Molten Salt Reactor PROGRAM

Salt Loop and Capability for Testing Sensors and Off Gas Components

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MSR Campaign Annual Review, April 22-24, 2025, PNNL

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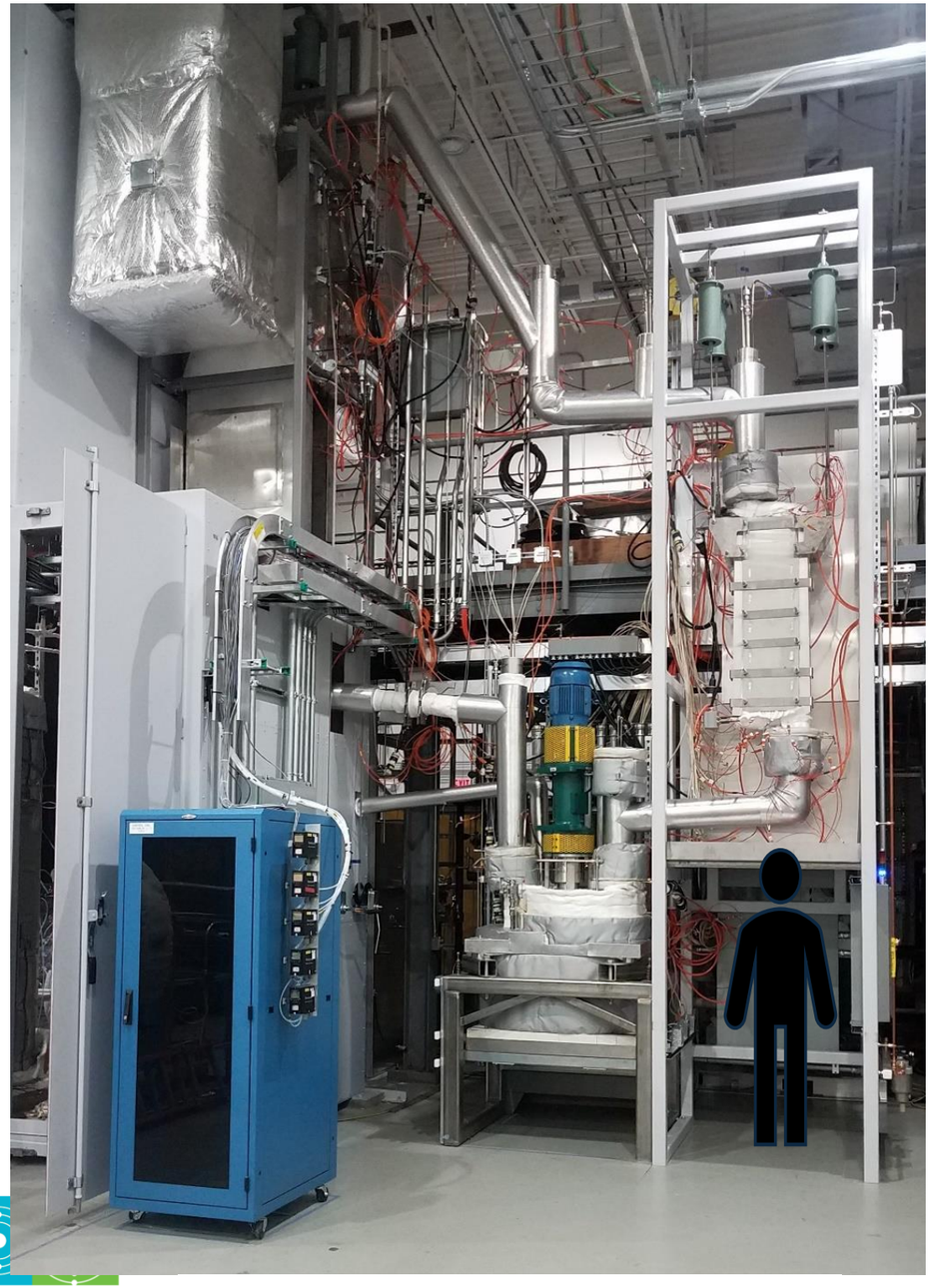
FY25 PICS milestones (upcoming M3)

Milestone Number	Description	Status as of 03-31-2025 (end of Q2)
M3AT-25OR0702021	Complete molten salt loop collaborative test campaign with novel sensors	Due 9-30-2025

Facility to Alleviate Salt Technology Risks (FASTR)

- High-temperature forced-flow **chloride** salt test facility
  - Largest chloride salt loop for open R&D to have operated (in open literature)
- Current goals:
  - Novel sensor tests (flow, pressure, and EChem)
  - Demonstration of chemistry and corrosion control
  - Demonstrate and de-risk components
  - Digital twin development and integration

Purification Vessel



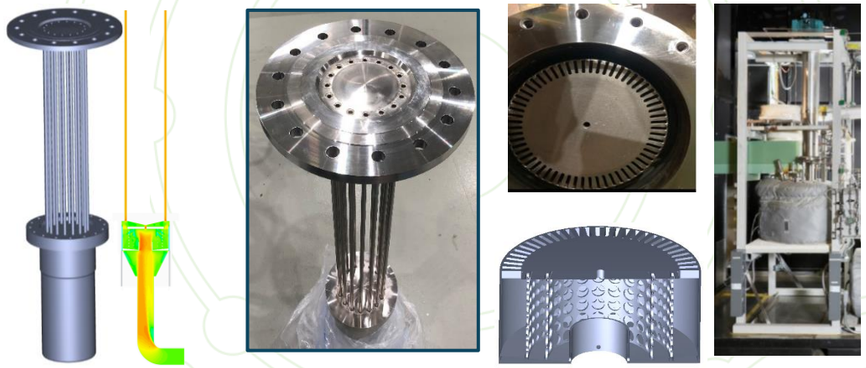
FASTR Forced-Circulation Loop

Salt	**$NaCl\text{-}KCl\text{-}MgCl_2$**
Operating Temp.	**725°C**
Flow rate	**≤7.0 kg/s**
Primary Material	**C-276**
Salt volume	**155 L**
Power	**400 kW**
Primary piping ID	**5.20 cm**
Initial operation	**Dec. 2022**

What are we trying to do?

1. **Re-establish foundational US infrastructure** (*facilities and personnel expertise)* to enable innovation and advance technologies for MSR applications
   - The facilities are the largest and most capable within DOE complex
   - Prepare the next generation workforce with hands-on experience on engineering-scale salt facilities.
   - Spur the supply chain and act as first mover on first-of-a-kind needs
2. **Accelerate MSR deployment** by bridging the gap between research and commercial deployment
   - De-risk sensors to monitor species transport and salt chemistry in situ.
   - Conduct component testing in prototypic environments, *beyond bench scale*, to understand practical operations and to optimize reliability, risks, and costs
   - Open to universities, laboratories, and component developers that don't have similar capability
3. **Enhance confidence in salt community** (MSR developers, regulators, component developers, and other invested entities)
   - Serve as an open test facility and trusted 3rd party with published results
   - Establish knowledgebase for code validation, component/system performance, and demonstrated successes

Reminder of Recent Journey



FY22

LSTL modification and preparation

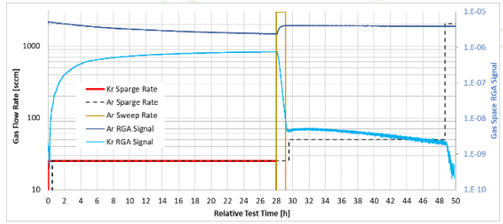
- Installed new test section, filter, and piping
- CFD analysis investigating flow field and forces
- Installed Raman probe (PNNL) and E-Chem sensor (ANL)

FY23

First operation of FASTR (ORNL/TM-2023/2846)

Operation of LSTL (ORNL/LTR-2023/3087)

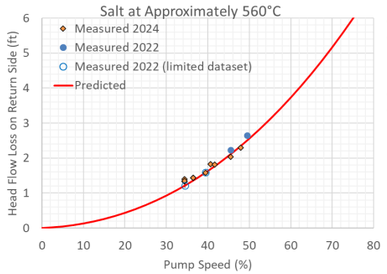
- Initial 4 aerosol tests
- Test flowmeter for VT (*NEUP*)
- Initial Kr injection/measure test
- Modeling info for SAM (ORNL) and MELCOR (SNL)
- Raman probe exposure (PNNL) and E-Chem sensor test (ANL)



FY24

Operation of FASTR (ORNL/LTR-2024/3671)

- 11 aerosol tests
- Ran 7 pump speeds
- Initial pump vibration data
- E-Chem sensor (ANL) run
- Raman probe (PNNL) exposed ~558h @ >500 C
- Test pressure and flow sensors (*SBIR*)



FY25

Operation of FASTR

- See later slides!

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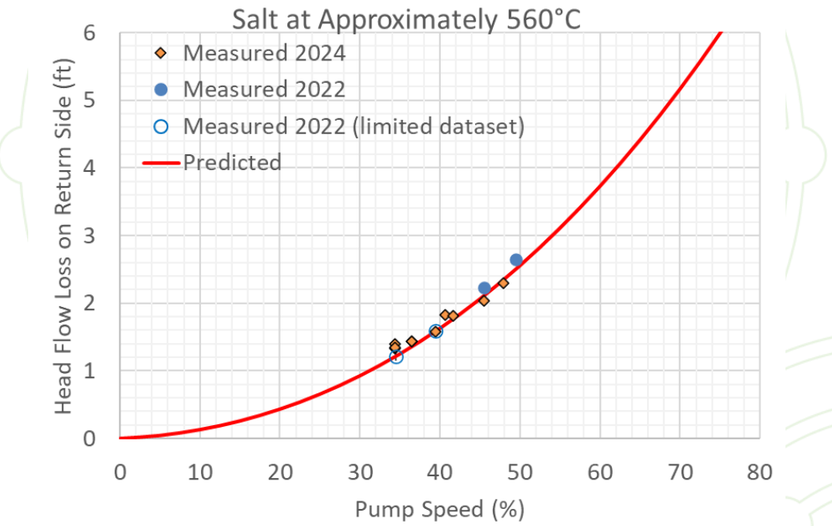
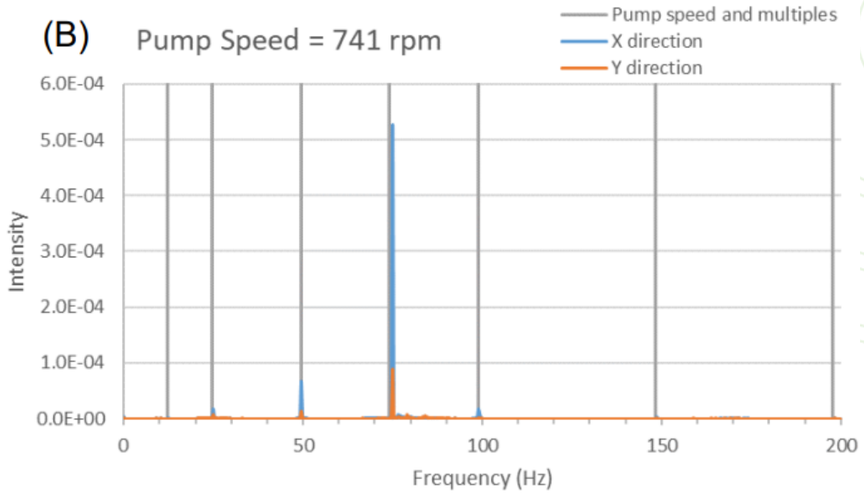
FASTR Progress FY24
(~after previous campaign review)

- Several maintenance activities were completed
- Conducted **eleven** aerosol tests
- Add accelerometers, ran 7 pump speeds, and collected first pump vibration data
- PNNL Raman probe exposed ~558h @ >500 C
- ANL sensor run, salt appears similar to last time it was run
- SBIR sensor tests of a pressure and flow sensor
- Collaborated with Sandia National Laboratories (SNL) and ORNL colleagues to develop computational models of the LSTL and FASTR systems.





ORNL/LTR-2024/3671

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FASTR Plans & Progress FY25

- Plans:
  - Install and test PNNL Raman probe and ORNL LIBS system
  - Operate ANL multifunctional voltammetry sensors
  - Aerosol characterization tests – try taking pump bowl measurement(s)
  - Add pressure transducer near pump outlet
  - Gain operation experience and time
  - Kr injection test (if resources allow)
  - Effort to test flow meter (if resources allow)
- Progress:
  - Installed 2x tachometer on pump to monitor shaft and seal speed (concern over potential seal slippage and/or other pump challenges)
  - Discussed plans with PNNL (Raman) and ORNL (LIBS) to test their sensors during next operation
  - Received gas mass flow controllers to replace temporary spares used last FY
  - Acquired flange and working to install salt-wetted pressure transducer
    - Enable pump discharge pressure measurement → hydraulic data → more useful dataset for modelers

FASTR Plans FY25

Category	FY24	FY25
Sensors	Expose PNNL Raman probe	Operate PNNL Raman system on off-gas
Sensors	Operate ANL multifunctional voltammetry sensor	Operate ANL multifunctional voltammetry sensor, extended duration
Sensors	*1st round testing for small business (P and Flow) EERE SBIR*	2nd round testing of sensors from small business (*P and Flow*)
Performance	7 pump speeds, initial vibration data	4+ pump speeds
Performance	Run time	Run time
Data		↑ obtain pump discharge pressure data
Data		↑ system hydraulic data
Aerosol Data	11 storage tank tests	≥1 pump tank tests
Species Transport Data		*Kr injection if resources allows*

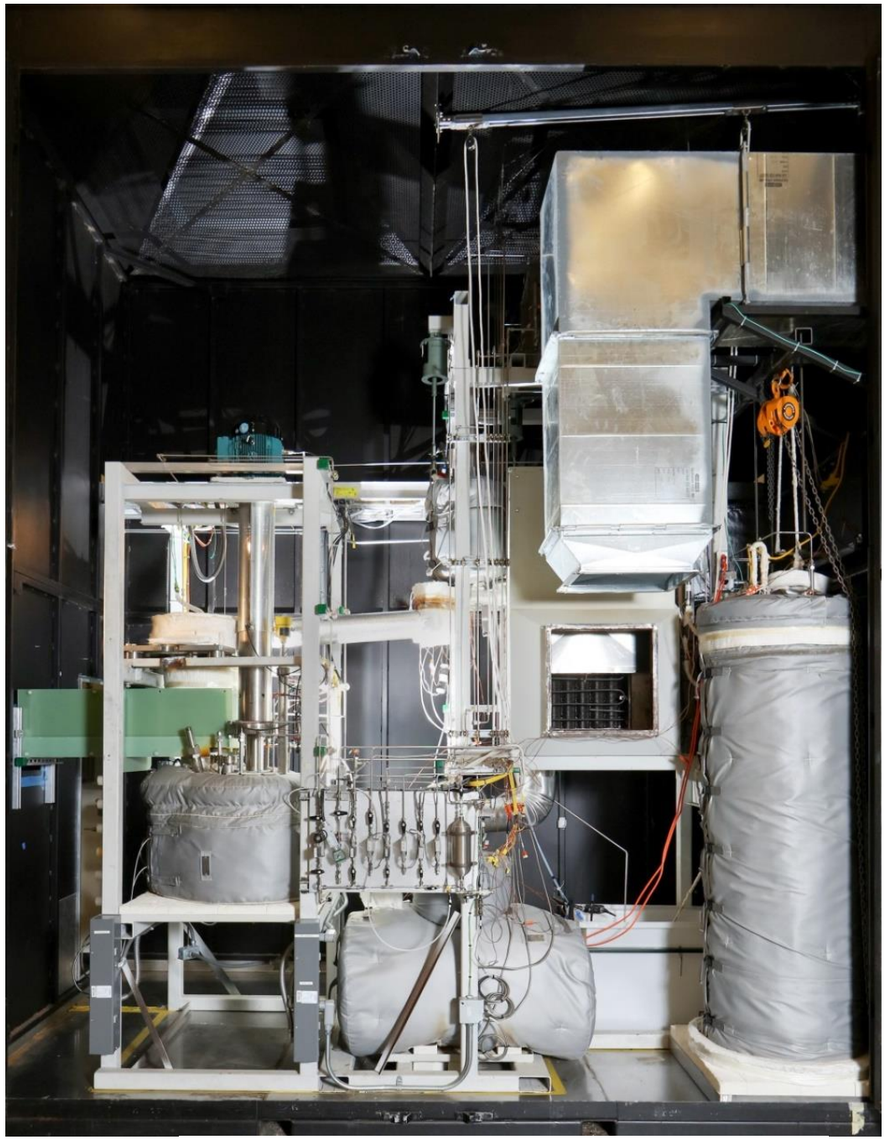
FASTR Future

- Similar to LSTL vision: Focus on species transport and sensor exposure/testing
  - Species injection, start with noble gases and work toward more interesting chemistry
  - Expose/test sensors (Raman, electrochemical, LIBS, traditional P, T, $\dot{m}$)
  - Demonstration corrosion control
- Continue aerosol characterization (Important for practical operations & mitigation measures)
- Add/increase focus on verifying flow measurement
  - Broad stakeholder need defensible flow rates
- Provide info for modeling: SAM (ORNL, ANL), MELCOR (SNL), others?
- Increase run time and socialize operation experience
- Run ΔT tests with high-powered heater/heat exchanger for more-prototypic condition testing

Liquid Salt Test Loop (LSTL)

- Versatile high-temperature forced-flow **fluoride** salt test facility
  - One of very few salt loops in the U.S., with salt re-purification capability, with relevant power and flow
  - FLiNaK provides relevant salt environment for RD&D

Salt	**NaF-KF-LiF**
Operating Temp.	**700°C**
Flow rate	**≤4.5 kg/s**
Primary Material	**Inconel 600**
Salt volume	**80 L**
Power	**200 kW**
Primary piping ID	**2.67 cm**
Initial operation	**Summer 2016**



LSTL Forced-Circulation Loop

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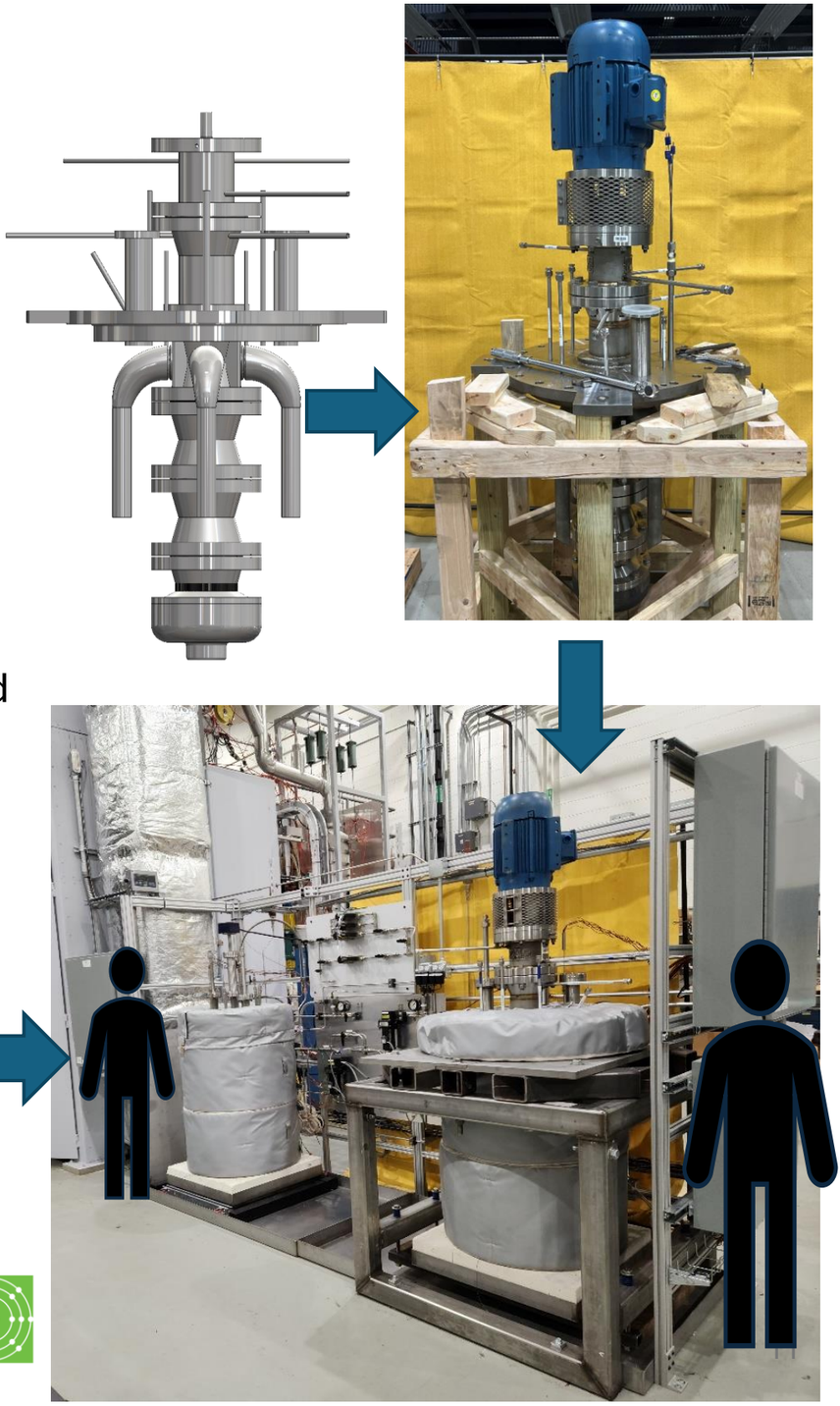
Salt Pot Instrumentation and Components Evaluation Experiment (SPICEE)

Salt	Cl or F-based
Operating temp.	710°C @ 0.3 MPa_{abs}
Flow rate	≤5.8 kg/s
Operating pressure	Up to 0.3 MPa_{abs}
Primary materials	SS & Ni
Salt volume	120 liters
Power	~27 kW trace
Primary piping ID	~2.50 cm (1 in.)
Initial operation	TBD!

- Demonstrate salt-wetted bearings to enable long-shaft pumps for pool-type reactors and larger sized pump
- Flow calibration stand for development of standards and to calibrate flowmeters for accurate and defensible data



DOE-NE MSR Campaign Support enables communication on lessons learned and safety

1. Participated in the IAEA led **Consultancy Meeting on the Development of a Technical Document on the Safety of Molten Salt Reactors (MSRs)**
2. Participated in a University's **component failure review**
3. Presented/Organized: **Chair's Panel: Experimental Practices** at MSR Workshop 2024
4. Finalized paper: "**Some Hazards and Mitigation Considerations for Molten Halide Salt Experiments**" for 2025 ANS Annual Conference
5. Attended Beryllium Health and Safety Committee's **FLiBe Subcommittee** online meetings

- *Outside MSR Campaign:*
  - *Presented at MIT IRP Led: Lessons Learned Workshop II: Design, Testing and Operation of Molten Salt Loops and Capsules*
  - *Contributed to summary: "Lessons Learned In How to Conduct Loop and Irradiated Salt Experiments: Workshop II" for 2025 ANS Annual Conference*

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Thank you

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