Molten Salt Reactor PROGRAM

Argonne NATIONAL LABORATORY

Salt Accident Analysis Facility Development Activities

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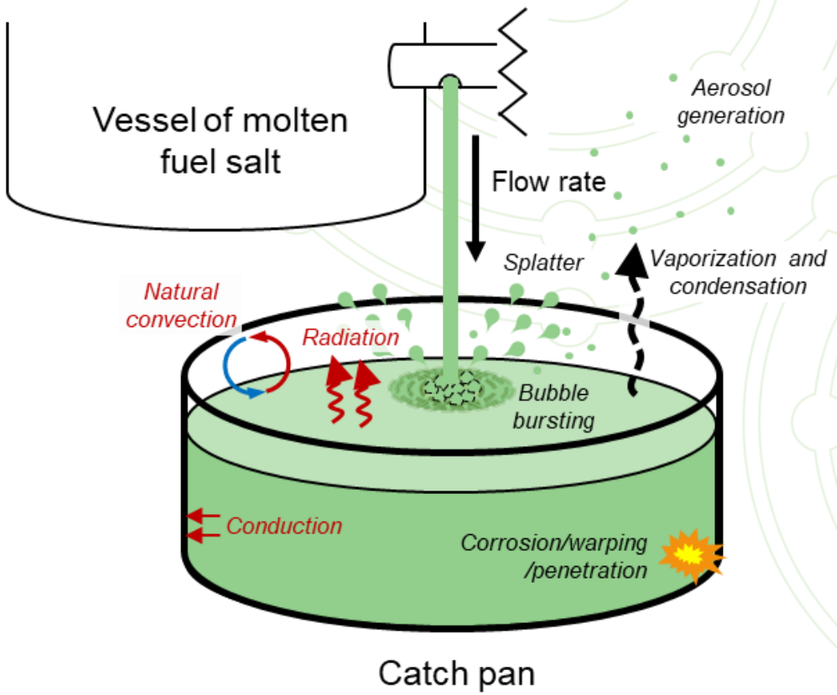
Advanced reactor licensing and accident analysis

- U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide 1.233 provides a modernized licensing framework for advanced reactors
  - Identify and evaluate the consequences of postulated accidents
  - Use validated models to predict accident progression and the mechanistic source term for expected radiological release
- All MSR developers will likely evaluate an unintended release of fuel salt
- Experimental data on the key processes that influence the safety-affecting outcomes of fuel salt release accidents are limited



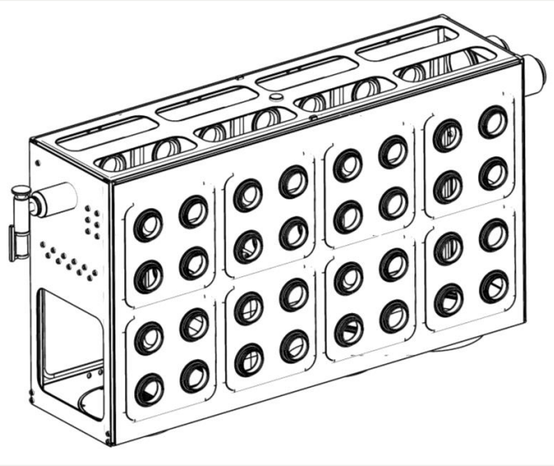
OBJECTIVE

Generate experimental data that quantify the consequences of fuel salt release accidents to support the development and validation of MSR accident analysis models

Need for engineering-scale MSR accident simulation and analysis capability

- Accident analysis models must be validated using experimental data generated at relevant scales
- Some safety-affecting behaviors associated with fuel salt release accidents may only manifest at large scales

Engineering-scale test facility design criteria



- Optimal scale
  - Large enough to represent key behaviors
  - Small enough to fit in existing glovebox facilities (minimize cost) and to minimize waste generation
- Versatile
  - Able to test a range of accident scenarios
  - Compatible with chloride and fluoride salts
- Real-time measurement of processes

Approach to developing engineering-scale testing capability

Development stage (laboratory-scale)

Phase 1

Conduct individual process tests
- Develop methods to simulate processes
- Develop measurement techniques
- Fill data gaps in process models

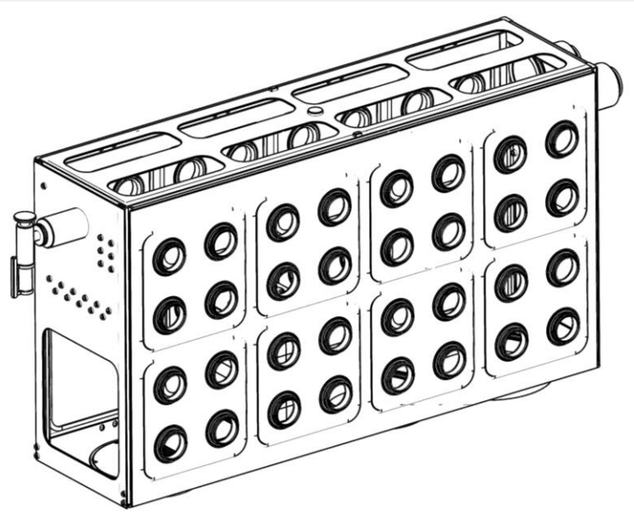
Phase 2

Conduct integrated process tests
- Gain experience with surrogate fuel salt and measuring processes simultaneously
- Fill data gaps in process models

Phase 3

Design and construct engineering-scale test system

Engineering-scale testing



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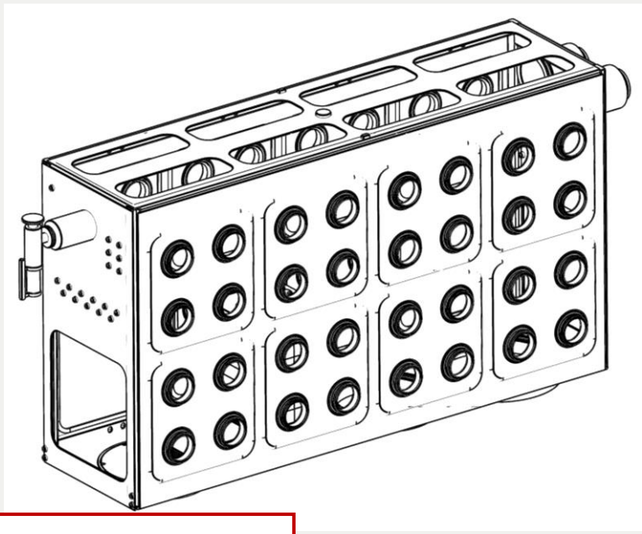
Engineering-scale testing



Initiated during FY25 with completion of preliminary design of Salt Accident Analysis Facility

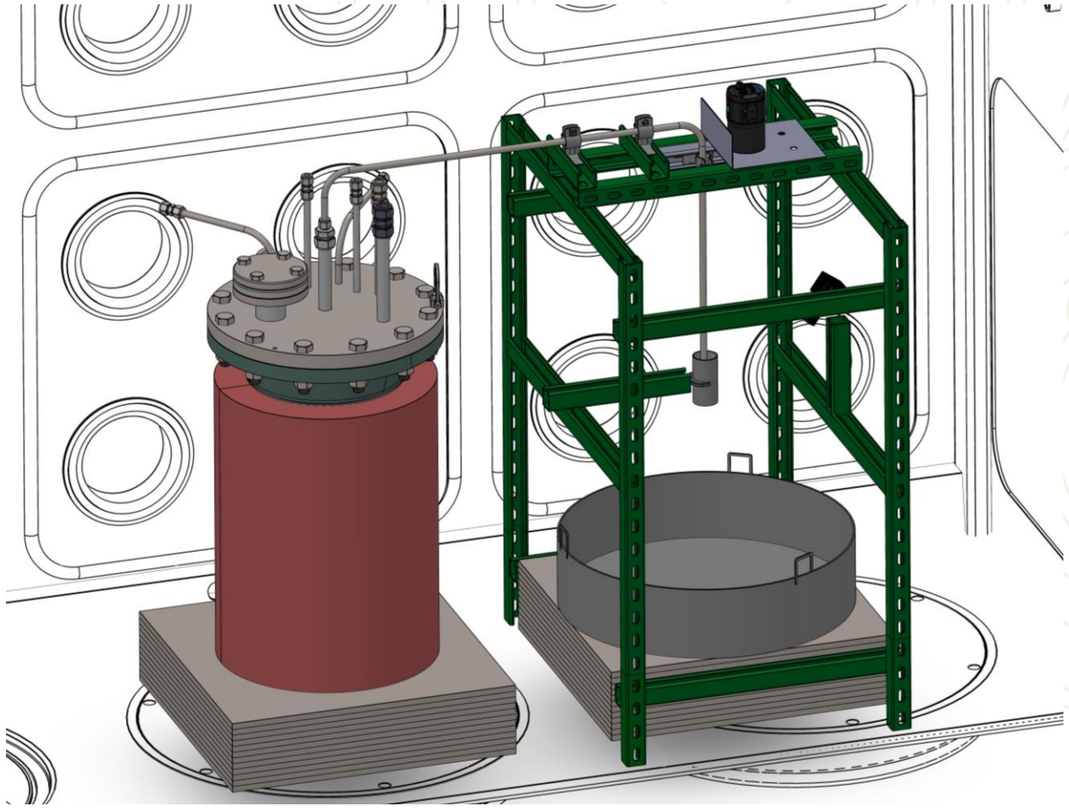
Thomas, Sara (2025) "Preliminary Design of Engineering-Scale Salt Accident Analysis Facility to Support Molten Salt Reactor Licensing." Argonne National Laboratory Report ANL/CFCT-25/1.

Overview of facility

- The Salt Accident Analysis Facility (SAAF, pronounced “safe”) is an engineering-scale experimental test system for simulating molten salt release accidents
- Located within an argon atmosphere glovebox
- Consists of two subsystems:

Molten salt transfer system	Salt containment system
• Consists of vessel, heaters, and molten salt transfer line • Heats salt to desired temperature • Transfers molten salt through tubing by pressurizing vessel headspace	• Adaptable • Stakeholders and target accident scenario dictate design, e.g.: – Catch pan open to glovebox atmosphere – Closed vessel isolated from glovebox atmosphere

SAAF configuration with **open catch pan**
(components are shown uninsulated)



Molten salt transfer system | Salt containment system

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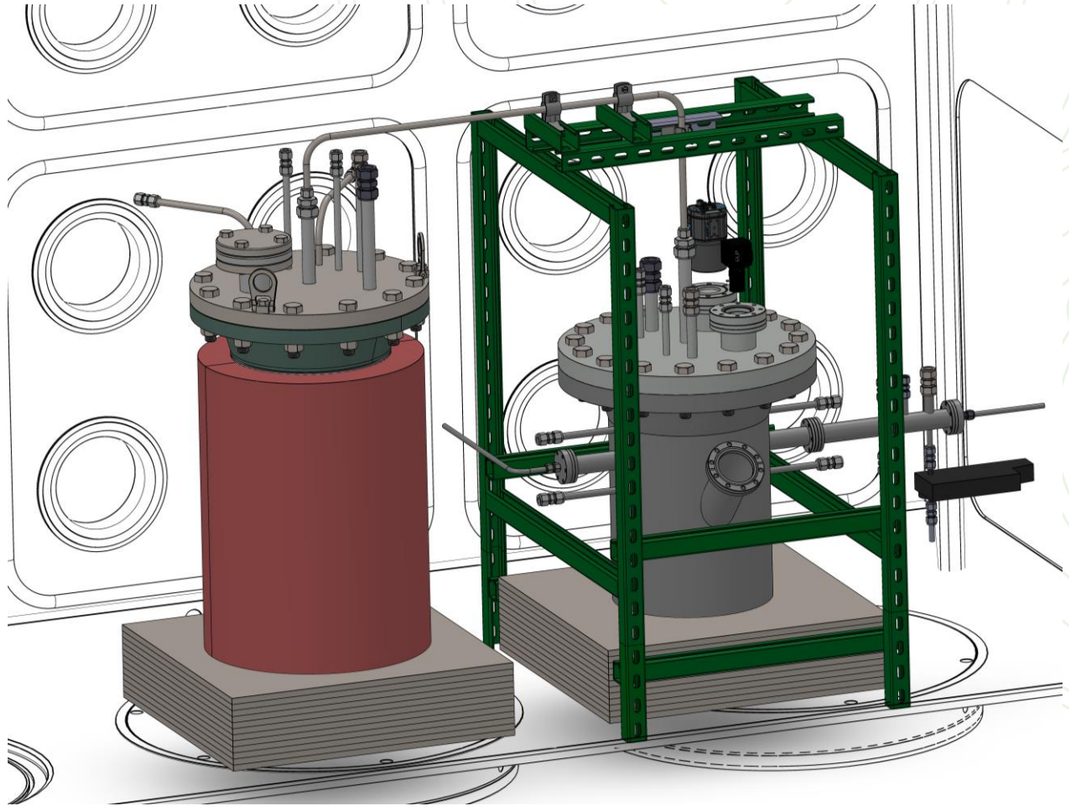
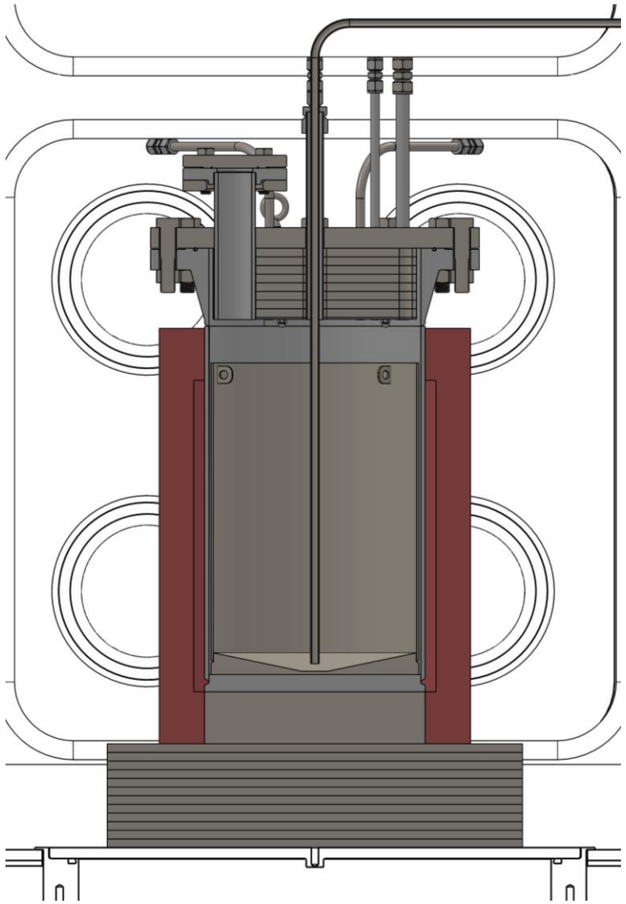
SAAF configuration with **closed containment vessel**
(components are shown uninsulated)



Molten salt transfer system | Salt containment system

Molten Salt Transfer System

Section view
(components are shown uninsulated)



- Design finalized in March 2025
- Velocity and flow rate at transfer line outlet determined by:
  - Initial headspace pressure
  - Initial salt level in vessel
  - Transfer tube inner diameter
  - Vertical position of transfer line outlet

DESIGN SPECIFICATIONS

ASME-stamped pressure vessel

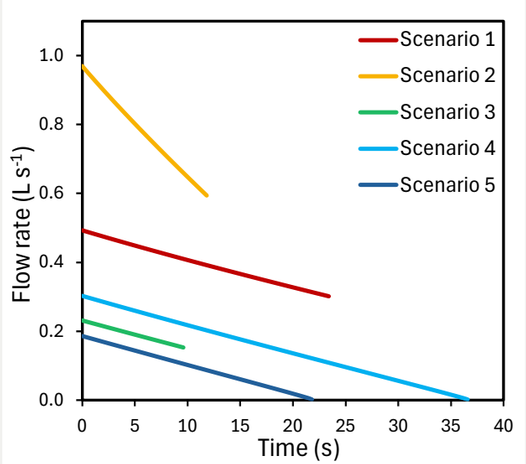
Material: 316H stainless steel

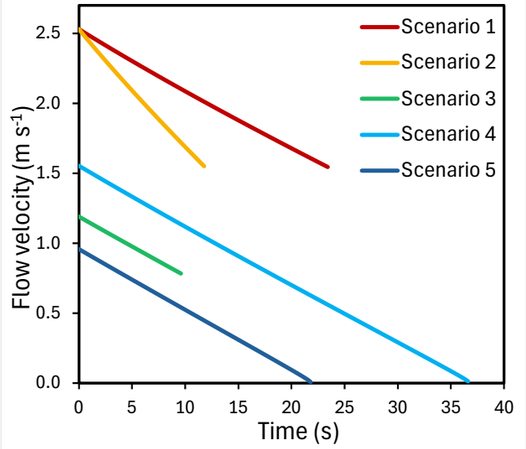
Salt volume capacity: 15 L

Maximum operating temp.: 800 °C

Nickel 201 liner

A variety of flow conditions can be achieved

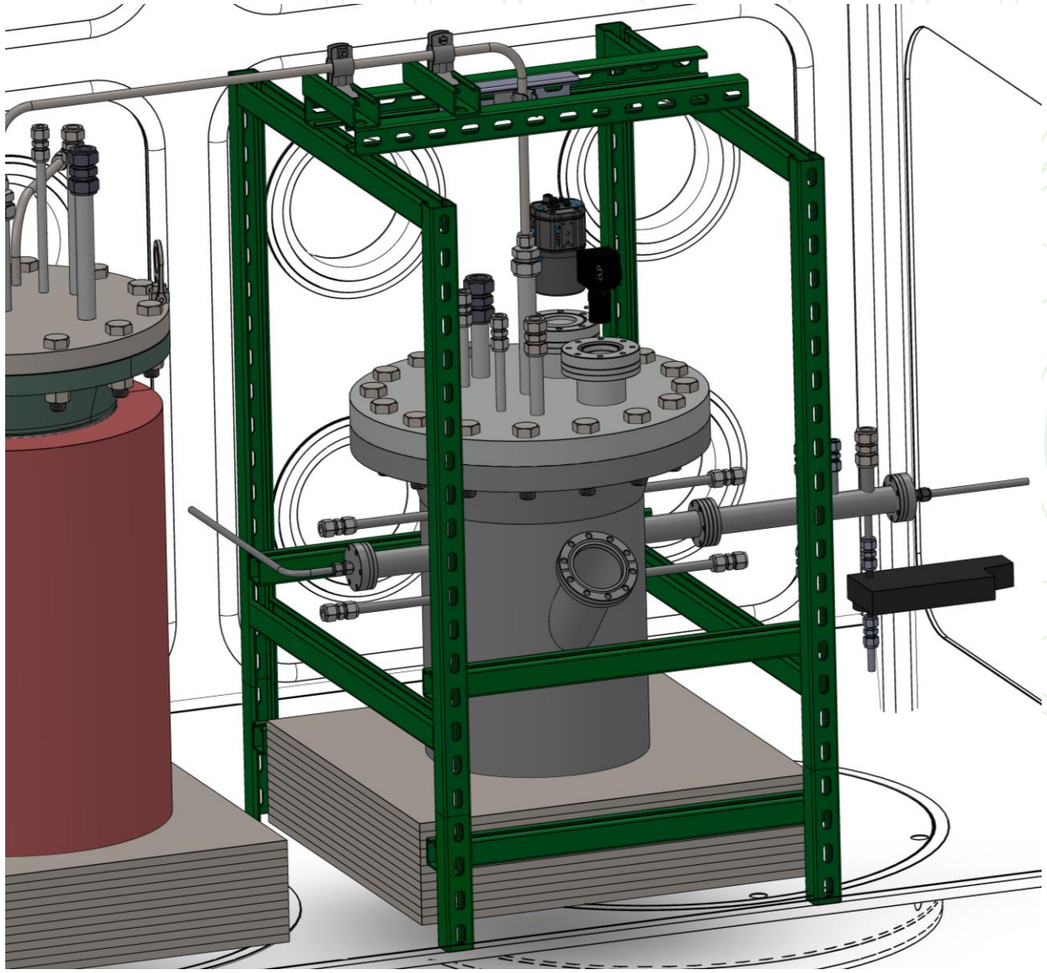




Test variables

- Salt composition
  - Chloride and fluoride salts bearing actinides and surrogate fission products
- Composition of atmosphere
  - Inert atmosphere
  - Air atmosphere (isolated from glovebox atmosphere)
- Salt release conditions, e.g.,
  - Rapid release of large salt volume
  - Slow release of salt (i.e., drips)
  - Salt release as a spray through a small orifice
- Containment configuration and materials, e.g.,
  - Size, geometry, and material of catch pan
  - Type, thickness, and location of insulation
- Additional variables can be considered, e.g.,
  - Entrained gas bubbles in salt prior to release
  - Salt leaking through insulation

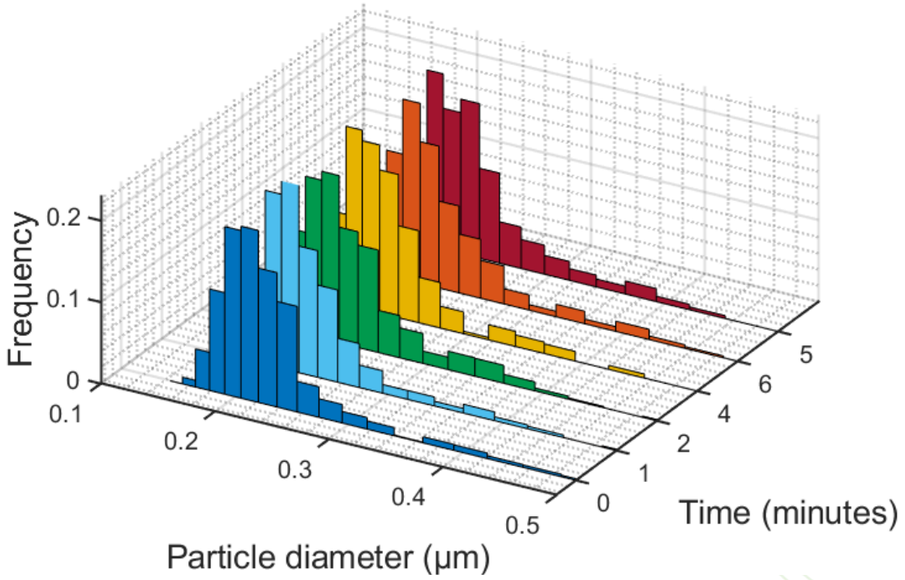
Salt containment system isolated from glovebox atmosphere
(components are shown uninsulated)



Measurement capabilities

- Leading edge and area measurements to quantify molten salt spreading by using an infrared camera
- Temperature measurements to quantify heat transfer
  - Thermocouples for structural material surfaces and atmosphere
  - Infrared camera for salt surface
- Size distribution and composition of salt splatter collected on coupons
  - Optical image processing for size distribution
  - SEM-EDS for composition of individual particles
- Elemental composition and distribution in bulk salt from samples collected after testing
  - ICP-MS for elemental composition
  - SEM-EDS for elemental distribution in prepared sections
- Real-time salt aerosol measurements
  - Optical light scattering for real-time salt aerosol size distribution and concentration (being developed at Argonne)
  - LIBS for real-time salt aerosol composition (being developed at ORNL)
- Real-time composition of gas headspace

Example of real-time salt aerosol size distribution measurements



Developed | Under development | Requires development

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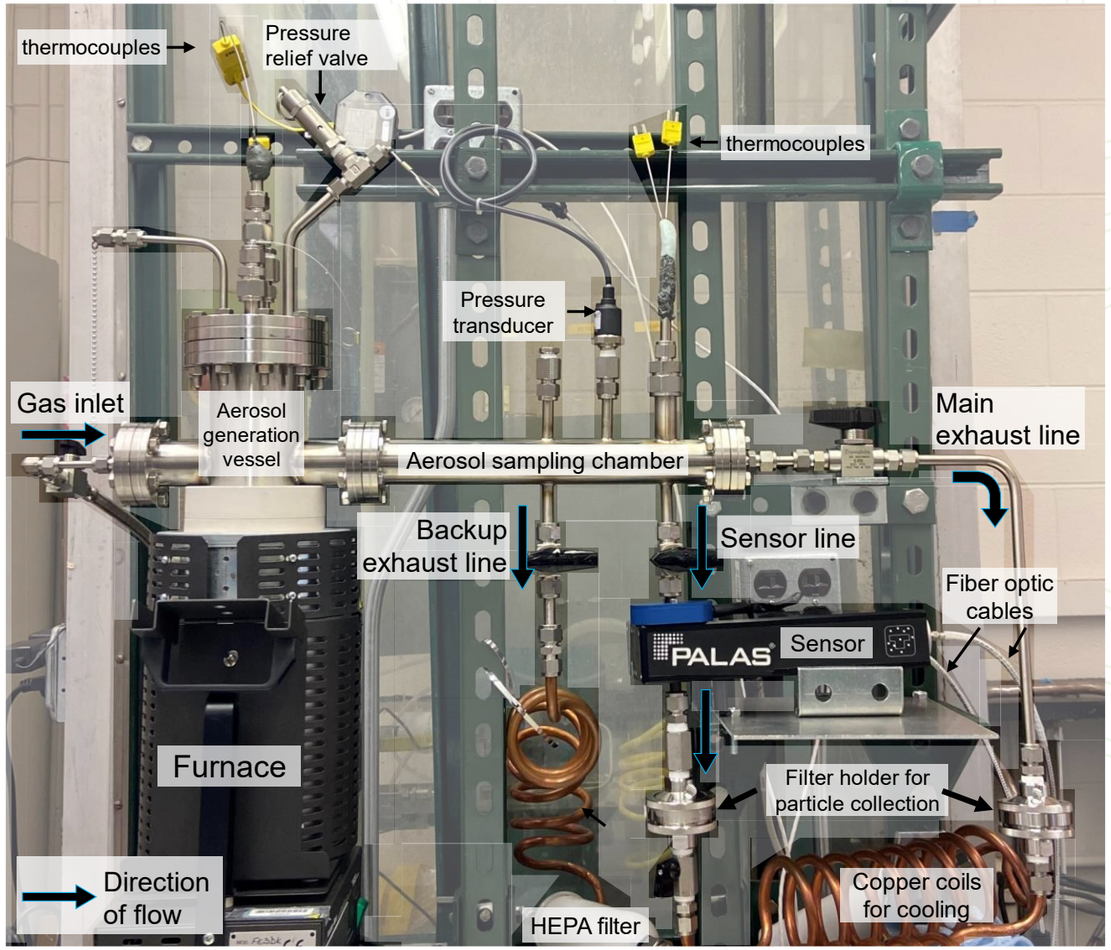
Argonne test stand for real-time salt aerosol characterization

- Laboratory-scale test stand to generate and characterize salt aerosols in real-time developed in FY24
  - Real-time size and concentration (optical light scattering)
  - Bulk elemental composition of particles collected on filters (ICP-MS)
  - Elemental composition of single particles (SEM-EDS)
- Motivation for developing Argonne salt aerosol test stand:
  - Addresses data gaps significant to accident consequence (formation of radionuclide-bearing aerosols)
  - Generates data on aerosol formation from molten salt systems through systematic and controlled testing
  - Provides salt aerosol measurement experience and method validation prior to use in Salt Accident Analysis Facility
- Designed for molten salt environments and a range of gas atmospheres:
  - Withstands corrosive and high temperature gas streams
  - Maintains measurement accuracy when gas composition and temperature change

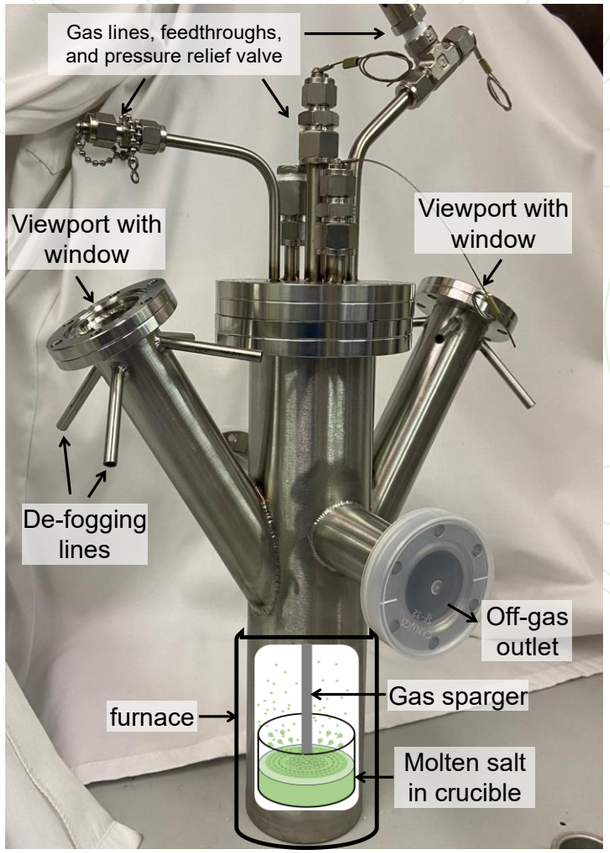


Thomas, Sara (2024) "Method for Real-Time Salt Aerosol Concentration and Size Measurements for Molten Salt Reactor Safety Assessments." Argonne National Laboratory Report ANL/CFCT-24/25.

Quantifying sensitivity of salt aerosol characteristics to formation mechanism

- FY25 objective is to quantify the size and concentration of salt aerosol particles generated from molten salt by different mechanisms:
  - Vapor condensation only (static salt)
  - Bubble bursting and vapor condensation (salt sparged with inert gas)
- Salt aerosols will be generated under a range of gas flow conditions
- Generated data will support development of models that predict the characteristics of salt aerosols that form from molten salt systems

New aerosol generation vessel with viewports



Demonstration of gas sparger in water


0.05 L min^{-1}


0.2 L min^{-1}


0.5 L min^{-1}

Summary of FY25 accomplishments and milestones

Task		Status
1	Document preliminary design and measurement capabilities of engineering scale salt accident analysis facility	Complete
2	Finalize design of molten salt transfer system and send drawings to vendor for manufacturing	Complete
3	Design and construct system for generating salt aerosols by sparging molten salt with inert gas	In progress
4	Measure real-time size and concentration of salt aerosols formed by vapor condensation and bubble bursting	In progress

Milestones

Milestone Number	Title	Due
M3AT-25AN0702041	Complete system component integration plan and preliminary designs for eng. scale test facility	Complete
M3AT-25AN0702042	Complete initial construction activities for automated salt transfer device	Complete
M3AT-25AN0702043	Complete demonstration of aerosol sensor sensitivity to aerosol formation mechanism	9/19/25 *on schedule*

Future work

Salt Accident Analysis Facility

- Construct and install molten salt transfer system
- Prioritize accident scenarios to simulate in facility
- Design and construct initial variation of salt containment system
- Simulate and assess accident scenarios using facility (install additional variations of salt containment system as needed)

Argonne test stand for real-time salt aerosol characterization

- Conduct separate effects tests on aerosol formation to generate experimental data that can be used to parameterize process models on aerosol formation, e.g.:
  - Effect of salt and gas composition and temperature
  - Effect of presence of humidity and oxygen in atmosphere

Recent reports:

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Thomas, Sara (2024) "Method for Real-Time Salt Aerosol Concentration and Size Measurements for Molten Salt Reactor Safety Assessments." Argonne National Laboratory Report ANL/CFCT-24/25.

Thank you

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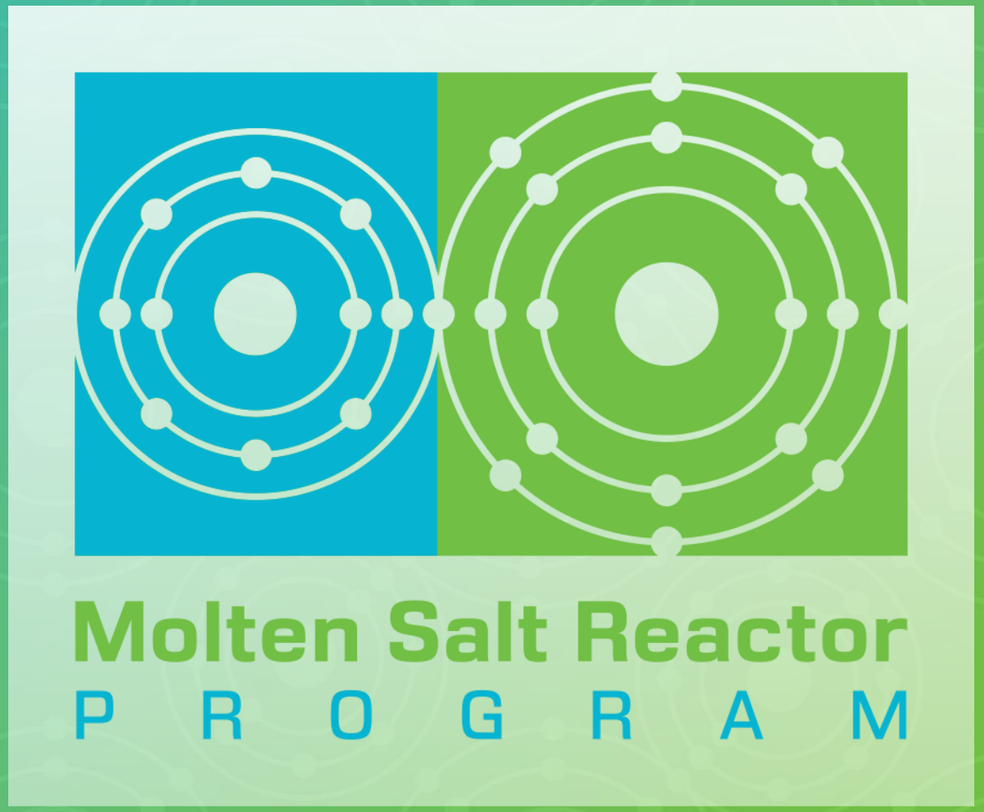

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