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Molten Salt Reactor PROGRAM

Salt Loop and Capability for Testing Sensors and Off-Gas Components FY23

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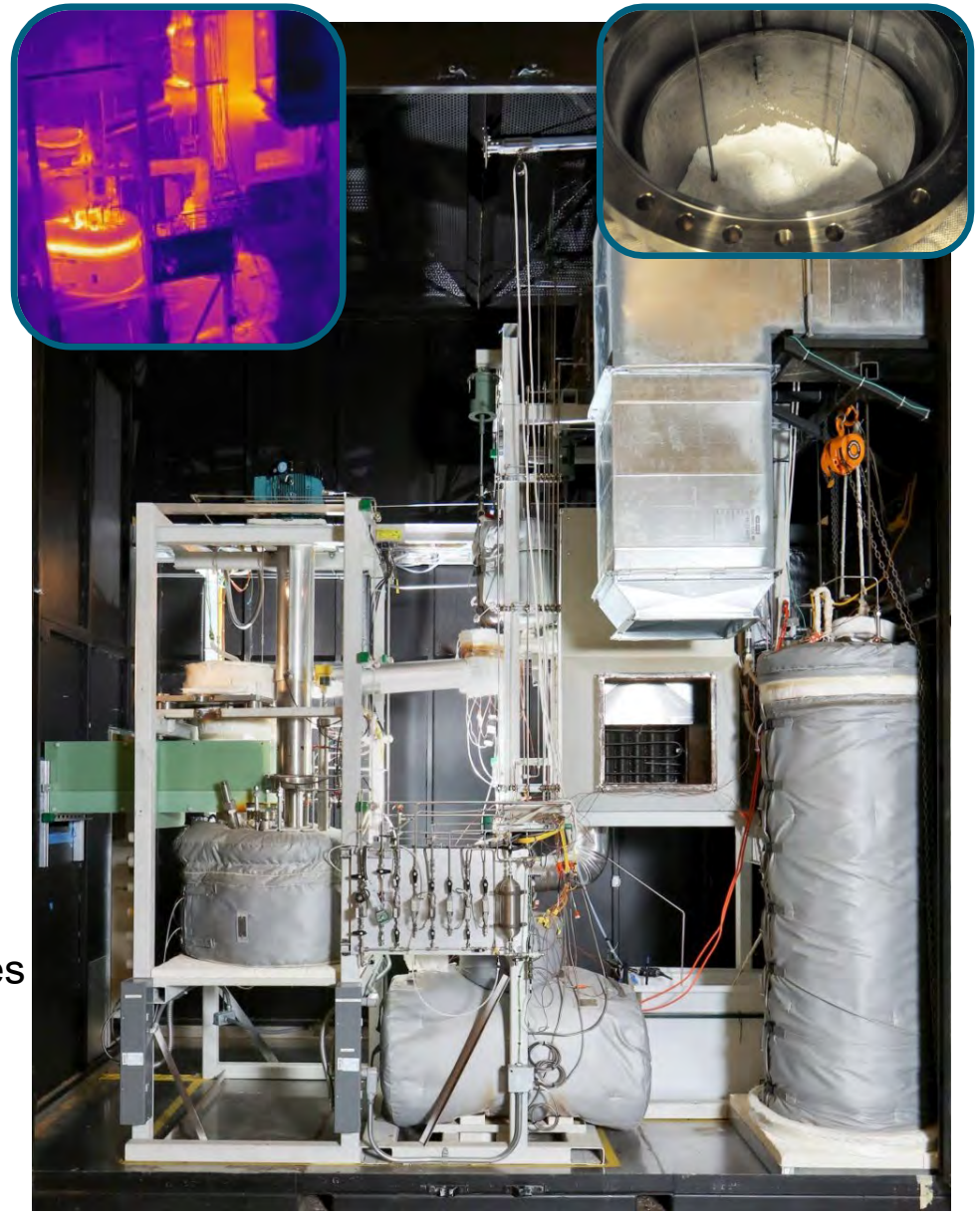
Annual MSR Campaign Review Meeting 2-4 May 2023

What is the Liquid Salt Test Loop? (LSTL)

Largest F salt loop in DOE

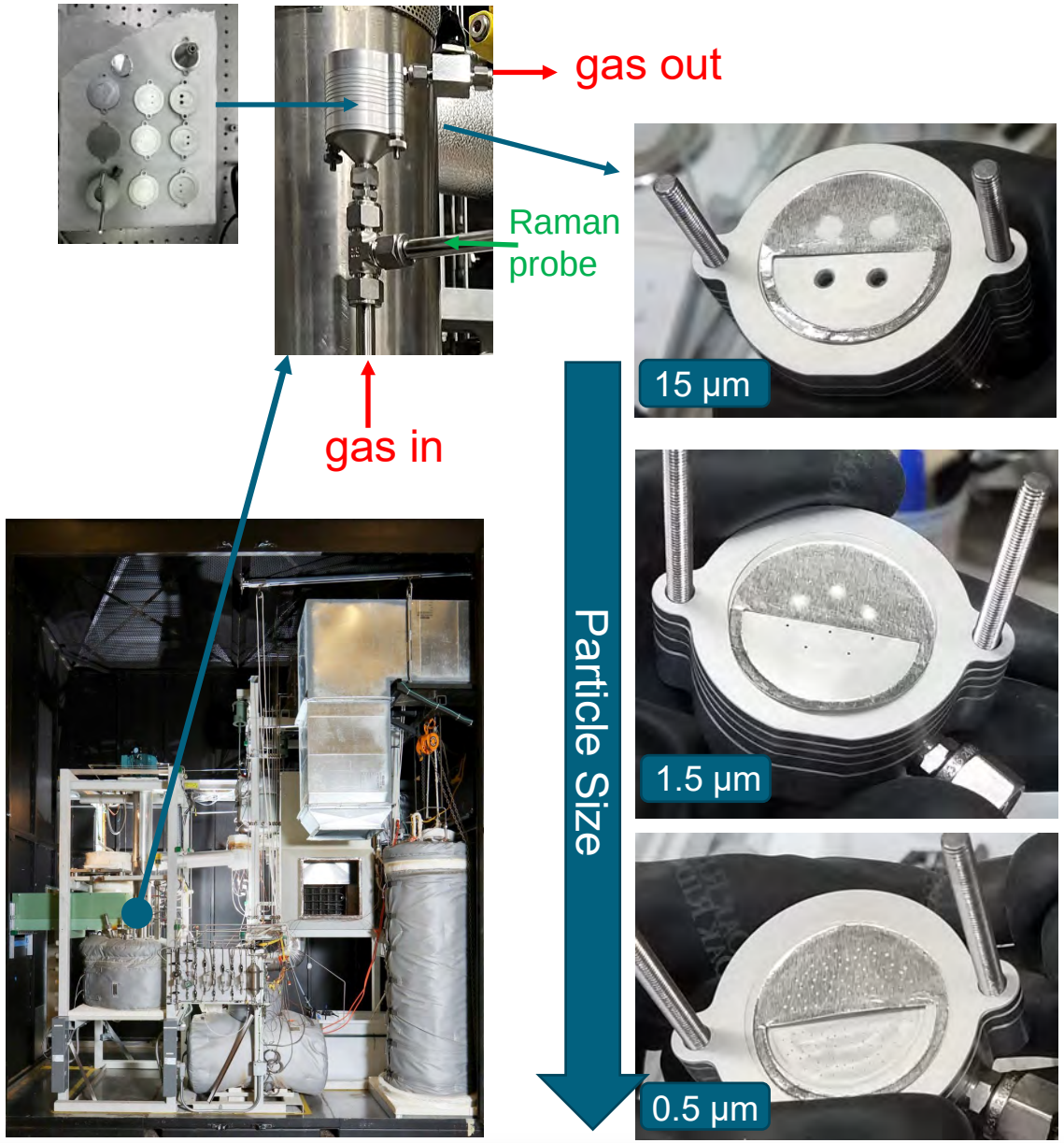
Salt	NaF-KF-LiF (FLiNaK)
Operating Temp.	700°C
Flow rate	≤4.5 kg/s (136 lpm)
Operating pressure	Near atmospheric
Primary Materials	Inconel 600
Loop volume	80 liters
Power	200 kW induction ~20 kW trace
Primary piping ID	2.67 cm (1.05 in.)
Initial operation	Summer 2016

- Integral environment for testing and demonstration of technologies
- Large batch (165 kg) purification system to prepare/refresh salt
- Appreciable power and I&C
- Was and still is state-of-the-art



LSTL FY23 progress

- **Restarted LSTL in Nov 2022 yielding initial experimental data on:**
  - PNNL Raman probe exposure (*separate pres.)*
  - ANL E-Chem sensors operation (*separate pres.)*
  - ORNL gas-space particle capture
  - New test section performance
    - 4 pump speeds, 4 hours, 600°C operation
- **Input into modelling:**
  - ORNL SAM model (*separate pres.)*
  - SNL MELCOR model (*separate pres.)*

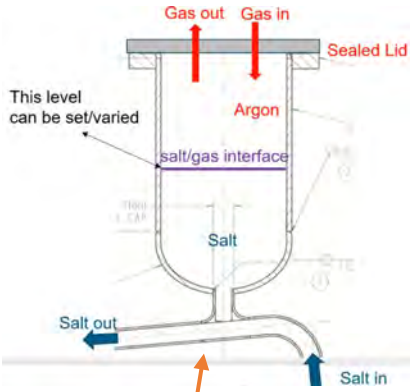


LSTL FY23 upcoming

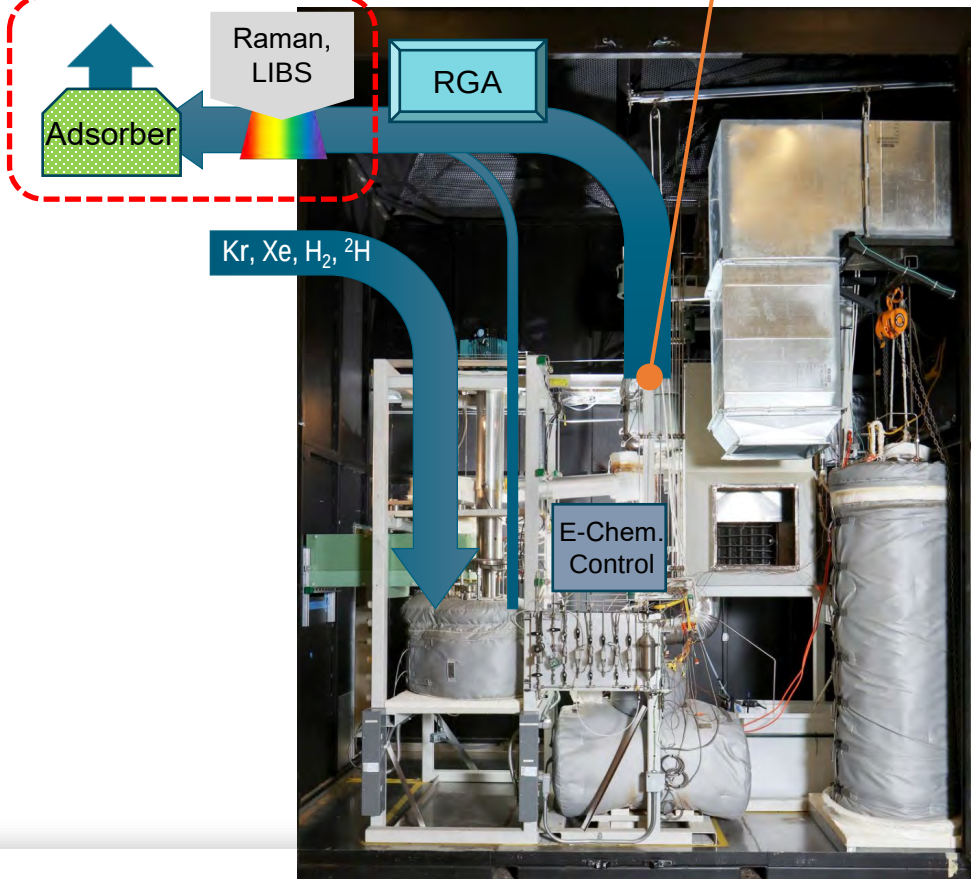
- **Planning 2nd test for FY23**
- **2nd round of testing for:**
  - PNNL Raman probe exposure
  - ANL E-Chem sensors operation
  - ORNL gas-space particle capture
  - Thermal hydraulic system performance
- **1st round of testing for:**
  - Species transport test
    - He, 4% H_2, and Kr injection
    - Monitoring of off-gas
  - NEUP Virginia Tech: flow meter
  - Small business: system PLC monitor

MSTDB-TC for test planning

Data output for specie transport code



future goal (separate presentation)



Milestone 9/2023: M3RD-23OR0602052: Molten Salt Loop Testing of Sensors and Off-Gas Components - FY23 progress

LSTL FY23 and beyond

- **Objectives for FY25 includes:**
  - De-risked sensor technology for industry adoption
  - Validation data sets for tools to support MSR analysis and optimization

FY	Objective
FY23	• Testing of optical and electrochemical sensors • Salt vapor and aerosol retention/transport • Noble gas species transport studies • Iodine, deuterium, cerium species studies • Expanded species transport studies, combined species effects • Test existing sensors from expanded collaborators (e.g. pressure, flow, corrosion, composition) • High-quality data for code validation, (e.g. SAM, MELCOR, TRACE) • Other piggyback tests – adv. materials/coatings, hardware, O&M methods
FY24	
FY25	

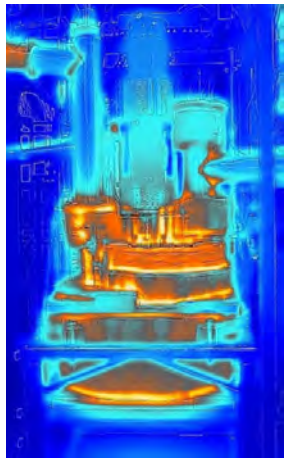
Facility to Alleviate Salt Technology Risks (FASTR)

Largest Cl salt loop in DOE

Salt	NaCl-KCl-$MgCl_2$
Operating Temp.	725°C
Flow rate	≤7.0 kg/s (228 lpm)
Operating pressure	Near atmospheric
Primary Materials	C-276 & Inconel 600
Loop volume	154 liters
Power	400 kW Main Heater ~71 kW trace
Primary piping ID	5.20 cm (2.05 in.)
Initial operation	December 2022

Compared to LSTL, FASTR is:

- 2x higher capacity pump
- 2x larger salt volume
- 2x larger pipe
- 2x thermocouples
- 2x main heating capacity
- 3x trace heating capacity
- 4x number of salt flanges



Development support by DOE-EERE SETO CPS 33875

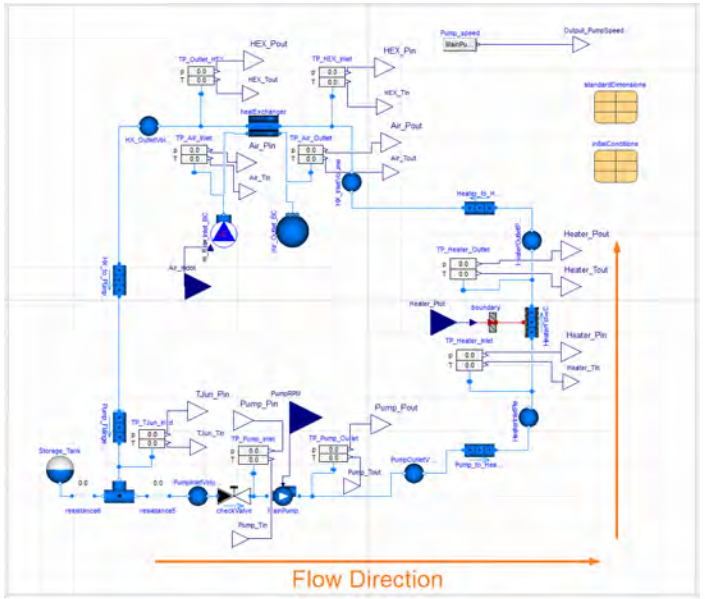
Robb, Kevin, and Kappes, Ethan. *Facility to Alleviate Salt Technology Risks (FASTR): Commissioning Update*. United States: **ORNL/TM-2023/2846**, 2023. Web. doi:10.2172/1960689.
Robb, Kevin, Kappes, Ethan, and Mulligan, Padhraic L. *Facility to Alleviate Salt Technology Risks (FASTR): Design Report*. United States: **ORNL/TM-2022/2803**, 2022. Web. doi:10.2172/1906574.

FASTR Example Synergy
DOE-NE Integrated Energy Systems

Physical Loop generating experimental data

System-level Representation

- Dymola IDE
- 1-D representation of components
- Avg. compute time on the order of seconds.
- Model validation currently underway.



Digital Twin (DT) for autonomous control

- DT of the Modelica model/ROM (using pyDMD) for faster runtime and calibrated to experimental data – currently underway.
- Connected to the DAQ system to inform operator on potential deviation from normal operation.
- Currently setup to only read the tags from the LogixDriver and run an FMU of the Dymola Model.

```
"""
Created on April 17, 2023

@author: Vineet Kumar

This script interfaces with the Allen Bradley and sends values to an FMU
"""
from pycomm3 import LogixDriver, CIPDriver
from runFMU import run_fmu

def find_attributes():
    values = []
    with LogixDriver('192.168.0.6/1') as plc:
        print(plc)
        tags = ['F_02_Ref','P_01_Ref','TC_MH_01']
        plc.read(*tags)
        for typ in plc.data_types:
            values.append(plc.data_types[typ]['value'])
    return values

values = find_attributes()
output = run_fmu(values)
print(output)
```

Studio 5000 Logix designer via Pycomm3

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Salt Flow Calibration and Bearing Test Stand

- Demonstrate salt-wetted bearings to enable long-shaft pumps for pool-type reactors and larger sized pumps
- Flow calibration stand for development of standards and to calibrate flowmeters for accurate and defensible data
- Funded external to DOE-NE
  - Unique circumstances in both projects led to insufficient support continuity to complete, to date

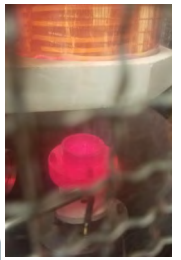
Candidate Selection
18 Materials

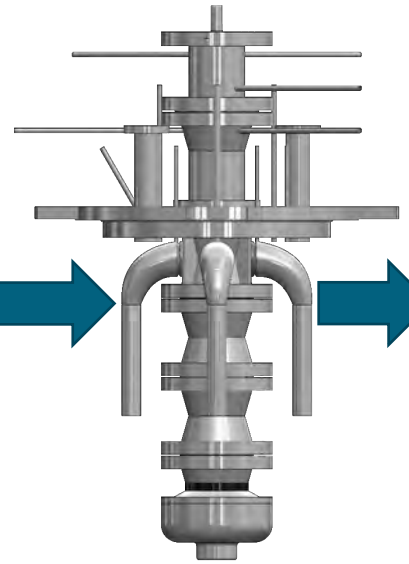
Corrosion Test
Static Capsules
10 Materials

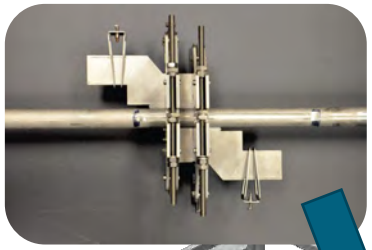
Tribology Bench Test
5 Materials, 7 Pairs

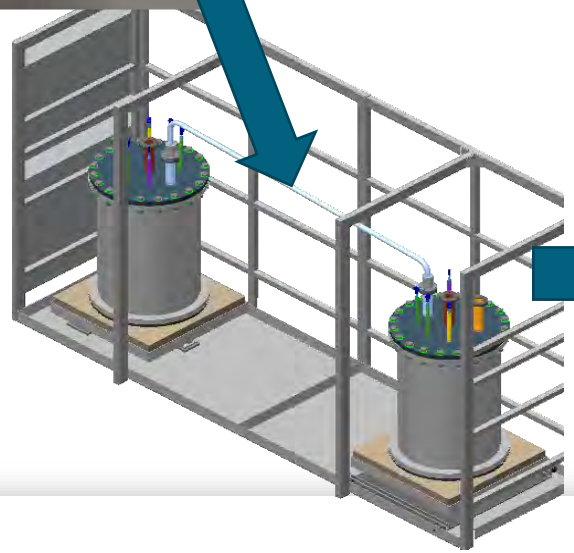
Tribology Test with
Particulate Added
2 Material Pairs

Full-Scale Bearing Test
1 Material Pair









Roles of this type of effort

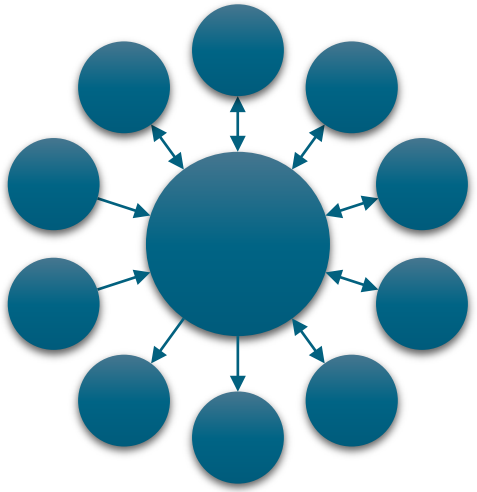
Forms a hub for technology:

- Advancement & demonstration
- Collaboration & communication
- Independent verification
- 1st mover risk/cost absorption
  - Supply chain motivator

University
- Coupon exposure (GT NEUP)
- Flow meter test (VT NEUP)
- Lesson learned communication
- Education experience (interns)

Small business
- Sensor demo. (SETO)
- System monitor demo. (LEEP)

Laboratory
- ANL e-chem sensor
- PNNL Raman sensor
- ANL/ORNL SAM V&V
- SNL MELCOR V&V
- INL/ORNL digital twin (IES)
- Gas space particle transport
- Specie transport plans
  - Off-gas monitoring
- Topical component studies
  - Pump
  - Valve
  - Heater
  - Heat exchanger
  - Flanges
  - I&C
- MOSARD (reliability database)
- Property databases (usage)
- etc…



Thank you

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