GAS-COOLED REACTOR

ADVANCED REACTOR TECHNOLOGIES PROGRAM

July 16, 2024

Separate-Effect Test Facilities Under Prototypical Conditions for Depressurization and Water-Ingress Accidents

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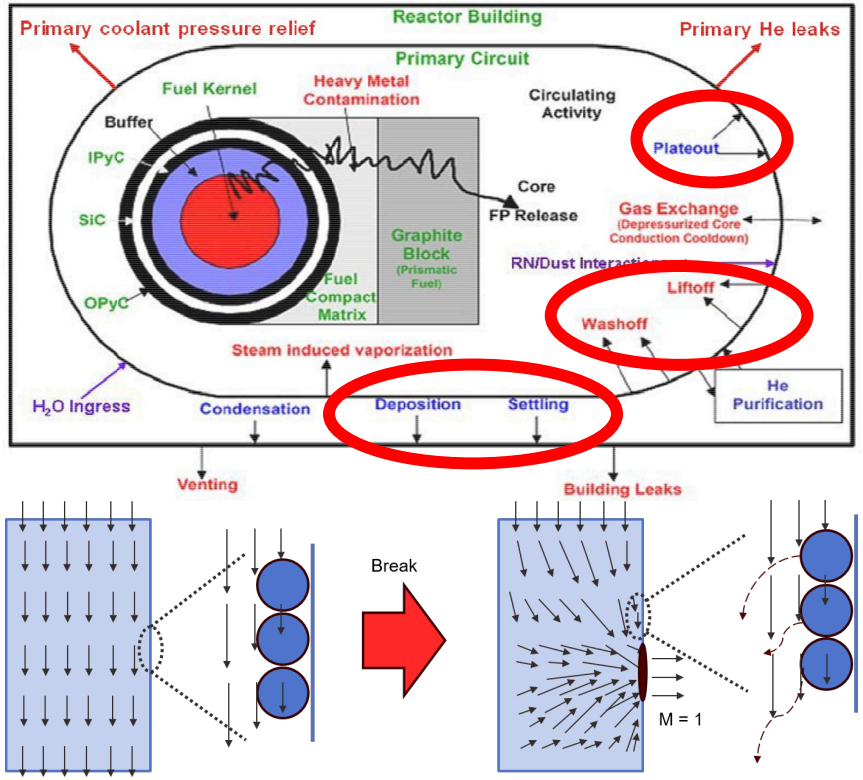
DOE ART GCR Review Meeting

Hybrid Meeting at INL

July 16–18, 2024

Project Background

- Analytical tools used to predict and determine radionuclide transport currently suffer from large degrees of uncertainty for specific transport modes.
- It is known that certain FPs have a propensity to sorb onto the surfaces of particulates ("dust").
- Recirculation, deposition, and resuspension of FP sorbed dust is of concern to due its ability for release upon a DLOFC.
- Plateout considers the mechanism in which condensable FPs deposit onto helium-wetted surfaces.
- Whether the FPs are primarily transported as an atomic species mixed into the coolant, or sorbed onto dust, liftoff accounts for the all transport methods which capture the resuspension of FP release upon a DLOFC.
- Washoff concerns the entrance of water into the primary circuit which then becomes the transport mode of FPs sorbed to metallic surfaces or dust.



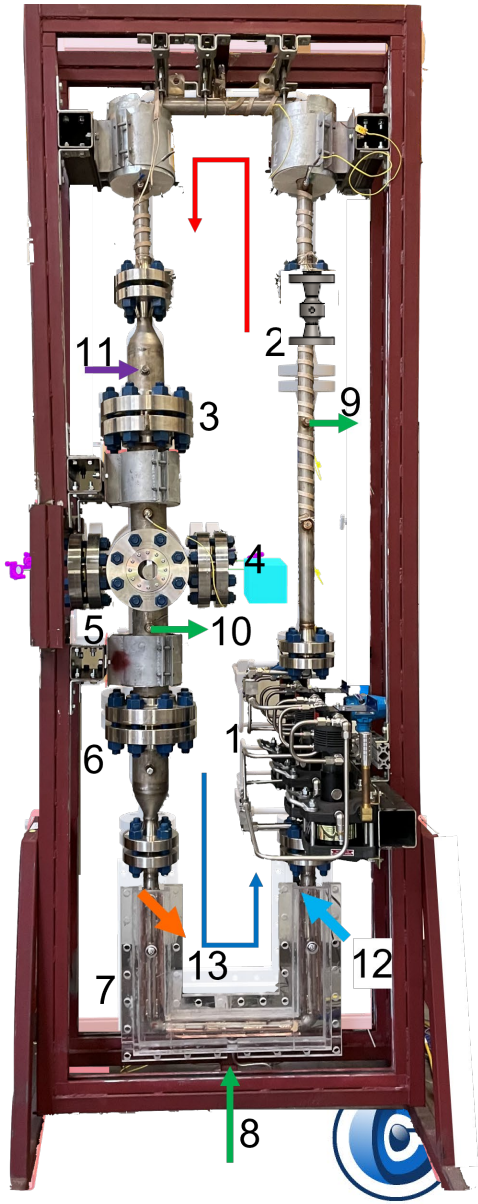
Experimental Facility for GCR Related Research

Prototypical Operating Conditions

Modern HTGR Operating Conditions: P,T > 7MPa, 750°C

Objectives:

- Perform experiments to obtain plate-out , lift-off and wash-off of dust facilitated fission product transport from scaled reactor components at both scaled and representative conditions using existing experimental facilities.
- Dust deposition & resuspension experiments under Normal Operating Conditions (NOC) and Depressurized Loss Of Forced Cooling (DLOFC).
- Implement models and perform simulations using the experimental conditions and match experimental data.
- Perform MELCOR simulations to compare with experiments and CFD.
- Derive numerical models and correlations from the generated data.



1. Gas Boosters
2. Orifice Flowmeter
3. Flow Conditioner
4. Test Article Mounting/Feedthroughs
5. Quartz Sight Glass Windows for Imaging
6. In-Line Filtration
7. Cooling Jacket
8. Gas Filling
9. Pressure Control Valve (PID)
10. Rapid Depressurization Valve
11. Liquid/Solid Aerosol Injection
12.-13. Cooling Jacket Water Inlet/Outlet

Methodology

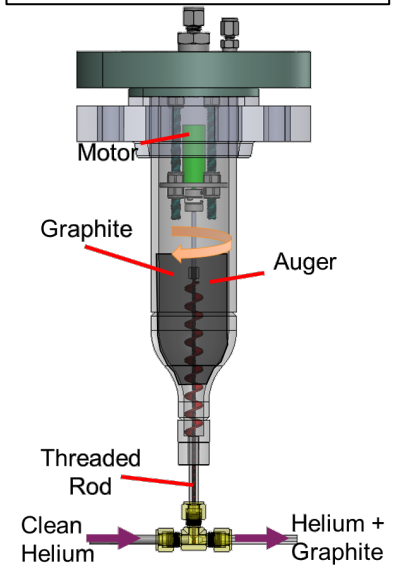
Flow Visualization & Instrumentation

- Instrumented Heated Sphere Test Article
- Moisture Removal "Bake-Out" under Vacuum
- Gas Booster Flow Circulation
- Quartz Sight Glass Windows
- Water Droplet Seeding
  - PIV & Wash-off Experiments
- Solid Aerosol Generator
  - Graphite Dust Plateout Experiments
- Remote Actuation/Data Collection
  - DLOFC "Liftoff" Experiments

Liquid Aerosol Generator

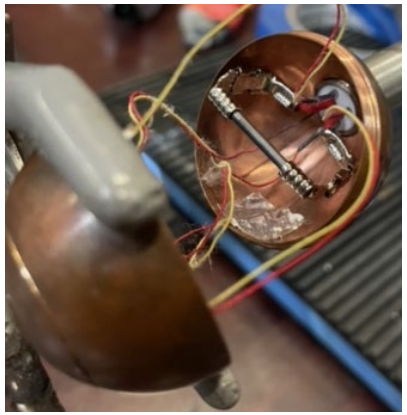
Selection Criteria	
Re #	16,780
Stk #	0.02887
$\dot{m}_{water,max}$	1.79 LPH
$D_{drop,\ max}$	12μm

Solid Aerosol Generator

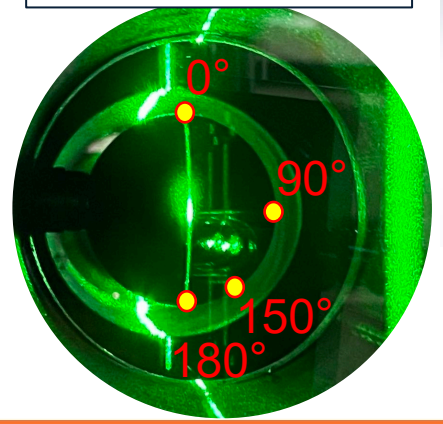


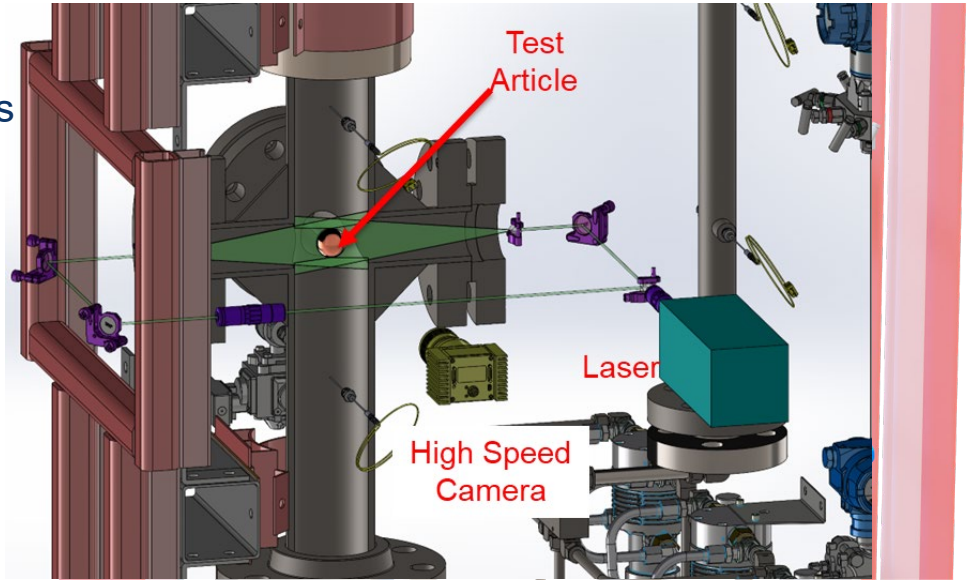
Reinforced Welds

Graphite Heater & TCs



Thermocouple Locations

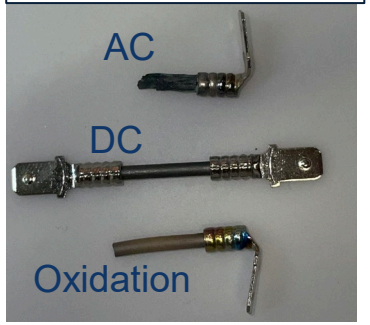




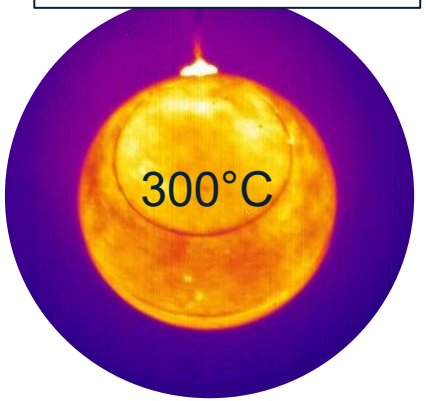
Shakedown Tests

Elevated P/T Flow Loop

Graphite Heater



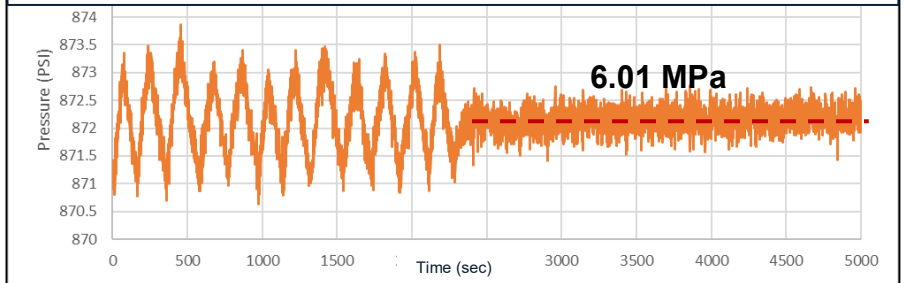
IR Image: Uniform Surface Heating



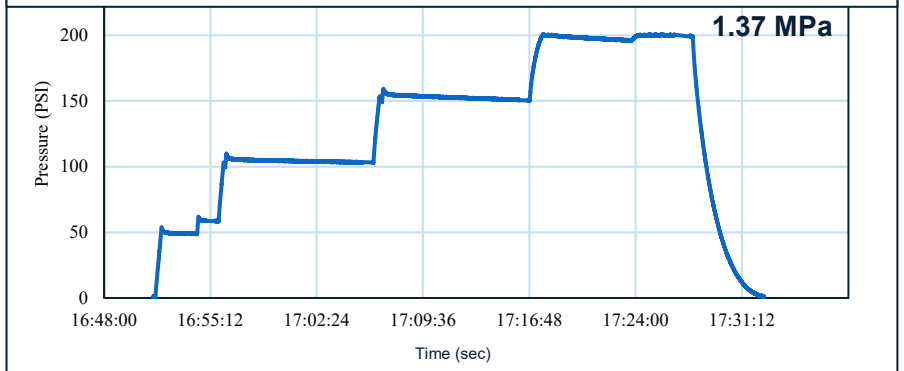
Remote Start/Stop Continuous Injection

Flow Meter & Compressor Shakedown

PID Pressure Stabilization



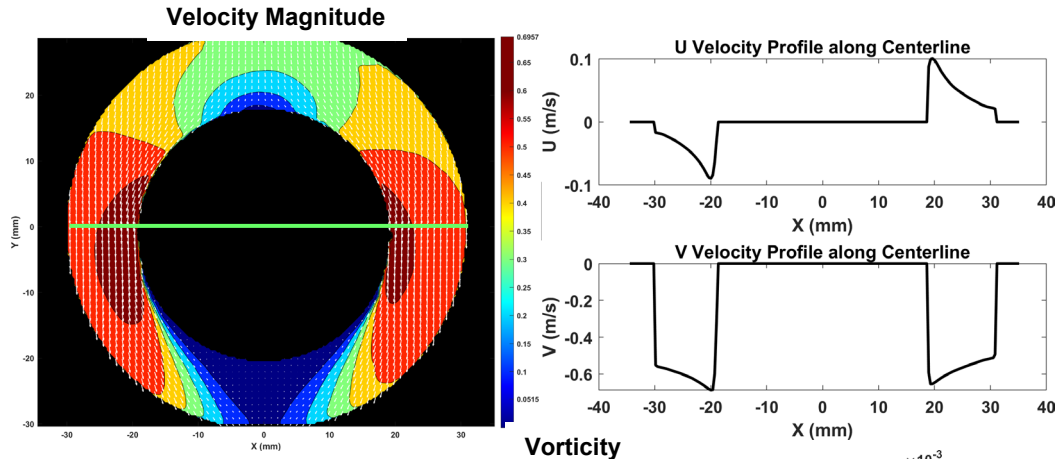
System Leak Testing

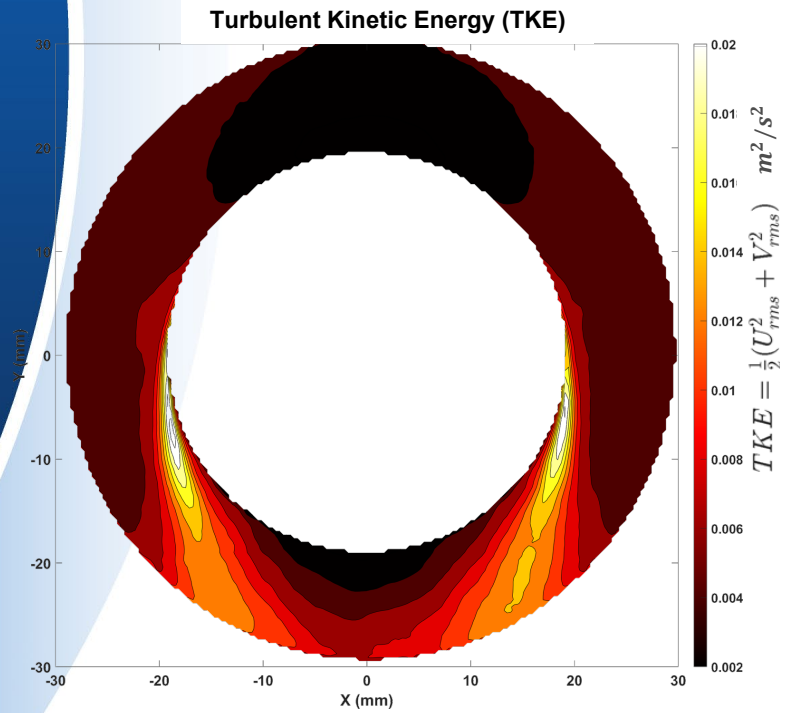


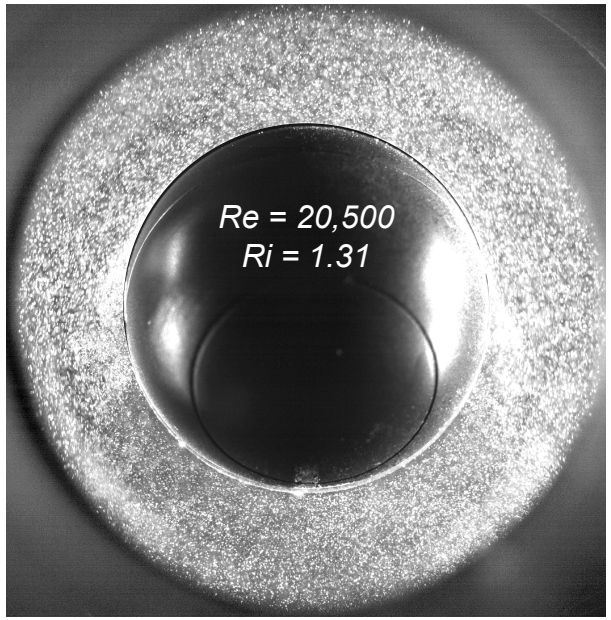
Time Resolved Flow Statistics

Insights

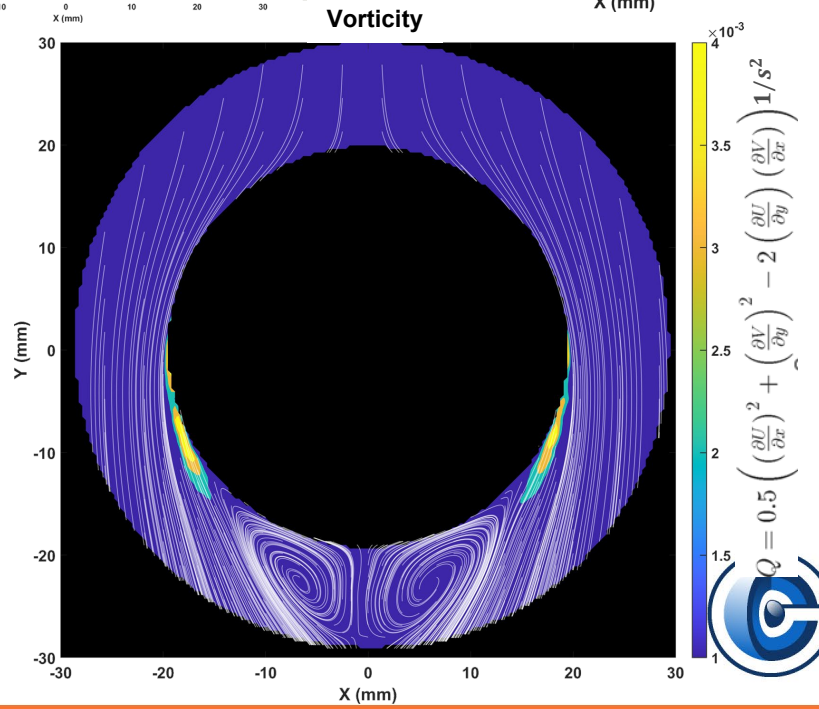
- Comparison & Development of Deposition Predictive Models
  - Wall Shear Stress, Deposition Velocity
  - Thermophoretic Force Influence
- Nondimensionalization
  - Reynolds & Richardson Number $Re = \frac{VD_s}{\nu}$ $Ri = \frac{Gr}{Re^2}$





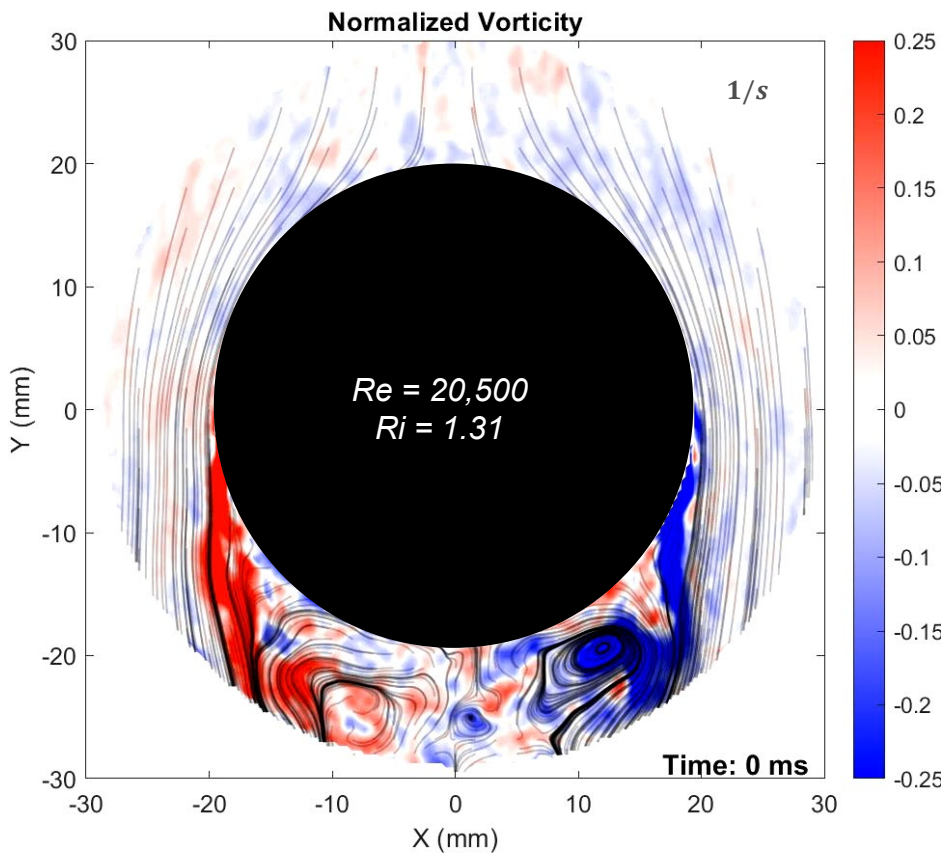


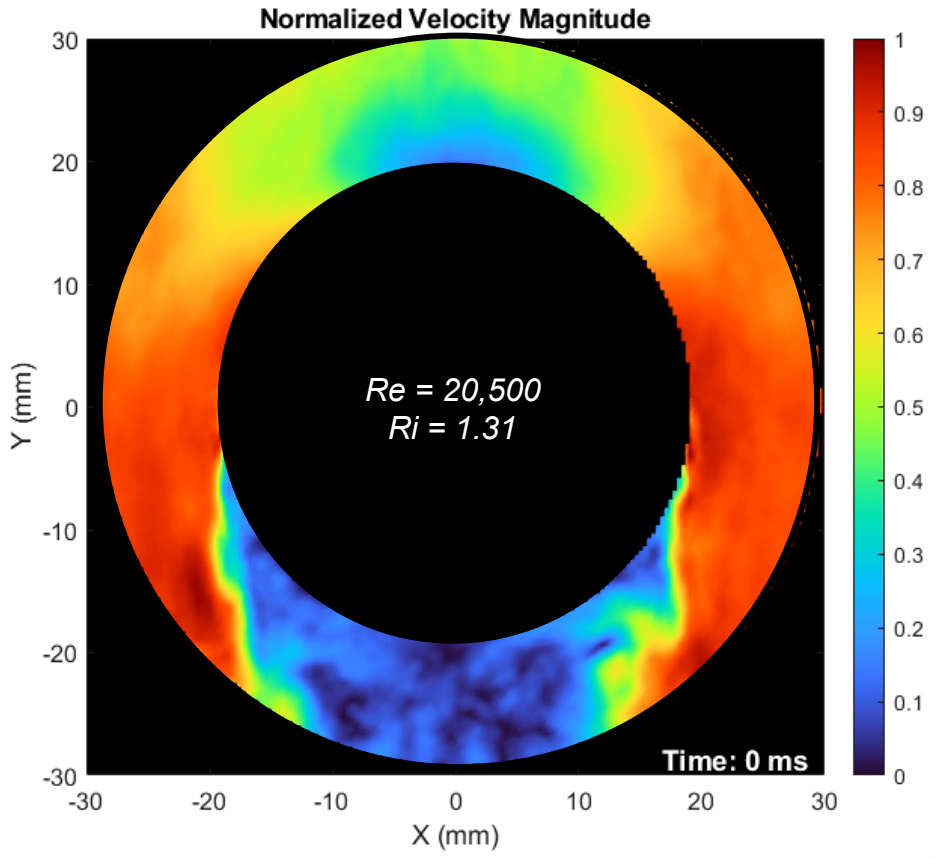
3 MPa, Flow Case #1, ΔT = 65°C



POD Flow Reconstruction

Heated Sphere Experiments – Opposed Flow Mixed Convection





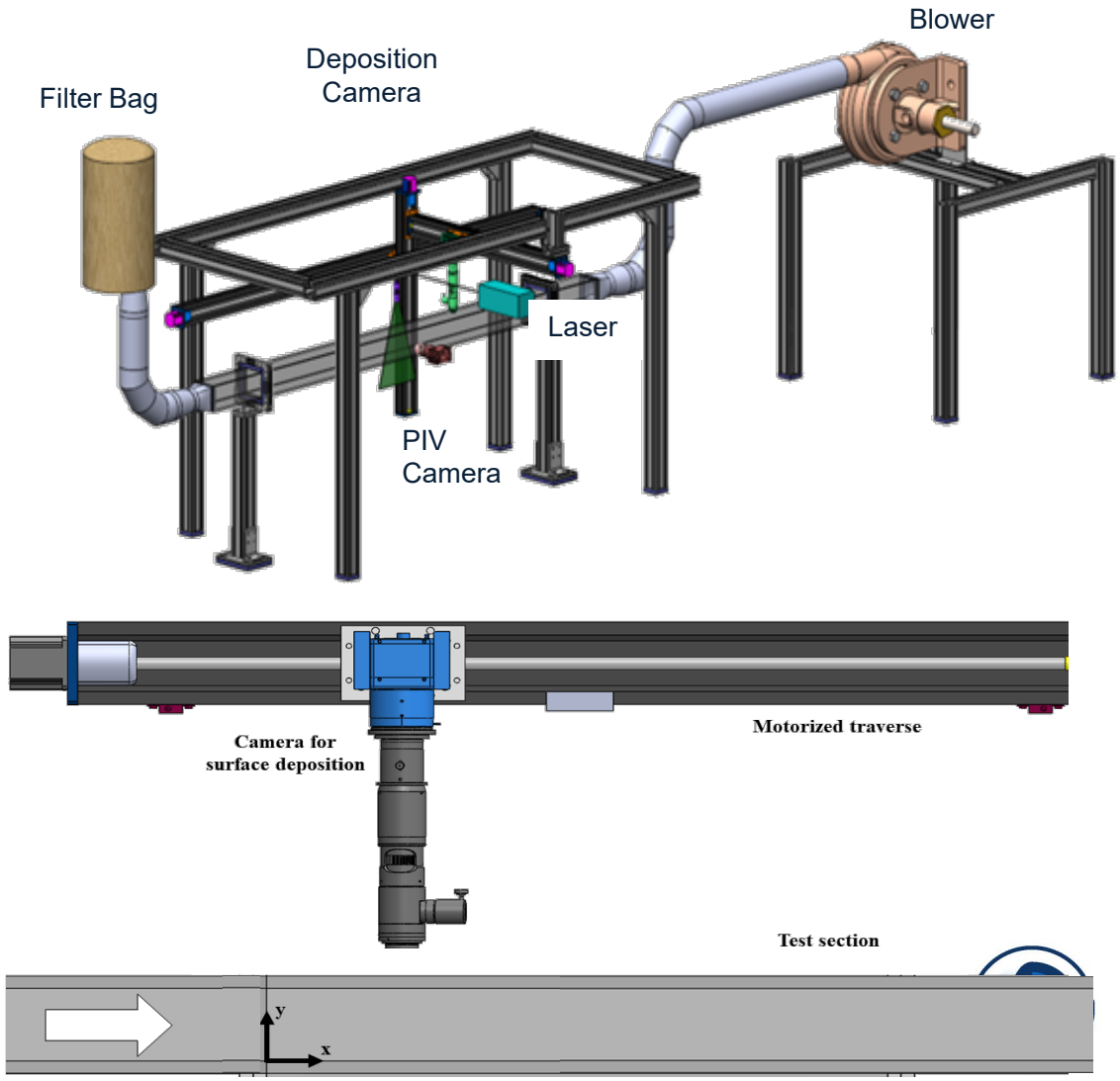
*Constructed from first 200 modes (99% Cumulative Energy)

Atmospheric P/T Deposition Experiments

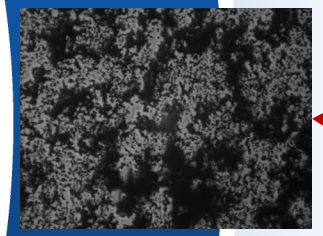
Purpose

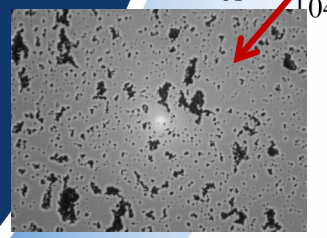
- Investigate graphite deposition patterns
- Saturation times for model comparison,
- Onset and growth of sedimentation patterns,
- PIV measurements for deposition velocity.

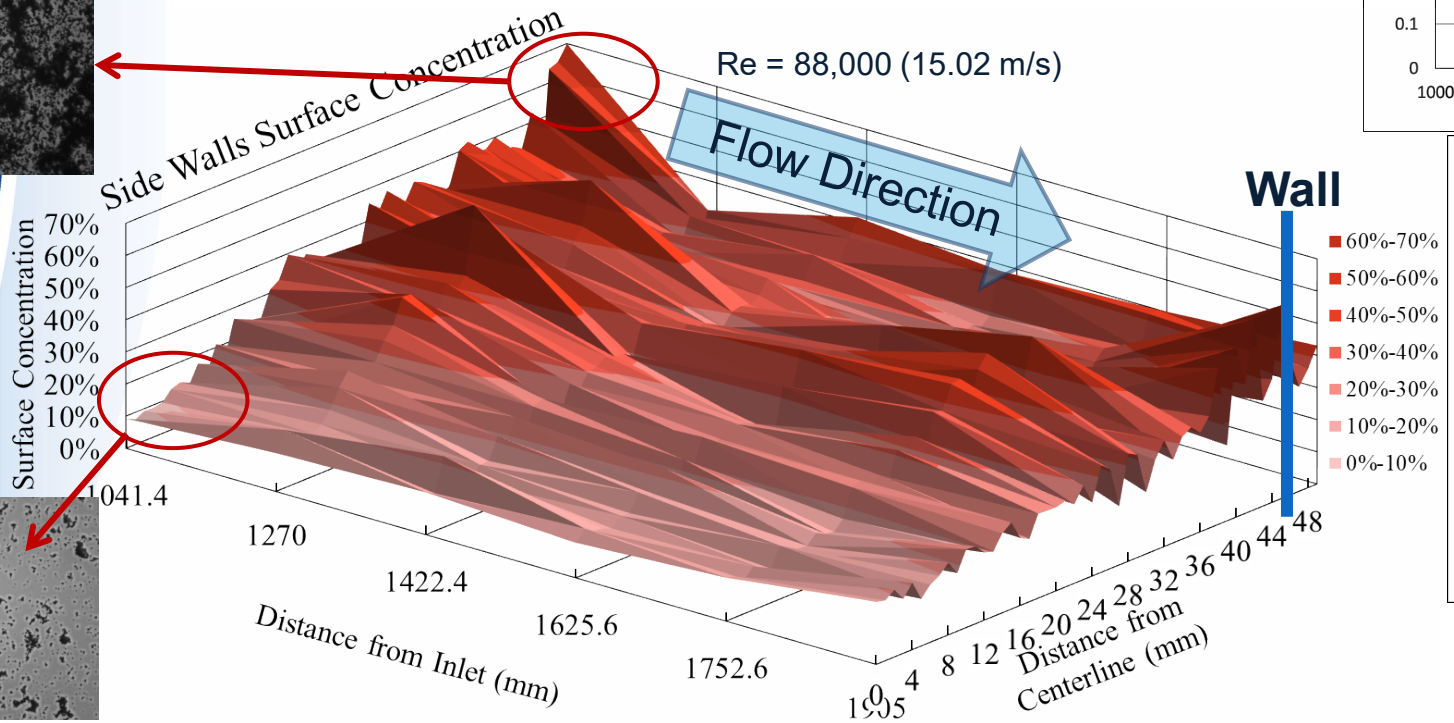
Re	V (m/s)
4,000	0.681
5,000	0.852
7,500	1.277
10,000	1.703
15,000	2.555
20,000	3.407
30,000	5.110
60,000	10.220
88,000	15.01

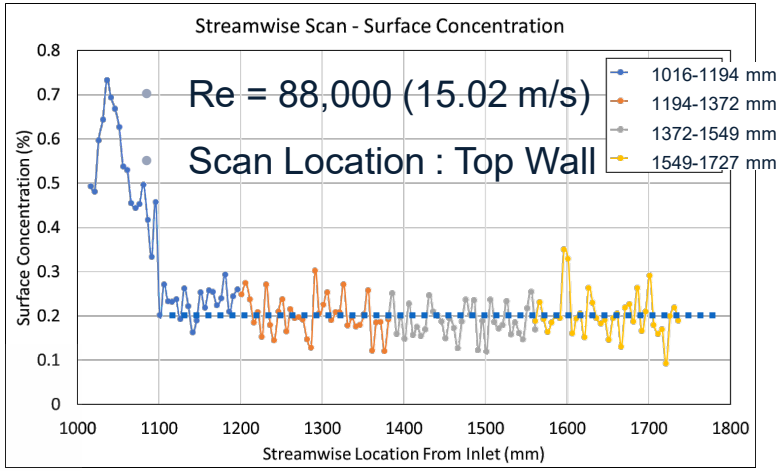


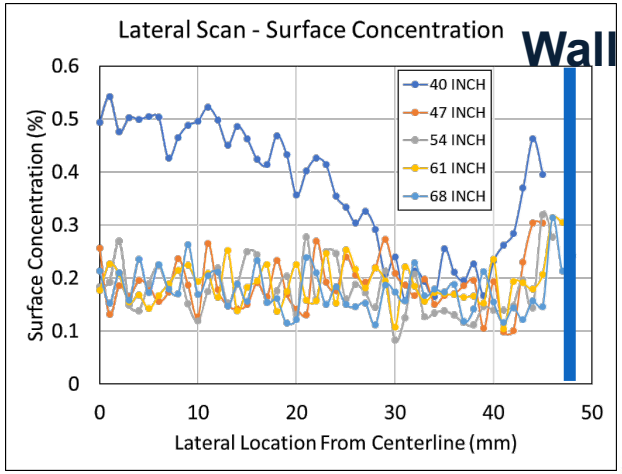
Graphite Dust Deposition: Channel Walls











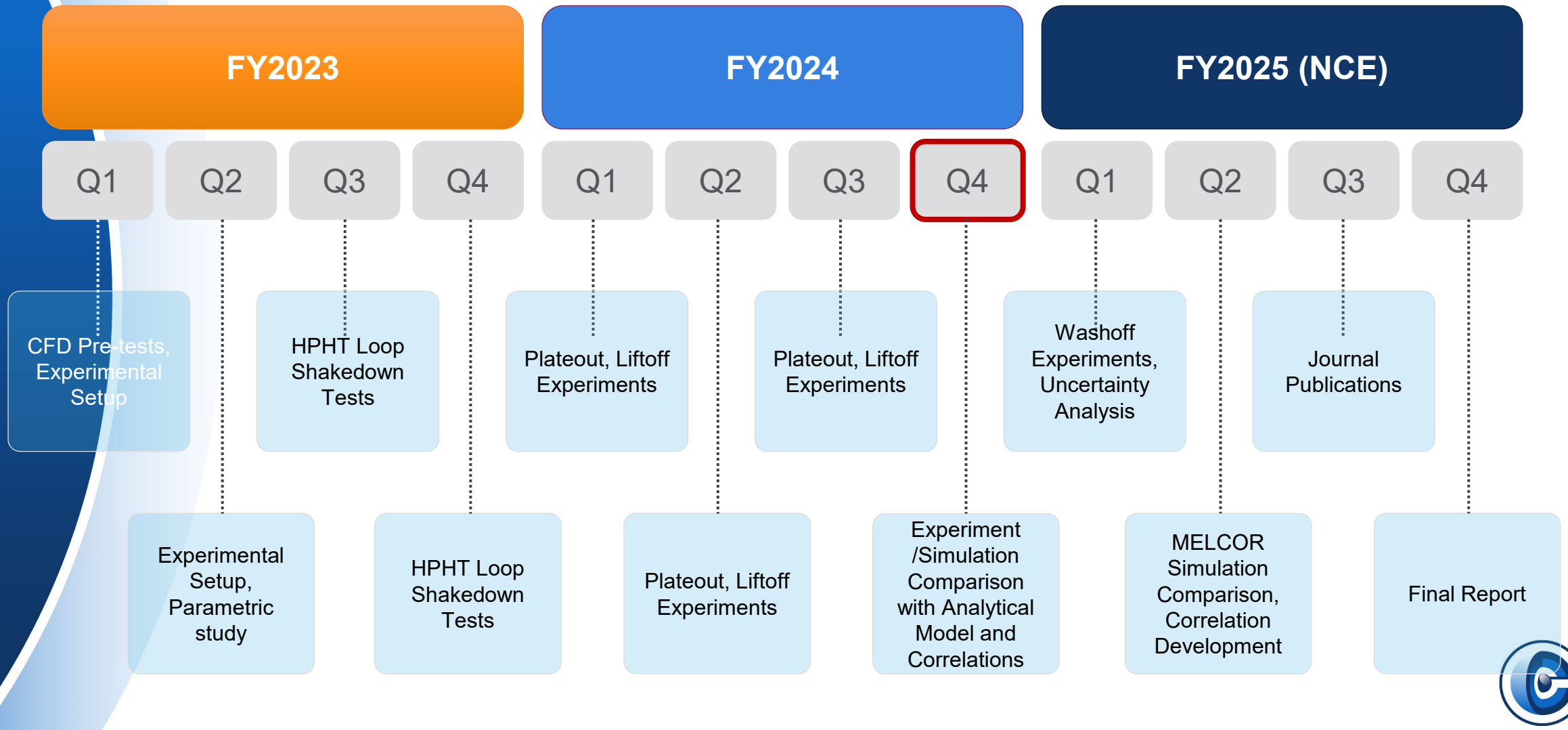
Upcoming Tasks

- Rapid Depressurization
  - ❖Upstream vs. Downstream Break
  - ❖Heated vs Unheated Test Article
- Graphite Dust (~5μm) Deposition onto Graphite Coated Heated Sphere
- Correlation Comparison & Development
- Publication Preparation

PRESSURE	FLOW	ΔT (T_SPHERE - T_FLUID)
6 MPa	1.0B	30°C
		40°C
		50°C
		60°C
	1.5B	40°C
		50°C
		60°C
		70°C
	2.0B	30°C
		40°C
		57°C
		73°C
	2.5B	70°C
		80°C
		90°C
		110°C
	3.0B	69°C
		76°C
		85°C
		100°C

*B = # Gas Boosters

Timeline to Completion



Acknowledgements

INL Idaho National Laboratory

TAMU

X energy

GENERAL ATOMICS ELECTROMAGNETIC SYSTEMS

Current & Past Students

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Thank You!

U.S. DEPARTMENT OF ENERGY