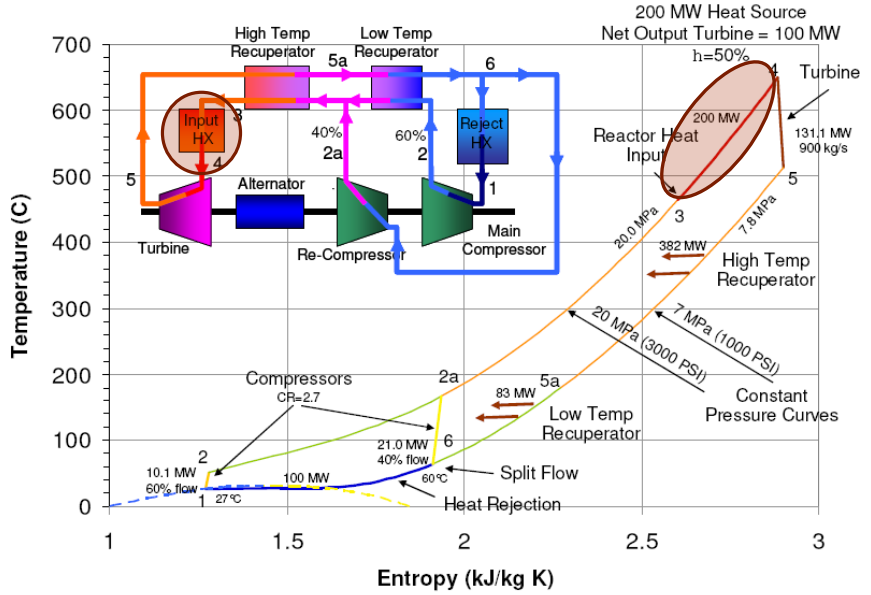
Flow Distribution

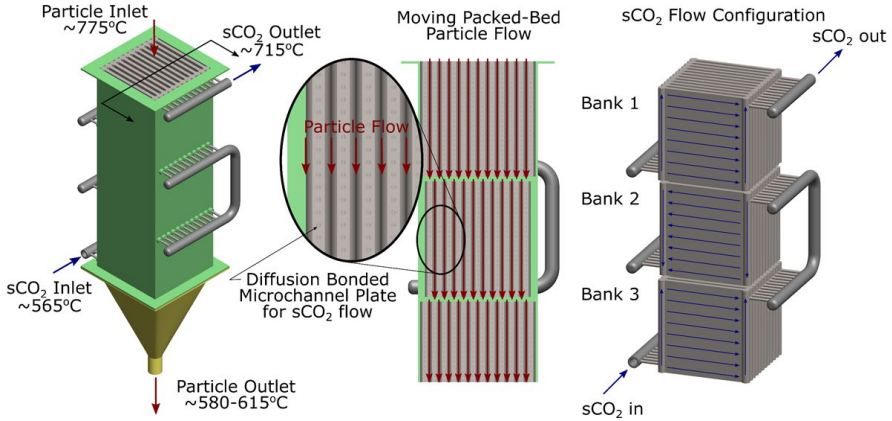


Development Needs & Knowledge Gaps

Heat Exchanger State of the Art: National Lab Perspective

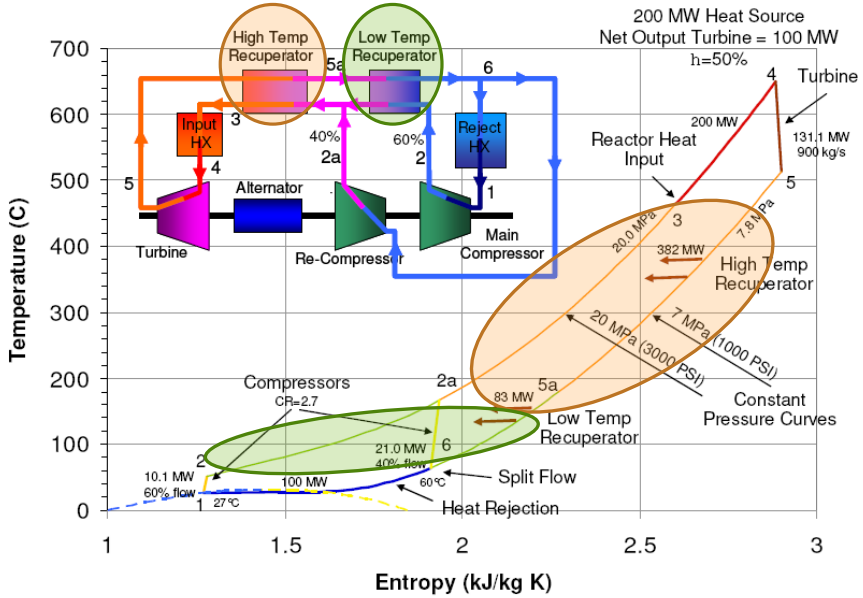
Development Needs: Primary Heat Exchangers

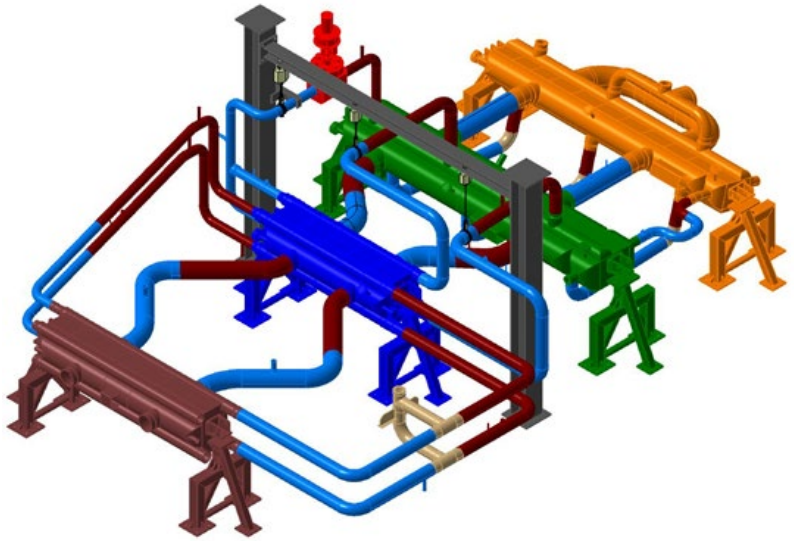




1. Hot-side fluid compatibility
   - Molten chloride salts
   - Liquid sodium
2. Header/manifold arrangements
   - Especially for wider plate spacings
3. Thermal fatigue/creep validation
   - Not required for ASME BPV Code Section VIII but important
4. Demonstration at ≥1 MWth scale
5. Faster, cheaper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

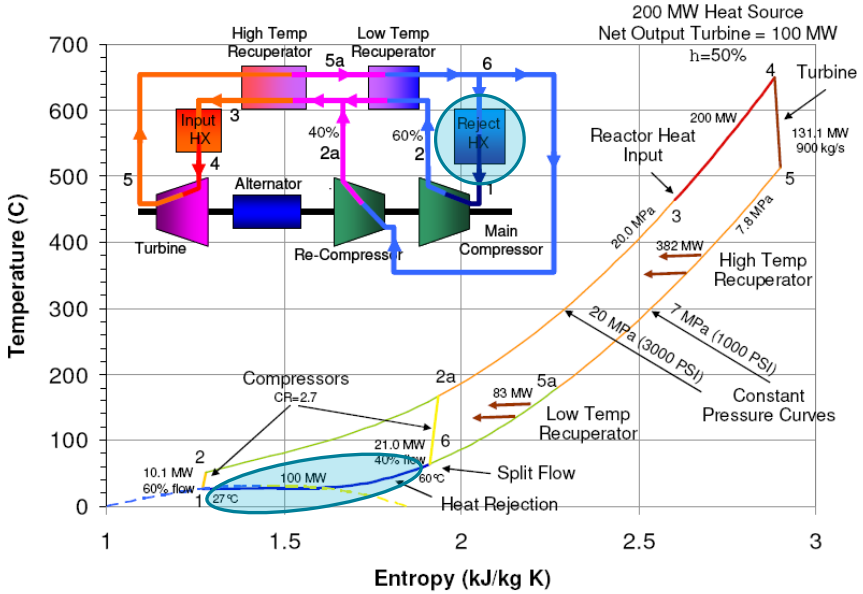
Development Needs: Recuperators

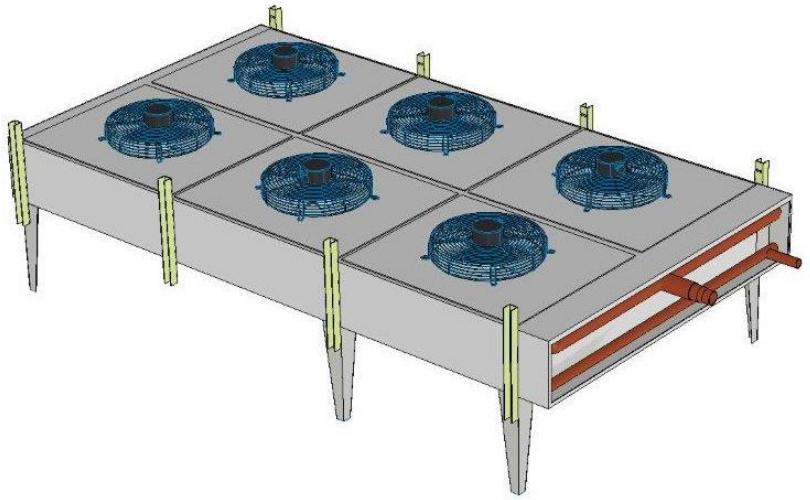




3. Thermal fatigue/creep validation
   - Not required for ASME BPV Code Section VIII but important
5. Faster, cheaper shim fabrication
   - Chemical etching is a major schedule and cost bottleneck

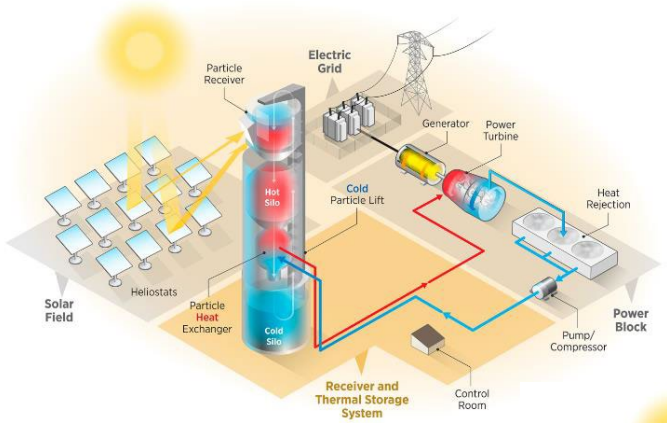
Development Needs: Direct Air Coolers



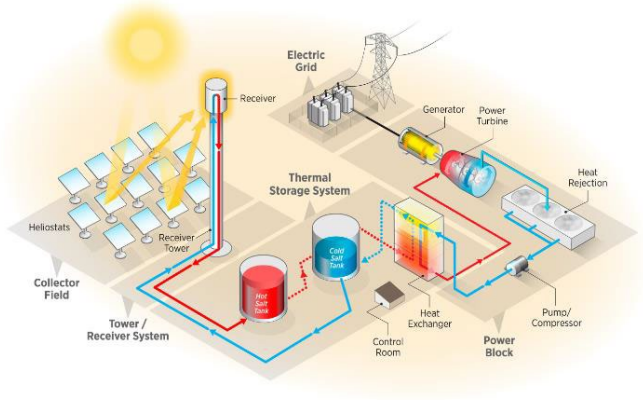


5. Faster, cheaper shim fabrication
   - Chemical etching is a major schedule and cost bottleneck
6. Balancing compactness and air-side blower size/cost
   - Large air-side heat transfer area
   - Increasing compactness increases blower size, cost, and ducting
   - Intermediate water loop adds considerable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

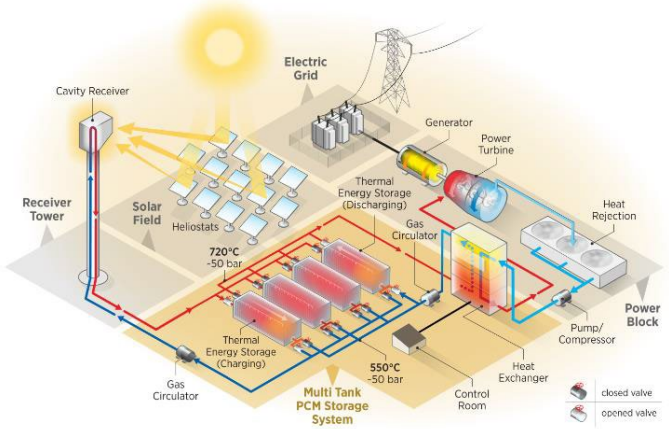
Conclusions



Solid



Liquid



Gas

- 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 MWth scale
  5. Faster, cheaper shim fabrication
  6. Balancing compactness and air-side blower size/cost