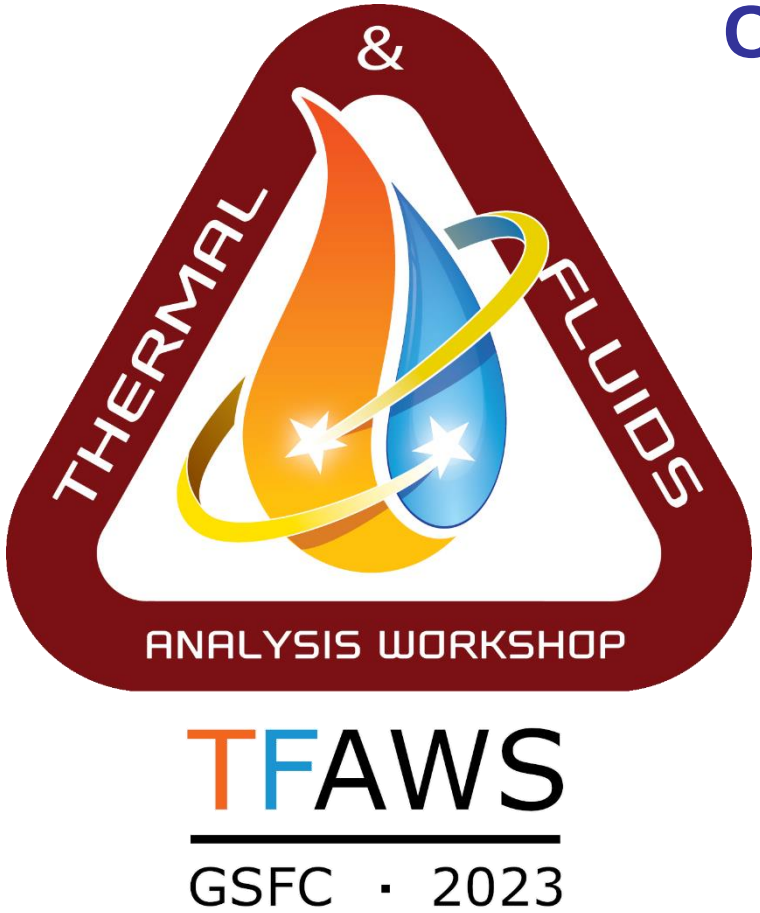

FREEZE-THAW TOLERANT DIRECT CONDENSATION RADIATOR FOR TWO-PHASE HEAT TRANSPORT SYSTEMS

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Greenbelt, MD

Outline

- Two-Phase Heat Transport Technology
- Operational Issues with Direct Condensation Radiators
- Proposed Freeze-Thaw Tolerant DCR Concept
- Proof-of-Concept Performance Demonstration
- Future Plan / Path Forward
- Summary Conclusion

Acknowledgements

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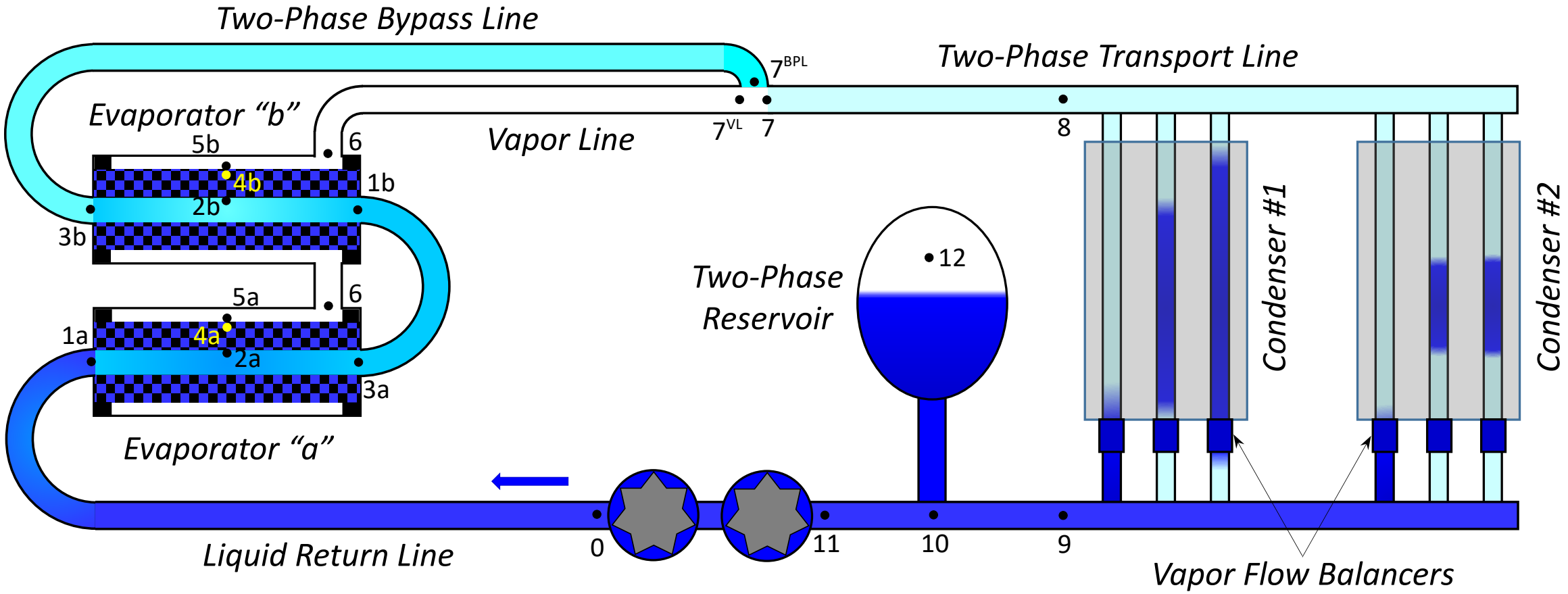
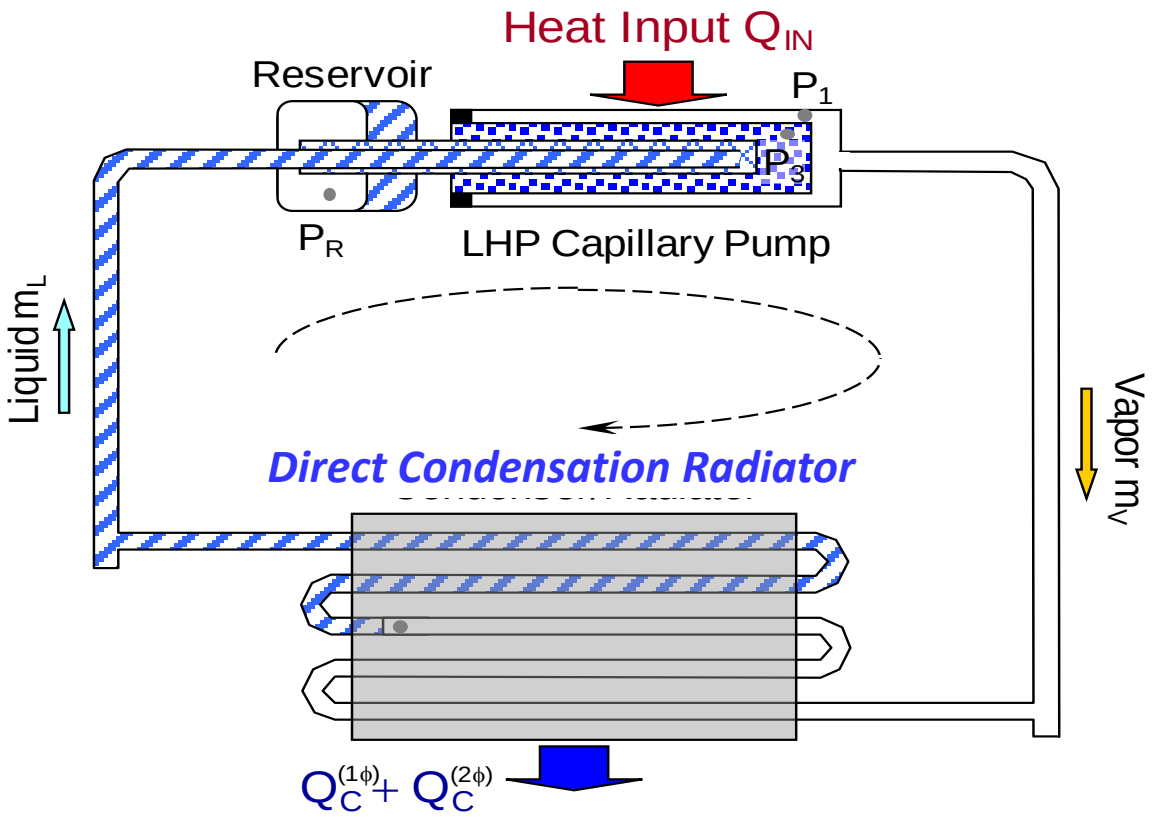
2. *As a project team member (subcontractor), AAVID Thermacore of Lancaster, PA was responsible for the design/fabrication/processing and instrumentation of the proof-of-concept demonstration test unit. All tests were also performed at Thermacore facility.*

Two-Phase Heat Transport Loop



Direct Condensation Radiator (DCR)



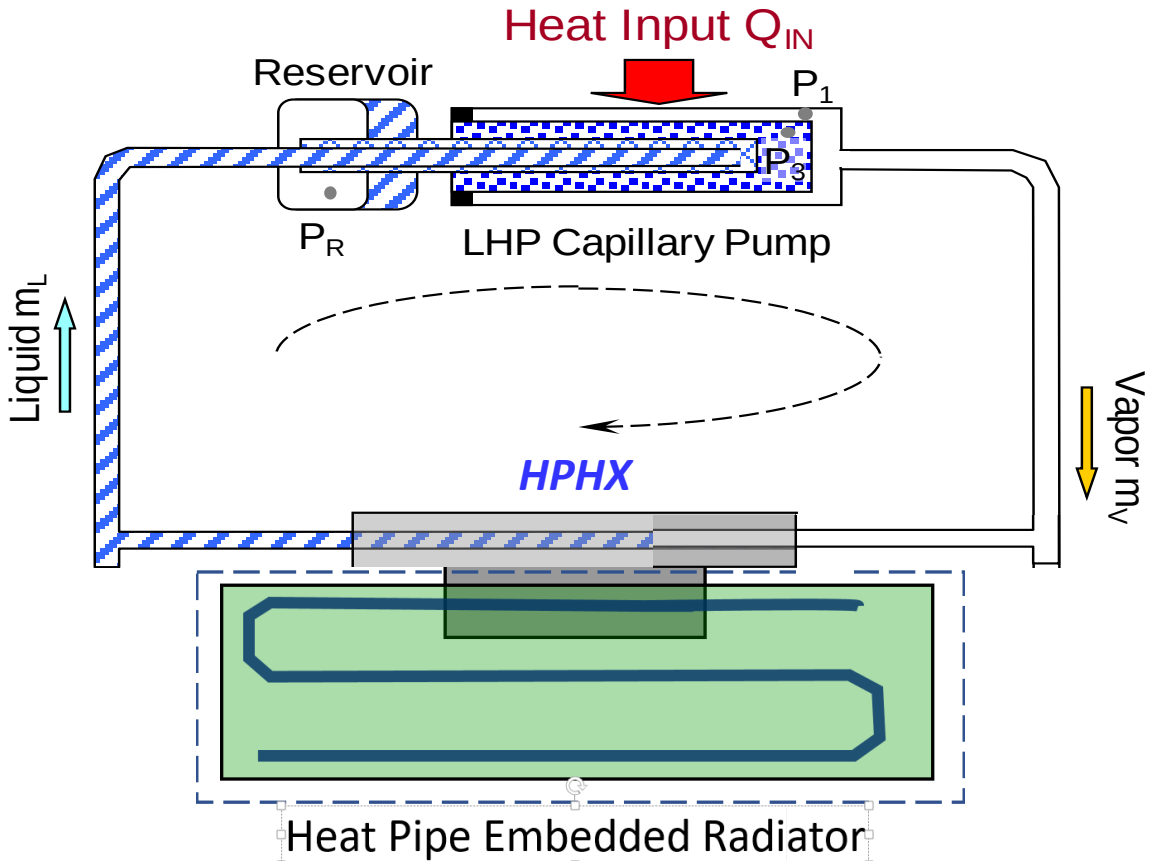
Freeze-Thaw of Fluid in DCR Line

- solid ice formed anywhere in loop ⇒ fluid flow ceases
- loop remains inoperative until completely thawed out
- potential structural damage to DCR when thawed

Operation in Cold Environments

- cold returning liquid
- survival heaters necessary to keep payloads above limit

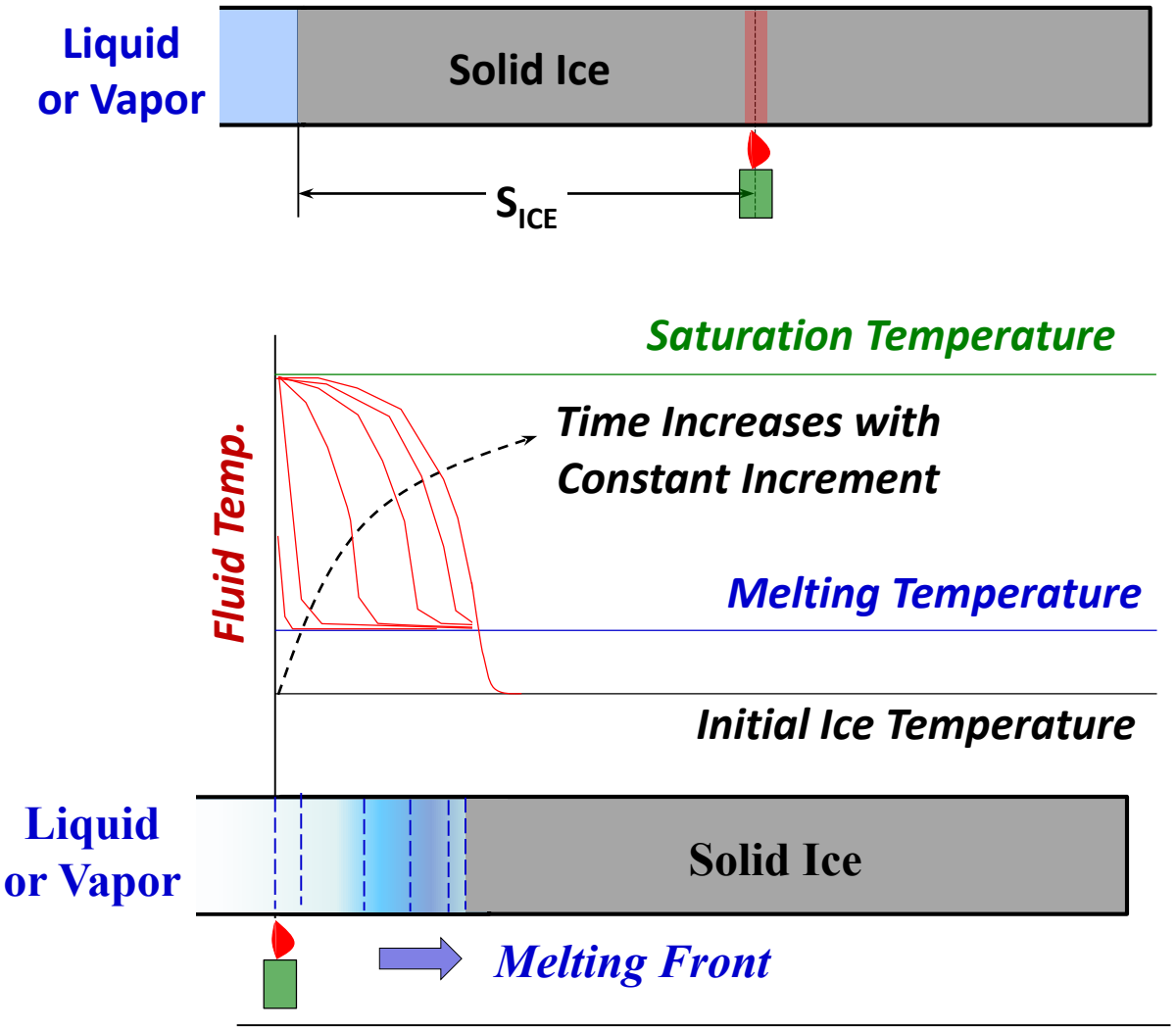
Direct Condensation Radiator (DCR)



Mitigation of Freezing in Practice

- heaters to keep DCR temp. above fluid freezing point
- low freezing point fluid
- Heat Pipe / Heat Exchanger

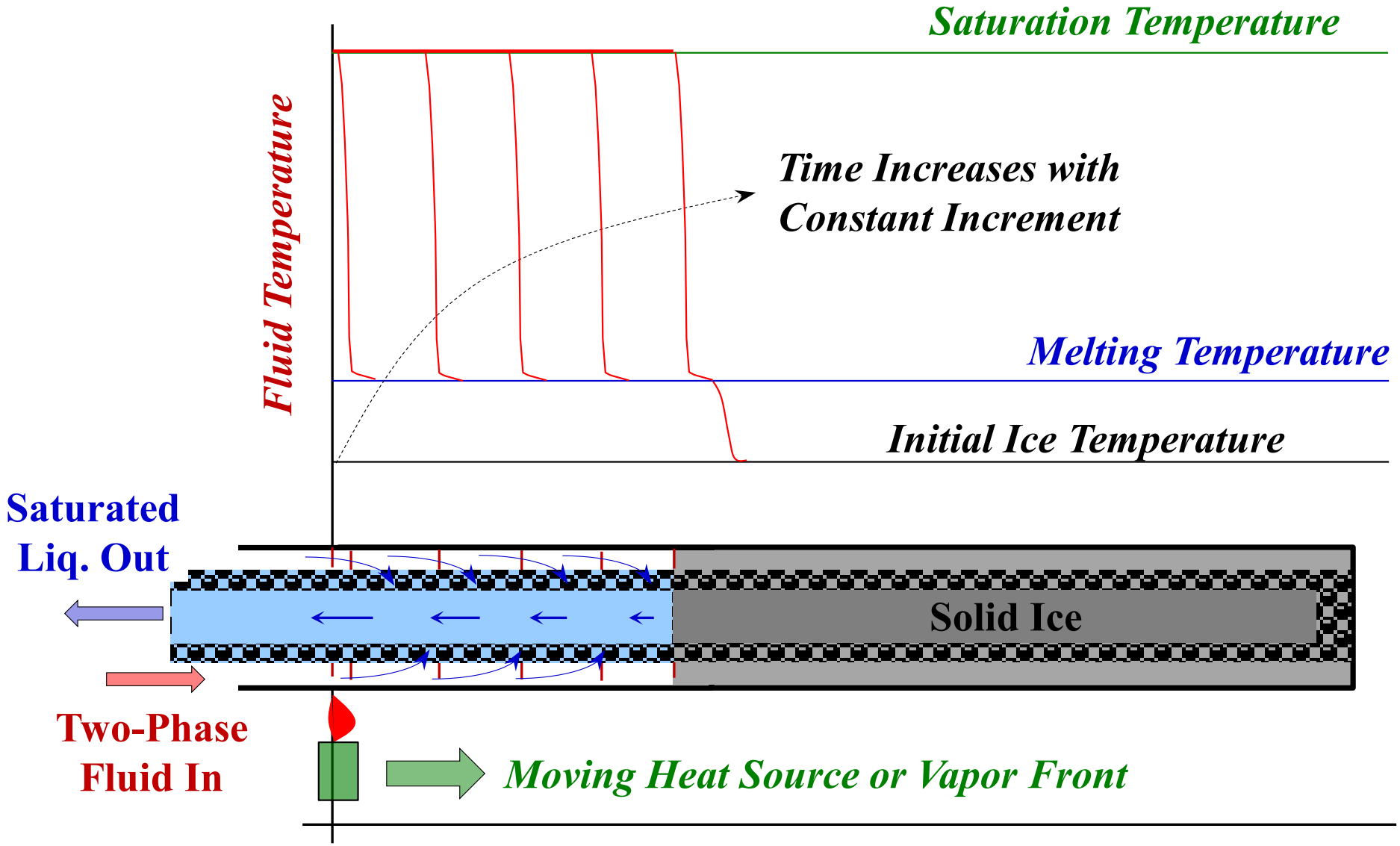
Difficulty of Thawing a Frozen DCR

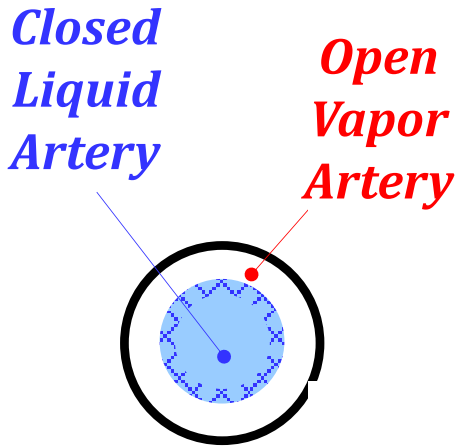


Most liquids contract when frozen but expand when thaw ⇒ DCR line rupture

Safe method of melting ice plugs is to heat from either end (or both) and let heat conducts gradually into ice ⇒ but shall take a long time

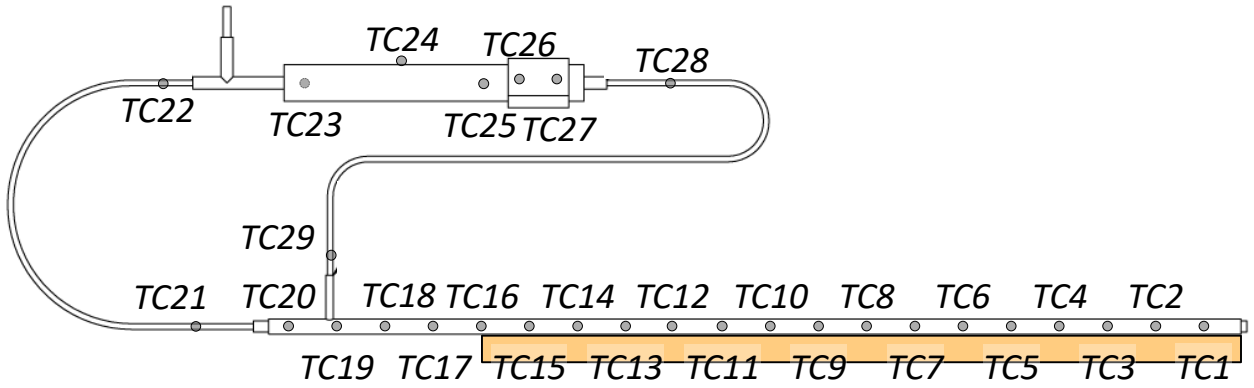
Proposed Method of Thawing Frozen-Solid DCR

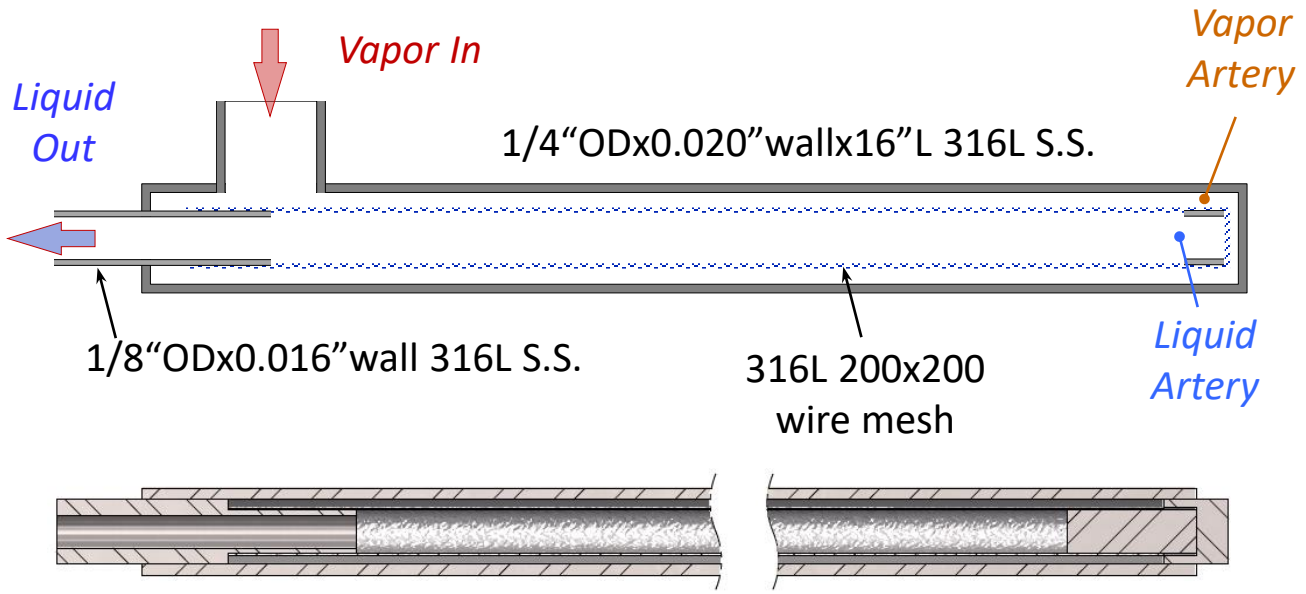




Proof-of-Concept Demonstration Test Unit

Ammonia mini-LHP



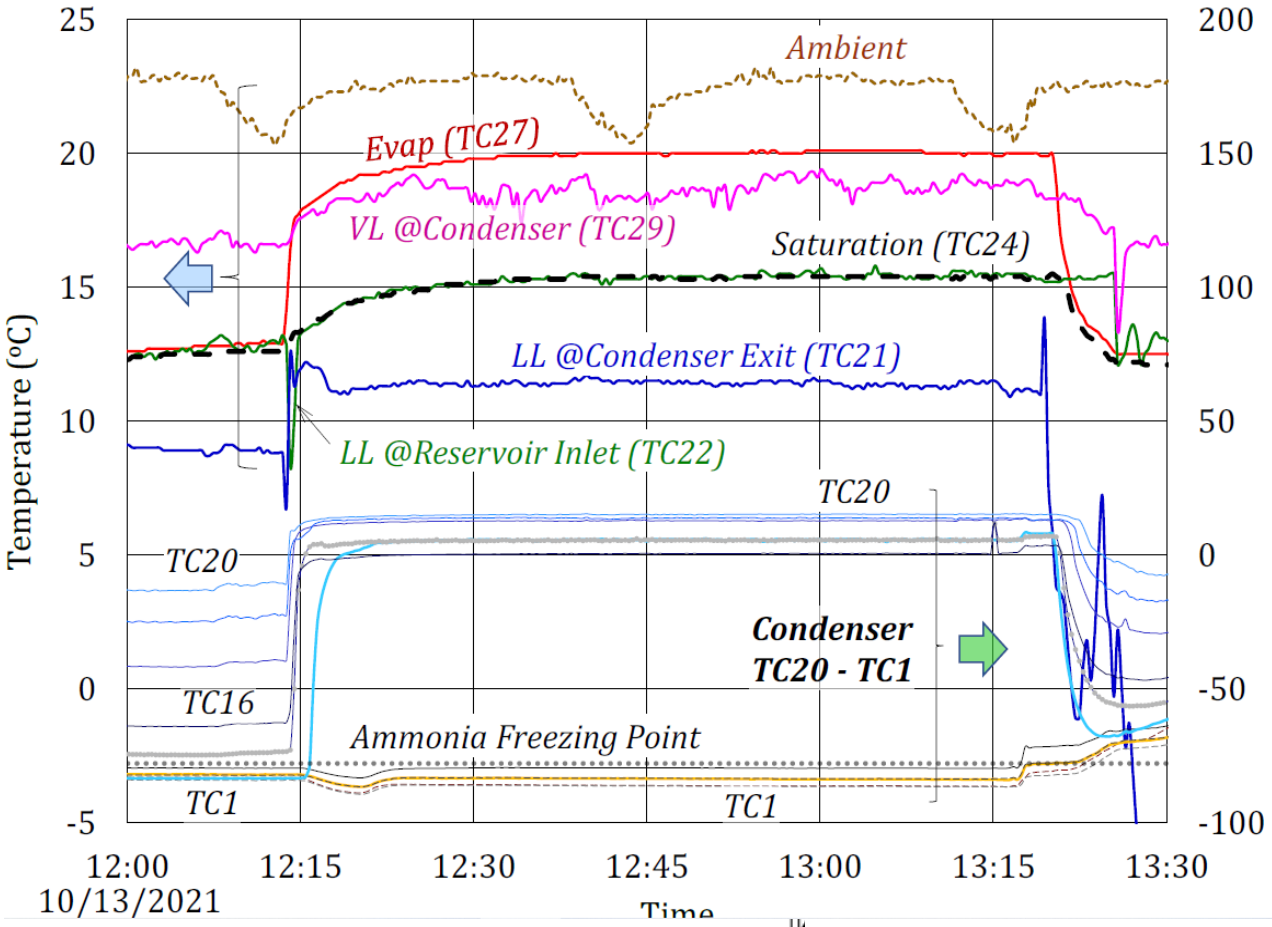


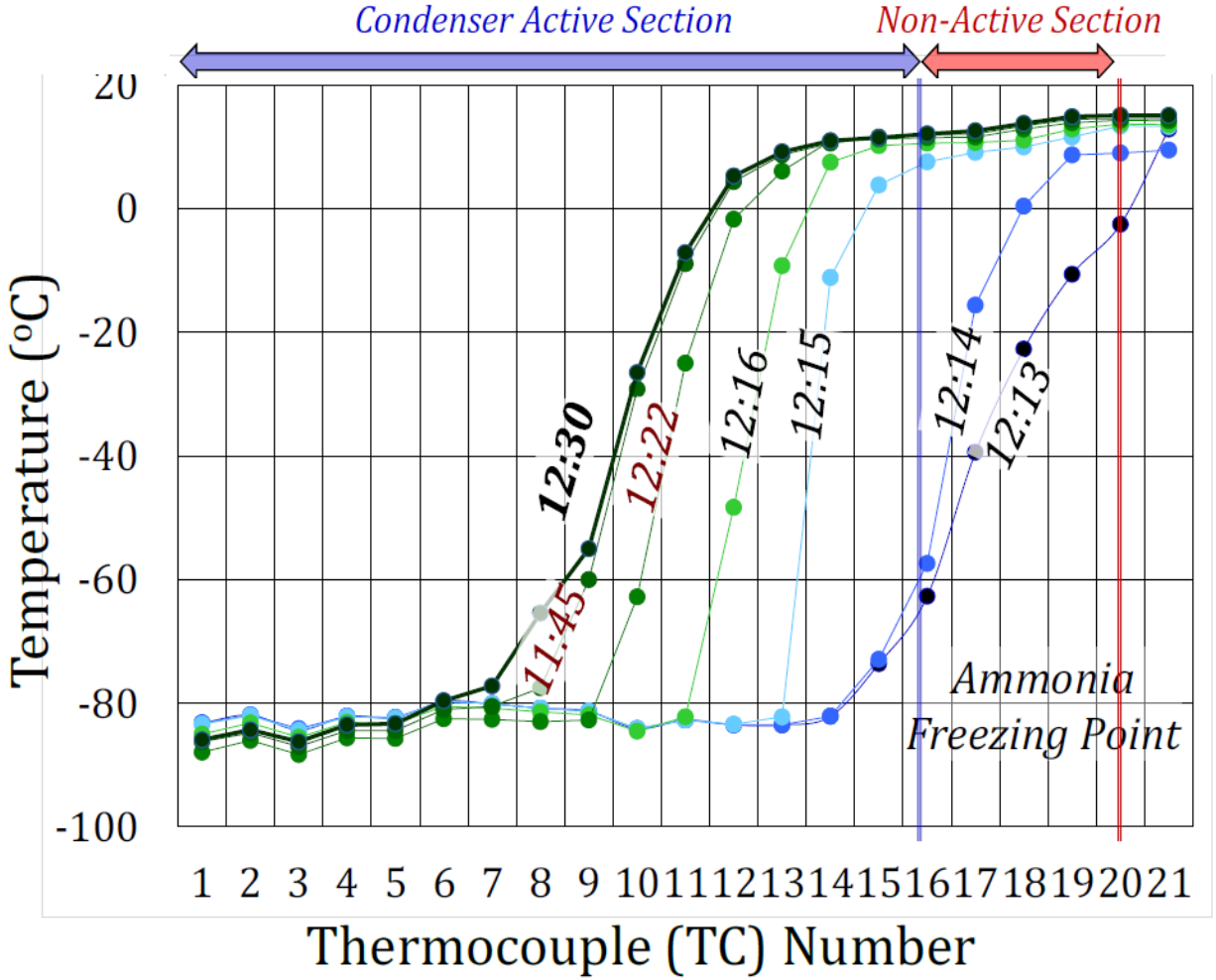
Proof-of-Concept Demonstration Test Unit

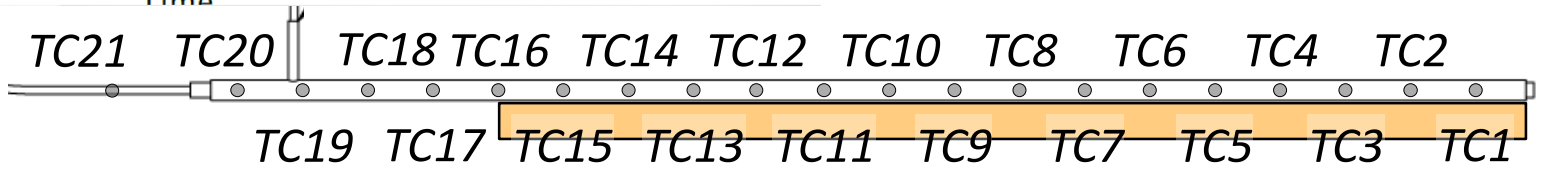
Table 1. Volume Breakdown of Phase I LHP DCR Test Unit

Components	Description	Volume (cc)		
		Vapor	2-f	Liquid
Capillary Pumps				
- Primary Wick	0.5"ODx0.2"IDx1.25"L 45% porosity			1.52
- Liquid Core	0.2"ODx0.125"IDx0.9"L		0.28	
- Vapor Grooves + Channels	Two 0.02"x0.08"x1" Axial Channels	0.05		
- Bayonet Tube	3/32"ODx0.016"wallx3.95"L			0.19
- Reservoir	0.5"IDx3"L		9.65	
Vapor Line	1/8"ODx0.068ID"x24.2"L	1.44		
Two (2) Uniton Sqagelok Fittings	0.095"IDx0.5"L	0.06		
Condenser Line	1/4"ODx0.194"IDx16"L	2.48		
- Screen Tube	0.16"ODx0.125"IDx16"L			5.27
Liquid Line	3/32"ODx0.056"IDx5"L			0.20
Pressure Gauge Tube	1/4"ODx0.194"IDx3"L			1.45
Total		**4.03**	**9.94**	**8.64**

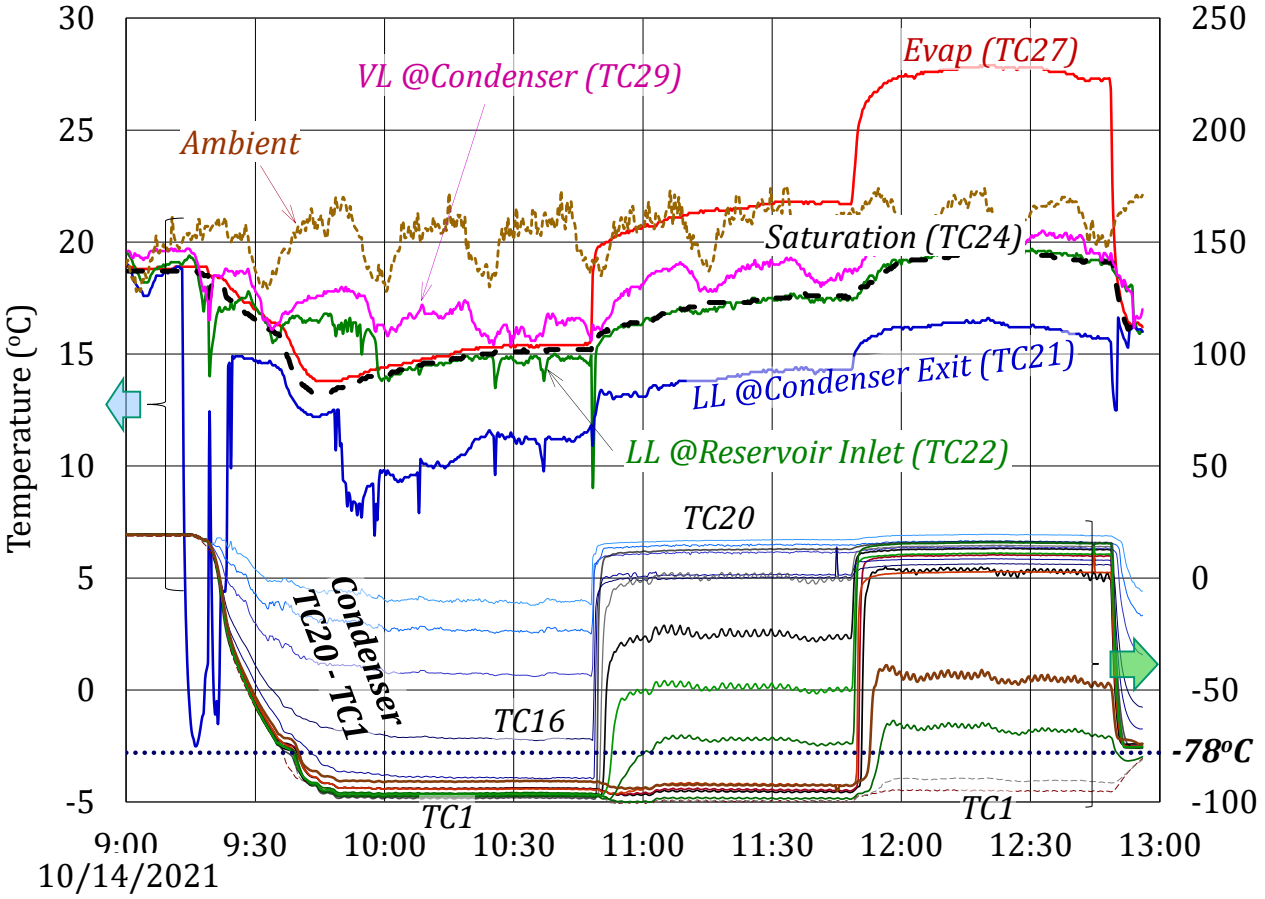
Freeze-Thaw Demonstration with Ammonia – Sink = -80ºC

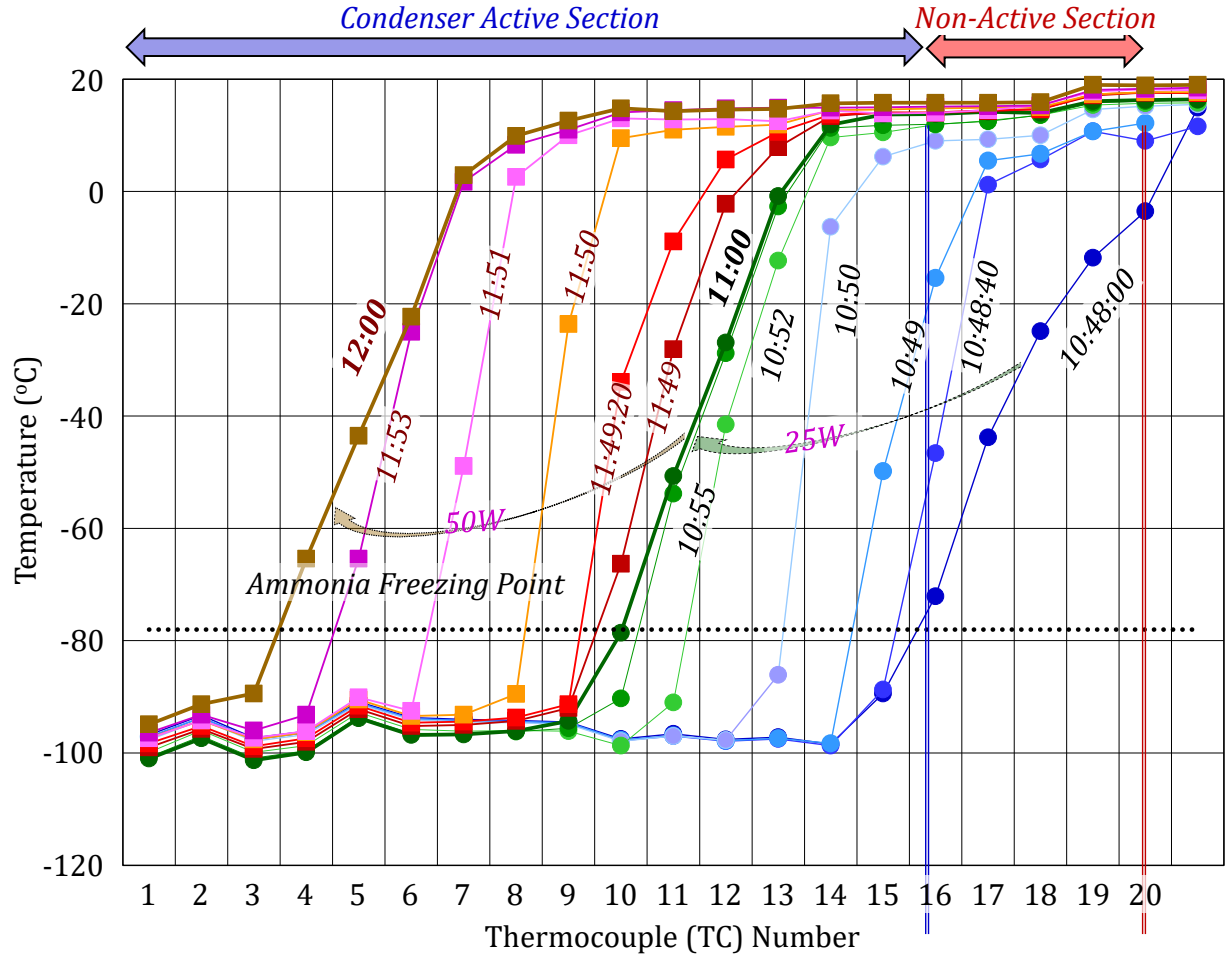


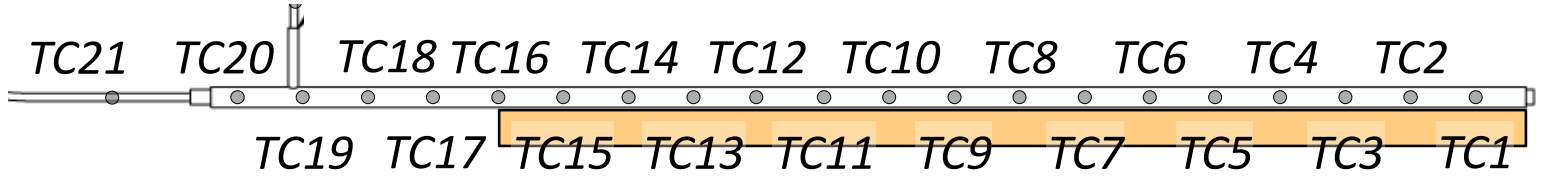




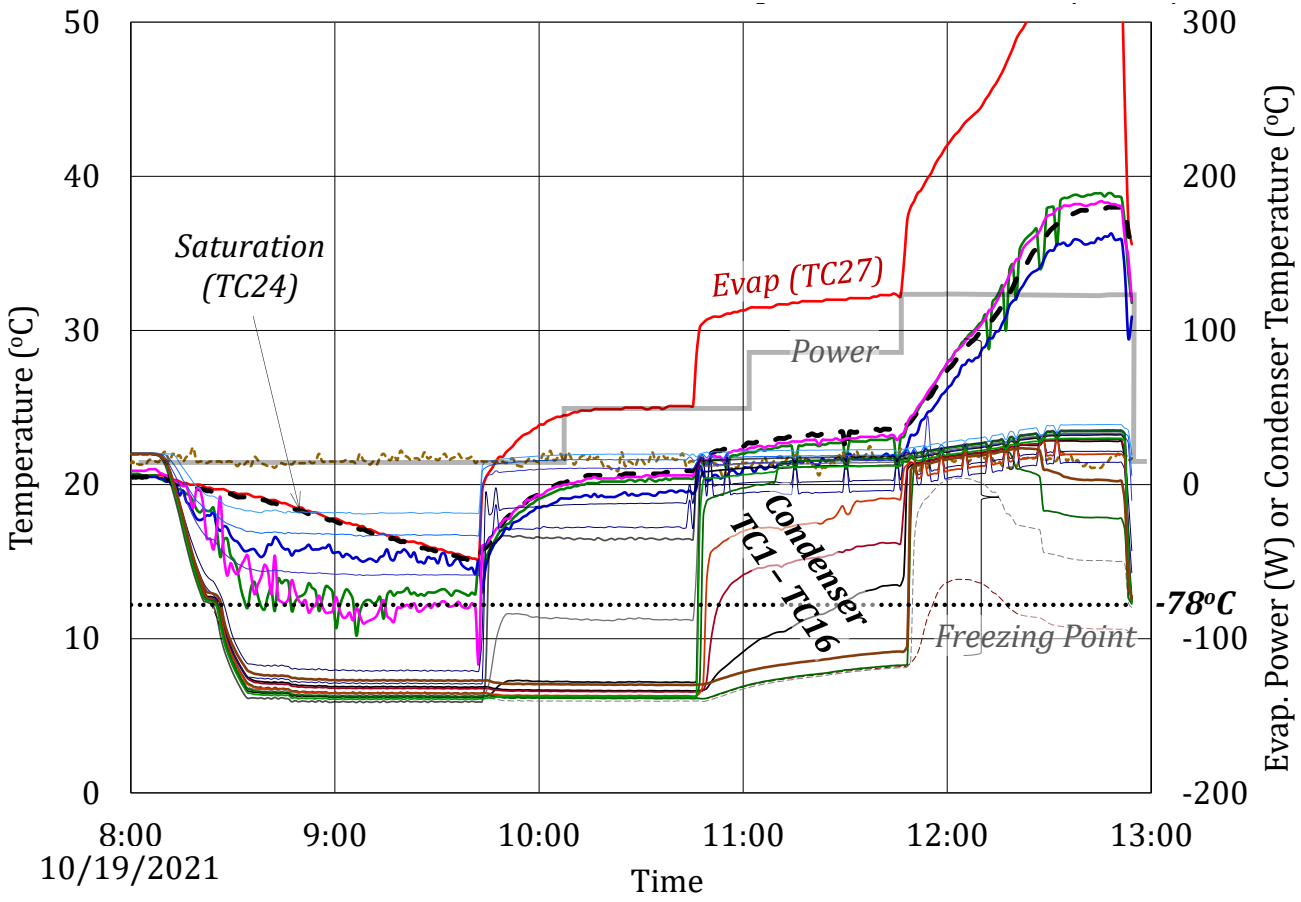
Freeze-Thaw Demonstration with Ammonia – Sink = -100ºC

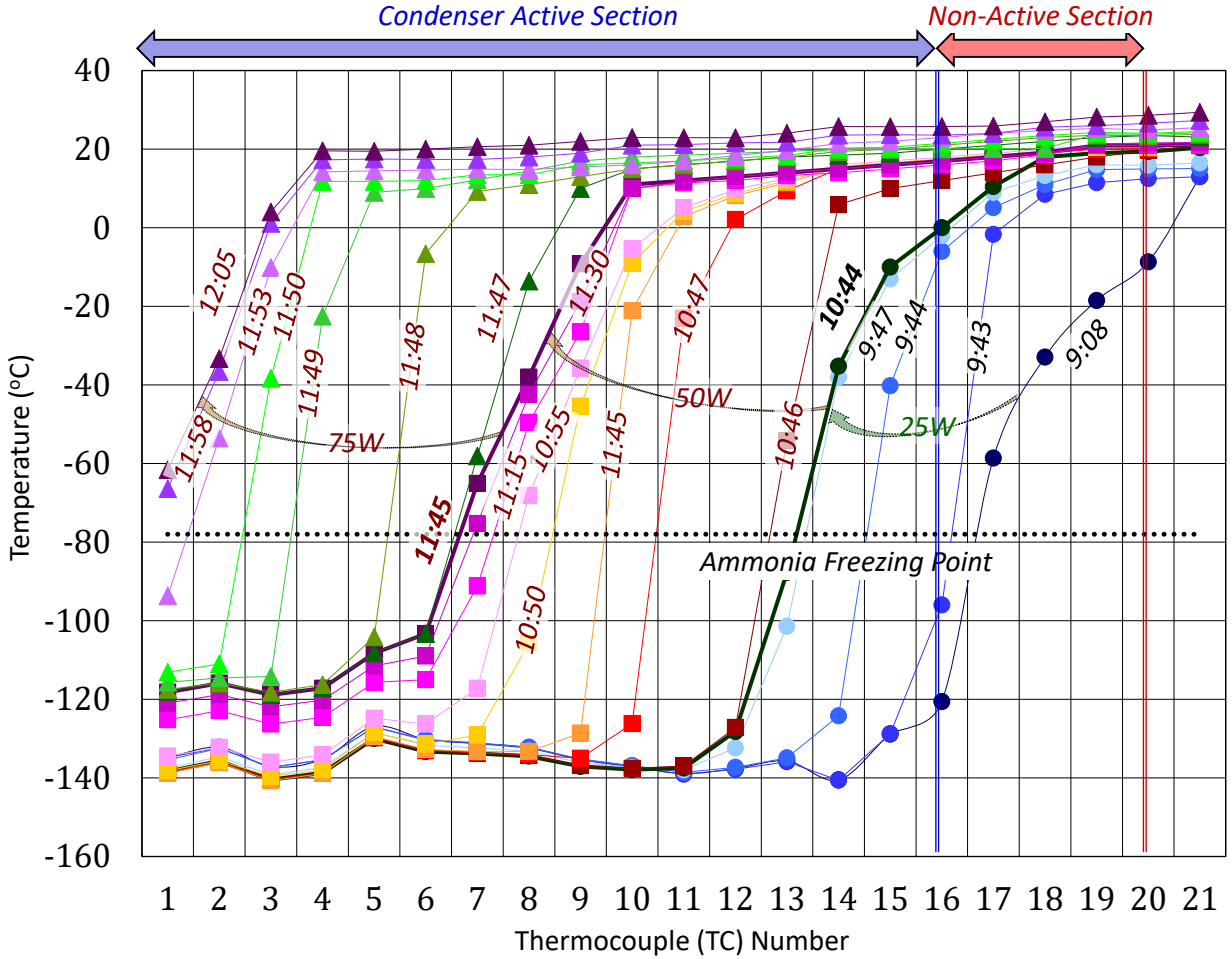


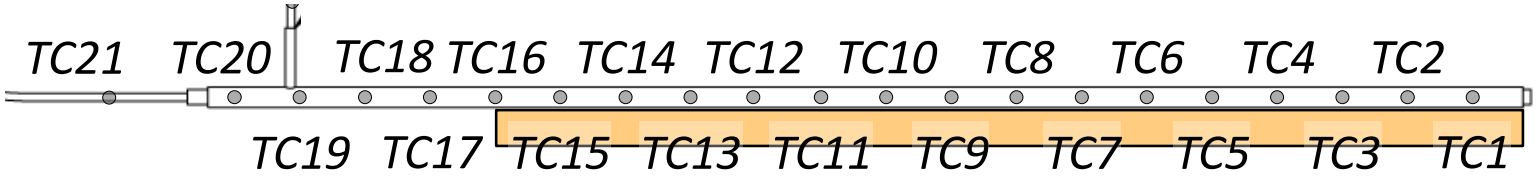




Freeze-Thaw Demonstration with Ammonia – Sink = -140ºC

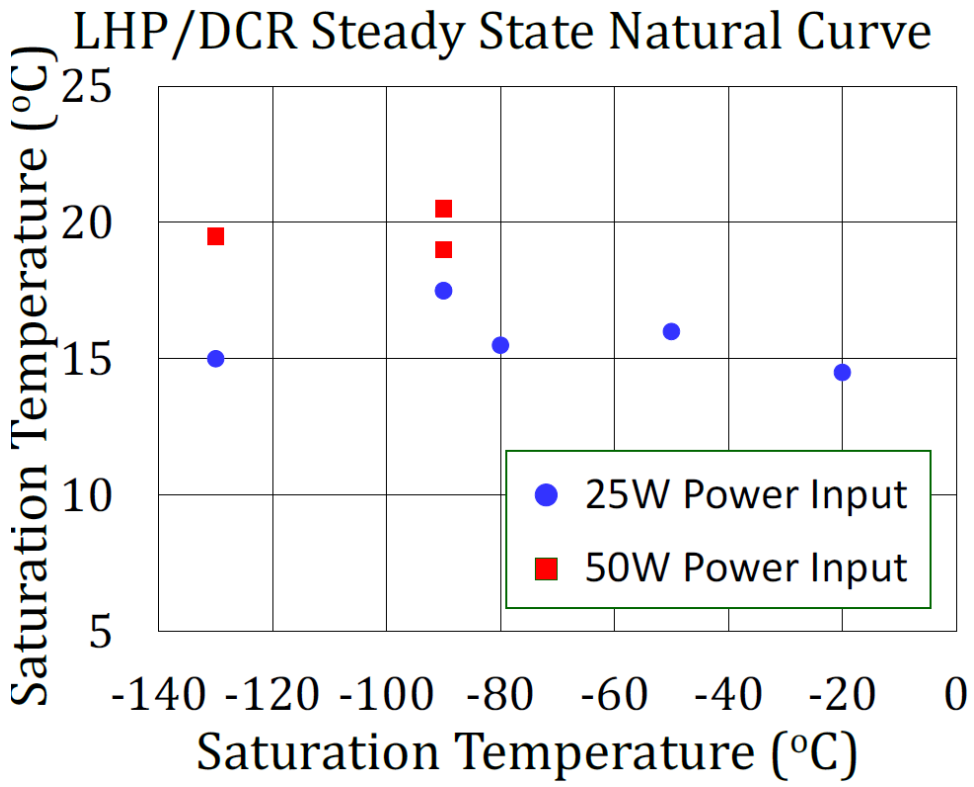






Other Test Results of POC Demonstration

Mini-LHP Steady State Temperatures



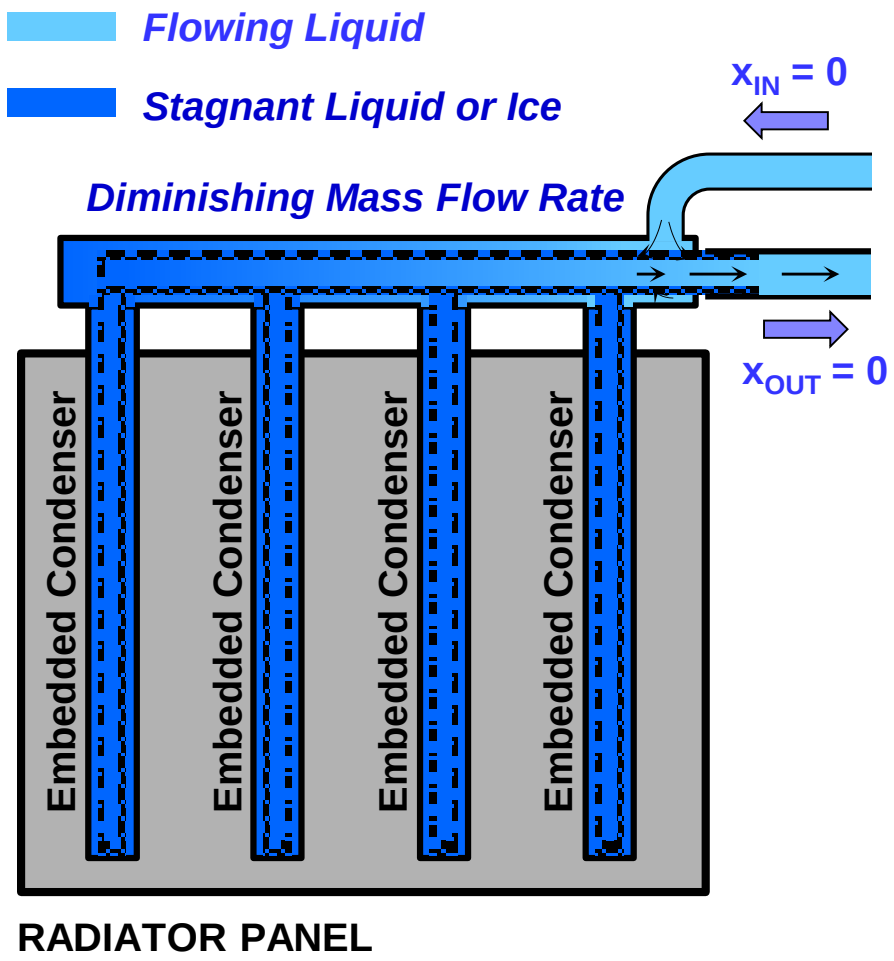
Pre- and Post Measurements of DCR

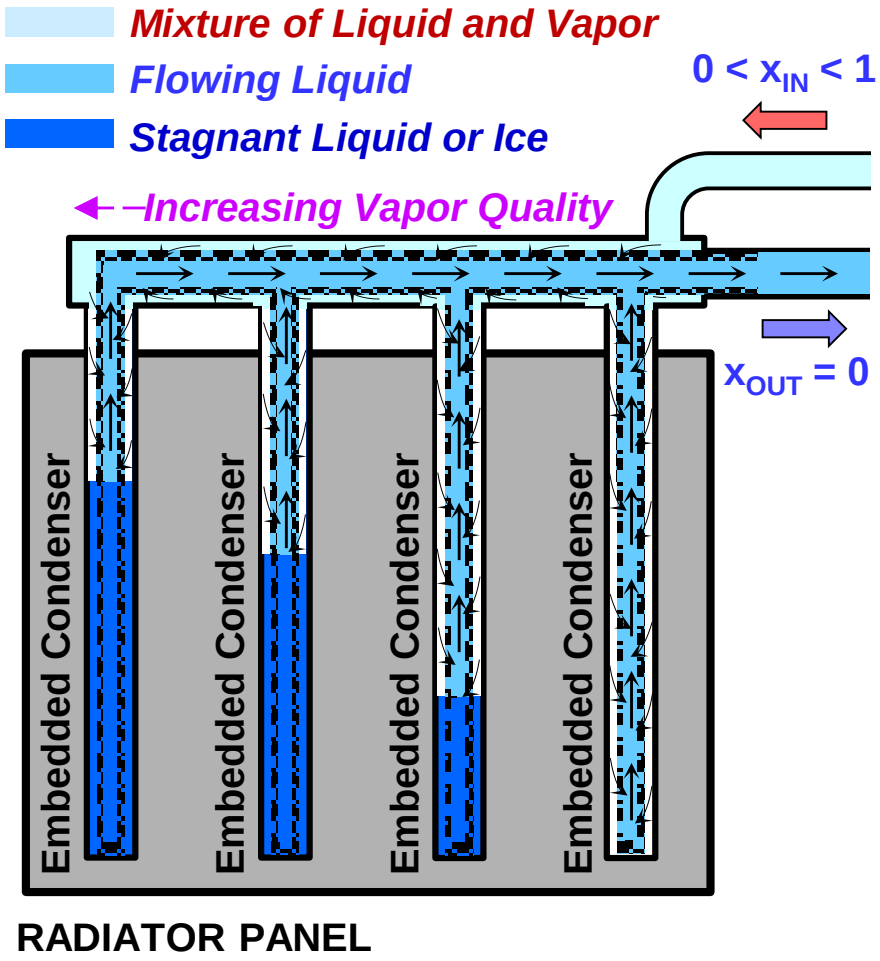
Location / Date	3”	7.5”	10.75”	7.5”
10/12/21	0.2505 / 0.2505	0.2500 / 0.2500	0.2500 / 0.2500	0.2500 / 0.2500
10/13/21	0.2500 / 0.2500	0.2505 / 0.2500	0.2500 / 0.2505	0.2500 / 0.2505
10/19/21	0.2505 / 0.2505	0.2500 / 0.2500	0.2505 / 0.2505	0.2505 / 0.2505
11/08/21	0.2505 / 0.2505	0.2500 / 0.2500	0.2500 / 0.2500	0.2500 / 0.2500

0.2500 top-bottom 0.2500 front-back

Path Forward

Multiple Parallel-Pass DCRs





Summary

- Proof-of-Concept Demonstration
  - cost and schedule constraints limited scope of research
  - Mini-LHP was chosen as testbed for it was readily available
  - a single-pass *freeze-thaw tolerant DCR* demo unit with an internal porous tube made of 200x200 S.S. wiremesh
  - unqualified success
- Demonstrated Operational Features
  - thawed a *frozen* DCR with waste heat from payloads attached to transport loop evaporator w/o restrictions
  - transport loop was fully functional even with partially frozen DCR
  - regardless of operating conditions, liquid exiting DCR was always at saturation temperature