NEUP Integrated Research Project Workshop 2:
FHR Benchmarking and VVUQ

Session 4: Separate Effects Test (SET) Research Programs

April 14, 2016

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Thermal-Hydraulics SETs
Motivation for the session

- **Separate Effects Tests are performed for several reasons:**
  - **Exploratory**
  - **Develop a basis for code validation**
  - **Develop data for closure models for systems level codes**
  - **Component-level testing**
- **What are the benchmark needs for SETs for FHRs?**

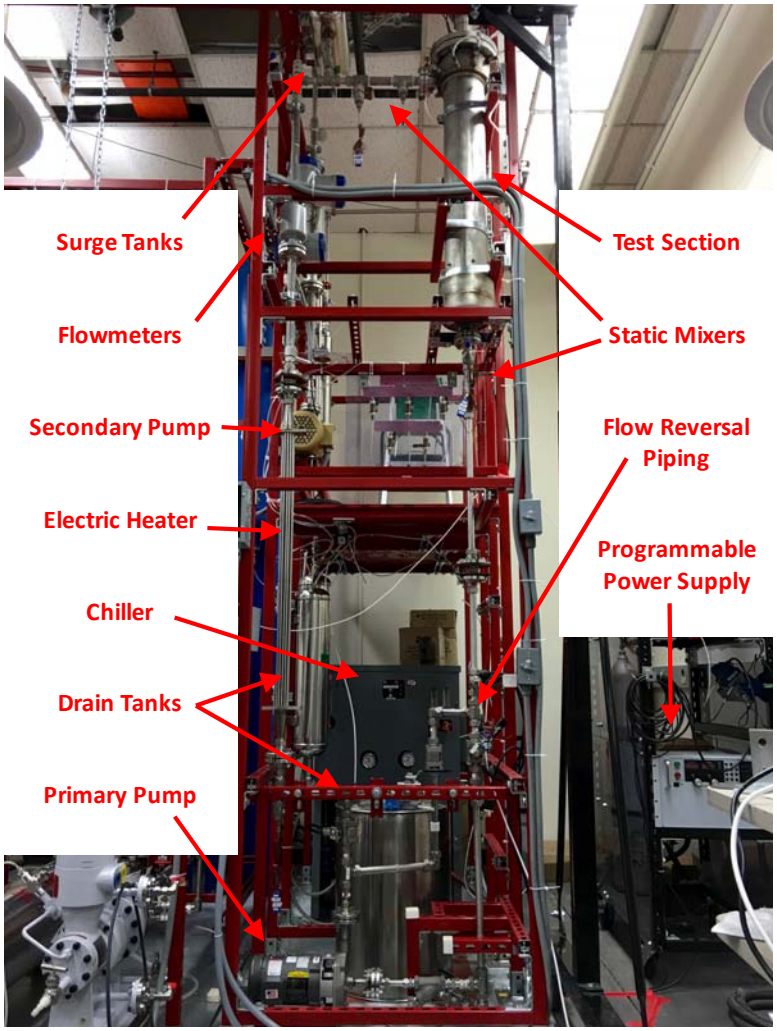
Thermal-Hydraulics SETs
Goals for the session

- **Provide high-level overview of SET work being performed at the participating universities**
- **Provide guidance for selection and design of benchmarking problems for thermal-hydraulics separate effects tests**
- **Establish next steps in benchmark development**

Thermal-Hydraulics SETs
UNM Experimental Overview

Facility

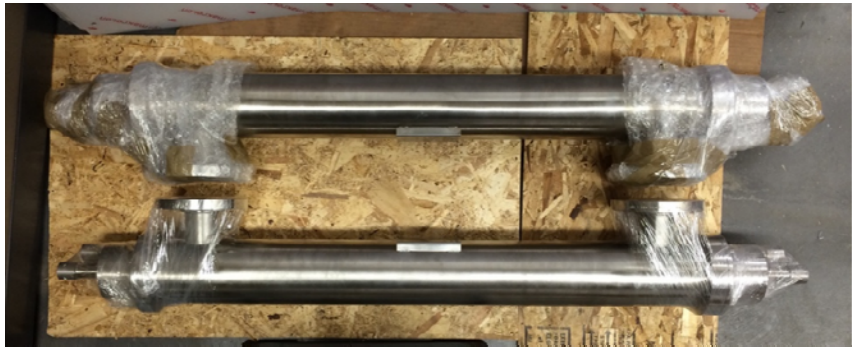
- **Reduced scale heat transfer facility constructed at UNM**
  - **Currently under shakedown testing**
  - **Primary loop**
    - » **Water initially – transition to Dowtherm A**
    - » **Natural + forced circulation flow modes**
    - » **Bi-directional**
    - » **Electrically heated**
    - » **Cooled in test section**
  - **Secondary loop**
    - » **Water initially – transition to Dowtherm A**
    - » **Forced circulation**
    - » **Heated in test section**
    - » **Cooled in secondary heat exchanger by chilled water**



Heat transfer facility at UNM.

Thermal-Hydraulics SETs
UNM Experimental Overview

Twisted vs. plain tube heat exchangers provided to UNM, masked for clarity (flange is behind support; photo credit: Hipex).

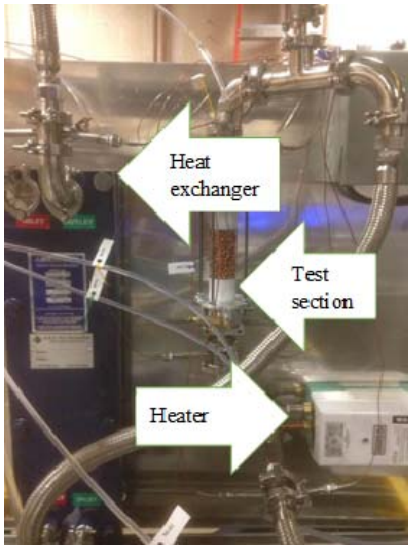


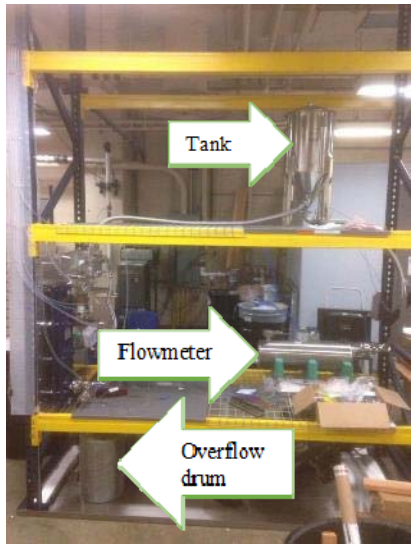
Twisted outer/plain inner vs. plain outer/plain inner tube heat exchanger.

Planned Tests

- **Enhanced heat transfer**
  - **Single-wall plain tube heat exchanger**
  - **Single-wall twisted tube heat exchanger**
  - **Focus on buoyancy effects**
- **Directional heat exchanger**
  - **Implement hydrodynamic experiment (DirEX^2) insights in designing a heat transfer experiment**
- **Double-wall heat exchanger**
  - **Plain outer/plain inner heat exchanger**
  - **Twisted outer/plain inner heat exchanger**
  - **Focus on double-wall performance**

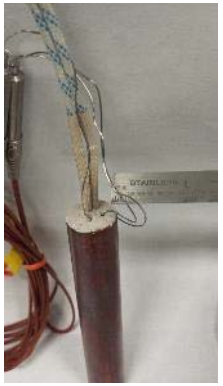
Thermal-Hydraulics SETs
UCB Experimental Overview

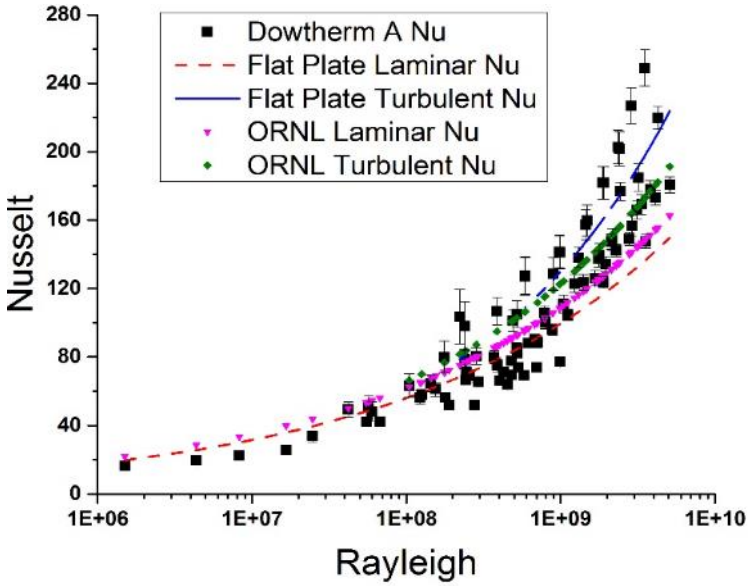




- **Measure heat transfer coefficient in a pebble bed test section as a function of position and time, for ranges of Prandtl and Reynolds numbers**
- **Collect data that could possibly be used for validating similitude of heat transfer oils and fluoride salts**

Thermal-Hydraulics SETs
UCB Experimental Overview

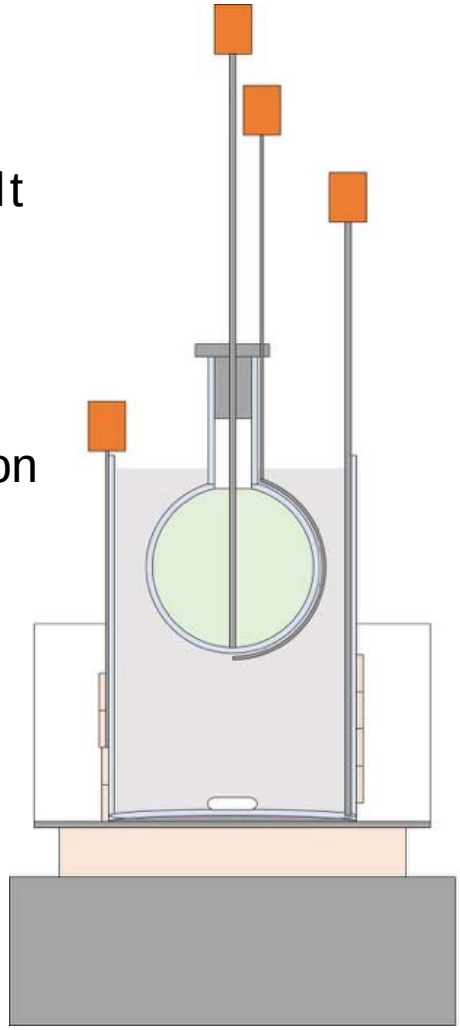




- **Need to demonstrate similitude between fluoride salts and Dowtherm A for natural convection heat transfer**
- **Immerse a heated element in flinak and Dowtherm A, and compare Nusselt numbers for matched Pr and Gr conditions**
- **Nusselt number can be predicted using correlations for natural convection heat transfer from a vertical flat plate**

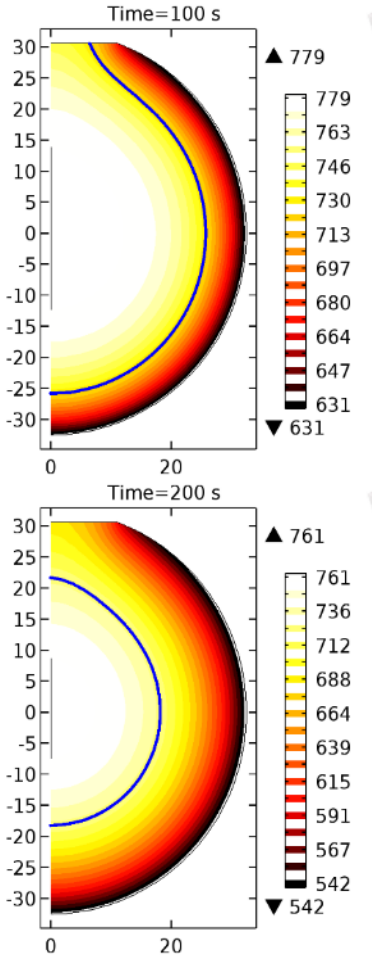
Thermal-Hydraulics SETs
UW Experimental Overview

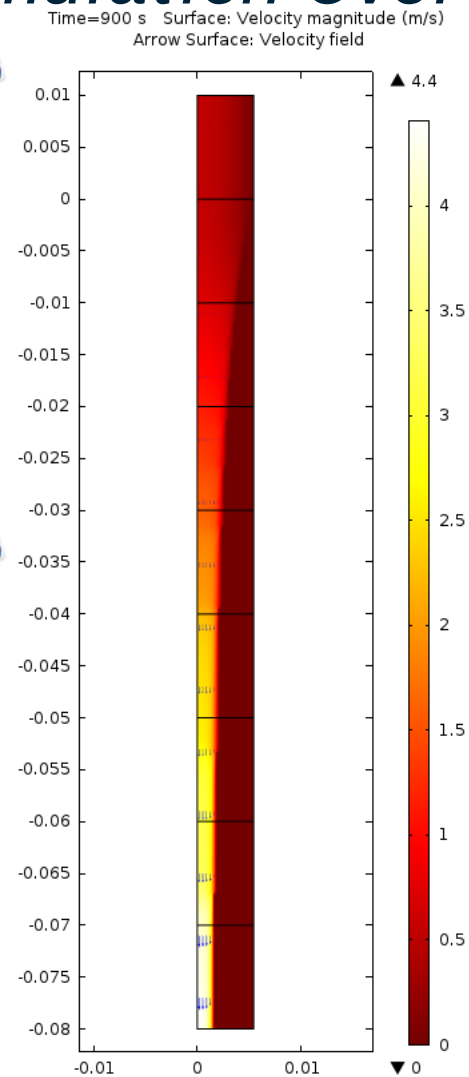
- **Static Freezing Experiments**
  - Molten salt sample immersed in cooler nitrate salt
    - » Stirred cold bath for uniform temperature
    - » Adding PID control of heaters
  - Explore different cooling rates and sample sizes
    - » What is the effect on freeze front propagation
    - » What is the effect on supercooling
- **Possible Property Measurements**
  - Bulk Measurements
    - » Density, thermal conductivity
  - DSC or other Measurements
    - » Latent heat, specific heat
- **Future Pipe Freezing Experiments**

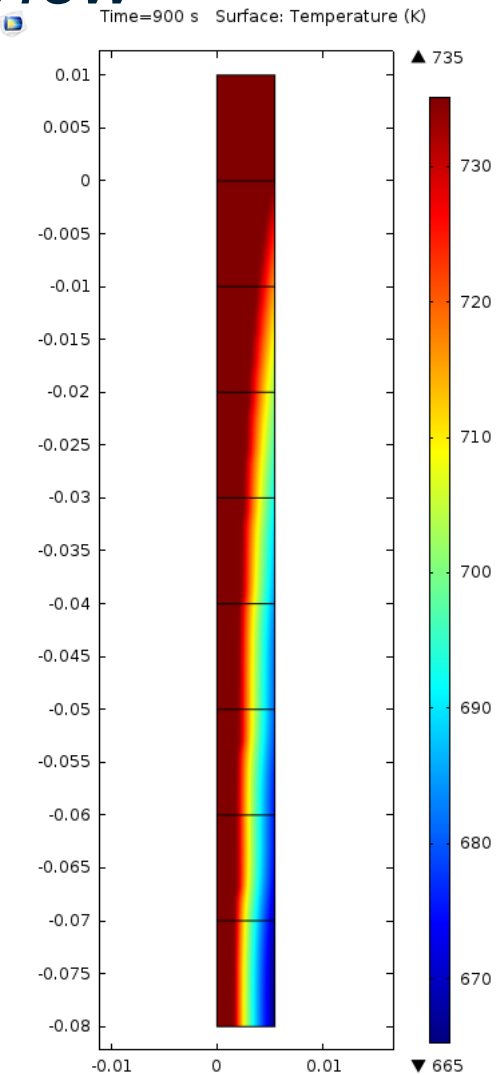


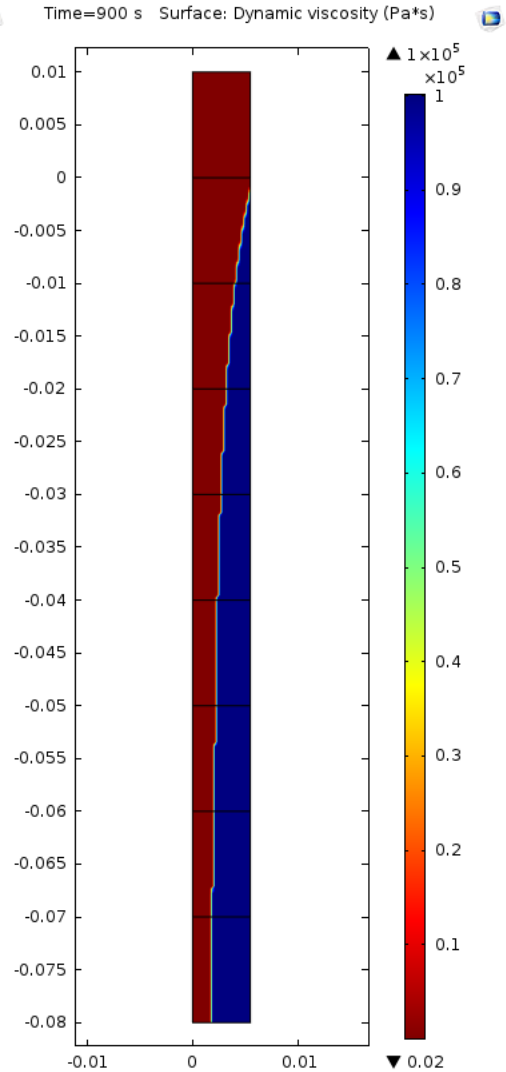
Thermal-Hydraulics SETs

UW Simulation Overview









Thermal-Hydraulics SETs
Discussion Points

- **Ensuring complete and appropriate benchmark selection will be important to avoid future delays**
- **How do we assess the completeness of the benchmarks selected in covering the important phenomenology?**
- **How do we determine which codes need to be benchmarked for which parts of the problem?**
- **Can we create a benchmark from an experiment which may involve proprietary vendor data?**

Thermal-Hydraulics SETs
Discussion Points

- **A large amount of the experimental work on FHR thermal-hydraulics is utilizing simulant fluids at a reduced scale**
- **How appropriate is the use of simulant fluids in benchmarking, considering some key phenomena will be missed (e.g. freezing/participating media during radiative heat transfer)?**

Thermal-Hydraulics SETs
Discussion Points

- **Fluoride salt properties have large associated uncertainties, and small applicable temperature ranges**
- **How can we reduce the uncertainties in property measurements, and take measurements for a wide temperature range?**
- **We need more accurate property measurements for flibe as well as other fluoride salts such as flinak**

Thermal-Hydraulics SETs
Discussion Points

- **Using codes to simulate SETs**
- What are the values/limitations of using CFD?
- Simulating certain phenomenology may require additional development of codes, for example freezing
- What SET simulations will provide useful results for development of system code and iterative design changes?
- What multi-physics coupling is needed?
- What experiments will be useful for validating codes?

Thermal-Hydraulics SETs
Next Steps

- **What are some of the additional SET needs?**
- Testing salt pumps, fluidic diodes, etc.
- Narrow down benchmark problems / define SET benchmarks for the FHR project

- **How will we move forward with SET data?**
- Generate experimental data with salts for code validation
- Use experimental and CFD data to provide information to TH system code for transient analysis