TEXAS A&M UNIVERSITY
Engineering

July 27, 2023

Victor Ugaz, Blake R. Maher, David Lanade, Yassin Hassan
Graduate Research Assistant, Department of Mechanical Engineering
Texas A&M University

Experimental Investigations and Numerical Modeling of Near-wall and Core Bypass Flows in Pebble Bed Reactors

DOE ART Gas-Cooled Reactor (GCR) Review Meeting
Virtual Meeting
July 25 – 27, 2023

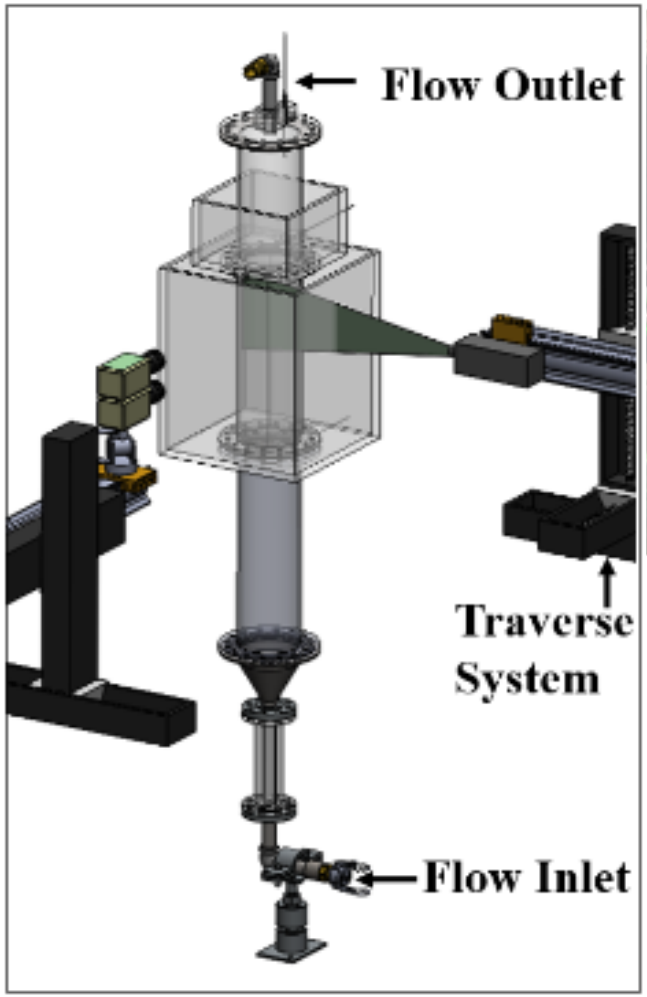
ART
Advanced Reactor Technologies

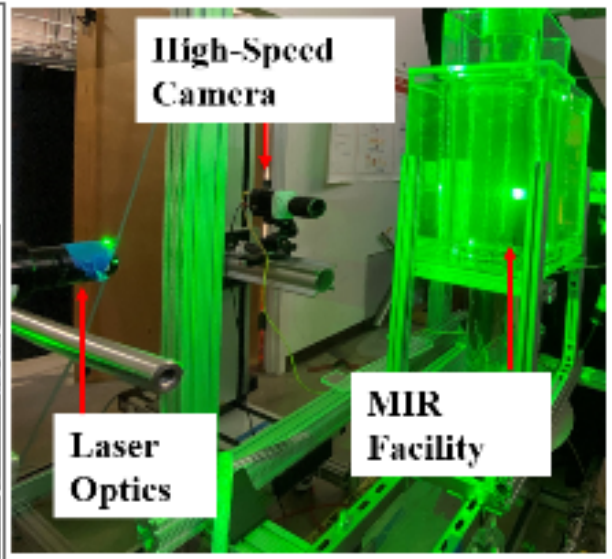
Objectives

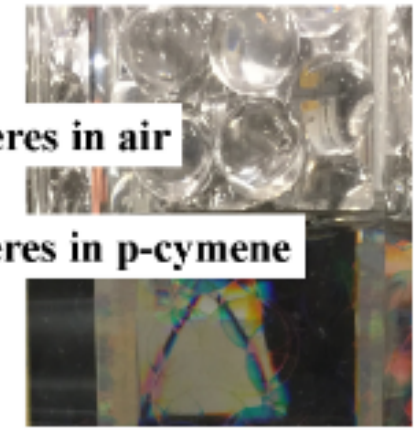
1. Acquire experimental measurements & high-fidelity simulations of transport process for near-wall flow region in PBRs, and use the database to derive closure models & correlations needed for porous media codes.
2. Experimentally investigate the near-wall and bypass flows in PBRs.
3. Perform high-fidelity simulations (Nek5000 DNS, LES, and RANS) using reconstructed geometries and boundary conditions from PBR experimental facilities.
4. Perform calculations using the developed CFD and Pronghorn models for the new experimental facility, and conduct validations using the measurements acquired.

Introduction

- There is a need for coordinated experimental and computational efforts to produce new correlations for pressure drop, as well as heat & mass transfer coefficients between pebbles, wall, and fluid to be implemented in porous media codes.
- Experimental data will support development & validation of Computational Fluid Dynamics (CFD) modeling.
- Experimental and CFD data will drive physical understanding & provide insight for the derivation of correlations.
- Combined approach will complement efforts in developing turbulence models & closure correlations for porous media approach.

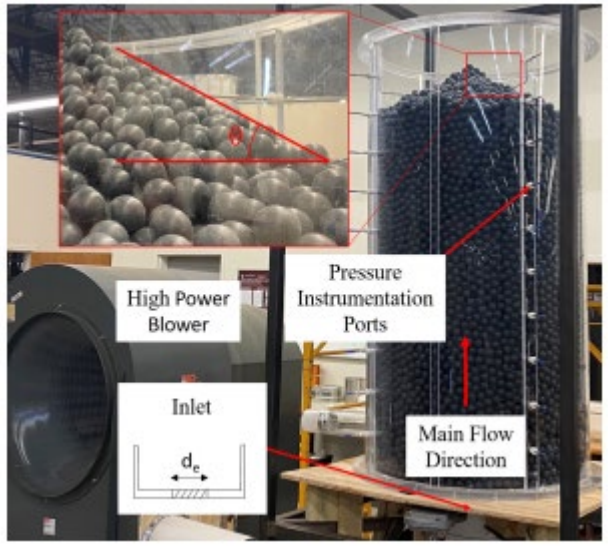


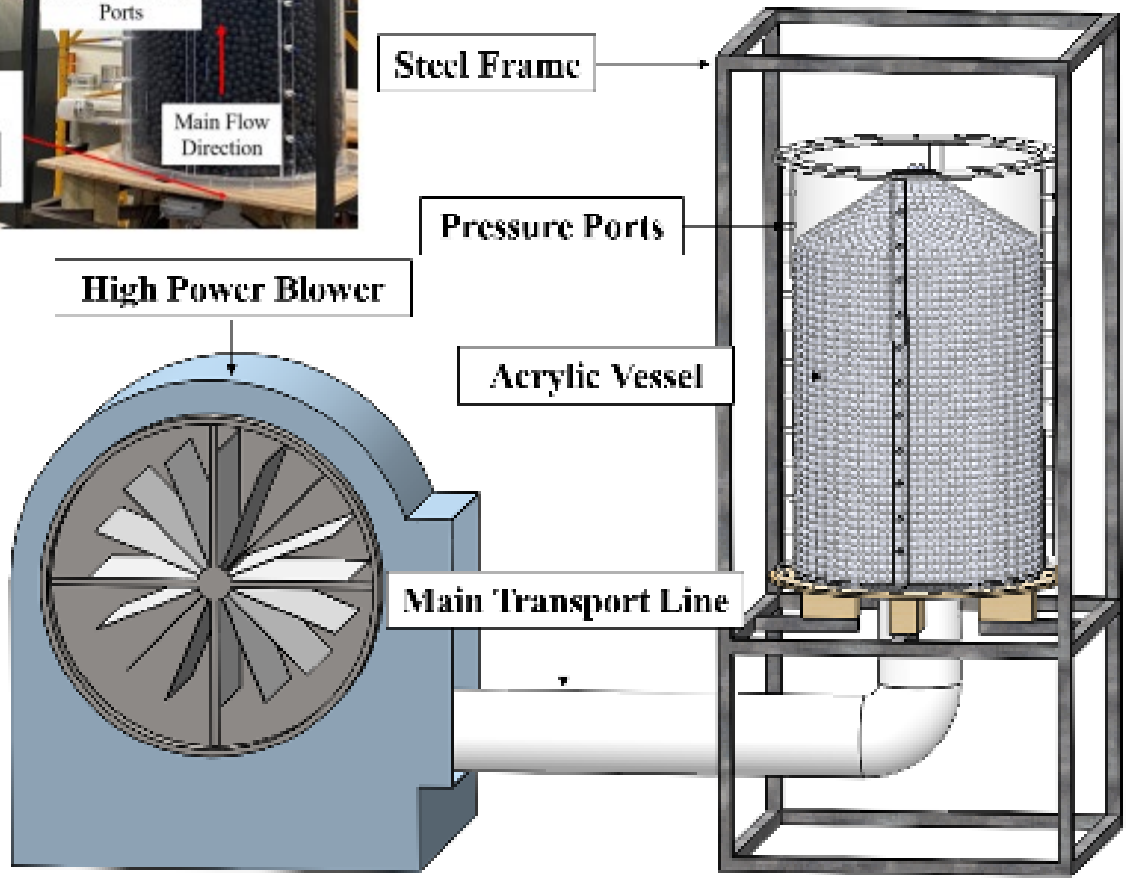




Low Pressure Air Test Facility

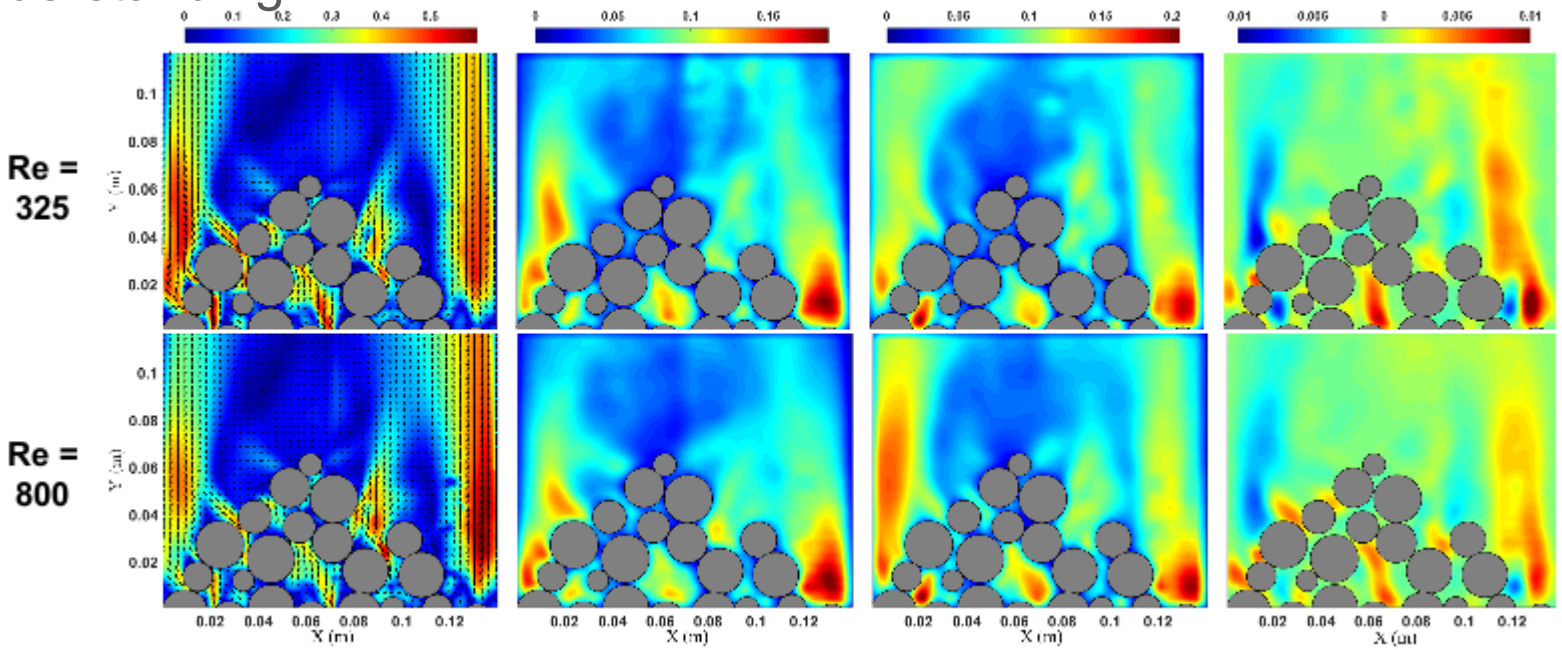
- Large scale facility employed for pressure drop testing and confirmation of entrance and outlet effects
- Comparison between measured pressure drop and KTA correlations
- Radial pressure drop at inlet measured to determine development length
- Axial pressure drop in cone shaped outlet region measured for comparison with KTA correlation

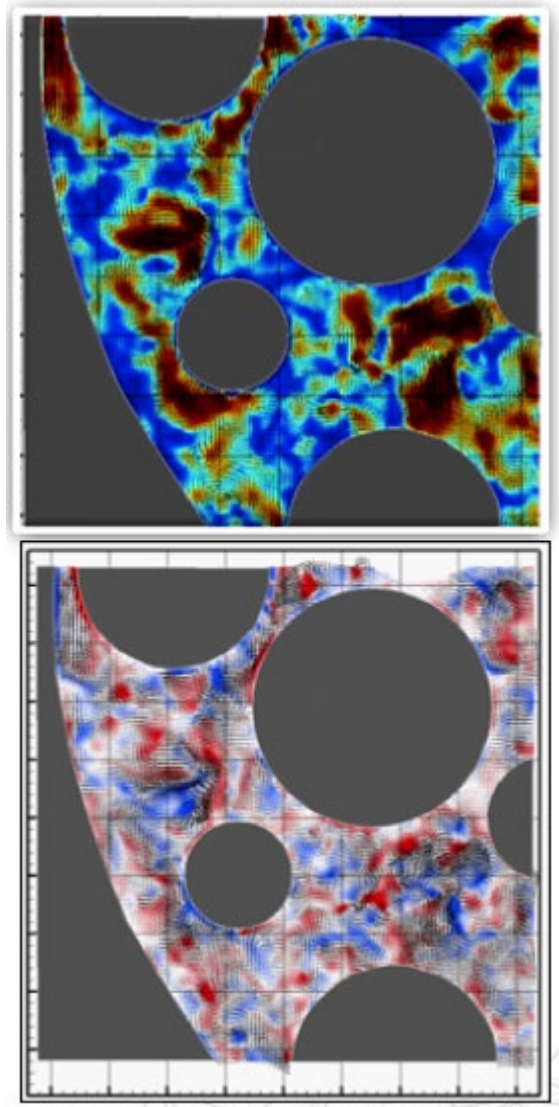




Isothermal Matched Index of Refraction Facility

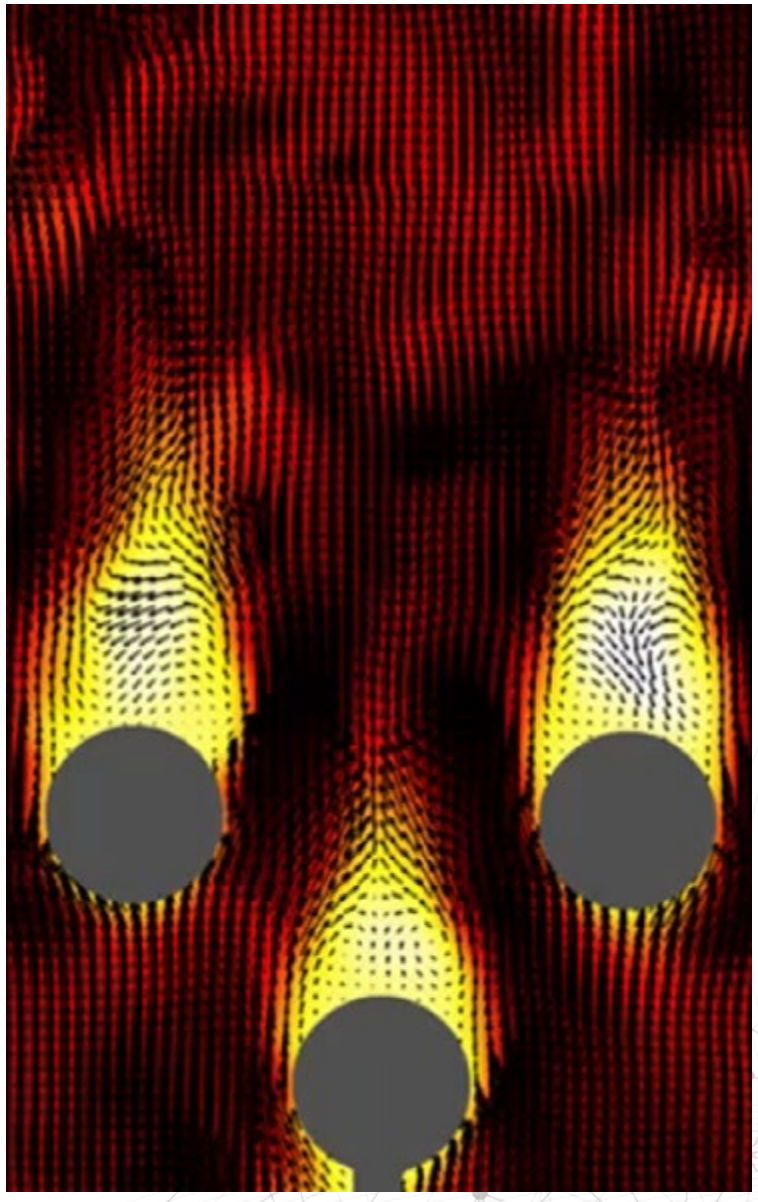
- Isothermal MIR facility employed for comparison of pressure drop measurements with air facility
- Velocity measurement using PIV allowed for initial study of near wall region at the outlet of the bed which shows flow preference toward bypass region of core
- Additional research using heated spheres was desired to better full system understanding





Non-Isothermal Three Sphere Experiments

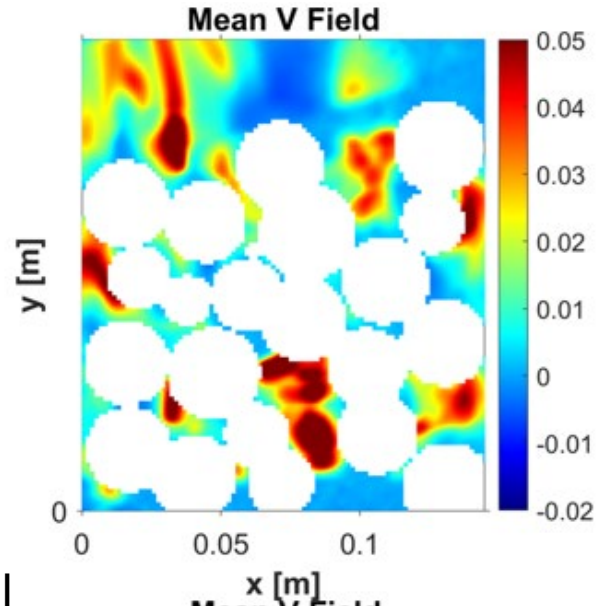
- Simplified experiment for flow over heated spheres using induction heating
- Served as shakedown test for MIR non-isothermal test facility
- Time resolved PIV and PLIF experimental setup
- Data processing using in house codes, multi-grid, multi-pass algorithm



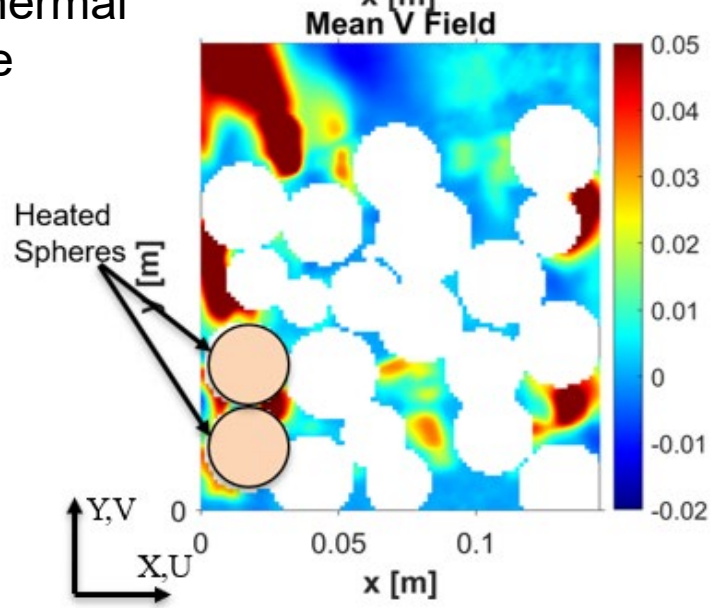
Non-Isothermal MIR facility

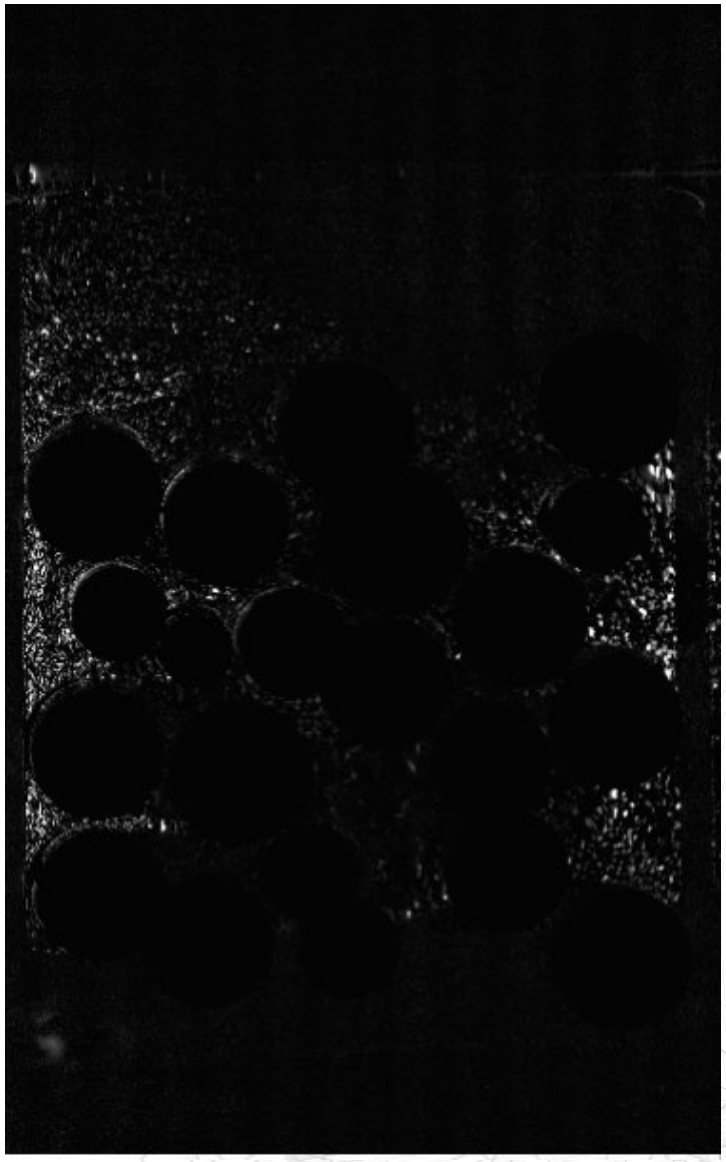
- Fluid temperature increase of 10 degrees Celsius near heated spheres
- Buoyancy effect results in increased axial velocity near heated spheres
- Indicates velocity distribution dependence with local heat flux of heated spheres
- Reduction in velocity near isothermal spheres reveals importance of proper quantification of heat generation within fuel elements for proper velocity and Nusselt number quantification

Isothermal
Test Case
Re = 160



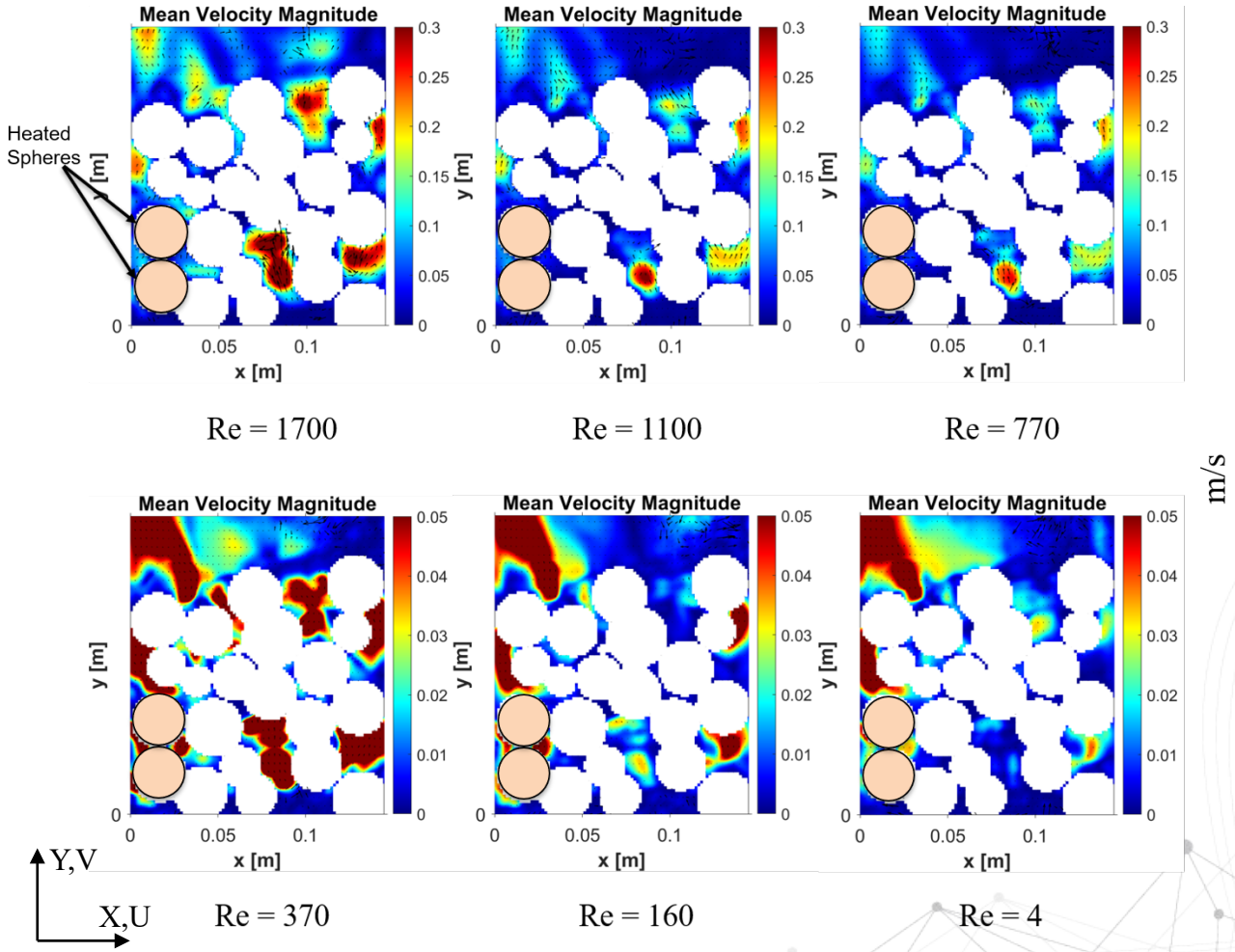
Non-Isothermal
Test Case
Re = 160





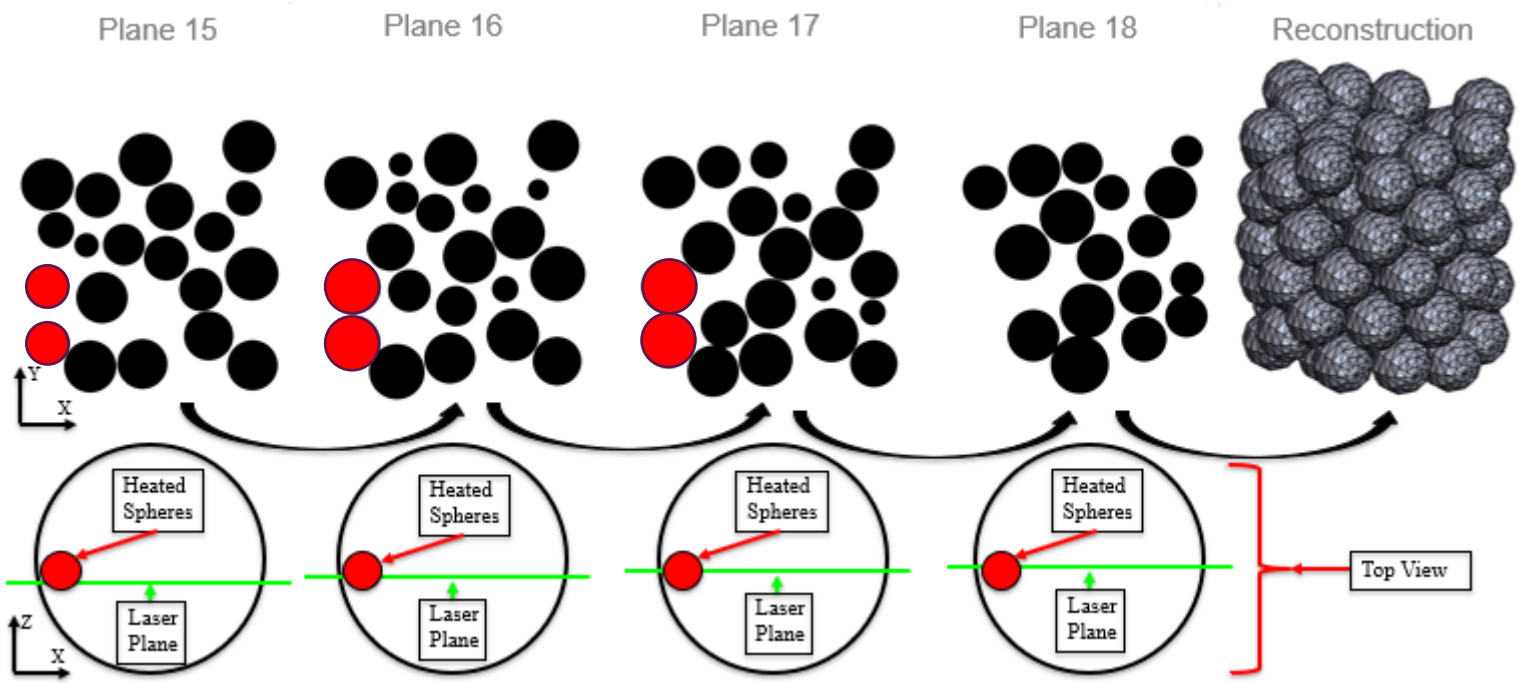
Non-Isothermal MIR facility

- Vertical velocity component increased in non-isothermal test cases as well as low Re cases (increased buoyancy force relative to surrounding profile)
- Natural convection case highlights non-isothermal aspect of entire flow profile at very low Re relevant to Loss of Flow accident
- Central duct velocity decreases slightly relative to isothermal test cases due to increase near heated spheres

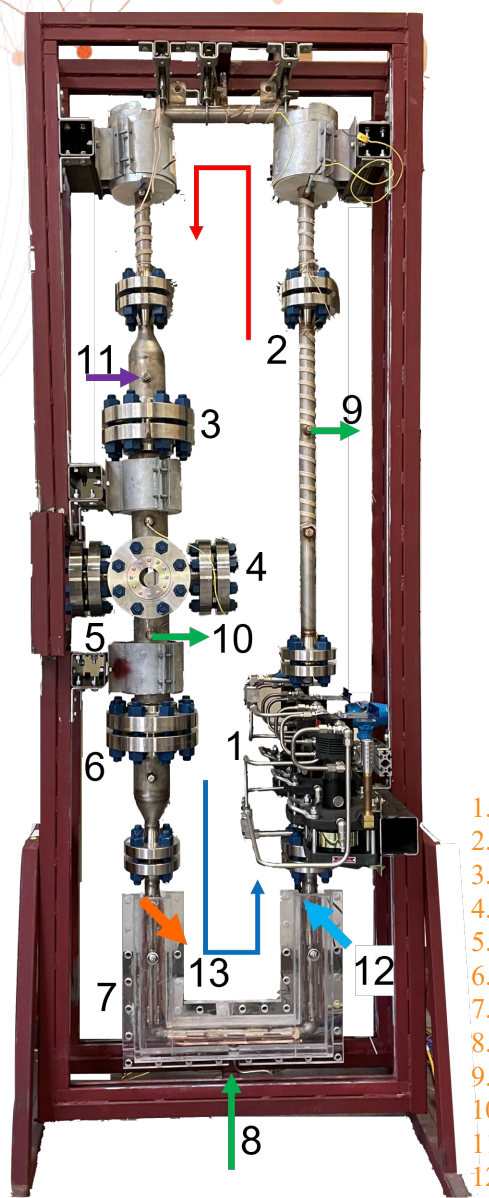


Isothermal Matched Index of Refraction Facility

- Full geometric reconstruction of visible region of spheres made possible using high resolution three dimensional traverse system, concentrically aligned lasers, and camera systems
- 31 planes captured and sphere locations determined using Hough transform and chord length formulas in order to generate CAD model of geometry for meshing in CFD



High Pressure High Temperature Facility



- Shared facility
- Pebble bed section housed in quartz sight glass section
- Operation with multiple fluids possible
- Heated sphere employing joule heating for proper heat flux quantification
- Visualization section small but near wall region visible
- Additional instrumentation includes high quality instrumentation for flow rate, temperature, and pressure

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