INL/MIS-25-86208-Revision-0

Air-Cooled RCCS CFD Modeling Validation 2025

July 2025

Sinan Okyay, David Alan Reger, Victor Coppo Leite, Elia Merzari, Gerhard Strydom, Paolo Balestra

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Idaho National Laboratory

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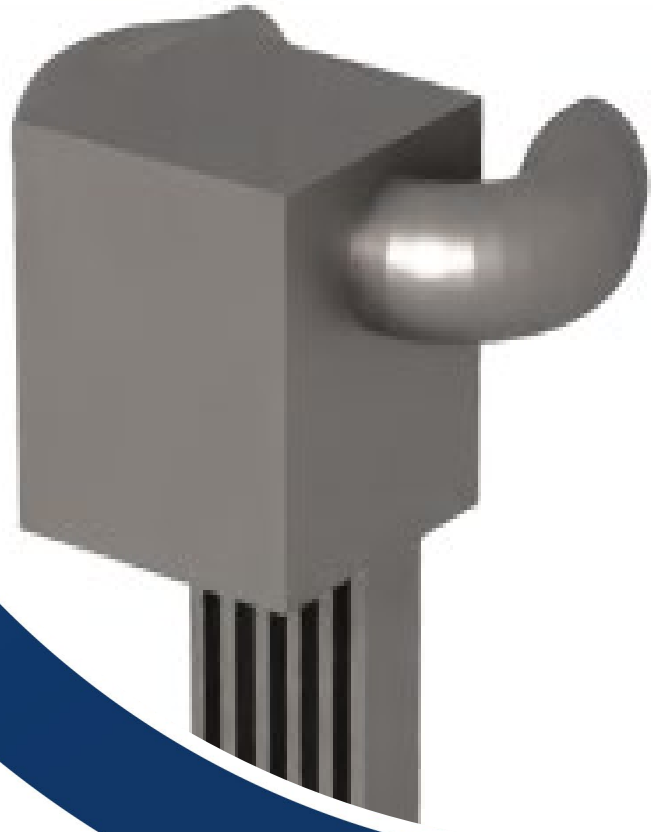
GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM



July 30, 2025

Air-Cooled RCCS CFD Modeling Validation

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Sinan Okyay, David Reger, Victor Coppo Leite, Elia Merzari, Paolo Balestra, Gerhard Strydom

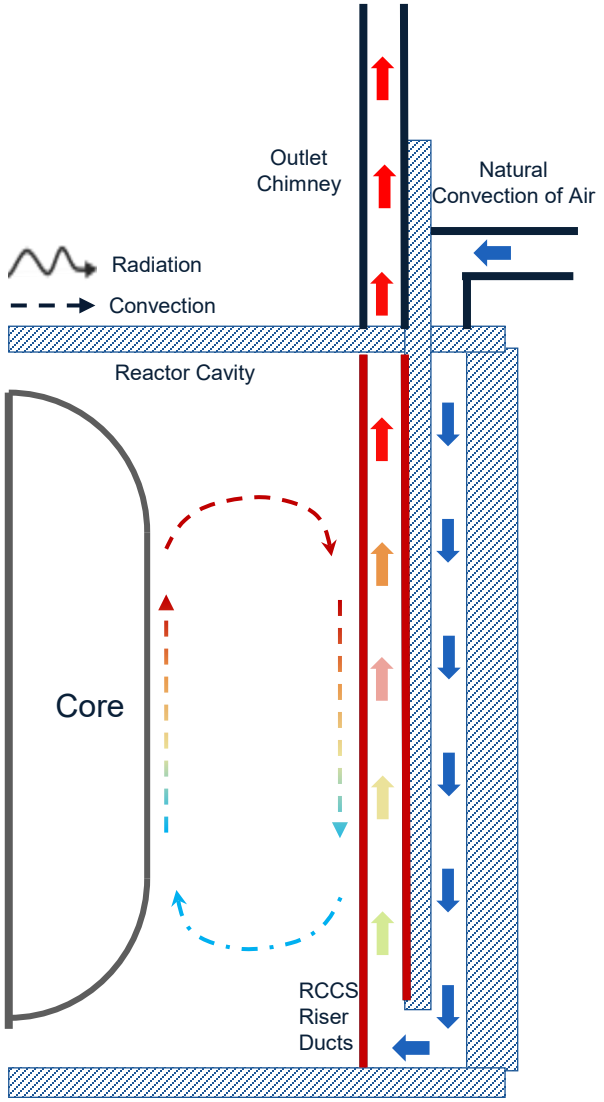
Graduate Fellow- INL

DOE ART GCR Review Meeting

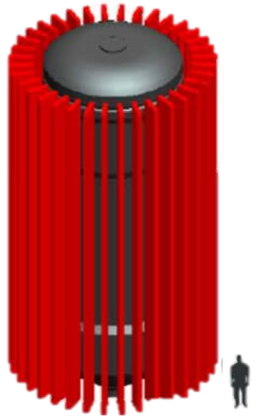
Hybrid Meeting at INL

July 29–30, 2025

Introduction



GA-MHTGR
Full Scale
Full Model



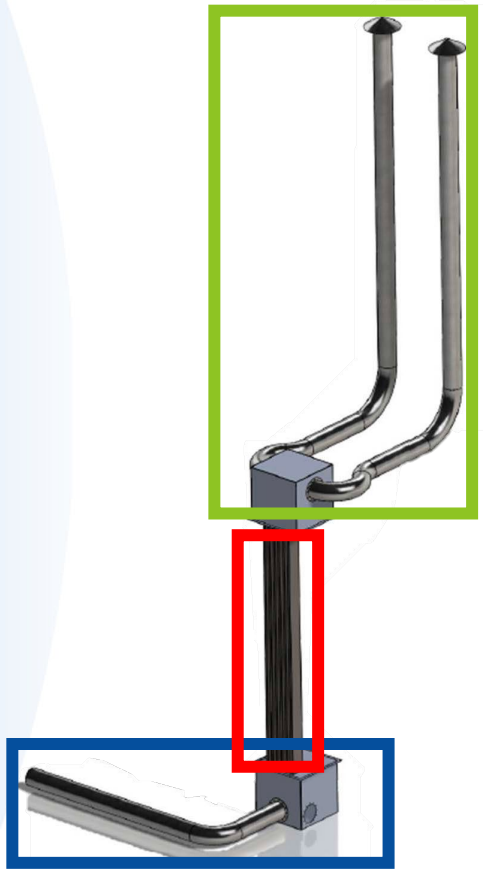
ANL NSTF
½ Scaled
19° Model

UW-Madison
¼ Scaled
10° Model

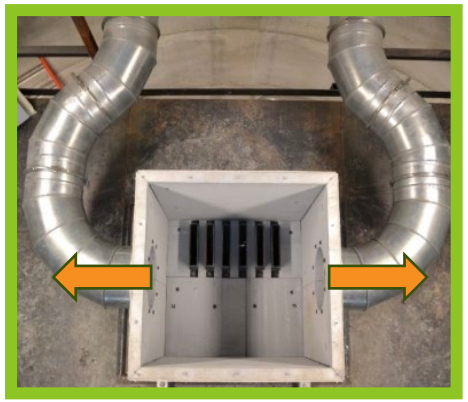
Texas A&M
⅛ Scaled
10° Model

- Numerical modeling of the experimental facility in UW-Madison.
- Benchmark the numerical results.

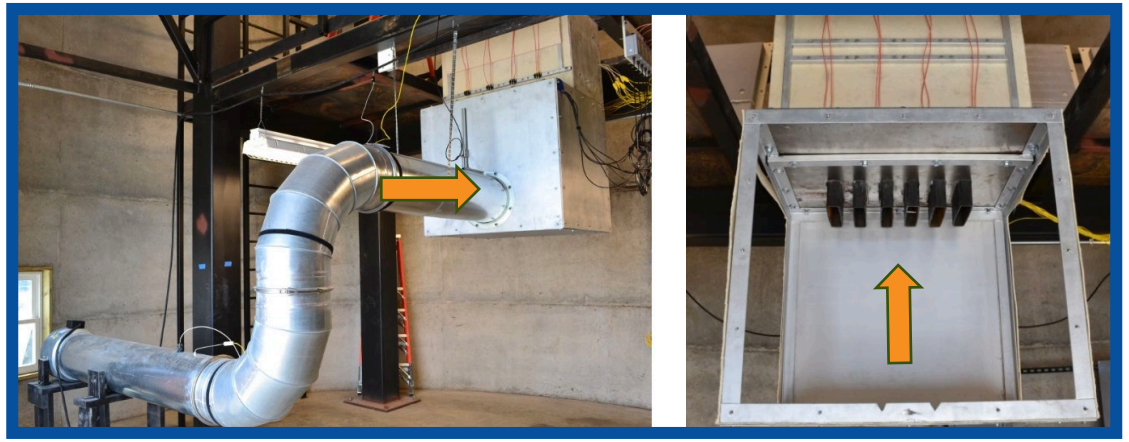
Experimental Facility



Outlet Plenum

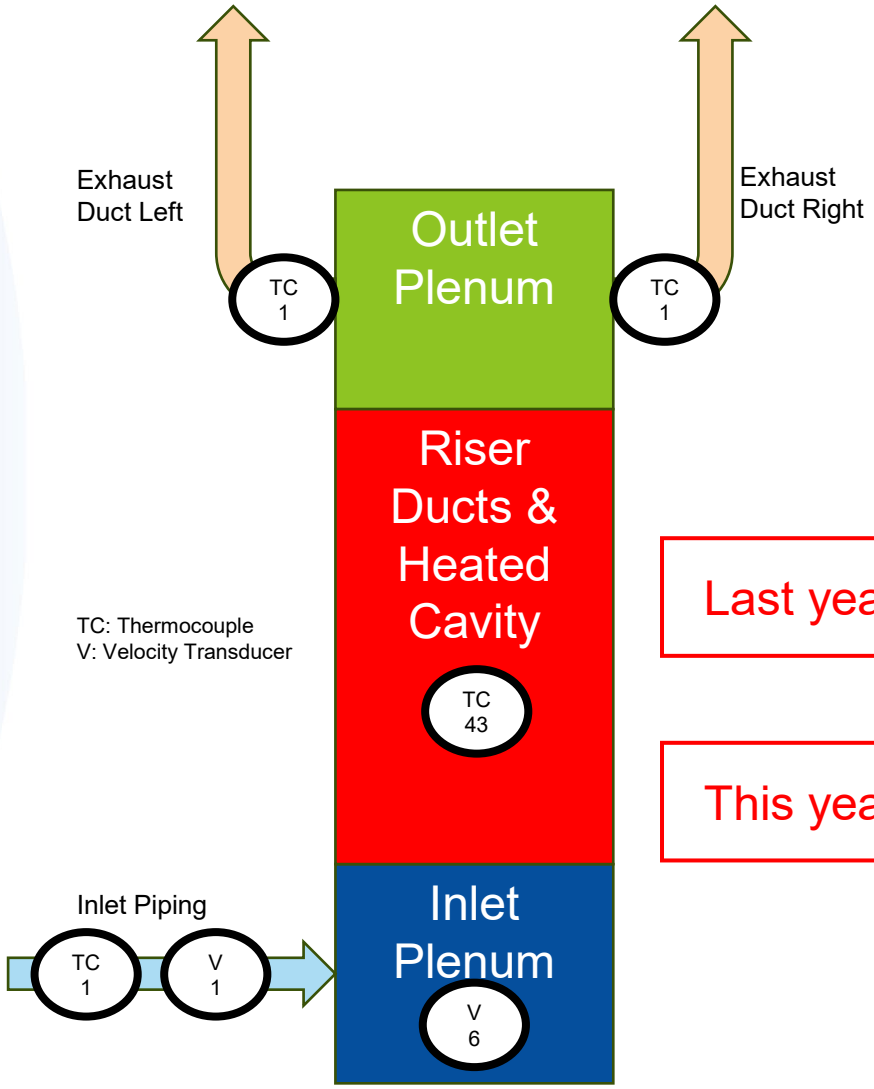


Inlet Plenum



Heated Cavity

Experimental Facility



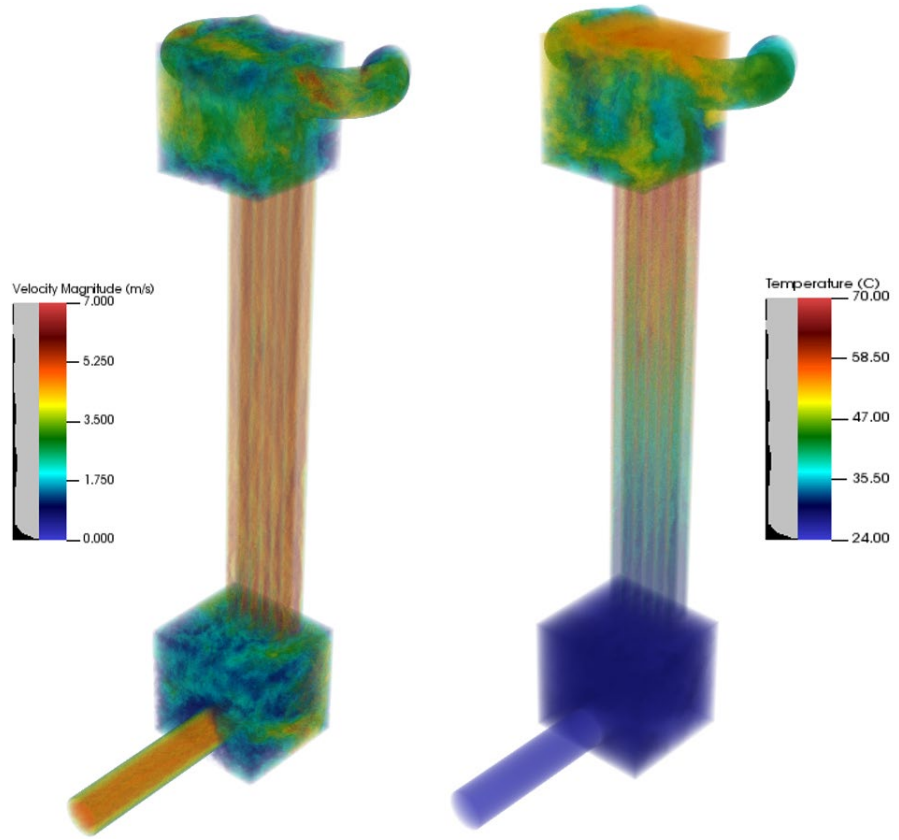
Last year

This year

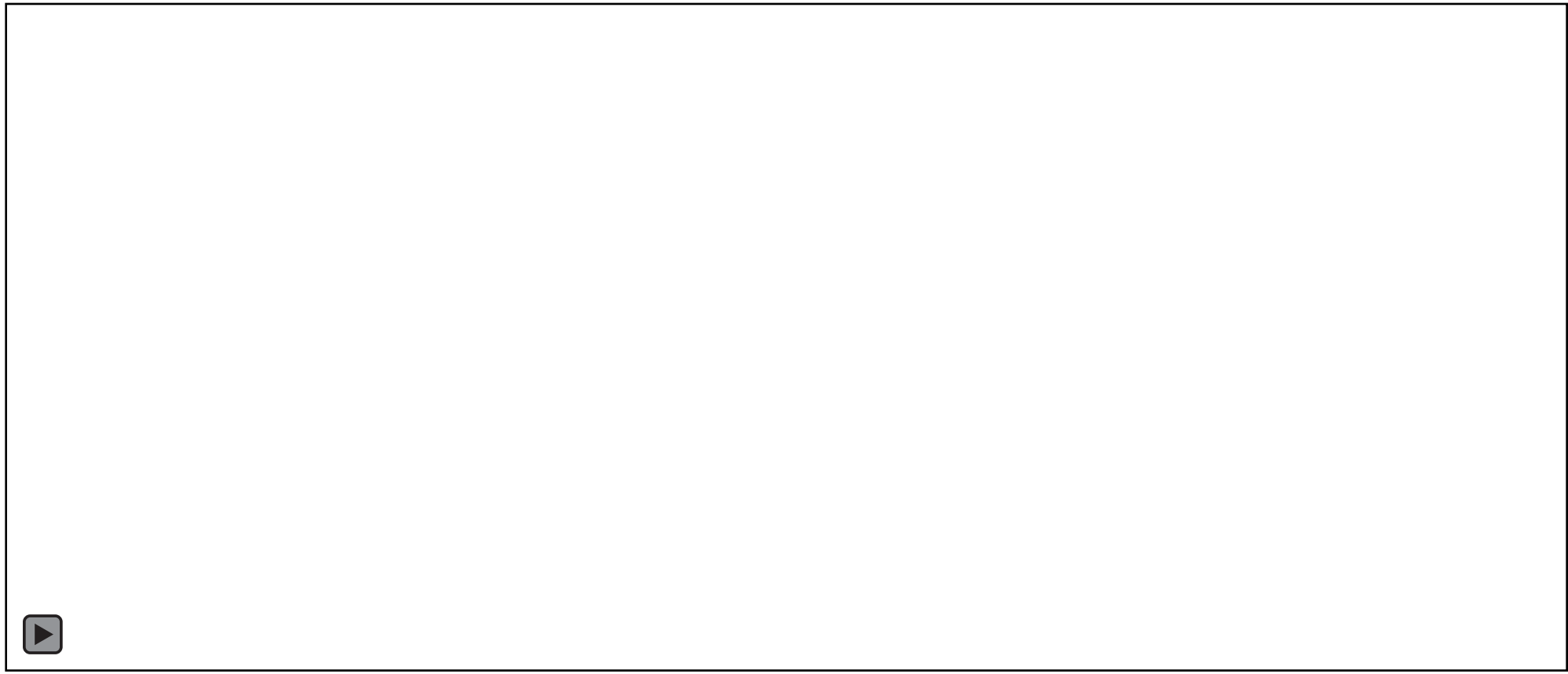
Experiment Summary			
Type	**Case**	**# of Experiment**	**Instability**
Forced convection	Forced Flow	4 (2 Power levels 2 Repeat)	no
Natural circulation	Constant Flux	4 (2 Power levels 2 Repeat)	no (1 exception)
	Asymmetric	4 (2 Power levels 2 Repeat)	yes

Last year accomplishments

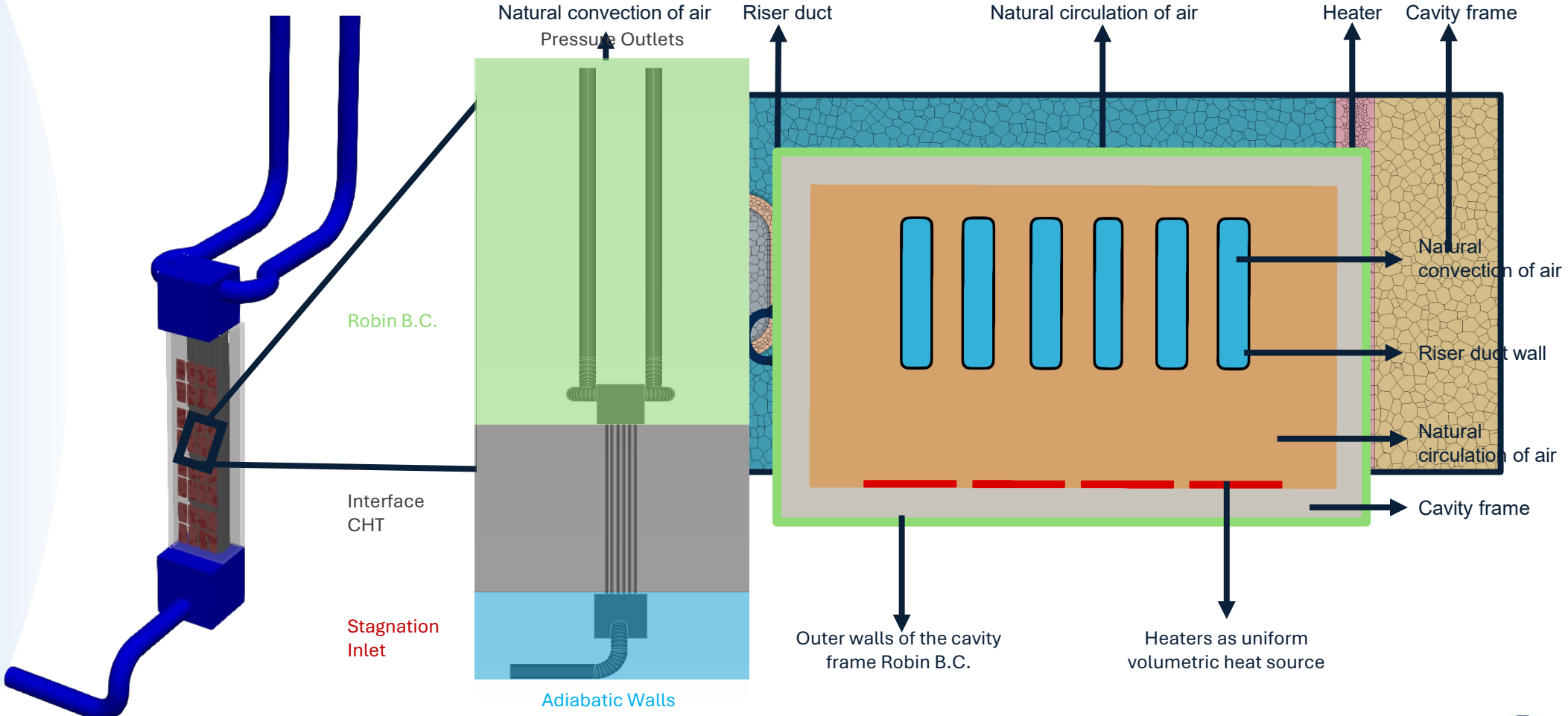
- ✓ High fidelity simulations are performed for the RCCS
- ✓ RANS simulations of the experimental facility performed and compared with the experiment.



RCCS Large Eddy Simulations (LES)



Numerical Model



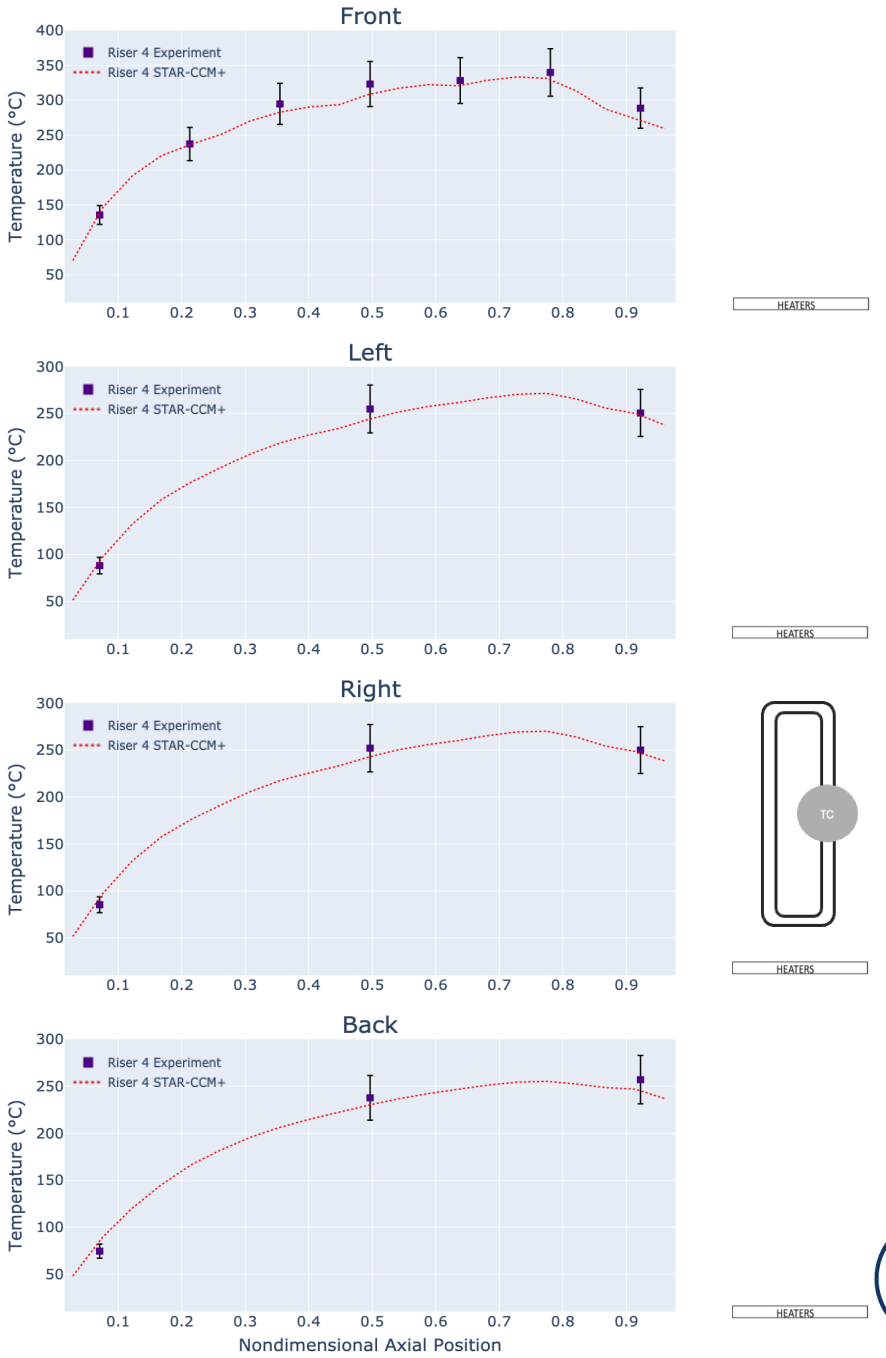
Natural Convection

Setup Parameters

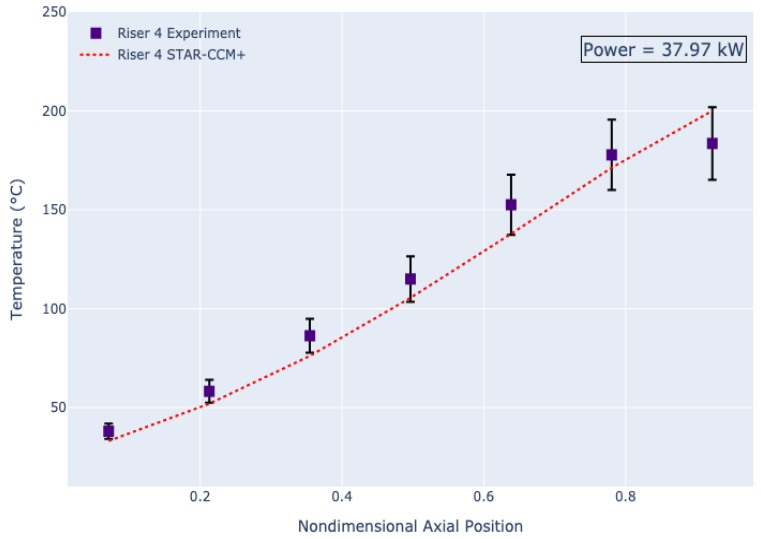
Modeling Strategy	RANS	
Solver	Segregated-Steady	
Methodology	Finite Volume Method (FVM)	
# of Elements	125.3 Million	
Turbulence Modeling	$k-\epsilon$ Low Reynolds	
Radiation Modeling	Net Radiation Method	
Buoyancy Modeling	Low Mach Approximation	
Wall Modeling	Wall resolved	
Experimental Test #	15	23
Power Levels	Low Power	High Power
Power	19.82 kW	37.97 kW
Inlet Temperature	301.6 K	300.2 K
Fluid Properties	Air	
	Density	Ideal Gas Law
	Viscosity	Sutherland's law
	Thermal Conductivity	Sutherland's law
	Specific Heat Capacity	Constant
	Pr_t	0.85

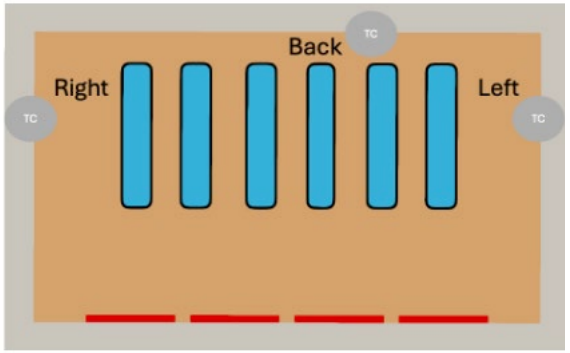
High Power

Name	*STAR-CCM+*	*Experiment*
Heat In	37.97 kW	
Power Removed by RCCS	23.03 kW	23.10 kW
Total Heat Losses	7.94 kW	8.15 kW
Additional Heat Sink	7.00 kW	Not measured
Heat Out	37.97 kW	31.25 kW
Mass Flow Rate	0.1450 kg/s	0.16 kg/s



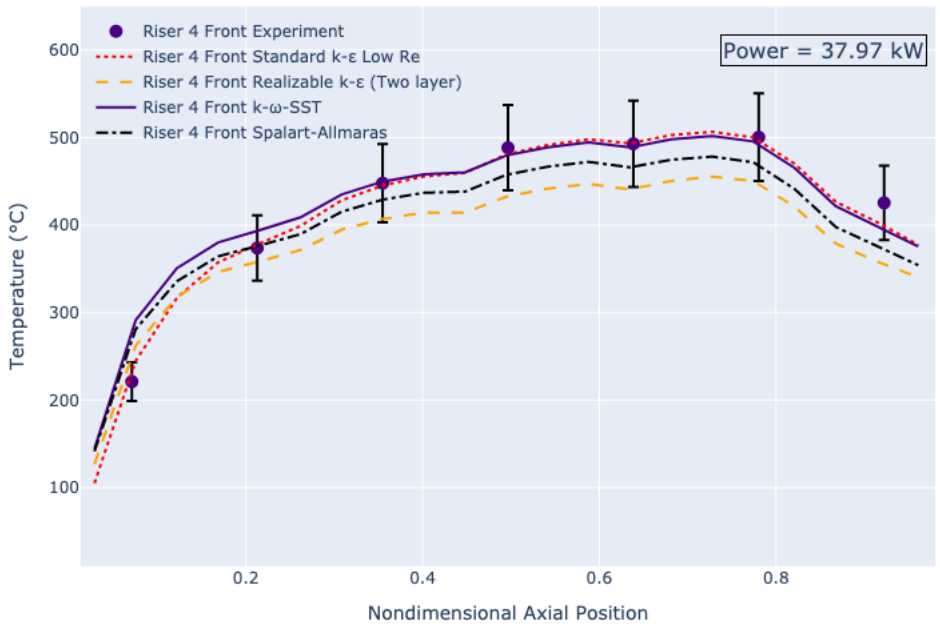
High Power

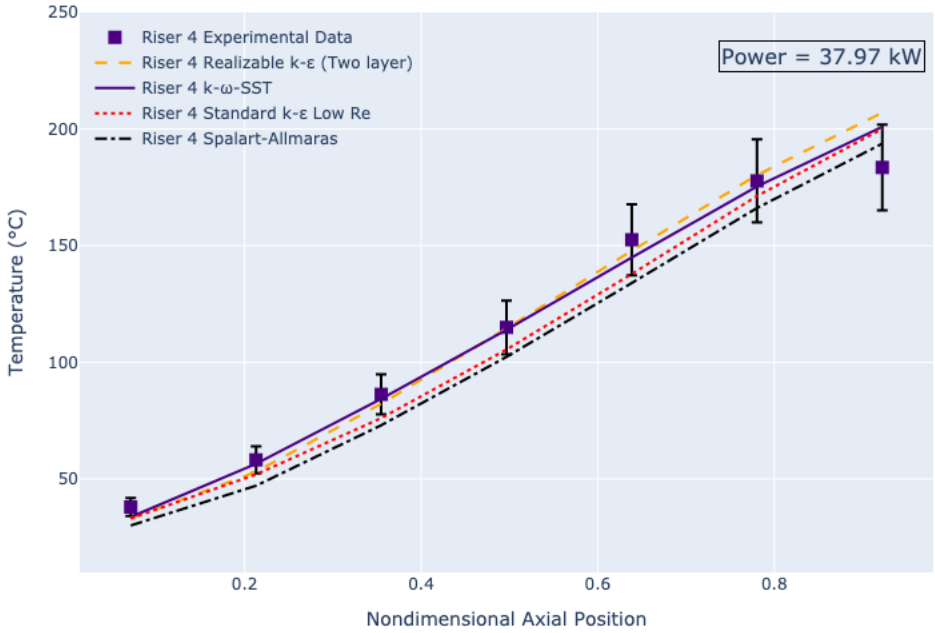




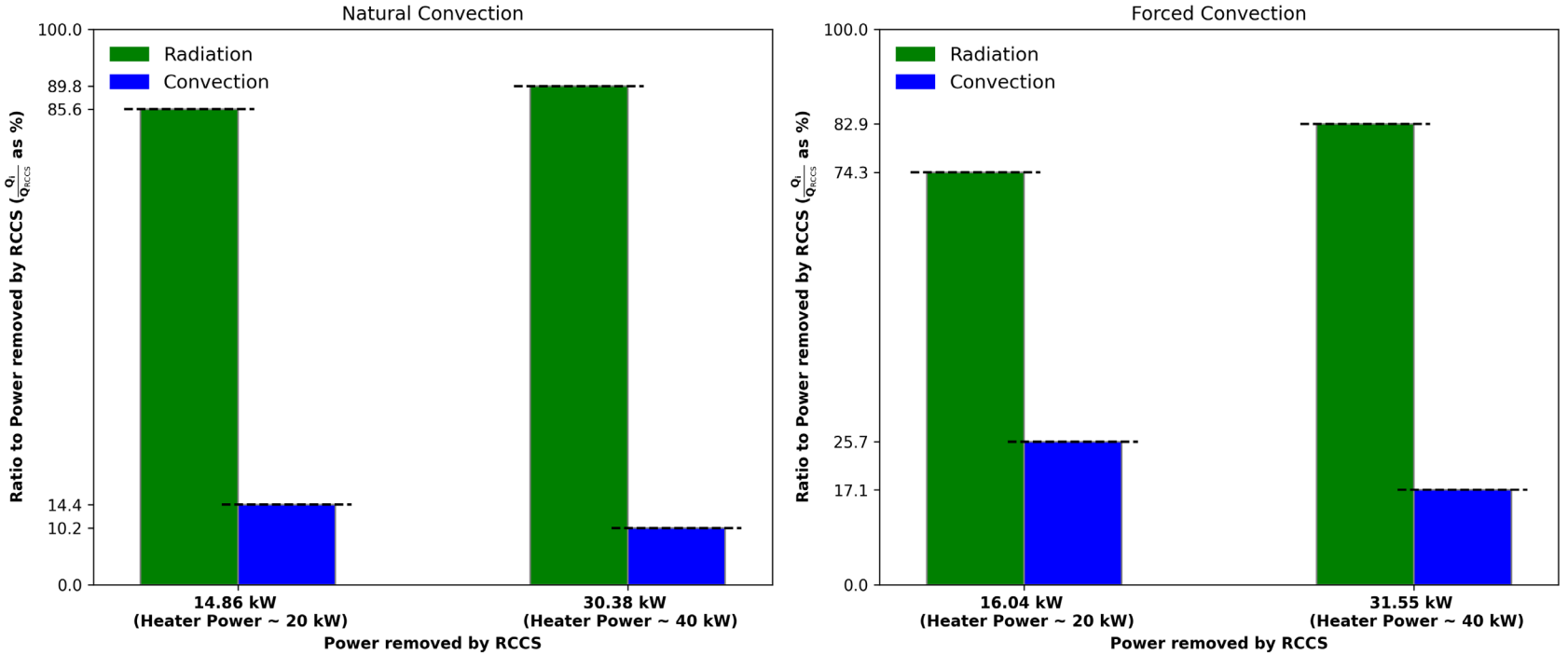
Name	STAR-CCM+ (°C)	Experiment (°C)
Left	461	431
Right	457	429
Back	378	387

Effect of RANS turbulence models





Heat Transfer Mechanism in Heated Cavity



Conclusion and Future Work

- Natural convection tests under uniform power are modeled and compared with experimental results.
- A journal paper titled "Numerical Simulation of a Natural Convection Driven Air-Cooled Reactor Cavity Cooling System Experiment" is in progress for submission to Nuclear Engineering and Design.
- Future work will focus on improving the benchmark description report and the feasibility of modeling asymmetric power profile cases using the existing numerical model.

Publications

- A journal paper to Nuclear Engineering and Design titled as “High-Fidelity Forced Convection Simulations of the University of Wisconsin--Madison Air-Cooled Reactor Cavity Cooling System” . (In Revision)
- A journal paper to Nuclear Engineering and Design titled as Numerical Simulation of A Natural-Convection Driven Air-Cooled Reactor Cavity Cooling System Experiment (in progress)
- Okyay, S., Cogliati, J. J., Coppo Leite, V., Reger, D. A., Strydom, G., & Balestra, P. (2024). *Summary Report of the FY24 DOE Contributions to the GIF VHTR CMVB* (No. INL/RPT-24-80355-Rev000). Idaho National Laboratory (INL), Idaho Falls, ID (United States).

Acknowledgment

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