

Material Analysis and System Design for Exploration Life Support Systems

**Introduction to ECLSS Air Revitalization
Support for Exploration Missions**

Gregory E Cmarik, Jacobs ESSSA, MSFC
Jim Knox, ES62/MSFC

National Aeronautics and
Space Administration

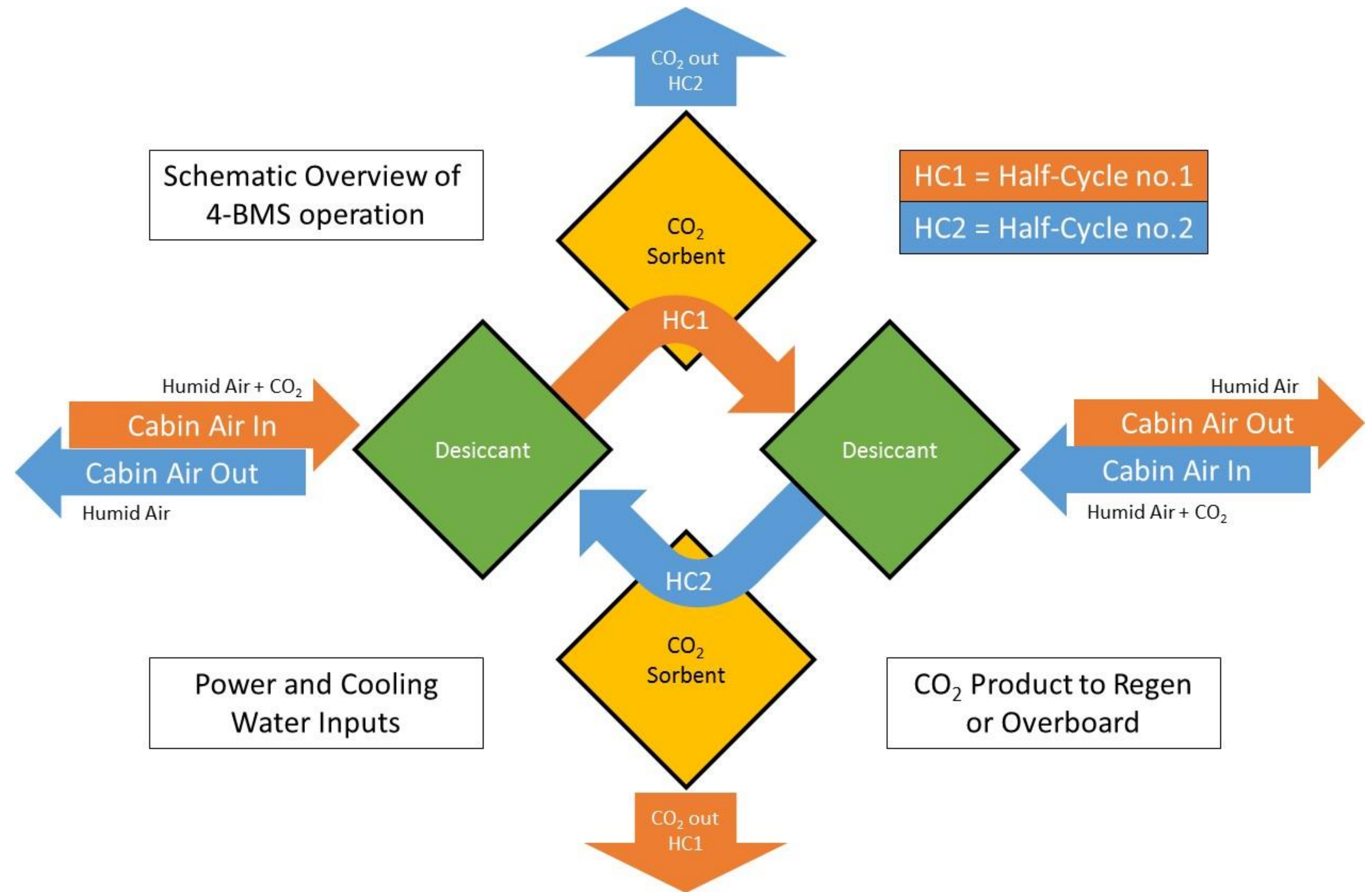


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- Life Support requires many continuous separation systems
 - Waste
 - Water
 - **Air**
 - Accomplished today with a Russian Vozdukh and two American CDRA systems



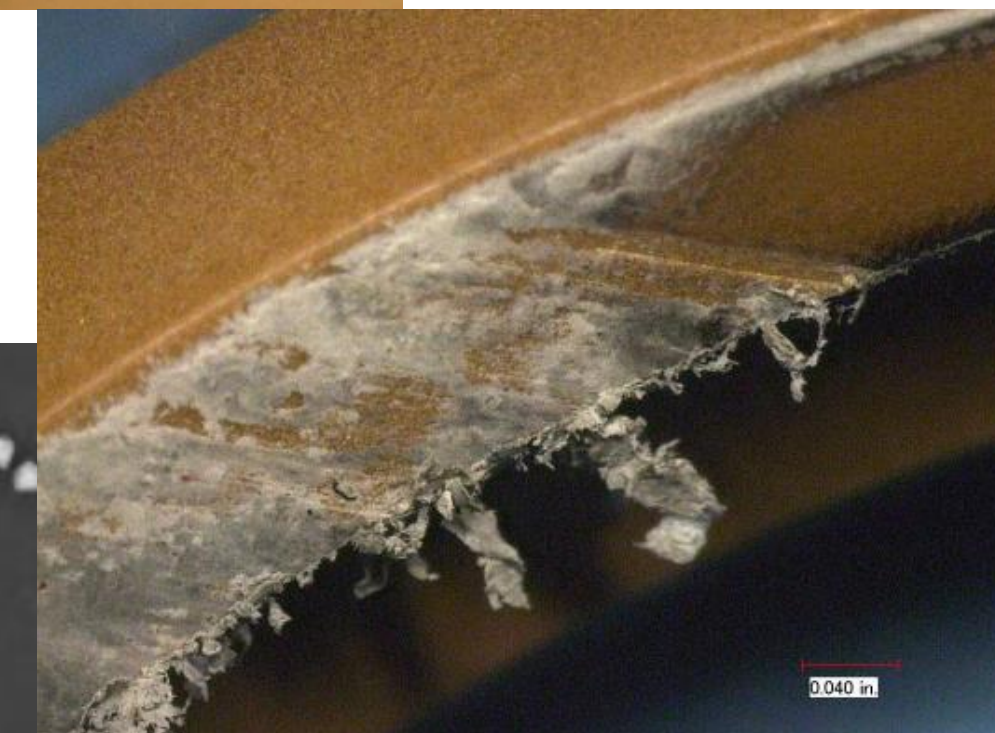
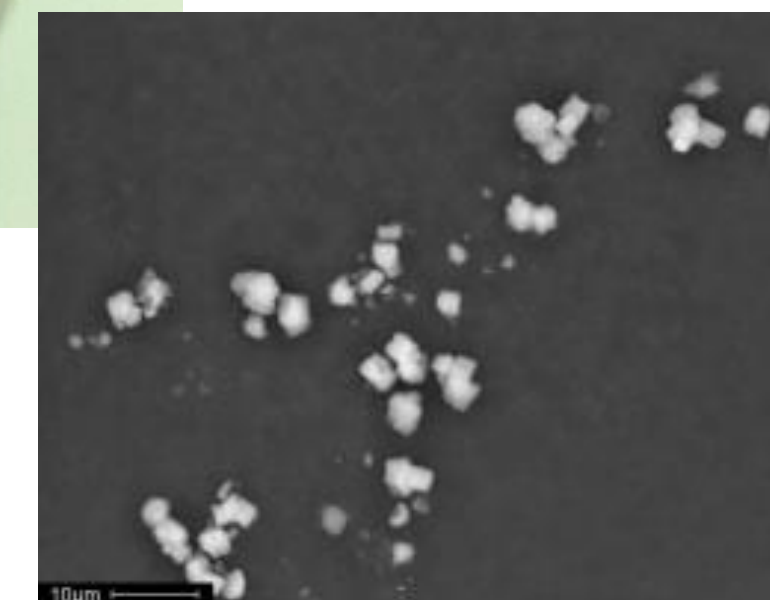
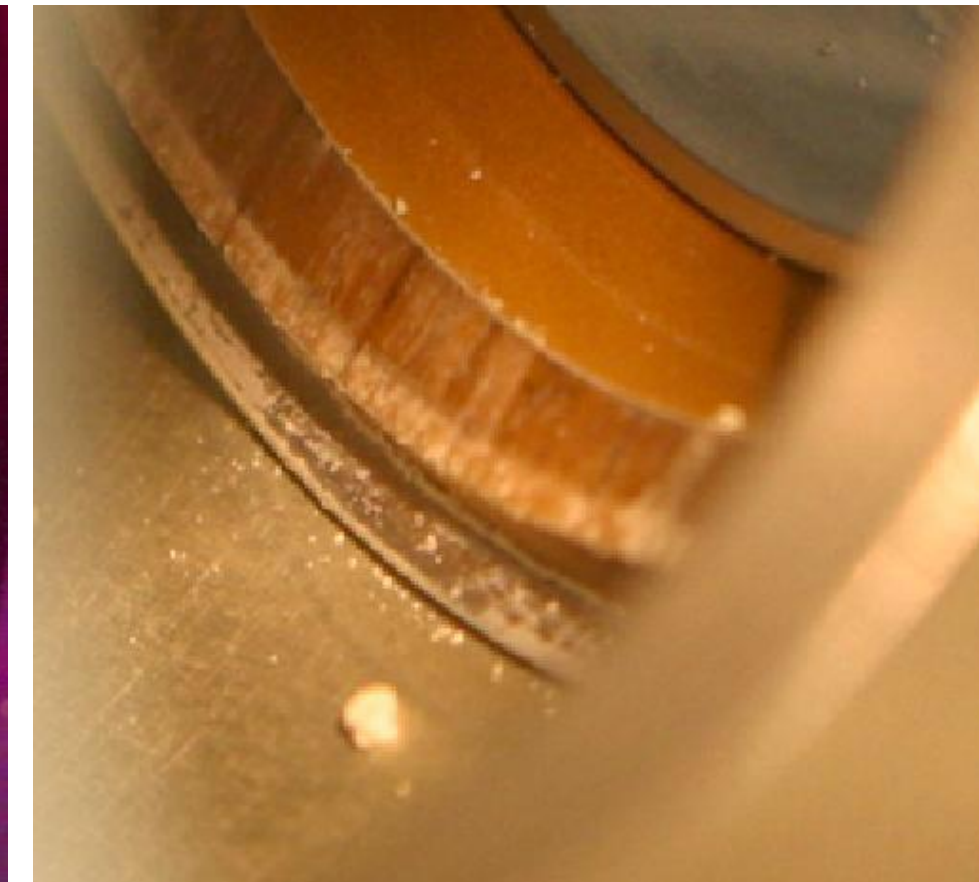
- CDRA is the flight version of a 4BMS system
 - 4-Bed Molecular Sieve
 - Cyclic operation
- Separate CO₂ out of humid cabin air
 - High purity product



- CDRA is now at iteration 5 due to...

DUST

- Many failures
 - Many identified possible causes
-
- Re-design required
 - Bring the process in house (ES62)
 - Mitigate and avoid all causes of dust



Identifying causes and solutions

- A few directly attributable failures:
 - Dust in valve => valve jamming/leaking
 - Dust on screen => flow blockage
 - Sheet heater delamination => heater short/failure
- Dozens of potential failure causes:
 - Large air velocity and pressure transients
 - Uncompacted voids which allow for free-floating particles and attrition
 - Thermal and moisture induced degradation of sorbents
 - Operating at the thermal limits of various components such as heater sheets and O-rings
 - Operator error due to difficult assembly of system

Final Goal is reliable operation for 4 crew for 3 years.



Full redesign of components for the future 4BMS

- Retain tested and proven operating architecture of CDRA
- Provide remedies for each known and suspected failure

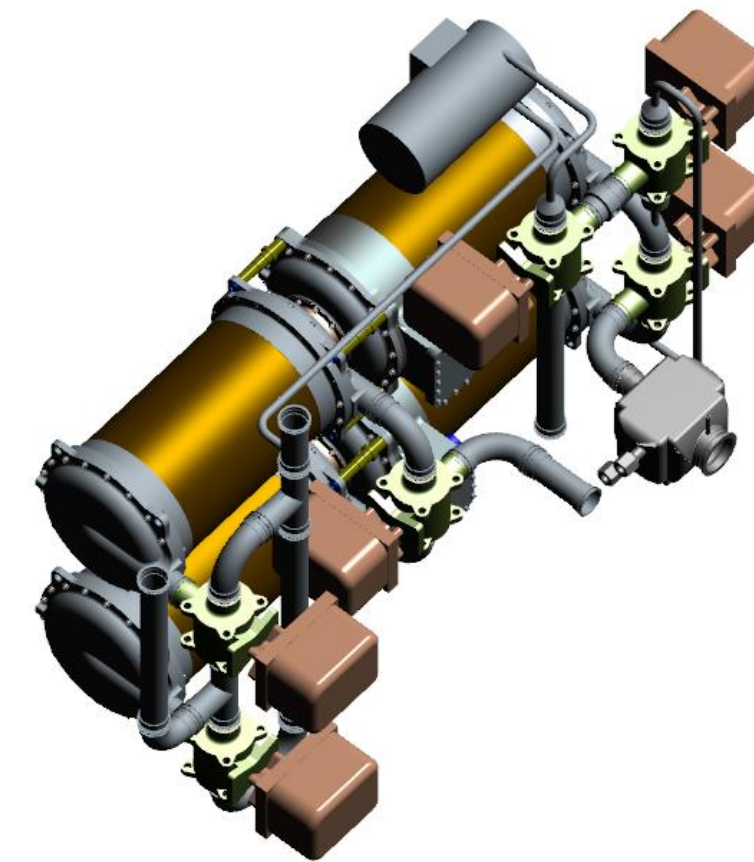
Original flight-like test beds
in 4BMS test stand



New components in build



Target flight-like
configuration

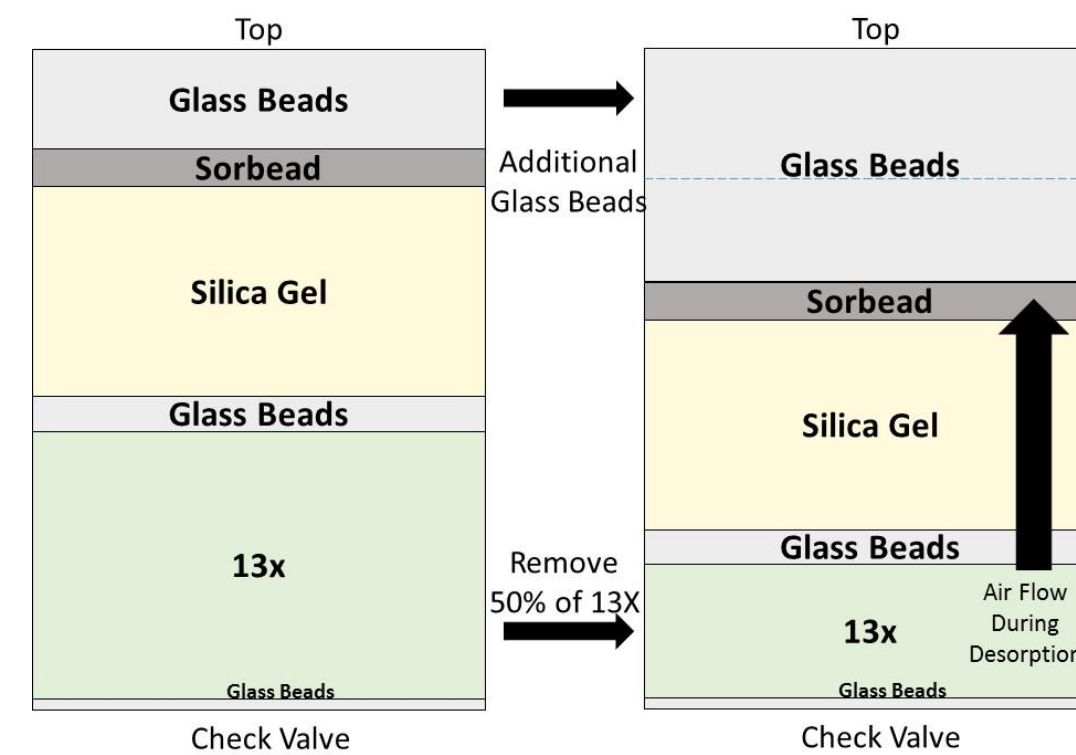
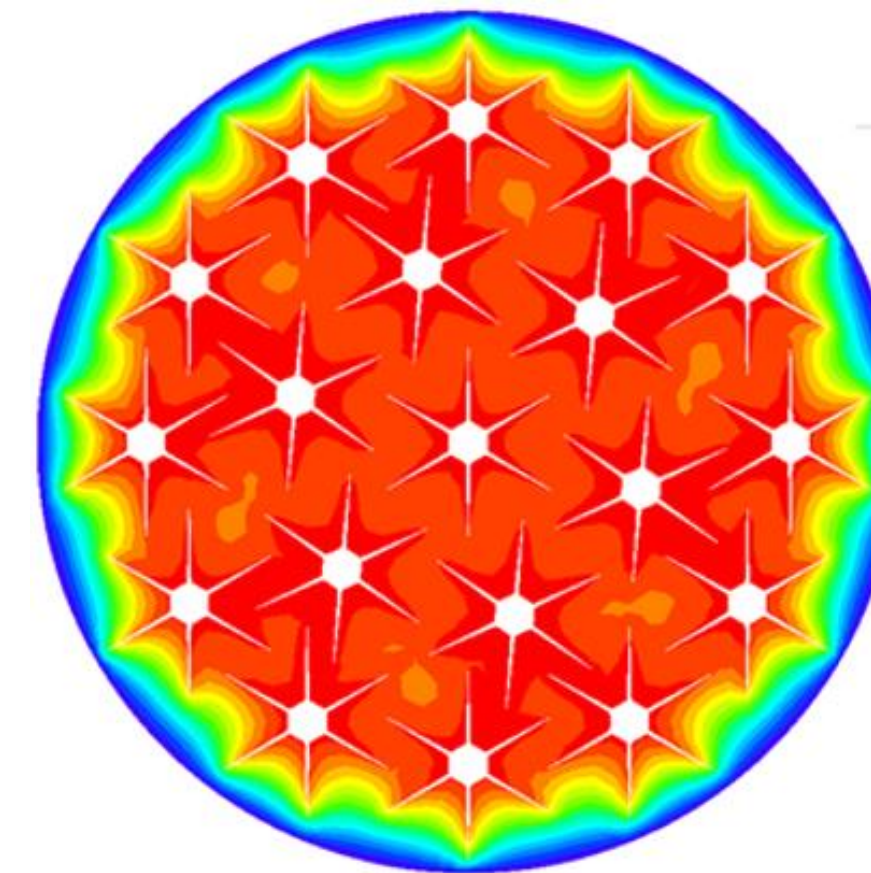


What goes into the decision process?

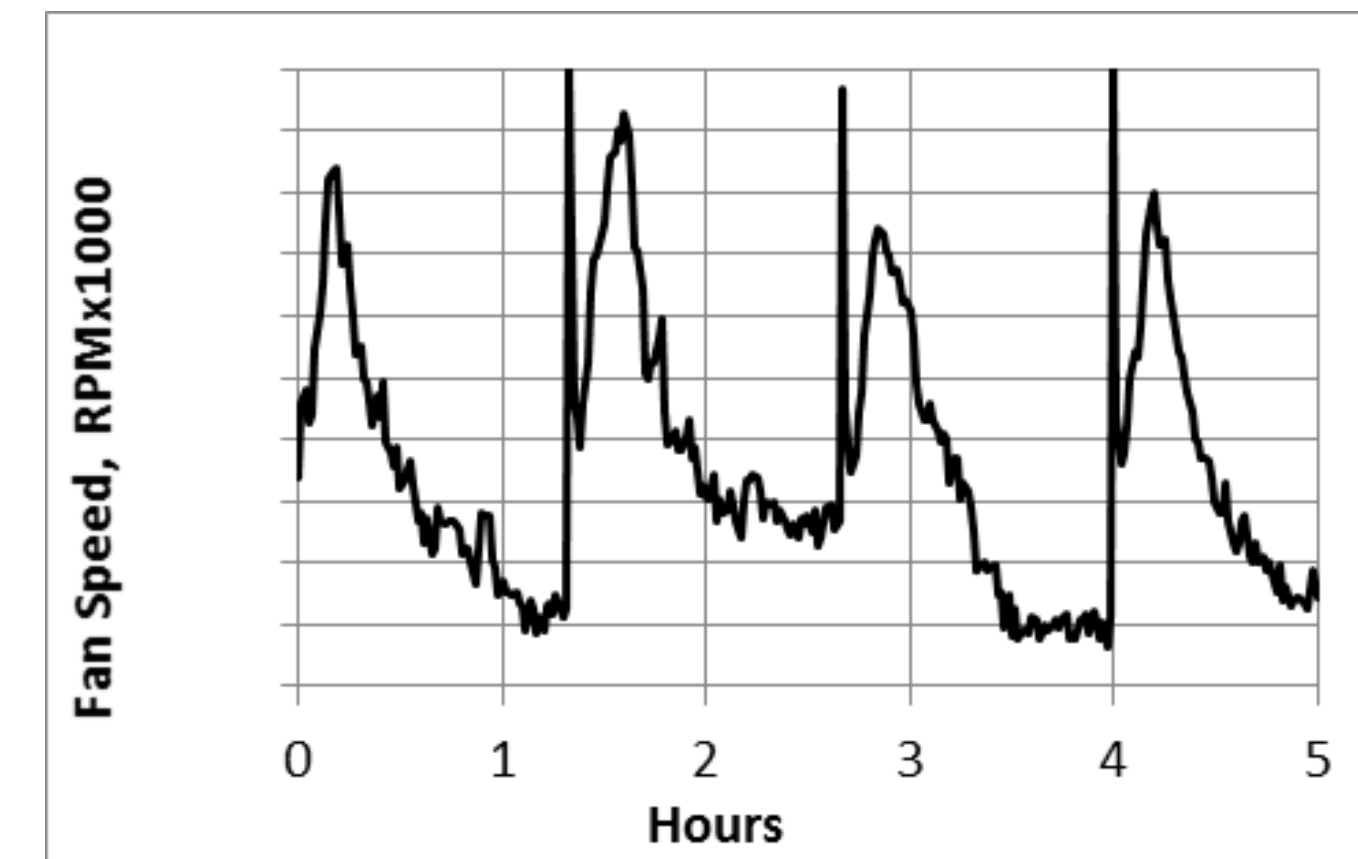
Sorbent selection

Material Type	Sorbent Name	Use/Potential Use	Form Factor	Pore size	Notes
Silica Gel	Grace Grade 40	Bulk Desiccant	Granular	Microporous	used in CDRA
Silica Gel	Grace SG B125	Bulk Desiccant	Beads	Microporous	used in CDRA
Silica Gel	BASF Sorbead H	Bulk Desiccant	Beads	Microporous	
Silica Gel	BASF Sorbead R	Bulk Desiccant	Beads	Microporous	
Alumino-Silica Gel	BASF Sorbead WS	Guard Layer	Beads	Microporous	Misting Stable, used in CDRA
Activated Alumina	BASF F200	Bulk Desiccant	Beads	Mesoporous	Misting Stable
Molecular Sieve	UOP ASRT 1995 and ASRT 2005	CO ₂ sorbent	Pellets	5Å	CaA Zeolite, used in CDRA
Molecular Sieve	UOP RK-38	CO ₂ sorbent	Beads	5Å	CaA Zeolite, used in CDRA
Molecular Sieve	Grace MS 564	Residual Desiccant	Beads	3Å	KA Zeolite
Molecular Sieve	Grace MS 514	Residual Desiccant	Beads	4Å	NaA Zeolite
Molecular Sieve	UOP UI-94	Residual Desiccant	Pellets	4Å	NaA Zeolite
Molecular Sieve	Grace MS 522	CO ₂ sorbent	Beads	5Å	CaA Zeolite
Molecular Sieve	Grace MS 544	CO ₂ sorbent, Residual Desiccant	Beads	10Å	NaX Zeolite, used in CDRA
Molecular Sieve	BASF 5A	CO ₂ sorbent	Beads	5Å	CaA Zeolite
Molecular Sieve	BASF 5A BF	CO ₂ sorbent	Binder-free Beads	5Å	CaA Zeolite
Molecular Sieve	BASF 13X	CO ₂ sorbent, Residual Desiccant	Beads	10Å	NaX Zeolite
Molecular Sieve	BASF 13X BF	CO ₂ sorbent	Binder-free Beads	10Å	NaX Zeolite
Molecular Sieve	UOP APGIII	CO ₂ sorbent	Beads	10Å	NaX Zeolite
Molecular Sieve	UOP VSA-10	CO ₂ sorbent	Beads	10Å	LiLSX Zeolite
Molecular Sieve	Tosoh NSA-700	CO ₂ sorbent	Pellets	10Å	LiLSX Zeolite

Heater core redesign and optimization



System sizing



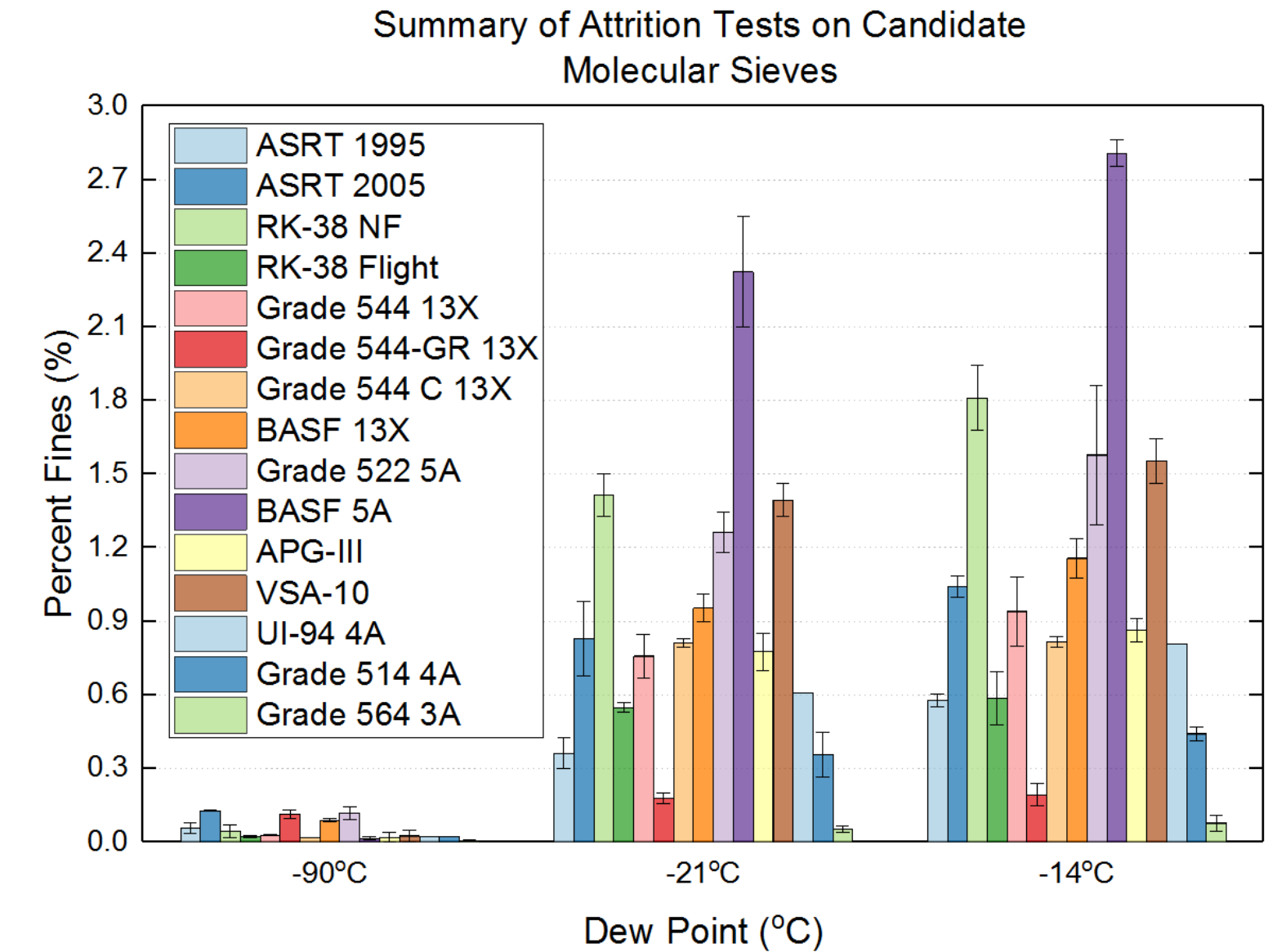
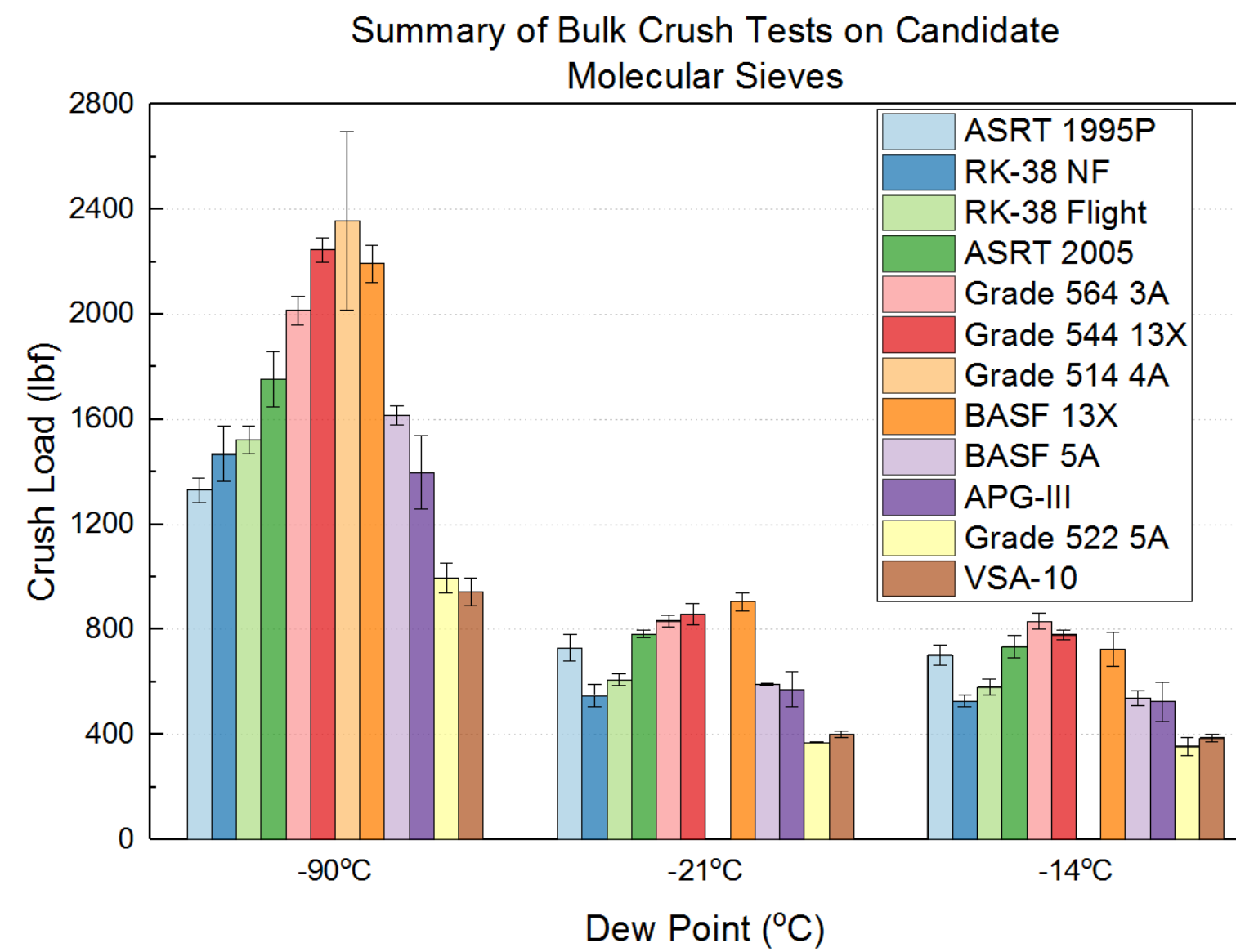
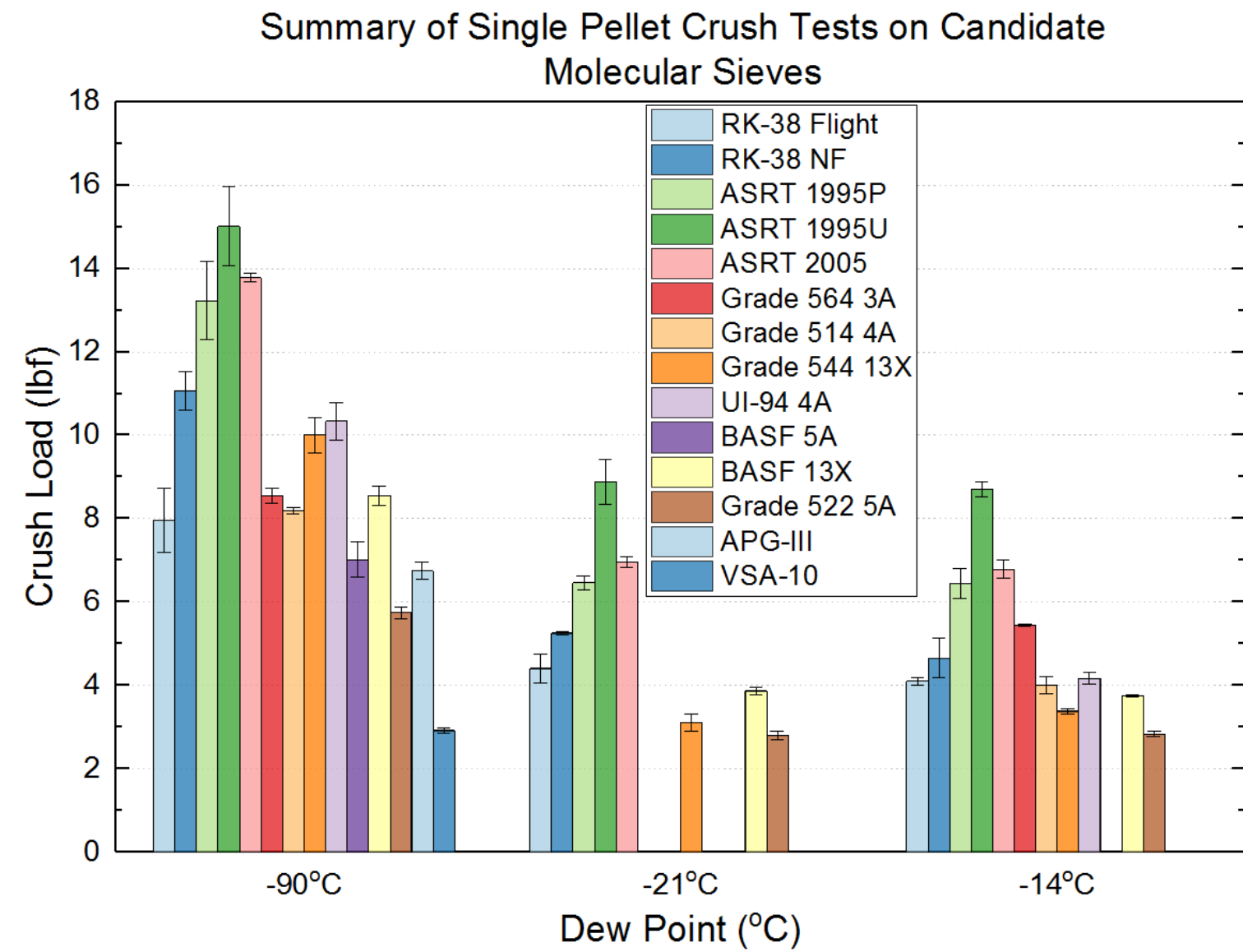
Design to address problems at transitions



- What goes into the decision process?
 - **Sorbent selection**
 - System sizing
 - Heater core redesign and optimization
 - Design to address problems at transitions



Sorbent Robustness



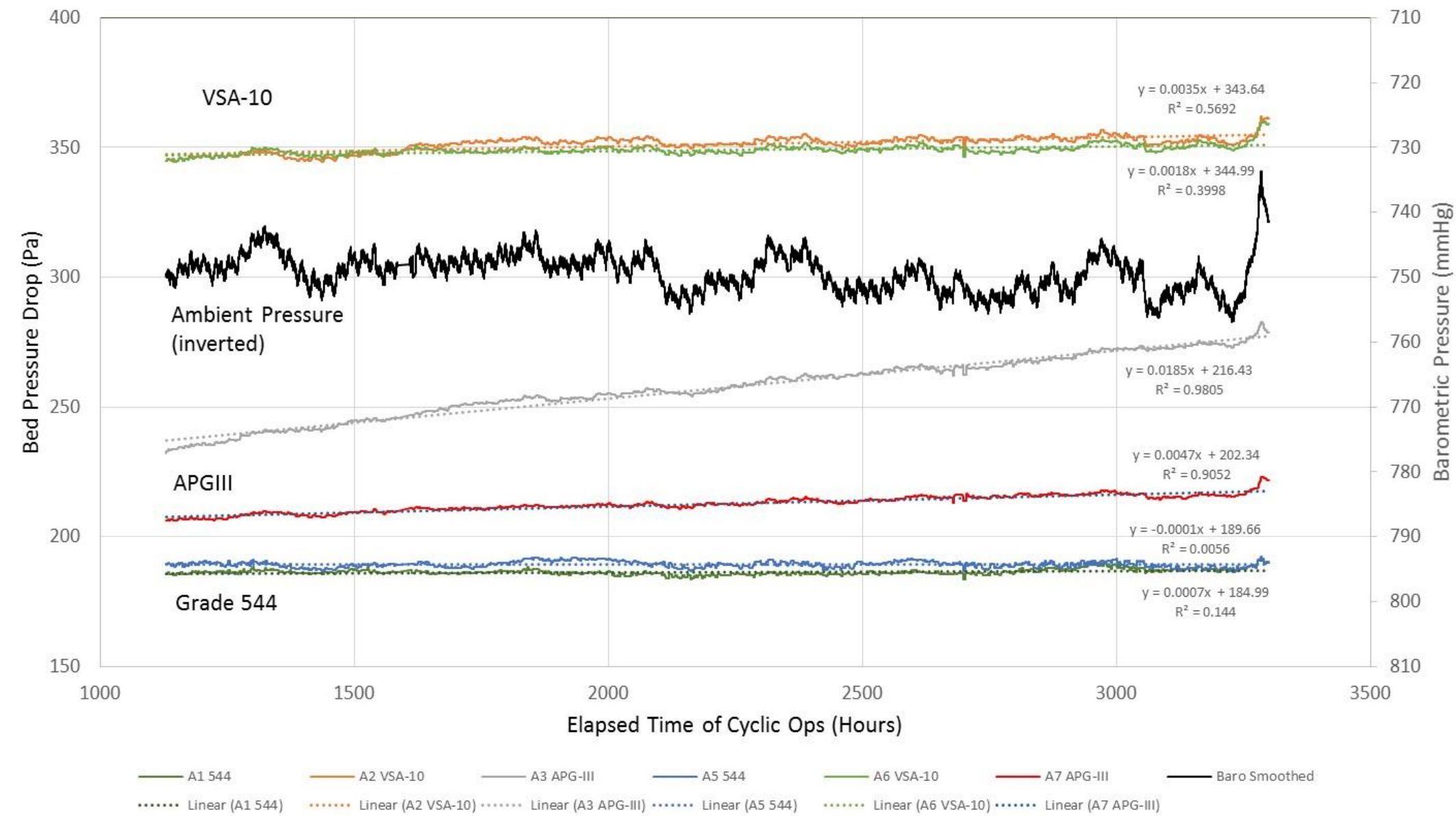
– Target: Outperform current material (ASRT)

- Two candidates considered from here out are 544 13X and BASF 13X

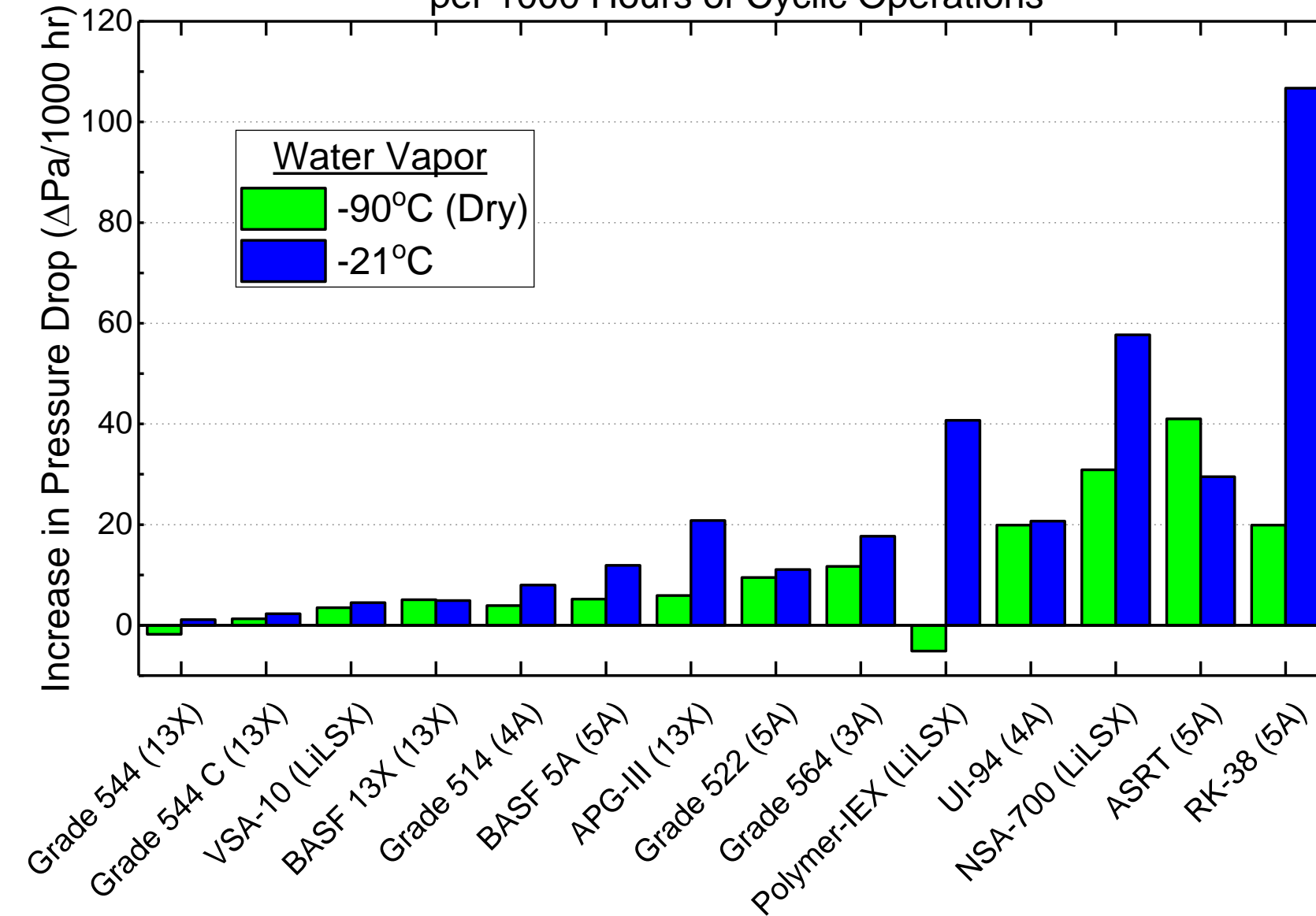


Sorbent Hydrothermal Stability

Hydrothermal Stability Test – Pressure Drop vs. Time Elapsed
Grade 544, VSA-10, and APG III at Dry and Humidified conditions



Increase in Pressure Drop across HST Bed Assembly
per 1000 Hours of Cyclic Operations

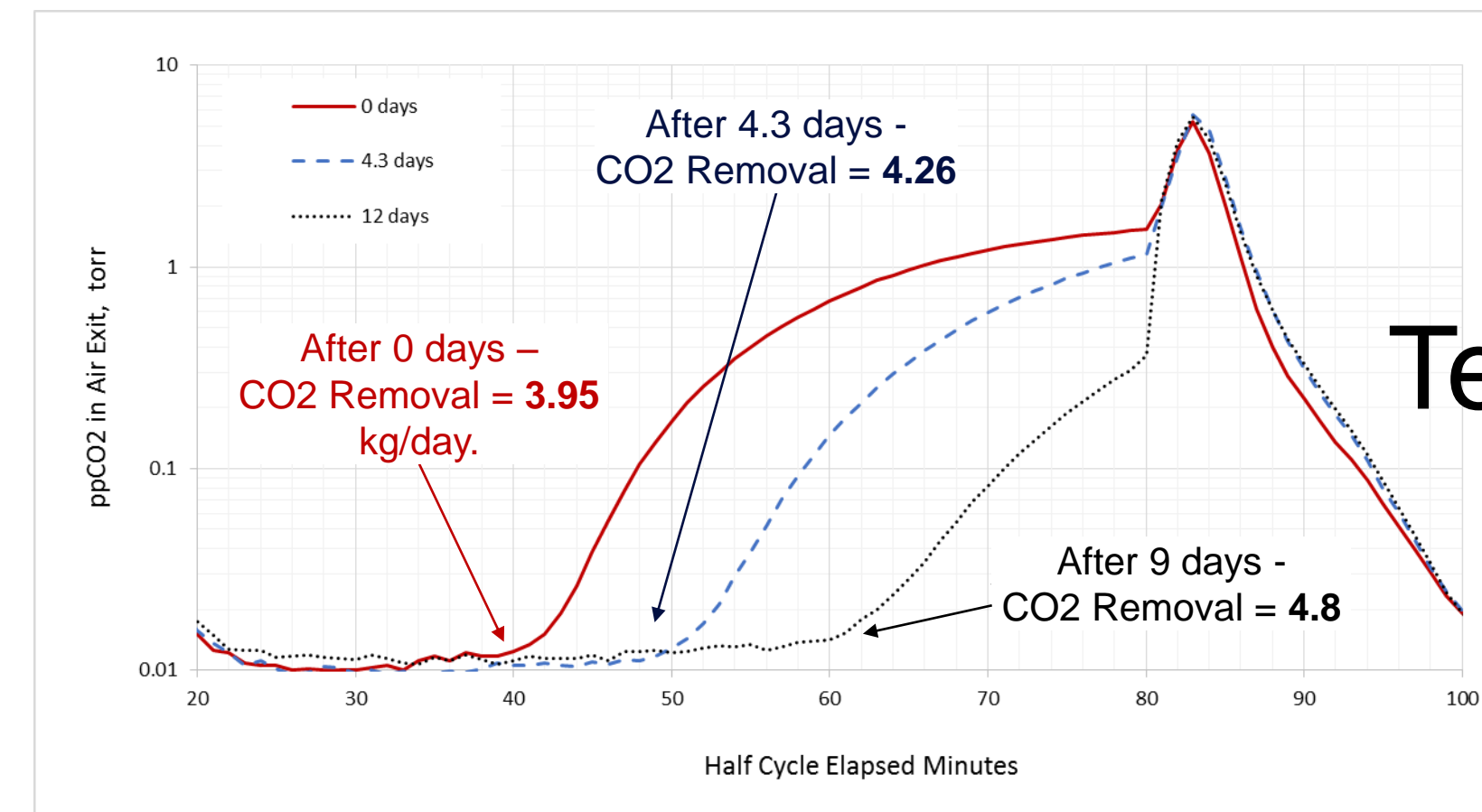
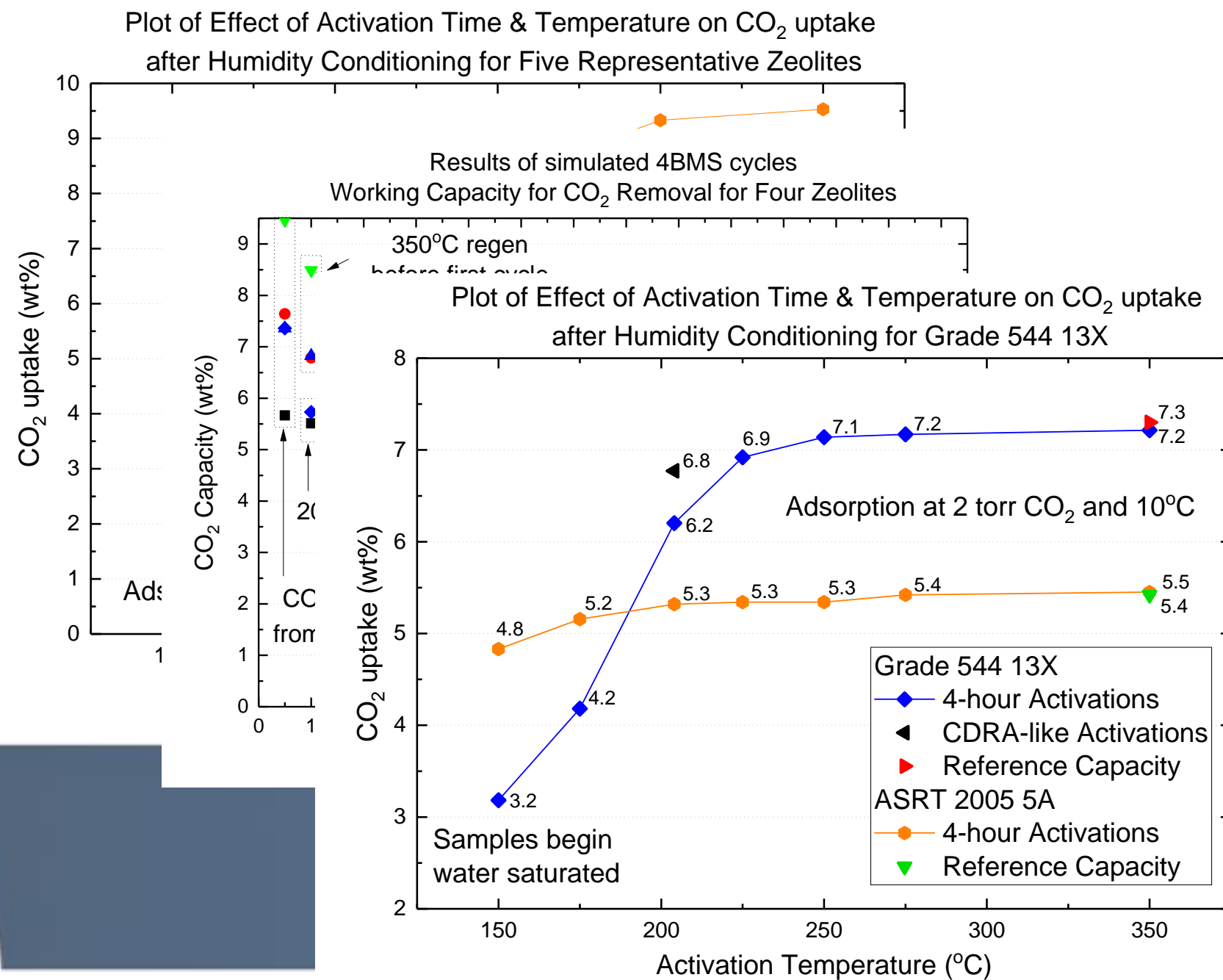


- Target: Minimize filter clogging over time (rising ΔP)
 - Grade 544 13X and BASF 13X perform well

Performance Recovery

- Off-nominal events may include water ingestion into CO₂ sorbent bed
 - Water blocks CO₂ removal performance, though lots of water is required to block entire bed

Subscale Test Predictions



Full Scale Test Results

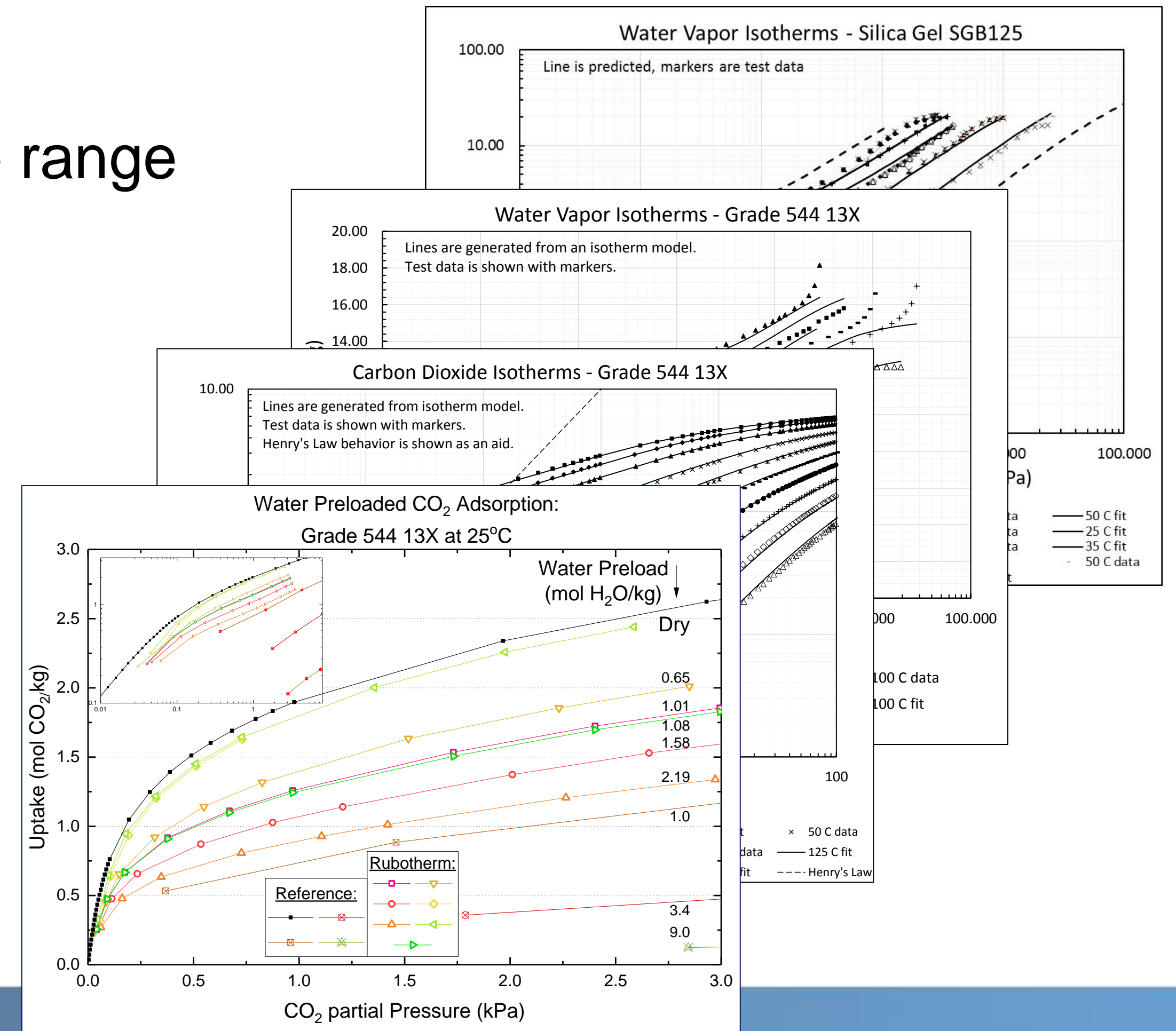


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 - Sorbent selection
 - **System sizing**
 - Heater core redesign and optimization
 - Design to address problems at transitions



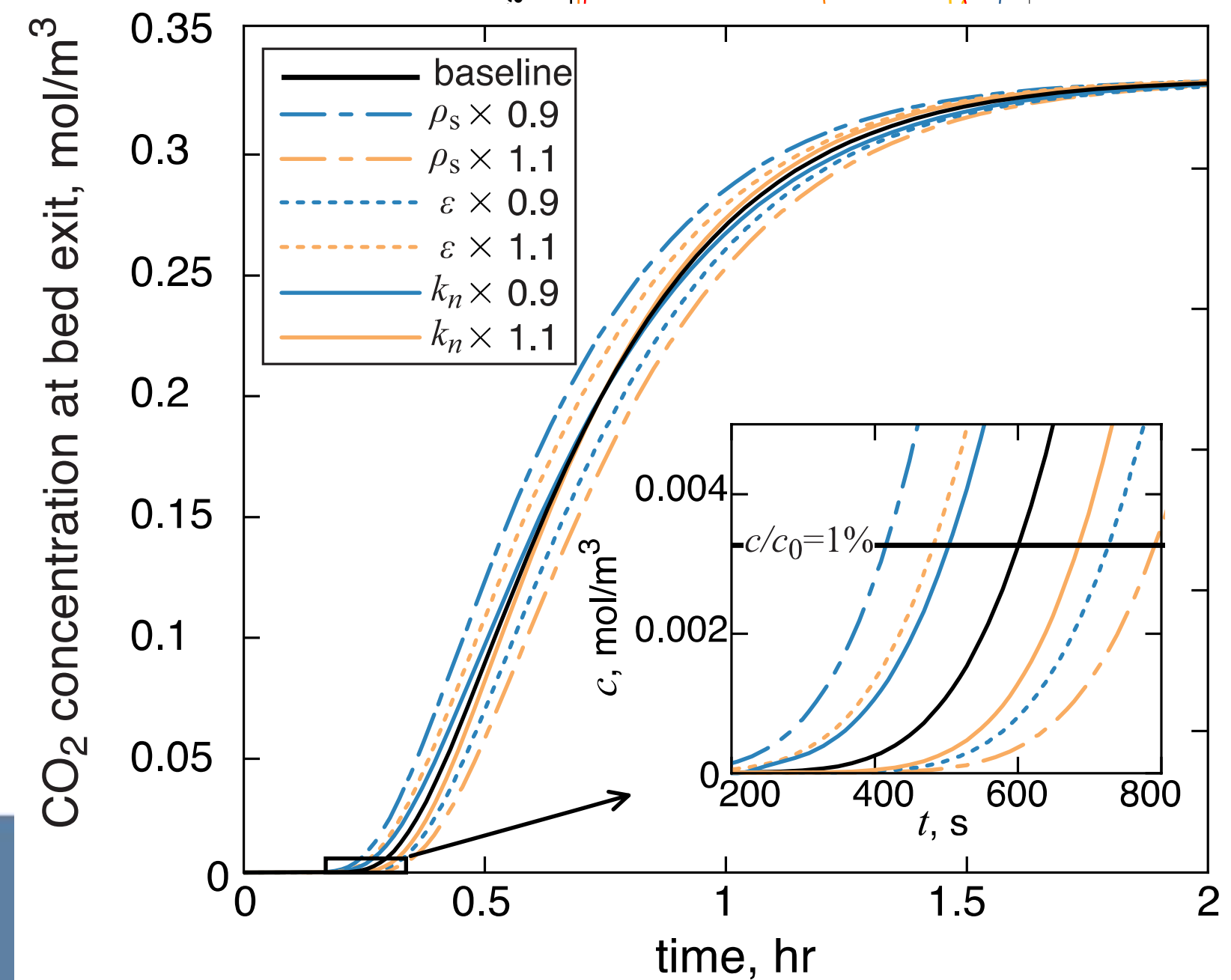
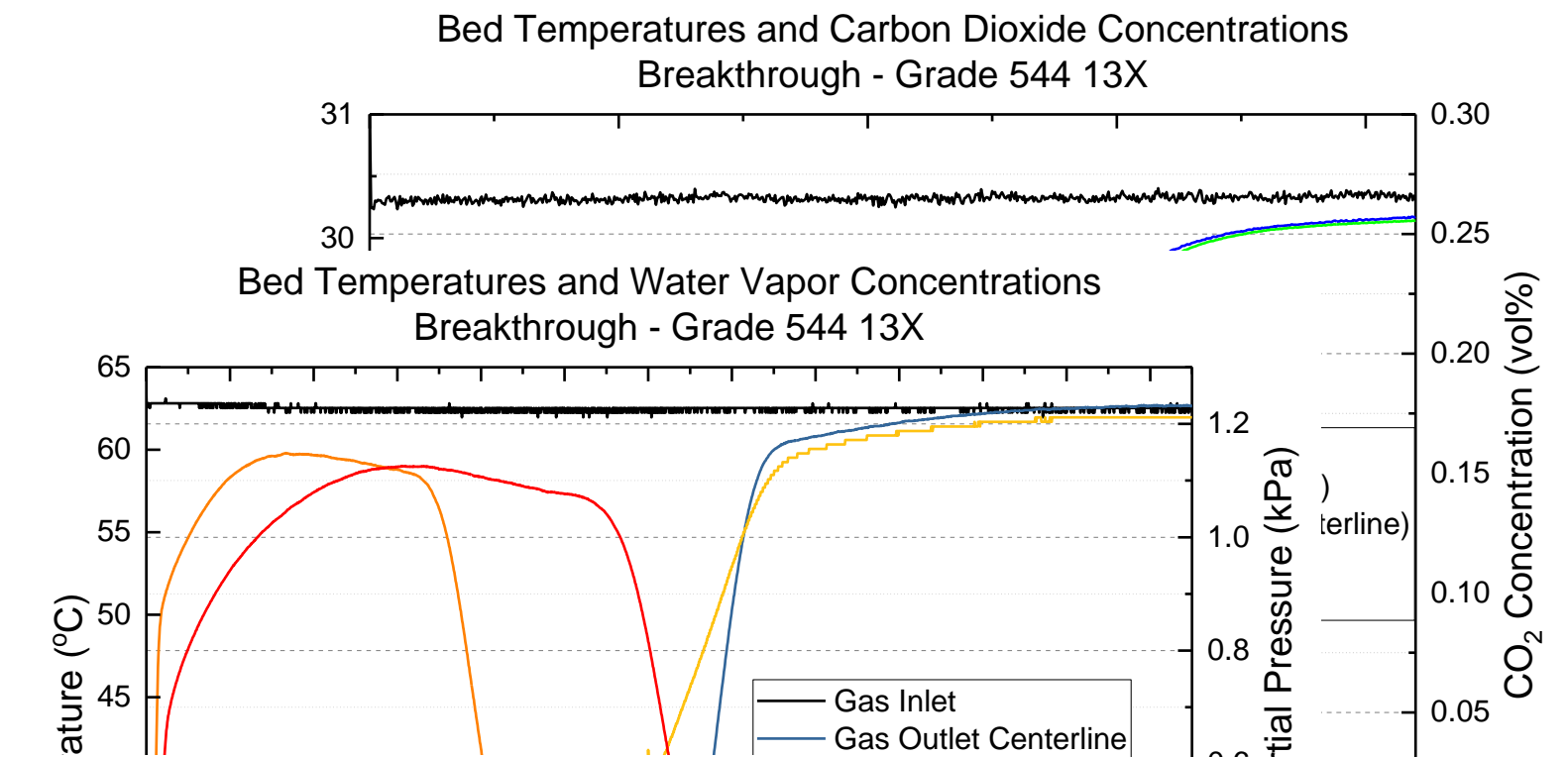
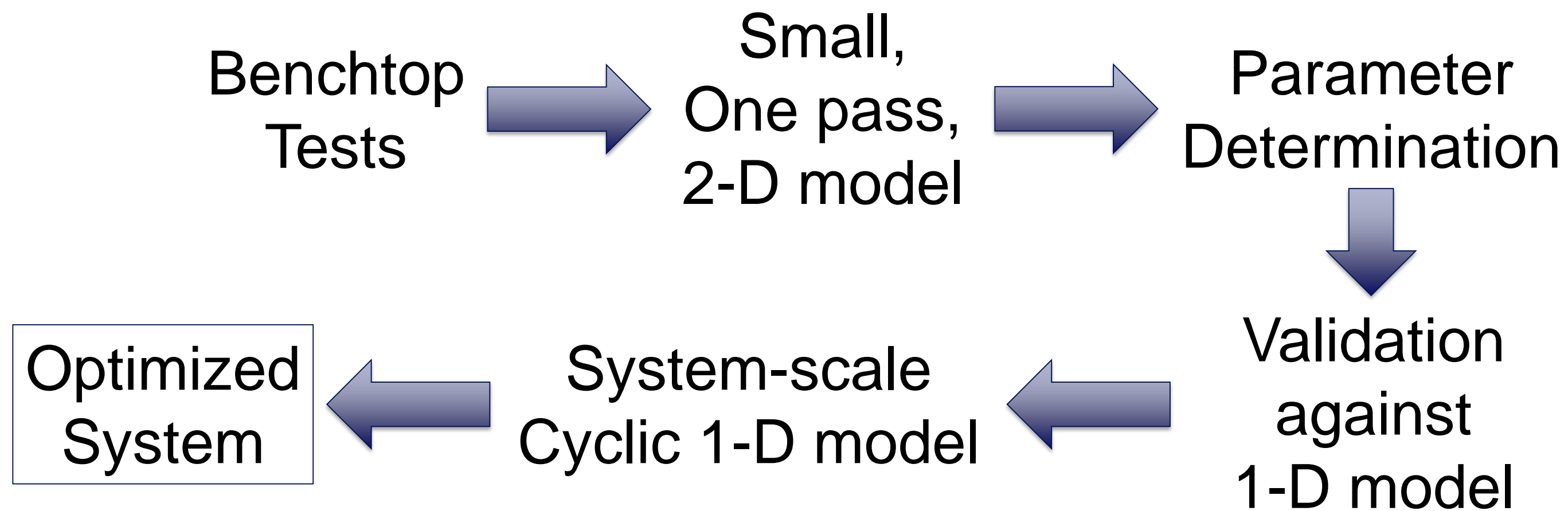
Sorbent Capacity and Performance

- Capacity for CO₂ and water
 - Across full temperature and pressure range
 - Input to models
- Mixture isotherms
 - Simulation refinement
 - Could optimize system size by 20%



Sorbent Capacity and Performance

- Breakthrough analysis
- NSTF fellow developed sensitivity analysis



- Redesign is well underway in ES62
 - System capable of scrubbing CO₂ for 4 crew
 - Maintain the newest medical recommendation of 2 torr CO₂
 - Retain proven, high TRL operating architecture
 - Mitigate dust at every turn

A decorative graphic in the bottom left corner features a stylized globe with a grid pattern, partially obscured by a blue curved shape. A solid blue horizontal bar spans the bottom of the slide, containing the word "Conclusions" in white text.

Conclusions