GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM

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Air-Cooled RCCS CFD Modeling Validation

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DOE ART GCR Review Meeting

Hybrid Meeting at INL

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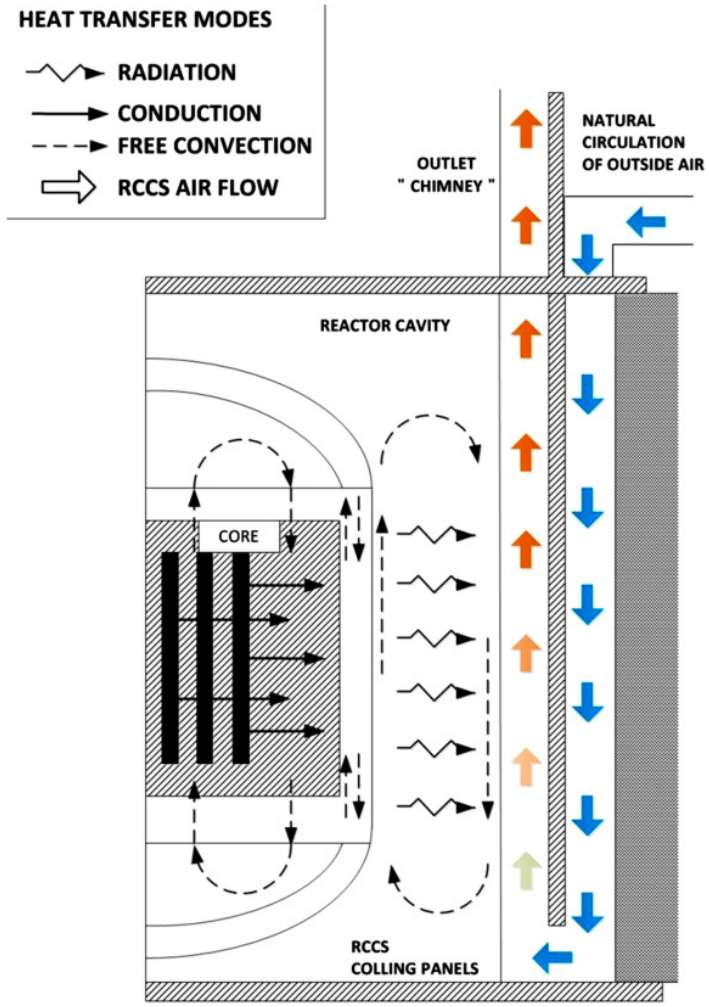
Introduction

- Passive Safety
- Low maintenance
- Cost effective



UW-Madison Experimental Facility

Figure 1: Scaled representation of GA-MHTGR's RCCS.

Figure 2: RCCS working principle [1].

[1] Takamatsu, Kuniyoshi, et al. "Comparison between passive reactor cavity cooling systems based on atmospheric radiation and atmospheric natural circulation." *Annals of Nuclear Energy* 151 (2021): 107867.

Experimental Facility at UW-Madison

Figure 3: UW-Madison air cooled RCCS experimental facility [2].

[2] Corradini, Michael, Anderson, M., Muci, M., Hassan, Yassin, Dominguez, A., Tokuhiro, Akira, and Hamman, K. *Thermal-Hydraulic Analysis of an Experimental Reactor Cavity Cooling System with Air. Part I: Experiments; Part II: Separate Effects Tests and Modeling*. United States: N. p., 2014. Web. doi:10.2172/1183658.

Experiment Instrumentation and Tests

Table 1: 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

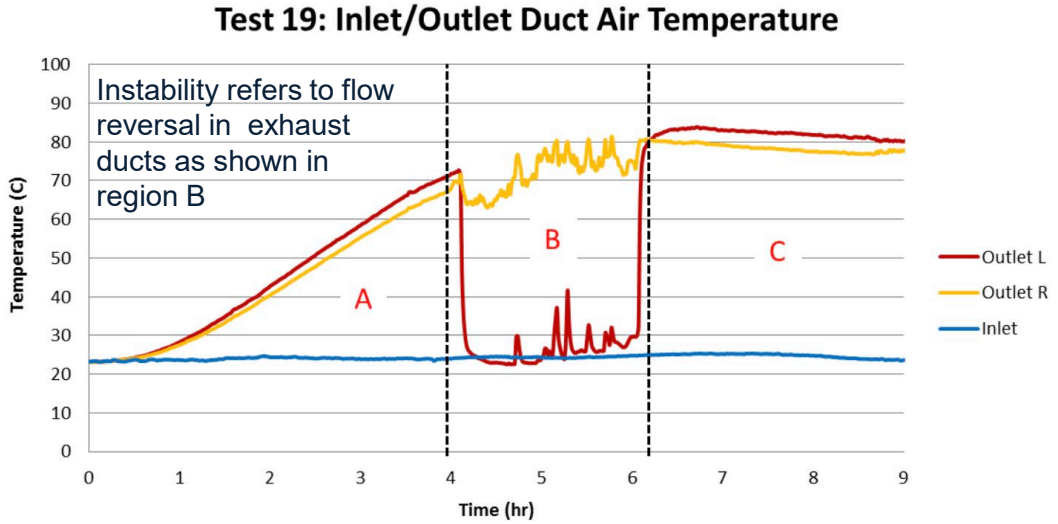


Figure 4: Instrumentation in the experimental facility.

Figure 5: Temperature measurements for Test19.

Modeling Strategies

Figure 6: Modeling strategies for the experiments.

Numerical Simulations

V & V models

- Thermal Model (MOOSE)
- Hydraulic Model (NekRS)
- Multi-Physics Model (Cardinal)

NekRS

Riser Duct Model

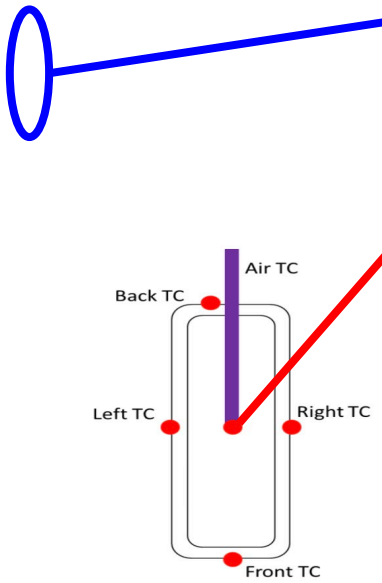


Figure 7: Numerical setup for riser ducts.

Figure 8: 4th Riser Instrumentation.

Riser Duct Model Results for Test 14

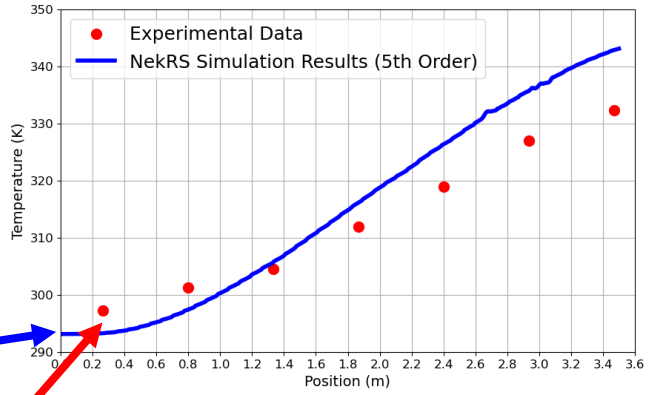


Figure 9: Temperature comparison of the results.

Riser Duct Model Mesh Convergence

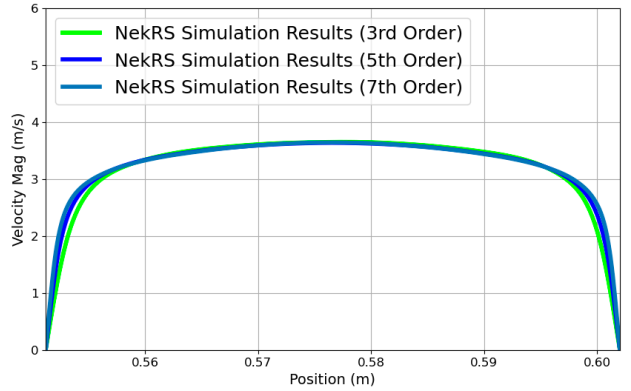
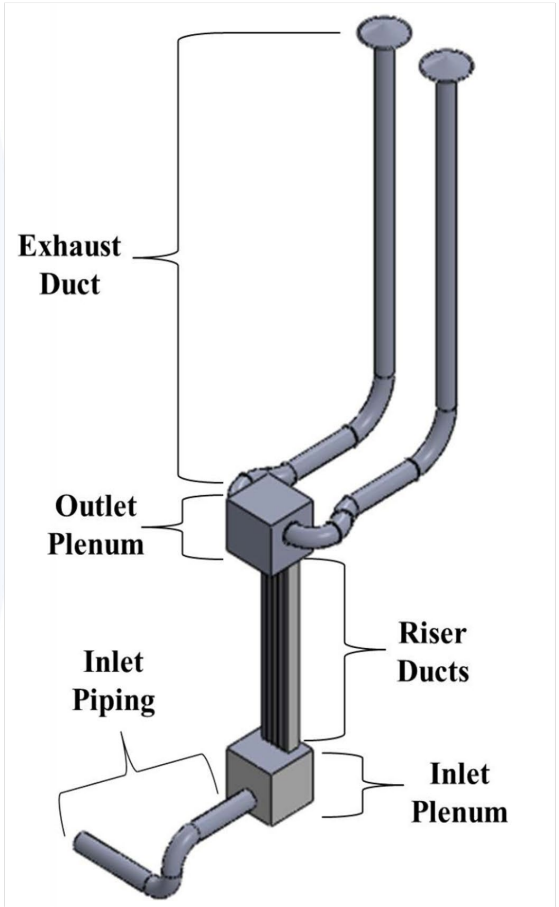


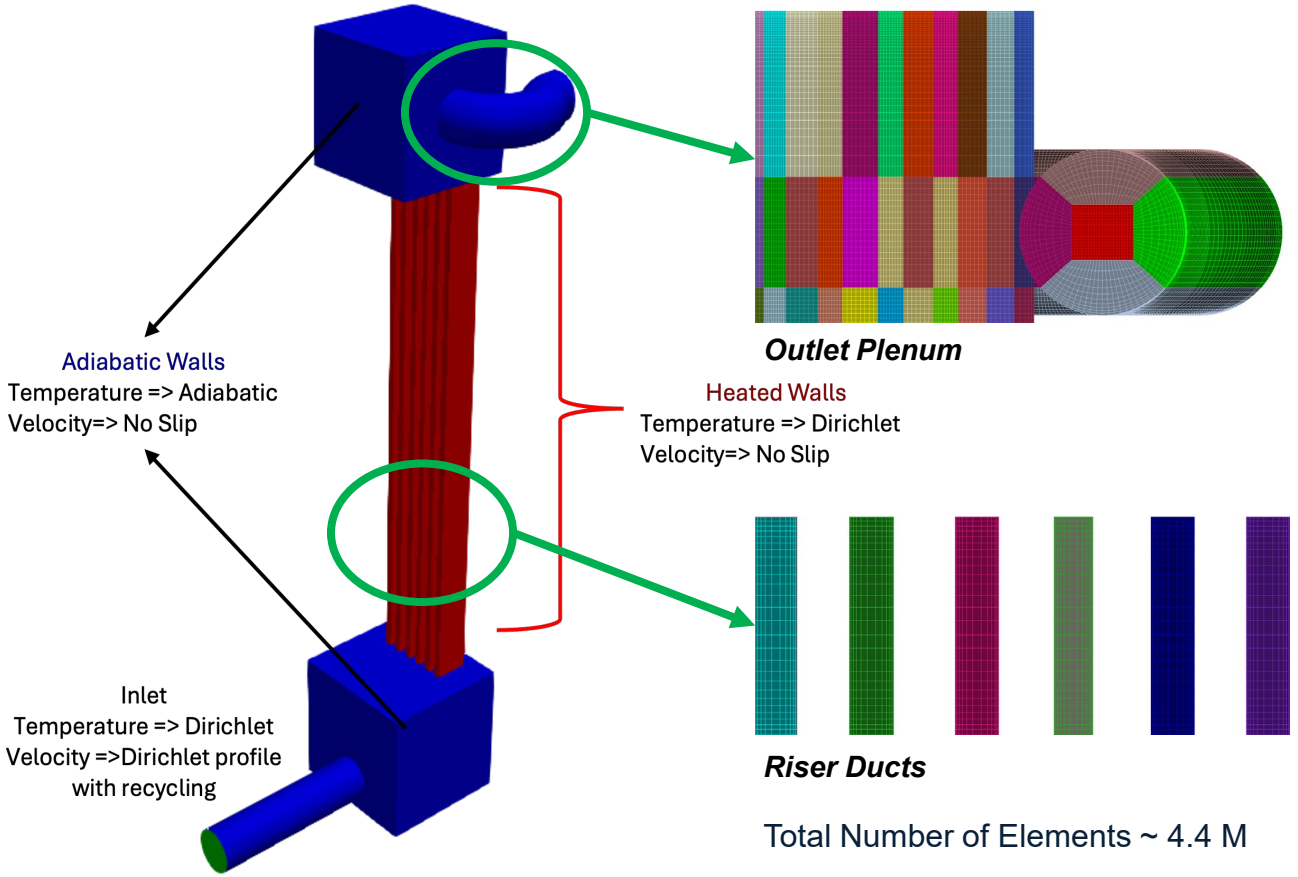
Figure 10: Velocity comparisons with different mesh resolutions.

RCCS Model

a-) Experimental Facility



b-) Numerical Model



Total Number of Elements ~ 4.4 M

Figure 11: a-) Technical drawings of the experimental facility, b-) Numerical setup, c-) Blocking strategy and mesh.

RCCS Results

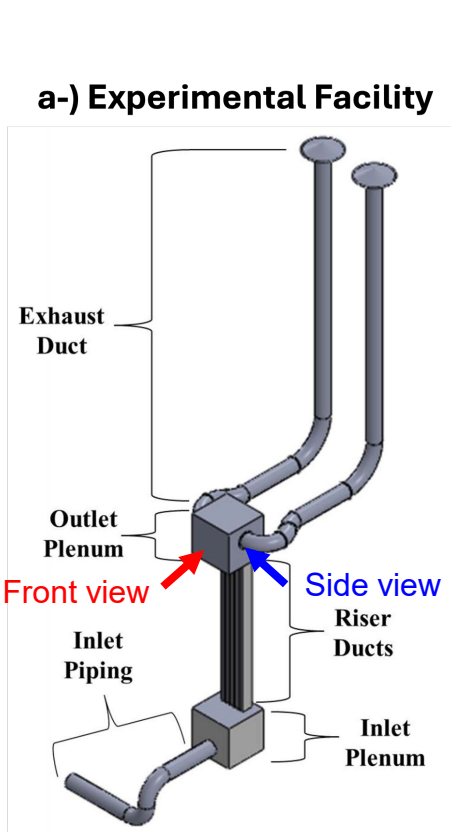


Figure 11.a: Technical drawings of the experimental facility.

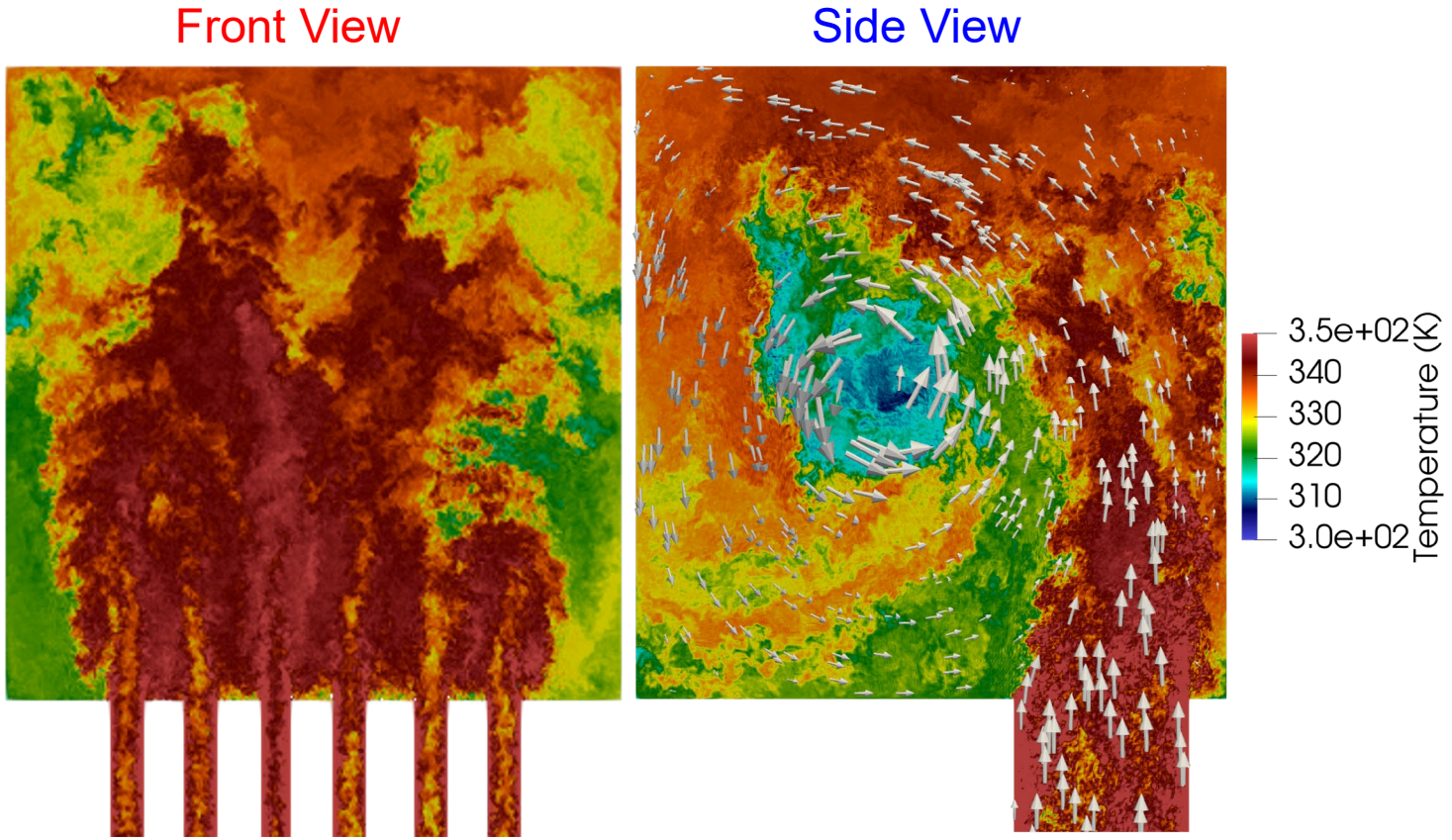


Figure 13 : Tempe Instantaneous temperature at outlet plenum at left (front view) and right (side view). (White arrows added to side view to show flow direction in outlet plenum).

RCCS Results

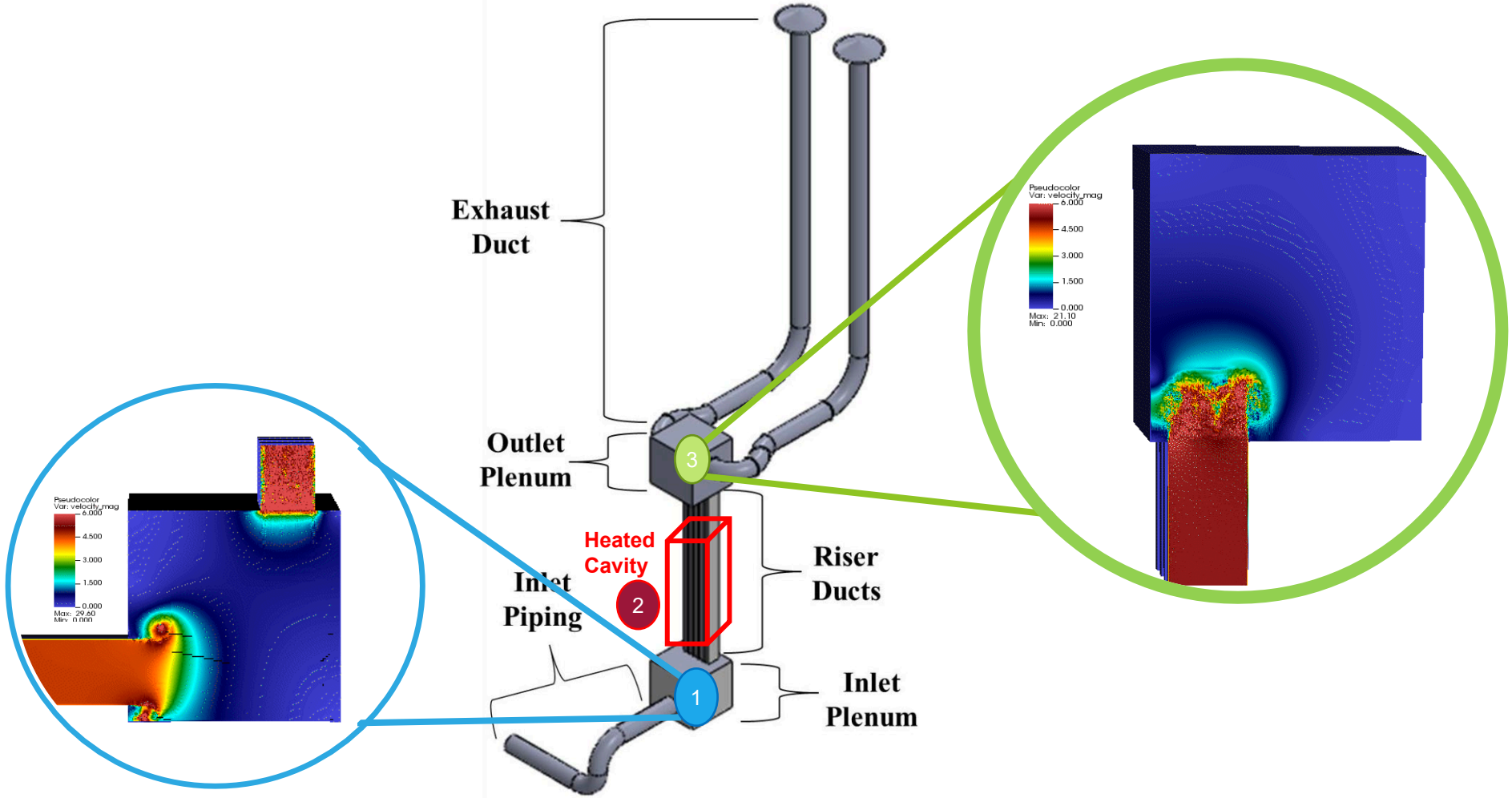


Figure 11.a: Technical drawings of the experimental facility.

Conclusion & Future Work

- The Multi-Physics methodology was developed and tested for the high-fidelity modeling of the experimental facility.
- The V & V models run to ensure the consistency of the numerical tools and methods.
- The benchmark specifications were prepared for the participants.
  - The RCCS model will be compared with the experiments for forced convection cases.
  - The Cardinal coupling strategy will be used on the RCCS model for the natural convection cases.

Scientific publications

- A full paper to Pacific Basin Nuclear Conference 2024 (PBNC), October 7–10, 2024, Idaho Falls, ID. (accepted)
- A technical report to GIF on “Thermal hydraulic code validation benchmark for air-cooled reactor cavity cooling system”. (produced)
- A technical poster to ECRA and Postdoc Program Annual Poster Session, June 4th 2024, Idaho Falls, ID. (presented)
- A full paper to Advances in Thermal Hydraulics (ATH 2024), November 17–21, , 2024, Orlondo, FL. (accepted)

Acknowledgment

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