ORNL Liquid Salt Test Facility

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Thermal Hydraulic and Related Technology Challenges

- General: high temperature, material selection
- Operations: maintenance, line plugging, unexpected cooling
- Endurance & reliability: creep & fatigue, pumps, valves, seals
- Salt prep. & handling: mixing, cleaning, freeze/thaw/transfer
- Instrumentation: temperature, material compatibility, non-intrusive
- Uncertainty: correlations, salt properties, I&C
- Special considerations: beryllium, tritium, special alloys, etc.

- Many challenges were overcome for MSRE; however, challenges remain for commercialization

ORNL Liquid Salt Test Loop (LSTL)

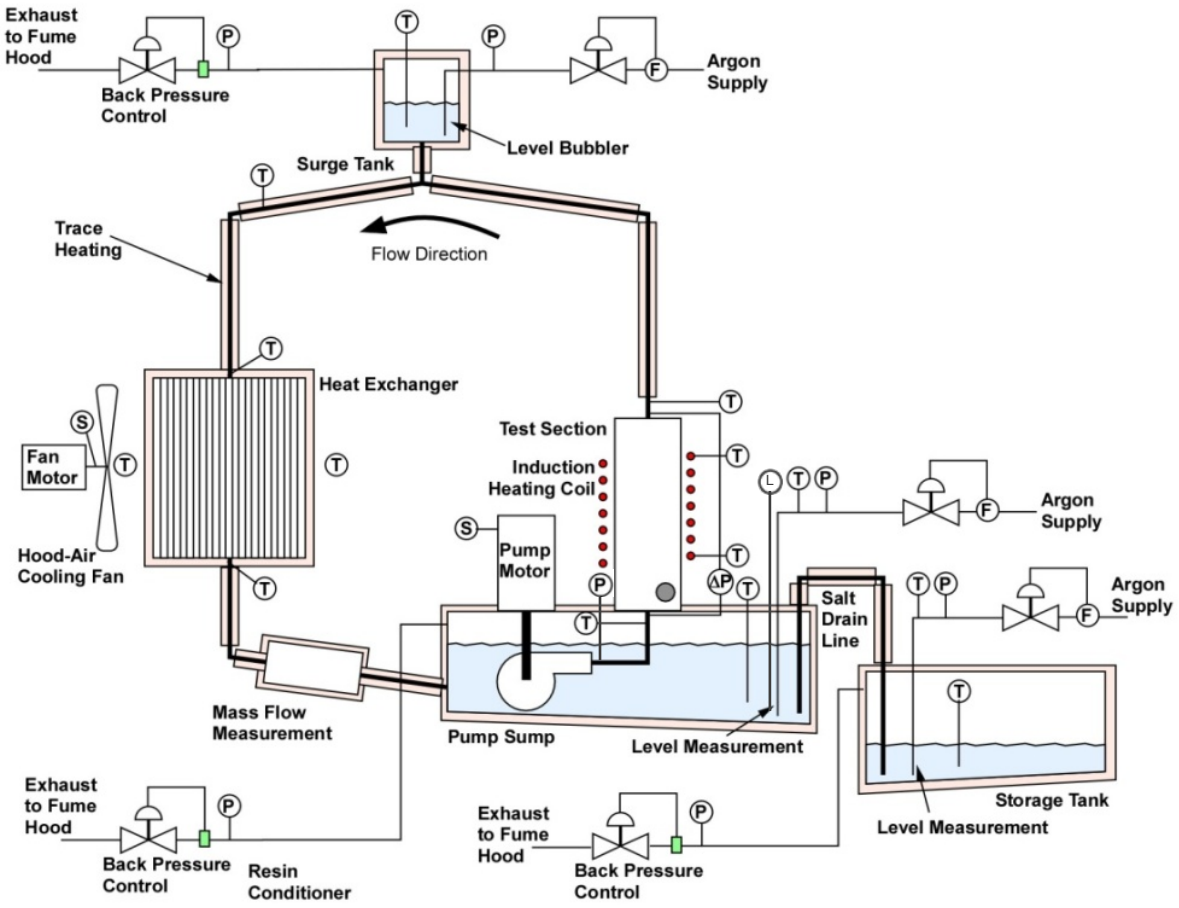
Initial Goals:

1) Provide infrastructure (operational knowledge and equipment) to test high temperature salt systems
2) Develop non-intrusive inductive heating technique that can be used for thermal/fluid experimentation
3) Measure heat transfer characteristics in a molten salt cooled pebble bed
4) Demonstrate the use of Silicon Carbide (SiC) as a structural material for use in molten salt systems

- Started with ORNL internal investment
- Currently supporting cooperative research with SINAP

LSTL – General Layout

- Storage tank
  - Long term salt storage allows re-solidification
- Pump sump tank
  - Sump type centrifugal pump
- SiC test section (pebbles)
  - Pebble heat transfer
- Surge tank
- Forced draft air cooler
- Trace heating and gas supply system
- A range of I&C



LSTL – General Specs

A versatile test facility

Salt	LiF-NaF-KF (FLiNaK)
Salt volume	~72 liters
Operating Temperature	up to 700°C
Flow rate	≤ 4.5 kg/s ~3.5 m/s (1in ID)
Operating pressure	~Atmospheric
Material of construction	Inconel 600
Operating run time life	2+ years
Primary piping ID	1.05 in
Heating	Trace: ~20 kW Induction: 200 kW
Heat rejection	Air-cooled heat exchanger

LSTL - Testing Phases

- 1st phase
  - Shakedown testing (seals, pump, I&C, HX)
  - Pebble bed heat transfer
- 2nd phase
  - Pump performance characterization
  - Corrosion in flowing salt (DOE-NE IRP)
- 3rd phase
  - To be decided

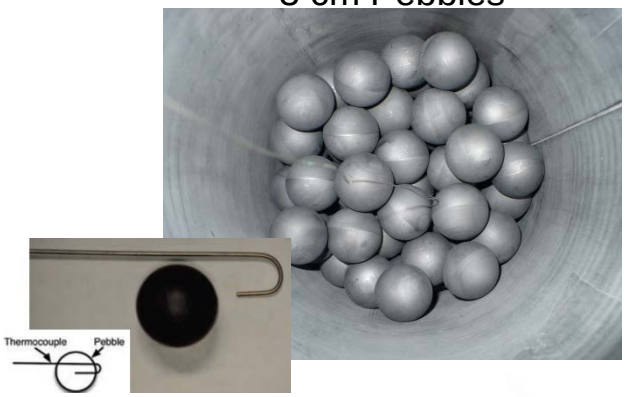
LSTL – Pebble bed testing

- Initial testing focused on pebble bed heat transfer
  - Important to predict peak pebble temperature during normal operation and transients

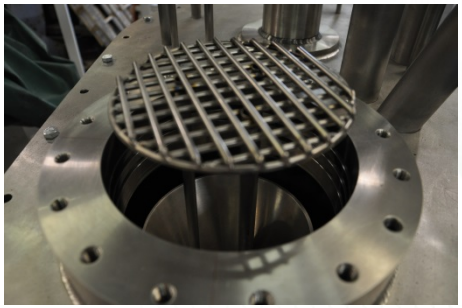
Power	≤ 200 kW total ≤1.28 kW/pebble
Fluid ΔT	≤ 20°C
Pebble Reynolds Number	≤ 2600
Pebbles	~500
Diameter	15 cm - Bed 3 cm - Pebble
Bed height	24 cm non-heated (top) 24 cm heated 24 cm non-heated (bottom)
Thermocouples	2 in pebbles 2 near pebbles 1 inlet 2 outlet

Top Screen

3 cm Pebbles



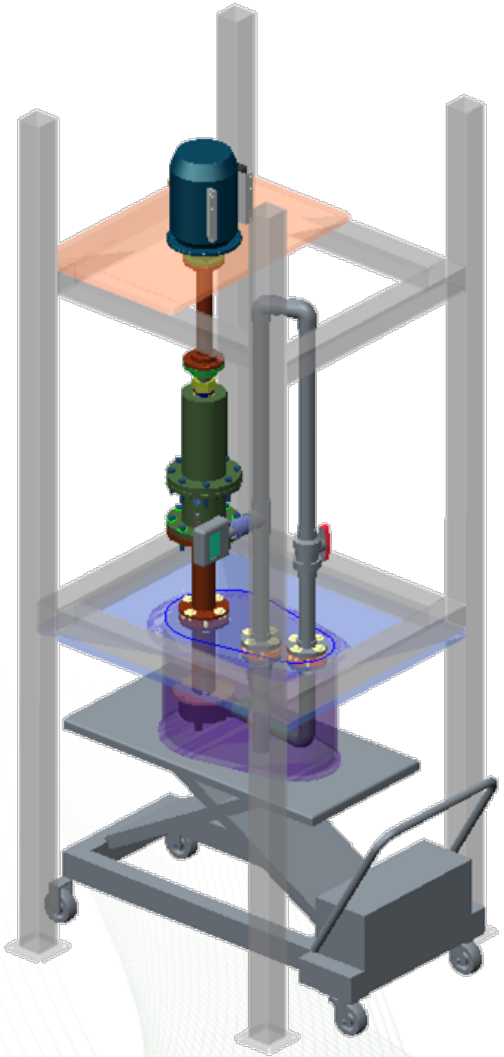
Bottom Screen



Large SiC Tube

Component Development & Testing Pumps

- Objectives:
  - Characterize the performance of the existing pump
  - Improve impeller & volute design and test for improvement
  - Develop selection & design guidance for salt pumps
- Status:
  - Using advanced simulation to aide impeller and volute design
  - Developing cold shakedown test stand
  - FY16 3Q, modify LSTL to develop pump curves
- Collaborative R&D with SINAP



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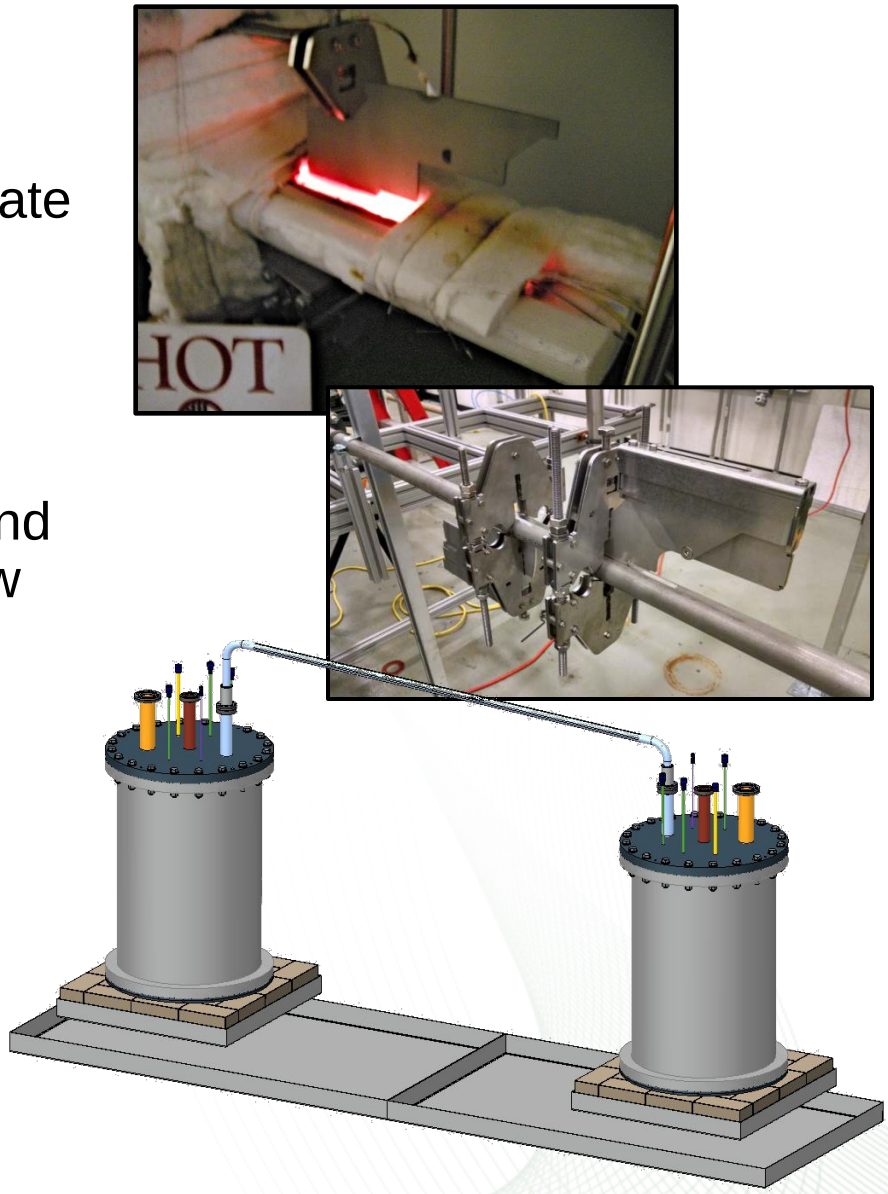
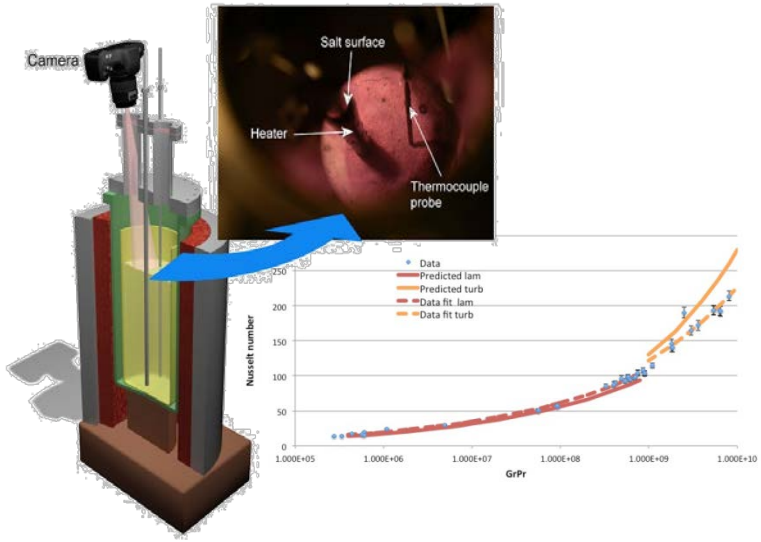
Component Development & Testing
Ultrasonic Flowmeter

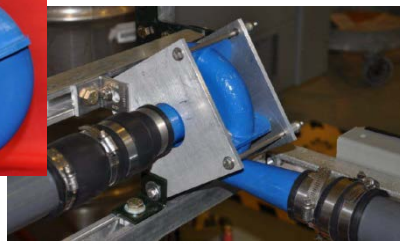
- Objectives:
  - Develop and test process to calibrate clamp-on ultrasonic flow meters
- Status:
  - Shakedown testing on water loop
  - Developed salt calibration test stand for well controlled & measured flow
  - Detailed uncertainty analysis
- Collaborative R&D with SINAP

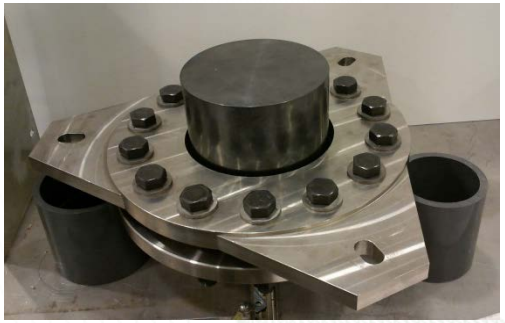


Component Development & Testing Additional

- Optical access, experimental techniques, natural circulation heat transfer[1]
  - Exploration of window access, Photography, IR Camera, and LDV
  - Natural circulation heat transfer data
- Fluidic diode[2]
  - A *'passive leaky check valve'*
  - Water testing and CFD modeling
- SiC-Metal Flange
  - Testing of flange, bolting, and gasket assembly procedure



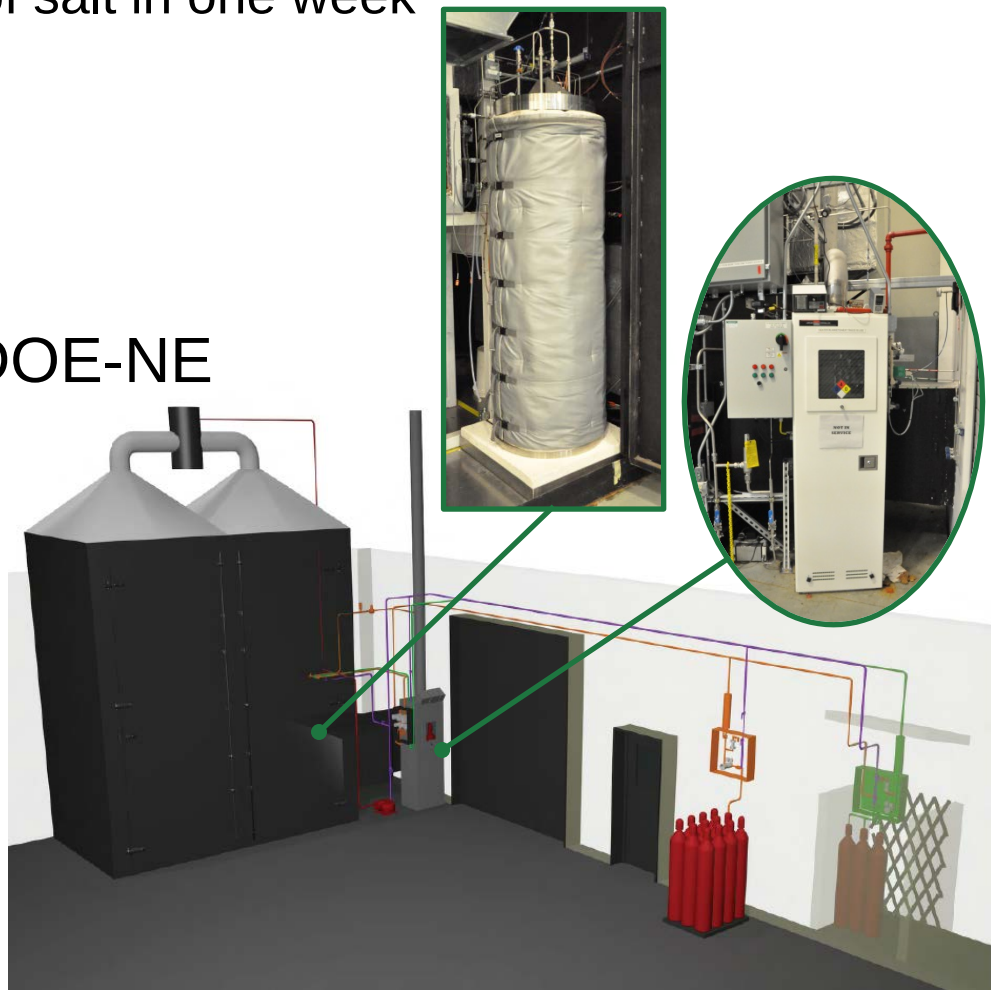




[1] G. L Yoder, et al., " Liquid Fluoride Salt Experiment Using a Small Natural Circulation Cell," ORNL/TM-2014/56, April 2014.
[2] G. L Yoder, et al., "Vortex Diode Analysis and Testing for Fluoride Salt-Cooled High-Temperature Reactors," ORNL/TM-2011/425, Sept. 2011.

Salt Cleanup Facility

- Removes trace impurities from salt
  - Enabling facility for salt studies
  - Batch process, cleans 150 kg of salt in one week
- Significant capability
  - Uses HF, H_2 and Ar
  - Large 2 m Nickel crucible
- Development supported by DOE-NE
- Currently developing smaller scale capability for Beryllium containing salts



Summary

- We need to address a variety of technology R&D and demonstration for reactor commercialization
  - Many common issues between FHR and MSR reactor classes
- The Liquid Salt Test Loop provides a versatile testing platform for a range of development needs
  - Planned testing includes shakedown, heat transfer, pump performance, and corrosion tests
  - Future tests could include:
    - Development: valve/seals, heat exchangers, etc.
    - Demonstration: advanced I&C, component endurance
    - Validation: tests for code benchmarks

Backup

LSTL – Instrumentation

Thermocouples	Numerous, (7 in bed)
Pressure	1 in salt 2 in gas spaces
Flow rate	Ultrasonic flow meter
Level	1 radar level in sump tank Heated thermocouple arrays 1x sump tank 1x surge tank