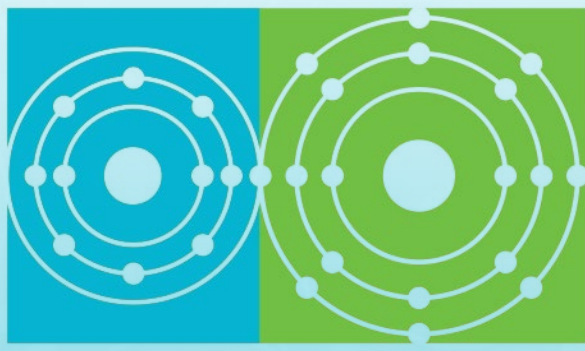




**Molten Salt Reactor**  
P R O G R A M

# Overview of the Technology Development and Demonstration Supporting MSRs

Joanna McFarlane

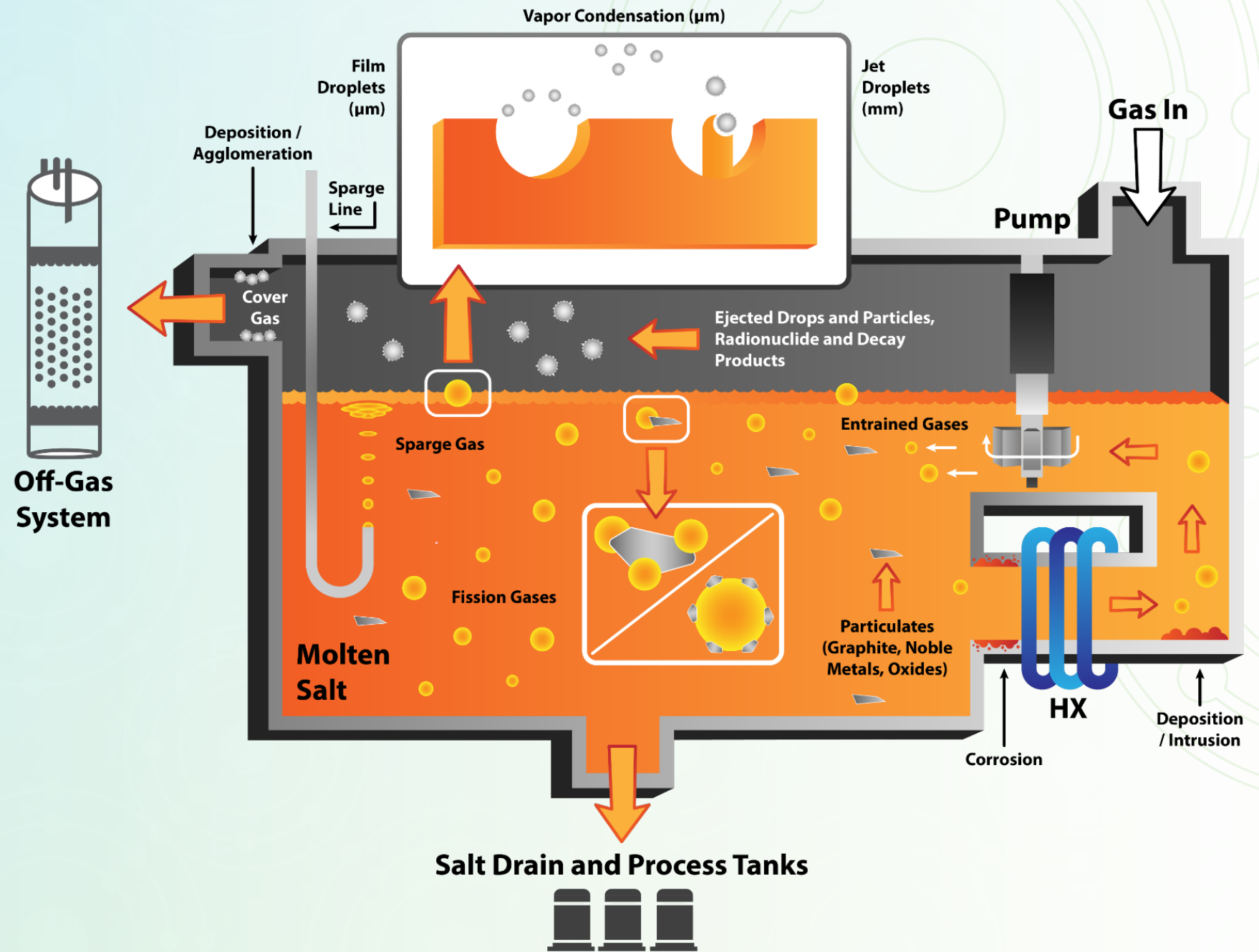
April 22, 2026

Sandia National Laboratory

[mcfarlanej@ornl.gov](mailto:mcfarlanej@ornl.gov)

# Goal is to address reactor safety and, thus assist with licensing

- Measure, model, and predict radionuclide transport
  - Normal operation
  - Salt spill events
  - During online operations
- Technologies for mitigation of release



# FY26 PICS milestones (M2) relevant to off-gas and radionuclide transport (MSR RD 1.15.06.02, ART 2.04.07)

| Milestone Number | Description                                                      | Status as of 03-31-2026 (end of Q2) |
|------------------|------------------------------------------------------------------|-------------------------------------|
| M2RD-2OR0602015  | Demonstrate Application of LIBS for Direct Probe of Molten Salts | Due 9-30-2026                       |
| M2AT-26OR0703021 | Complete MSR off-gas road map                                    | Due 9-30-2026                       |



# FY26 PICS milestones (M3) relevant to off-gas and radionuclide transport (MSR RD 1.15.06, ART 2.04.07)

| Milestone Number | Description                                                                                               | Status as of 03-31-2025 (end of Q2) |
|------------------|-----------------------------------------------------------------------------------------------------------|-------------------------------------|
| M3AT-26PN0702063 | Complete analysis of irradiated MOF engineered particles in collaboration with ORNL and NSLS-II           | Completed 2-27-2026                 |
| M3RD-26SN0602031 | Complete model and implementation and demonstration for particle size in MELCOR                           | Due 6-30-2026                       |
| M3RD-26OR0602016 | Complete visualization and analysis of transport of noble metal particles by attachment to sparge bubbles | Due 6-30-2026                       |
| M3AT-26AN0702034 | Complete tests on salt aerosol formation from molten salts bearing surrogate fission products             | Due 6-30-2026                       |
| M3AT-26PN0702072 | Complete literature review of tritium capture                                                             | Due 8-31-2026                       |
| M3AT-26OR0702012 | Initiate liquid salt test loop refurbishment with replacement of the old pump and pump tank               | Due 9-2-2026                        |
| M3AT-26OR0702081 | Complete development of experimental apparatus for measuring the speed of sound in molten LiCl-KCl        | Due 9-30-2026                       |
| M3RD-26SN0602032 | Complete model implementation and demonstration of fate and transport of model gases in MELCOR            | Due 9-30-2026                       |
| M3RD-26IN0602021 | Complete an Initial Framework for the Computational Modeling of Generic MSRs                              | Due 9-30-2026                       |
| M3AT-26PN0702051 | Complete development of models for the simultaneous quantification of multiple gas-phase species          | Due 9-30-2026                       |

## FY26 M3 PICS milestones continued

| Milestone Number  | Description                                                                                                                                                           | Status as of 03-31-2025 (end of Q2) |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|
| M3AT-26IN0702042  | Complete evaluation of deuterium in flowing FLiNaK salt at varying source terms, flow rates, and temperatures within MSTTE (Molten Salt Tritium Transport Experiment) | Due 9-30-2026                       |
| M3AT-26PN07040122 | Complete simultaneous measurement of multiple gas-phase analytes                                                                                                      | Due 9-30-2026                       |
| M3AT-26AN0702034  | Complete tests on salt aerosol formation from molten salts bearing surrogate fission products                                                                         | Due 9-30-2026                       |
| M3AT-26PN0702064  | Construct and test a modular off-gas system to treat MSR off-gas xenon and krypton                                                                                    | Due 9-30-2026                       |

## FY26 M4 PICS milestones

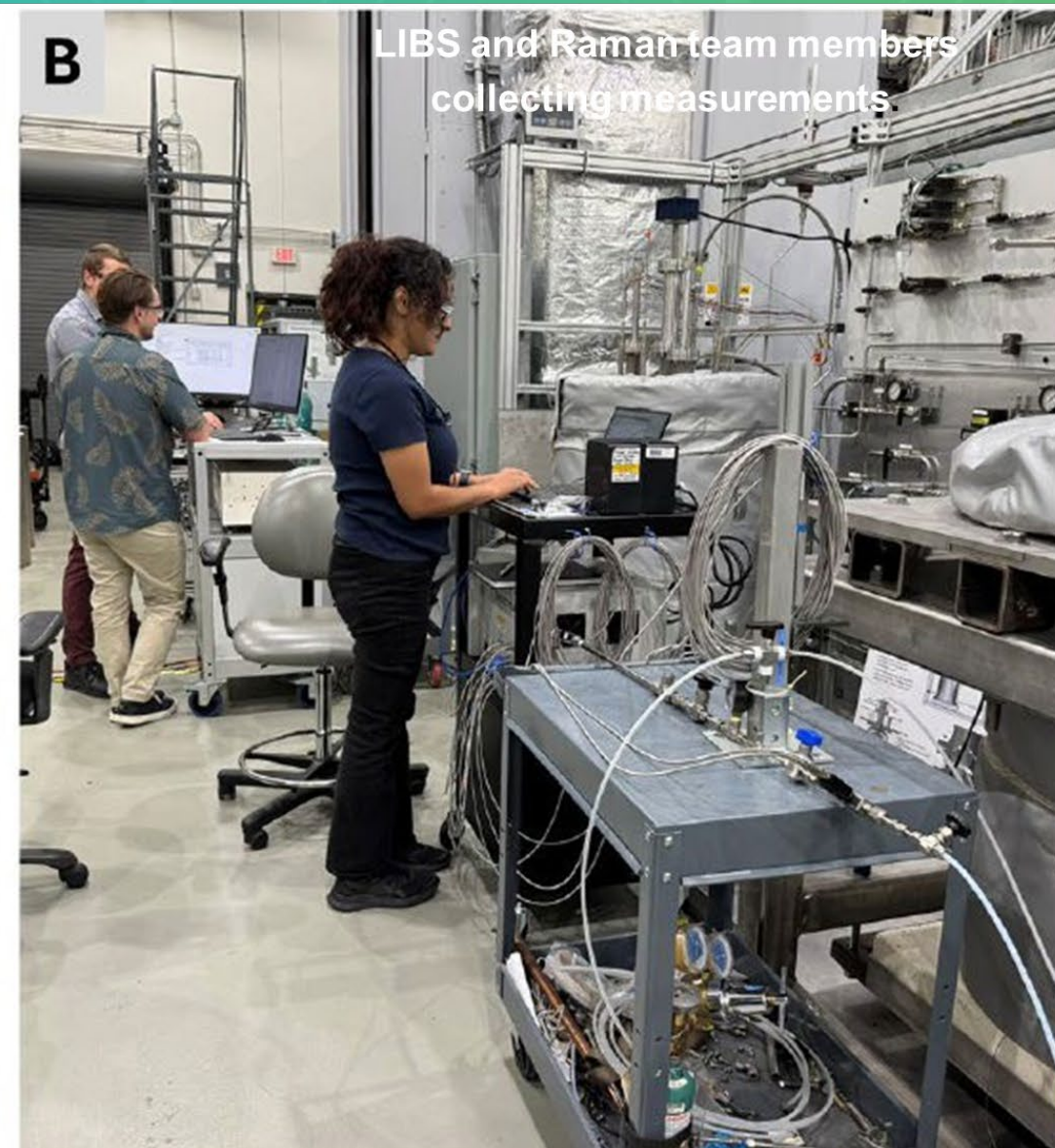
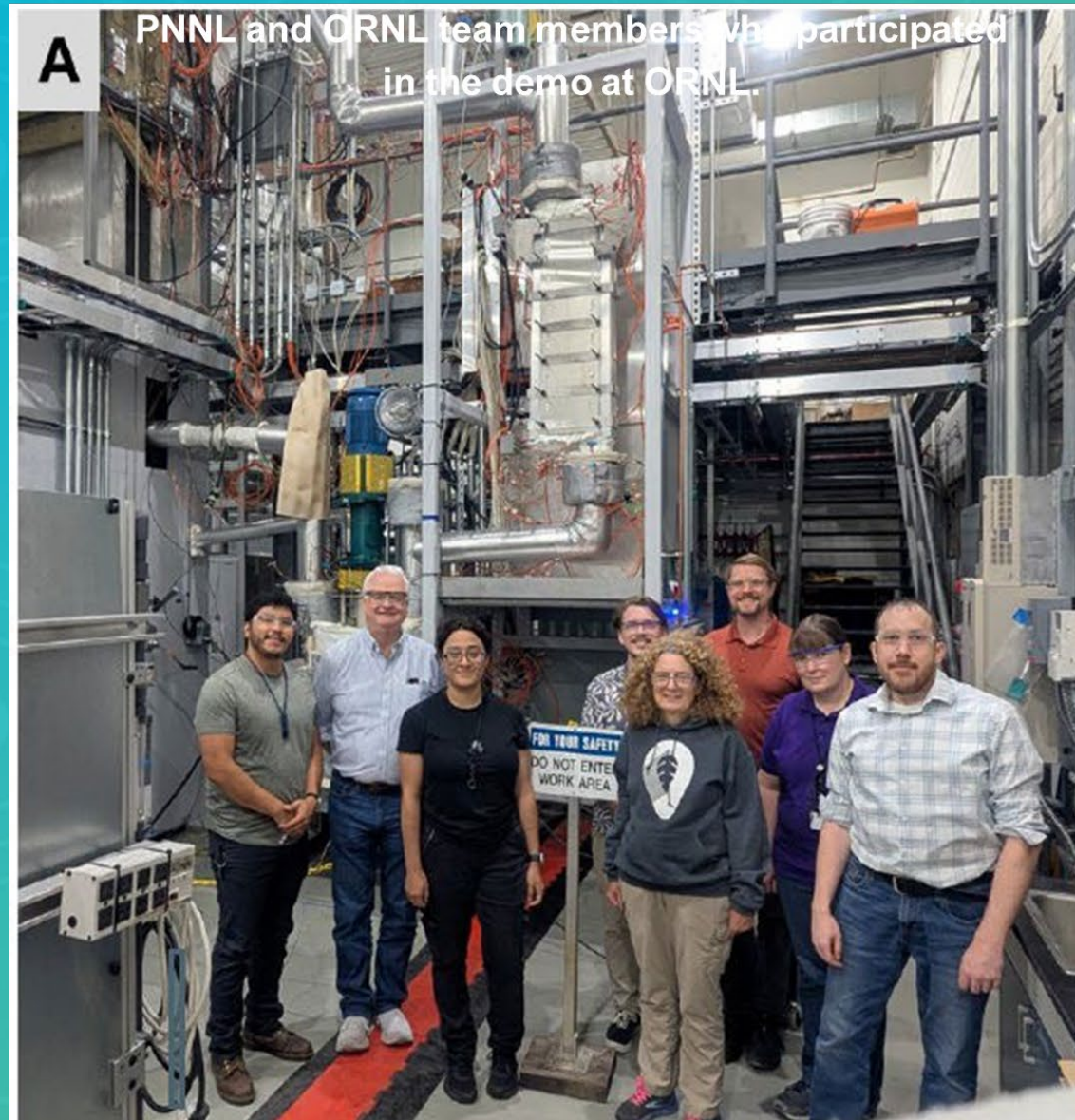
| Milestone Number | Description                                                                   | Status as of 03-31-2025 (end of Q2) |
|------------------|-------------------------------------------------------------------------------|-------------------------------------|
| M4AT-26PN0702071 | Compile status of tritium capture technologies                                | Due 6-30-2026                       |
| M4AT-26AN0702023 | Complete molten salt sensor operations at the FASTR salt loop located at ORNL | Due 9-30-2026                       |

# Highlights in FY25





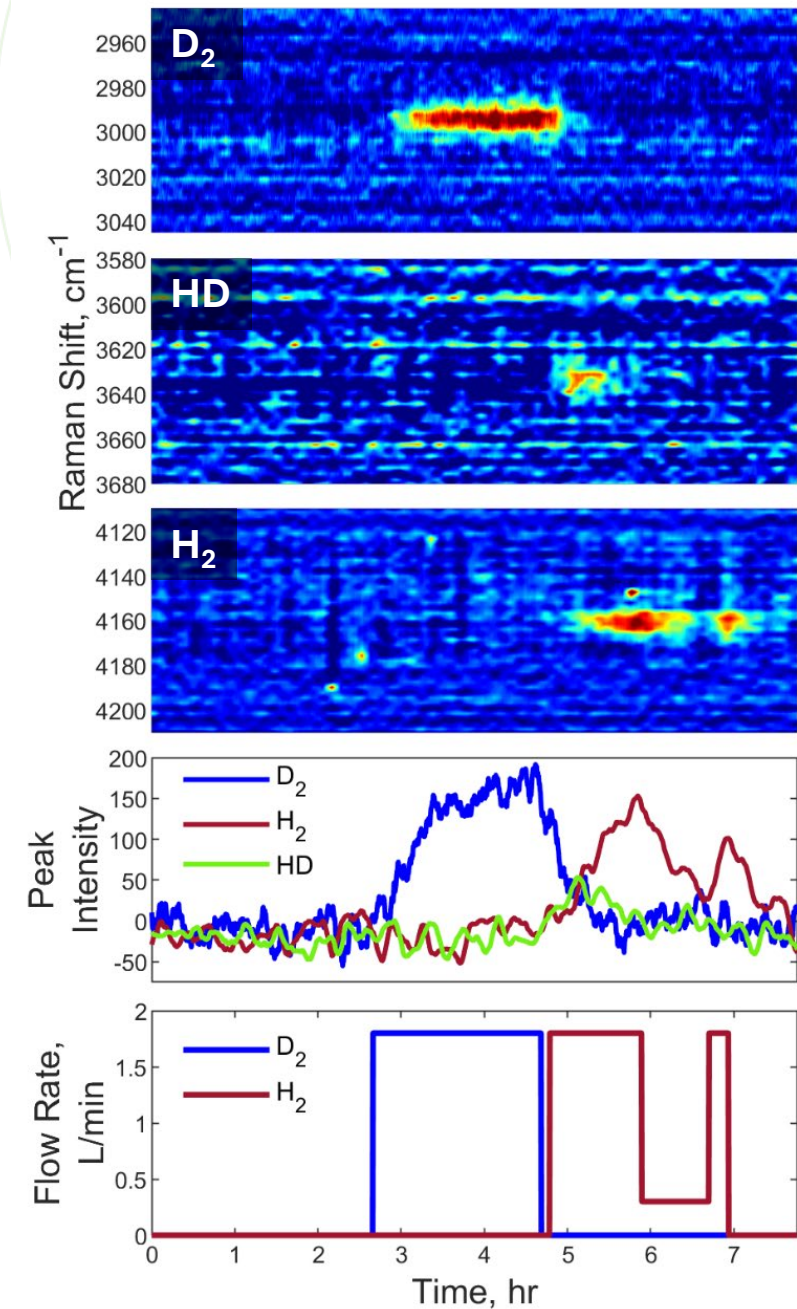
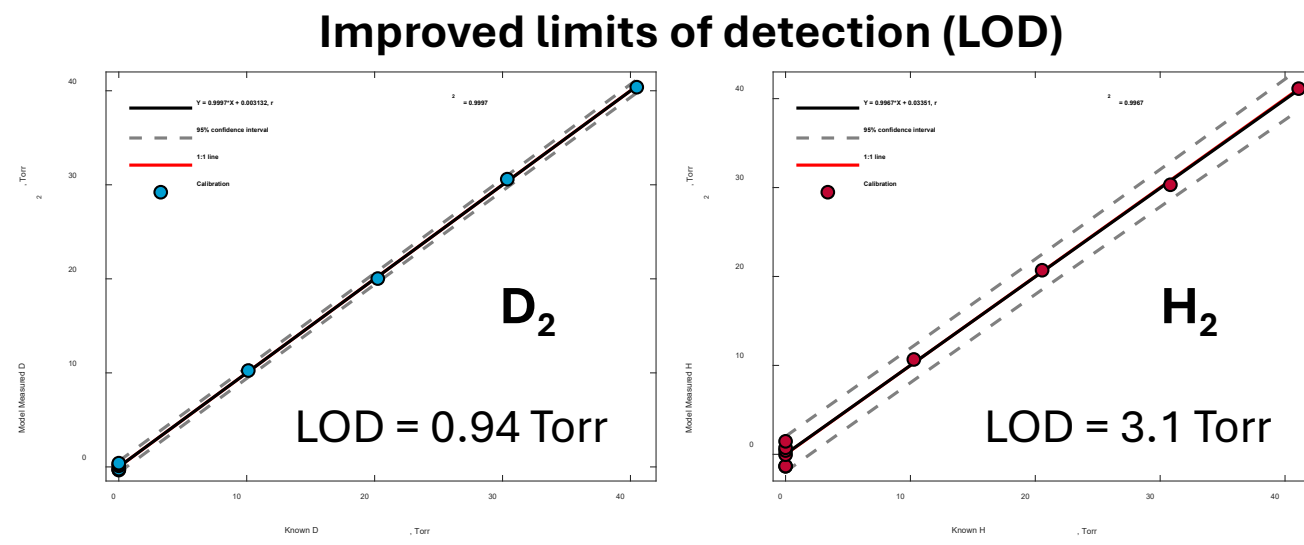
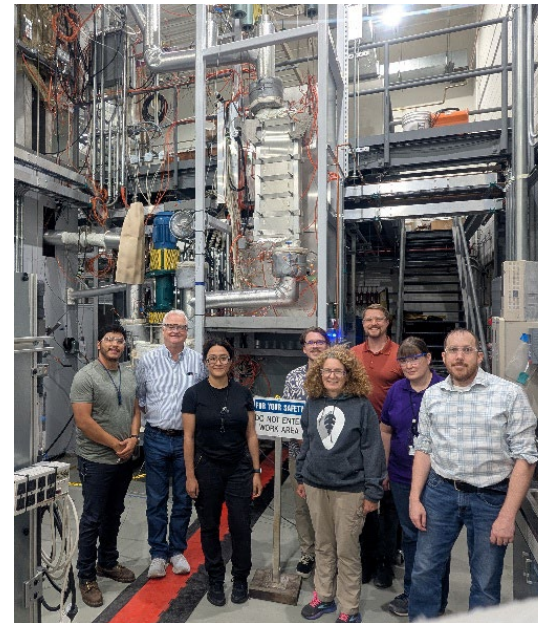
# Tandem use of Raman, LIBS, and redox probes, flow sensors demonstrated in FASTR





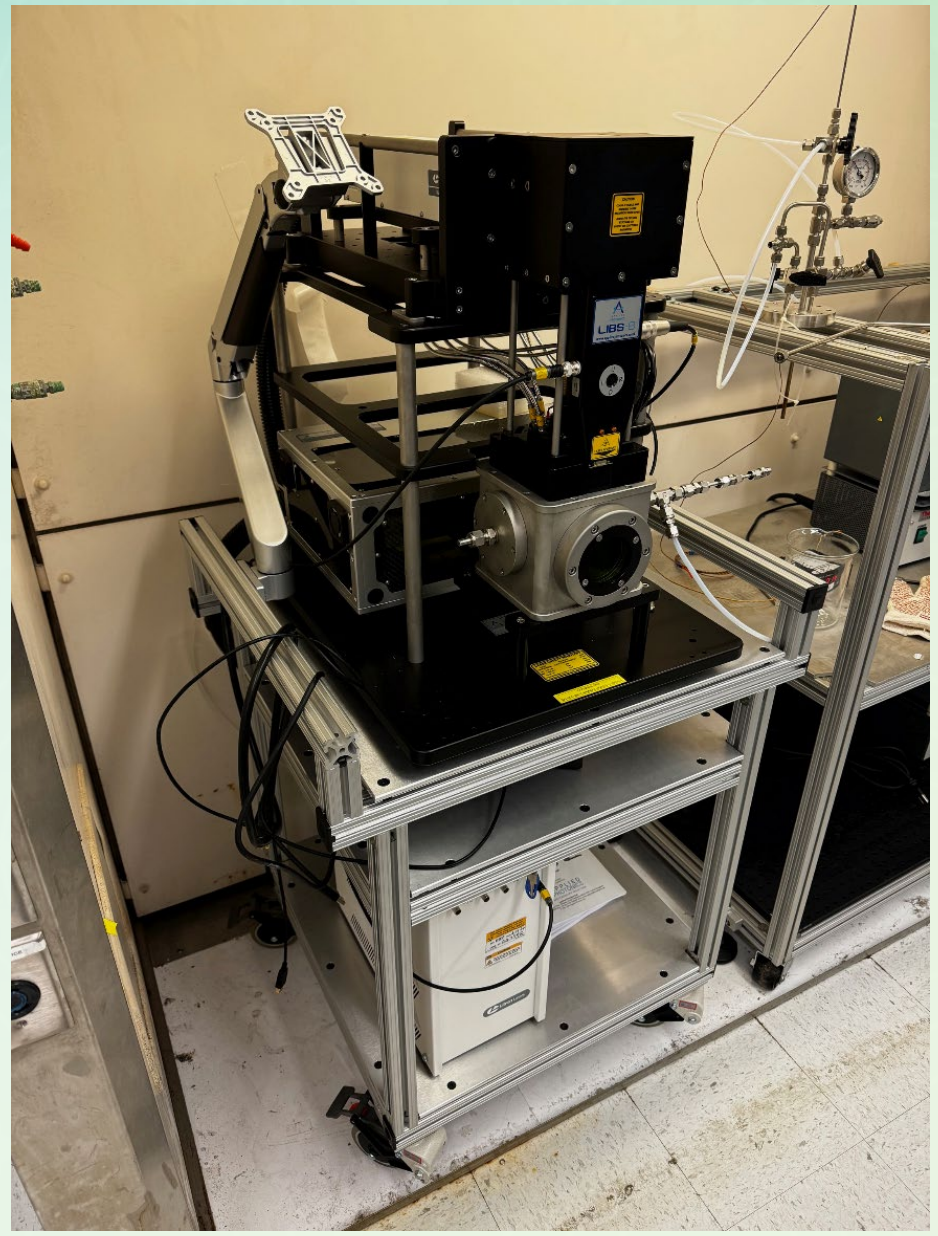
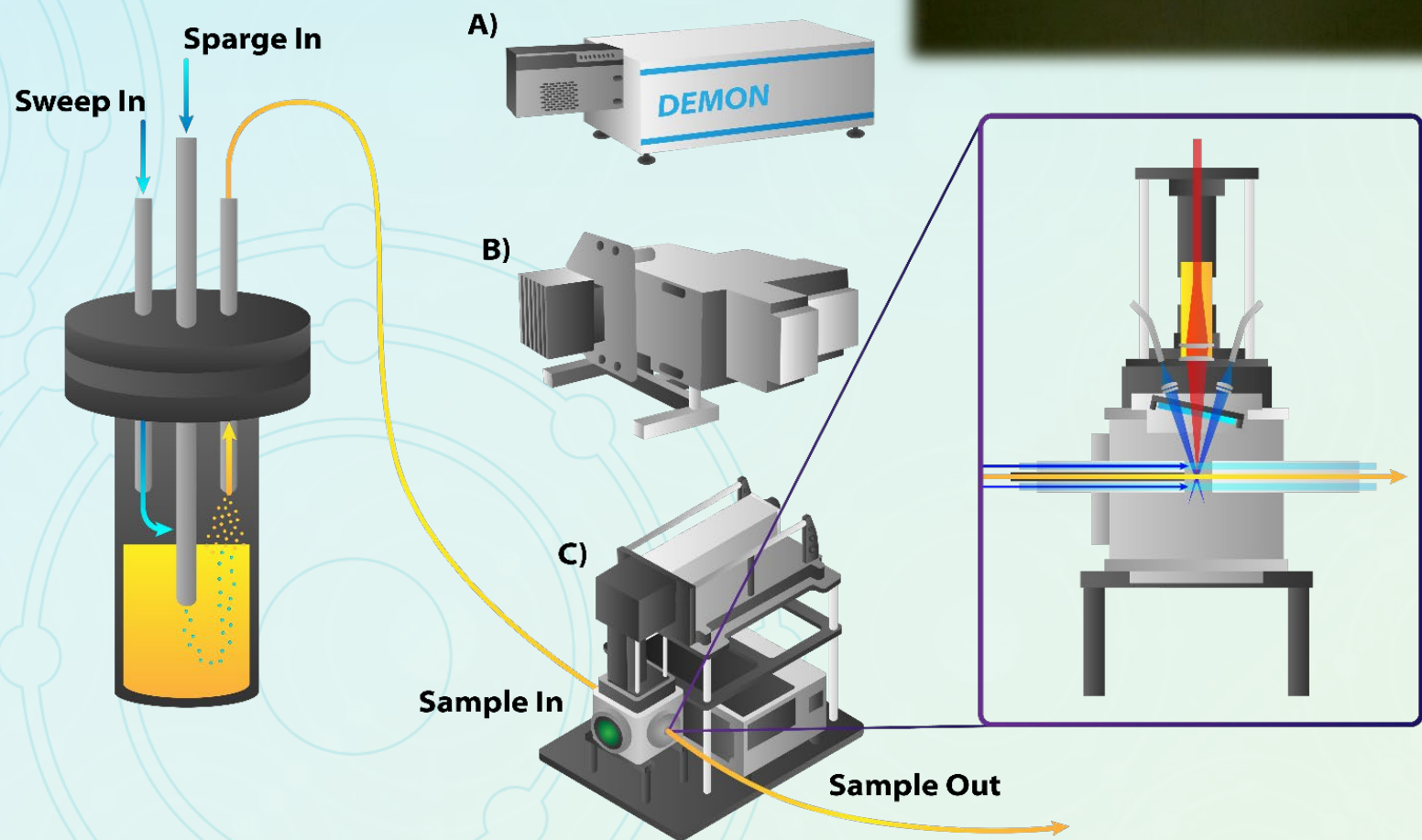
# Onsite demo of Raman at ORNL-FASTR

- Successfully deployed Raman system at ORNL in August 2025
- Monitored multiple locations in FASTR loop
- Detected D<sub>2</sub>, H<sub>2</sub>, and HD in gas phase above salt storage tank
- In tandem with LIBS and RGA
- Continuing data analysis and collaboration





# Mobile LIBS platform and molten salt aerosol sampling deployed at ORNL-FASTR

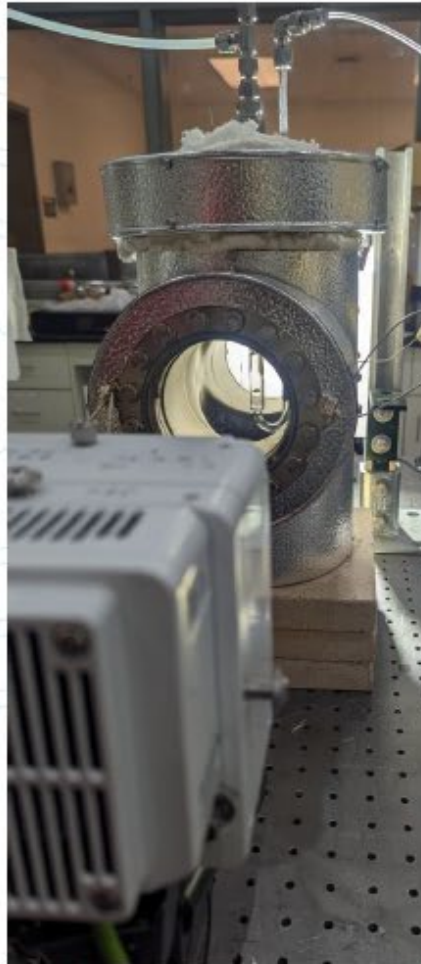


Hunter Andrews, andrewshb@ornl.gov

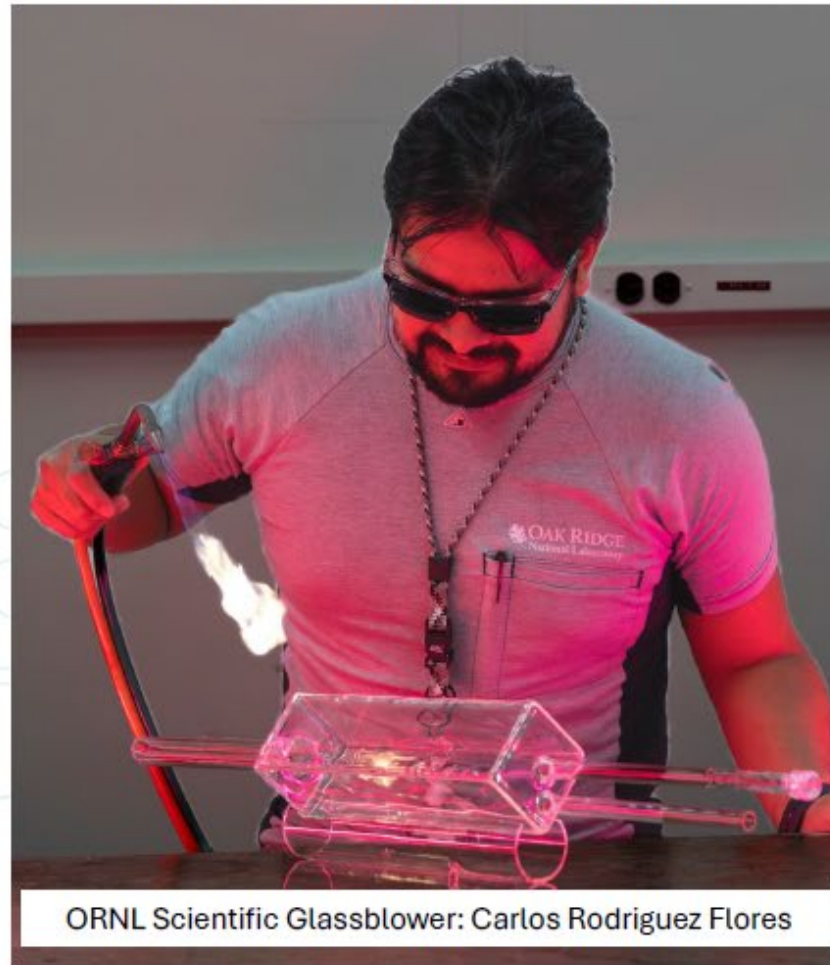


# ***Molten salt visualization was scaled up to minimize edge effects***

Where we started

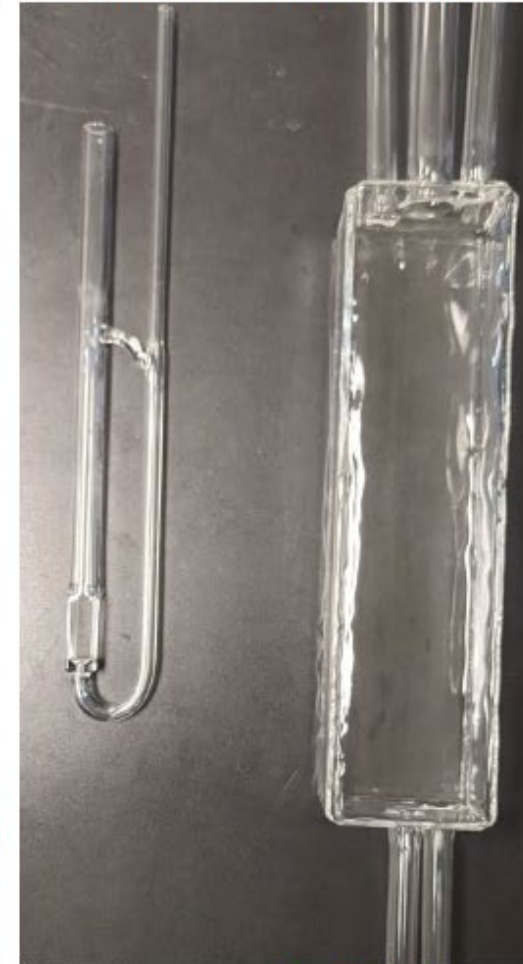


Flow Cell Improvements

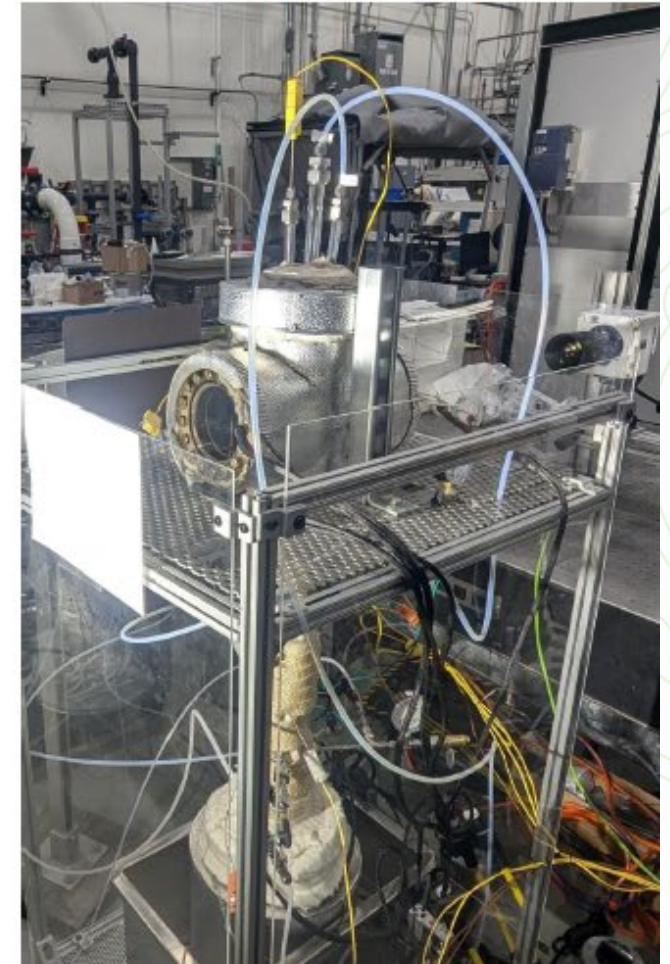


ORNL Scientific Glassblower: Carlos Rodriguez Flores

10 mL to 1,000 mL



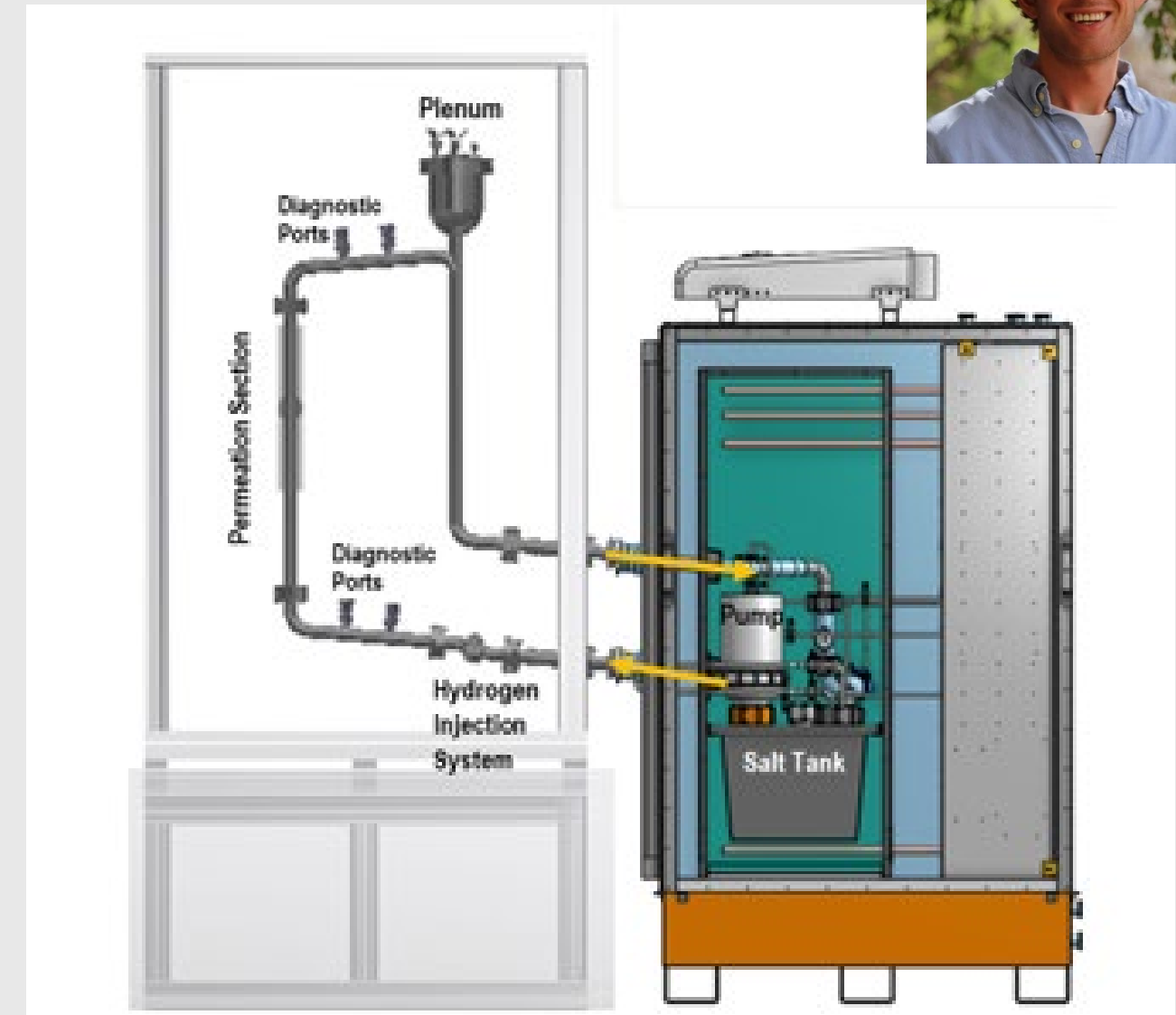
Current status





# The Molten Salt Transport Experiment Loop (MSTTE) has been built and is being commissioned at INL

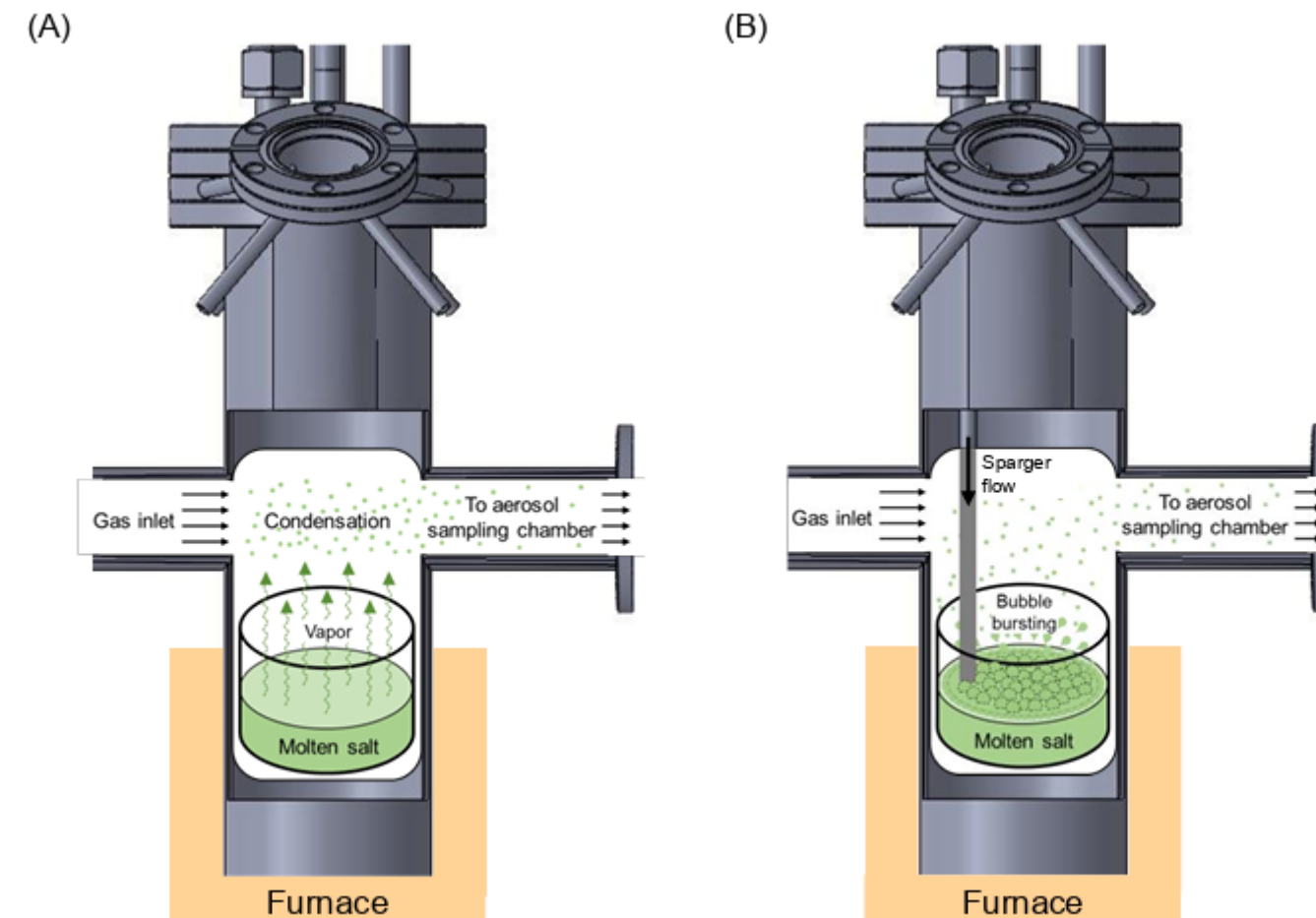
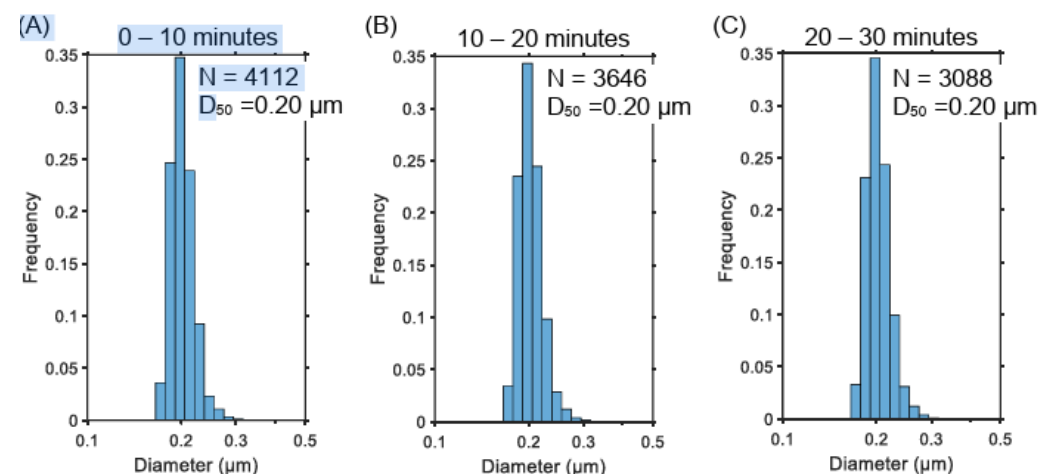
- Loop will be used to understand tritium transport through molten salt
- Features include a hydrogen injection system and a permeation test section



# Argonne highlights

## Characterization of salt aerosols in real time.

- Data to support development and validation of safety analysis models
- MSR Aerosols collected in a sampling chamber
- Aerosol spectrometer
  - Light scattering to get size distribution & volumetric concentration



**Figure 1:** Section of aerosol generation vessel with schematic that depicts salt aerosol generation from (A) static and (B) sparged molten salt within the vessel interior.

Sara Thomas, [sathomas@anl.gov](mailto:sathomas@anl.gov)

ANL/CFCT-25/18

4/23/2026

Radionuclide Transport and Sensors Program



Molten Salt Reactor  
P R O G R A M



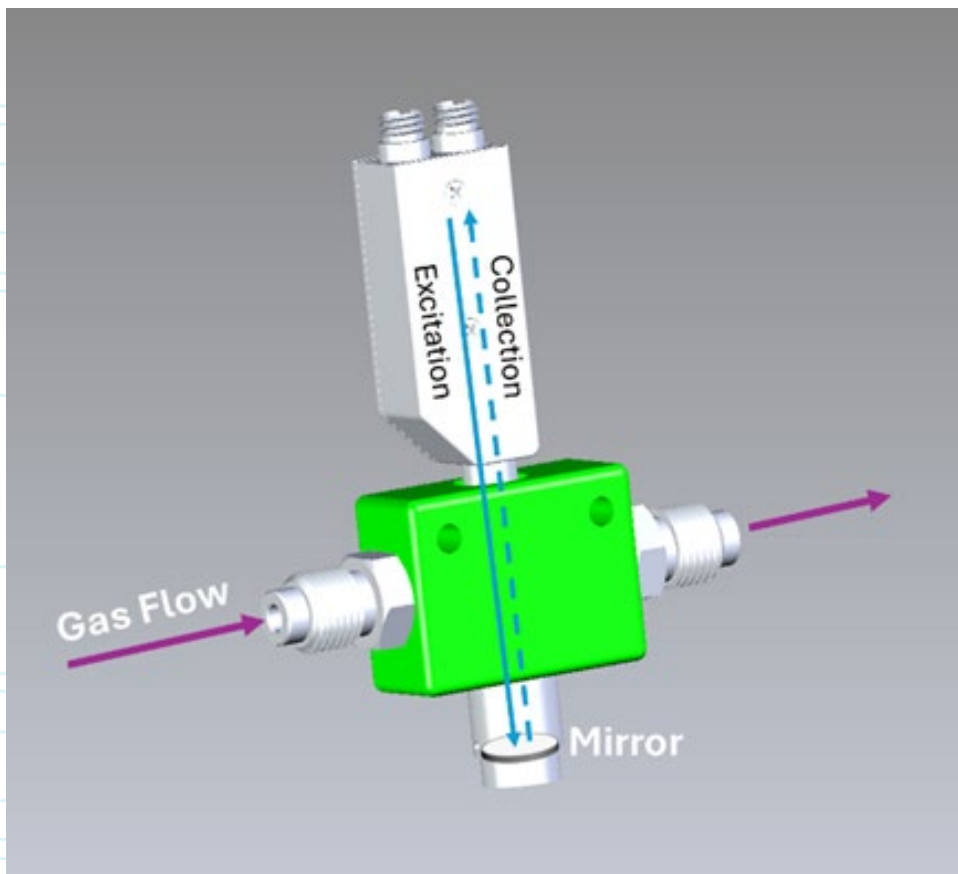
U.S. DEPARTMENT  
of ENERGY  
Office of Nuclear Energy



# Underway in FY26

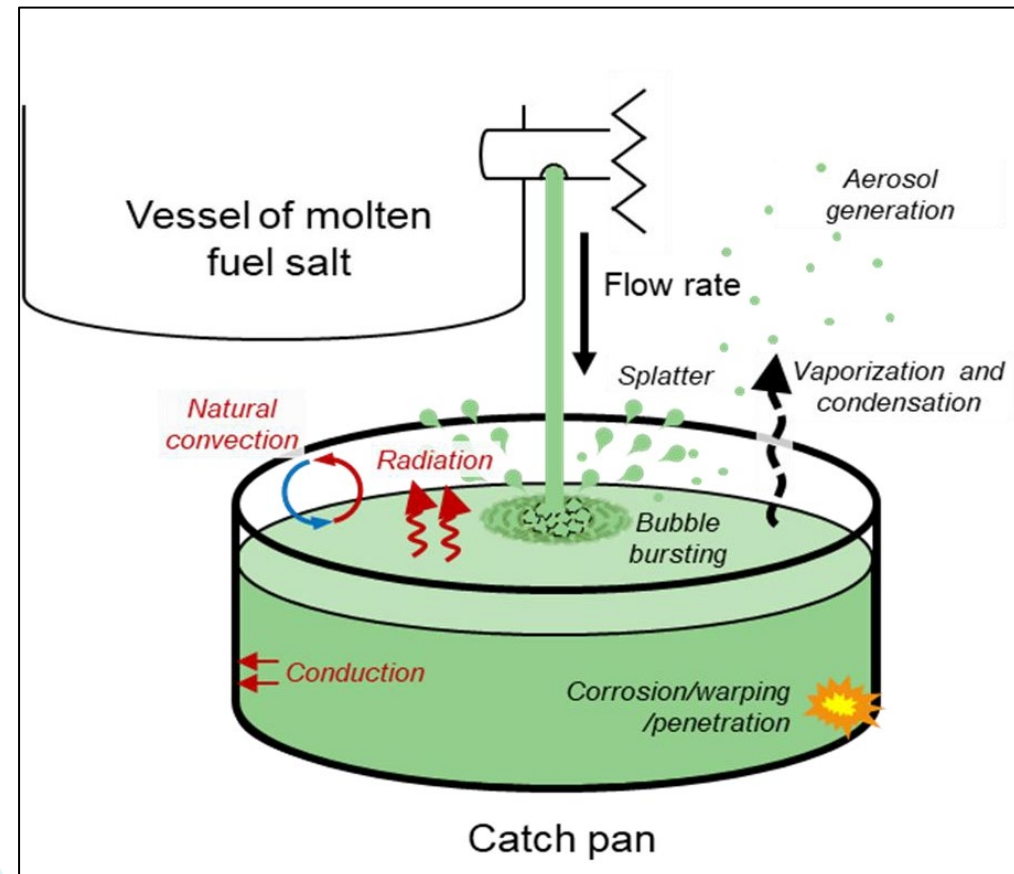


# Sensors development: new MSR applications



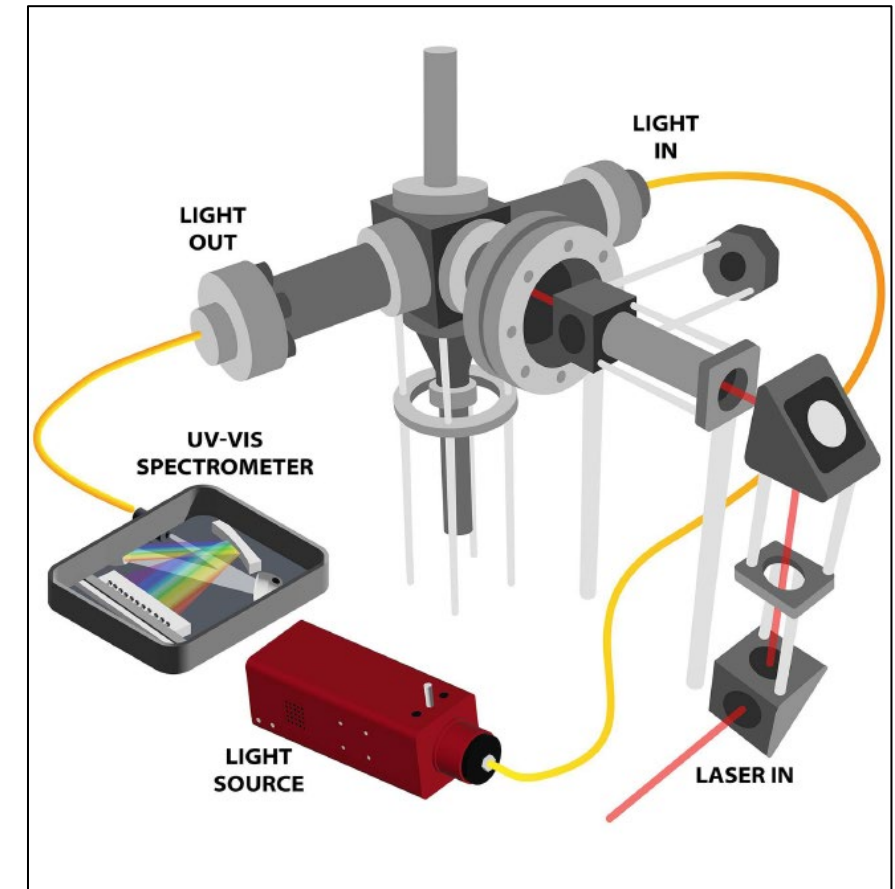
Hydrogen isotopes in methane by Raman.

Heather Felmy, Sam Bryan, et al.



Online salt aerosol sensor, sizes and composition in real time from sparged and static systems

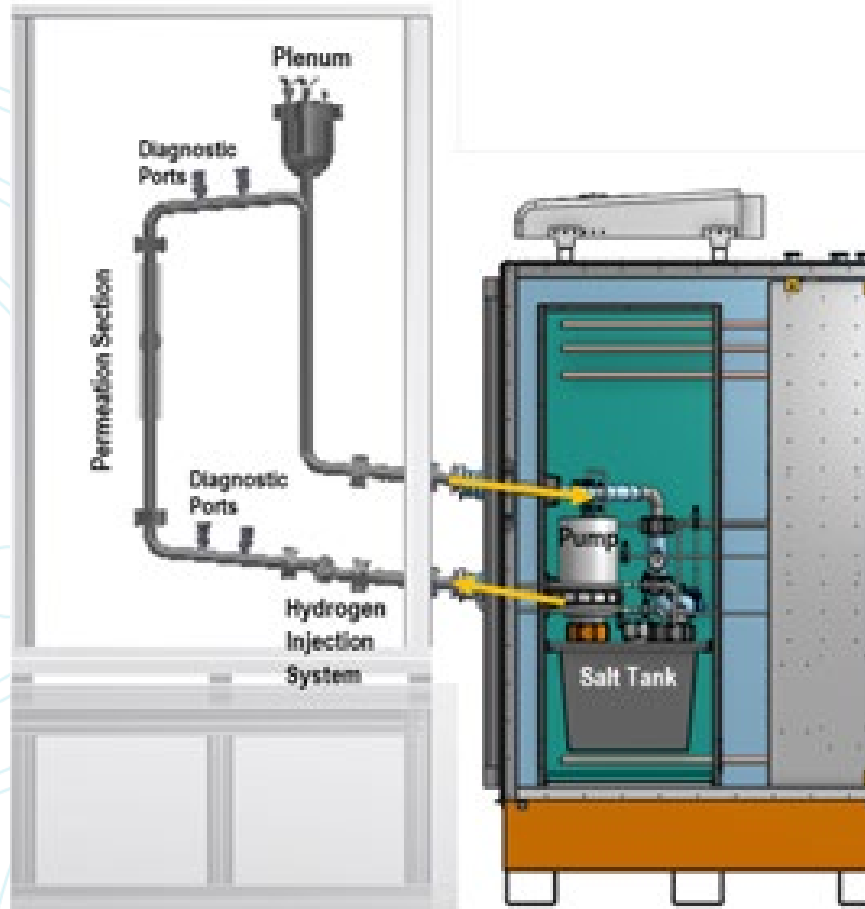
Sara Thomas et al.



Liquid analysis by LIBS-UV VIS, Prototype published by Hunter Andrews et al. in Applied Spectroscopy 2026

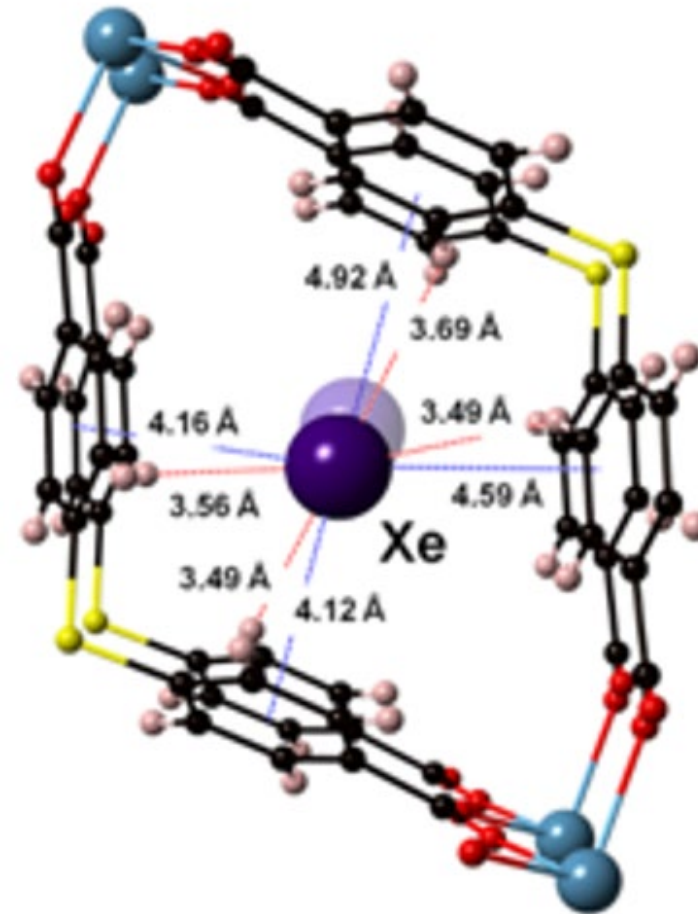


# Technology development and testing for radionuclide capture



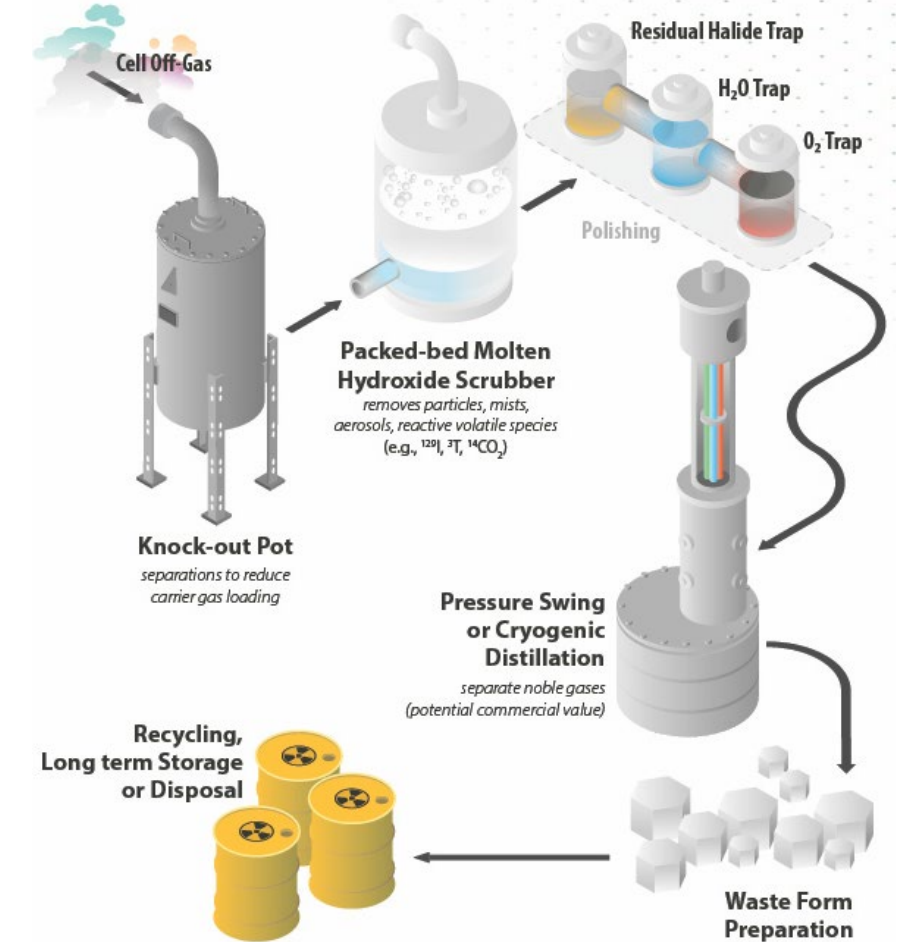
Commissioning of MSSTE and introduction of  $D_2$

Tommy Fuerst, Anthony Bowers, INL



MOF – testing capture of Xe and Kr after irradiation

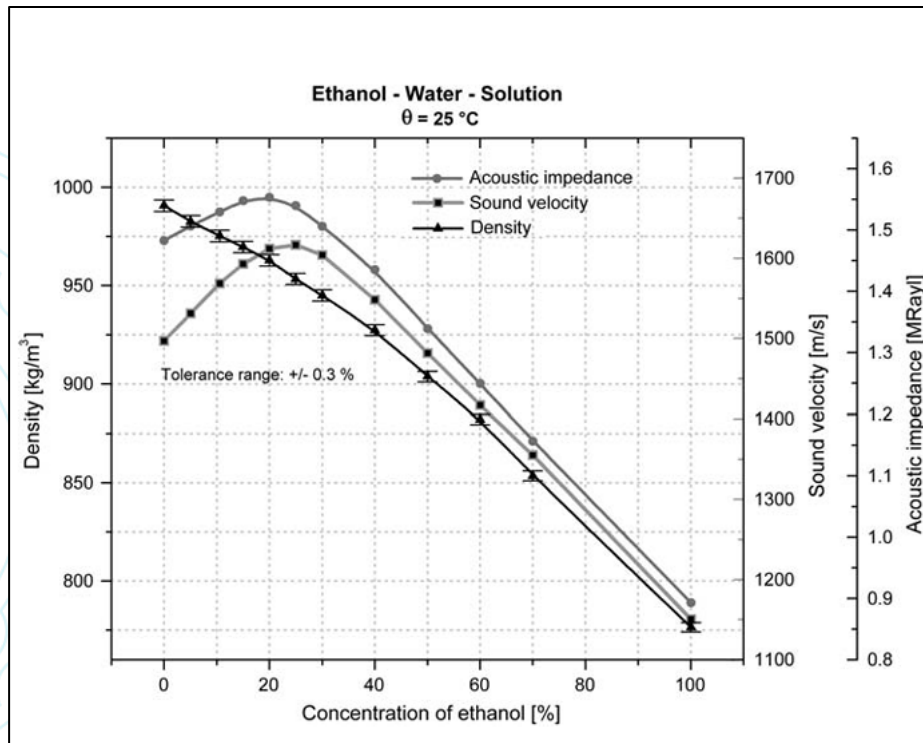
Praveen Thallapally et al.



Hydroxide dissolution of PyC and SiC

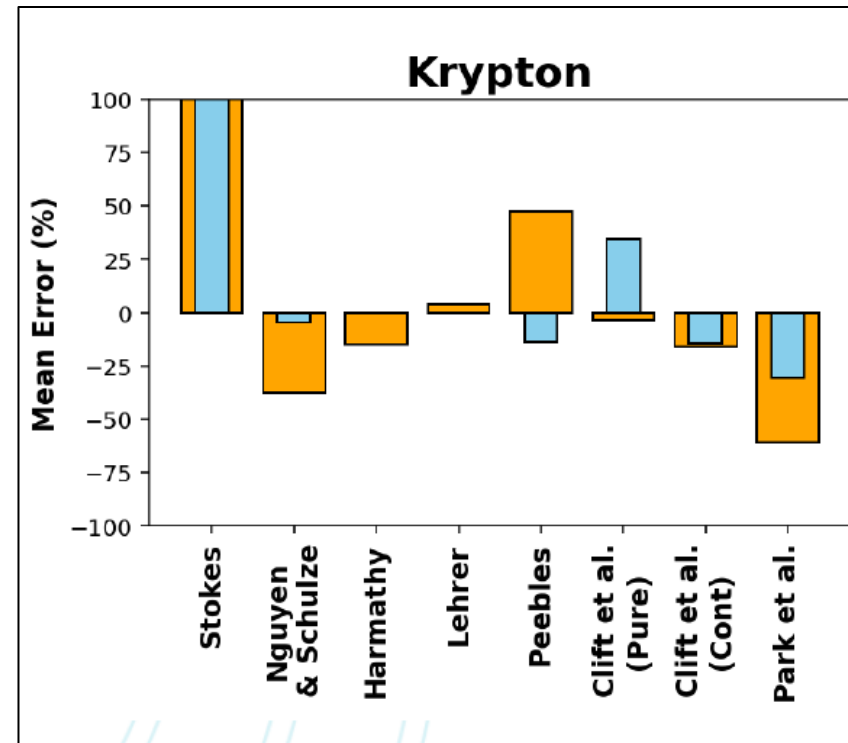
Daniel Orea & Katie Johnson

# Generation of transport data for modeling



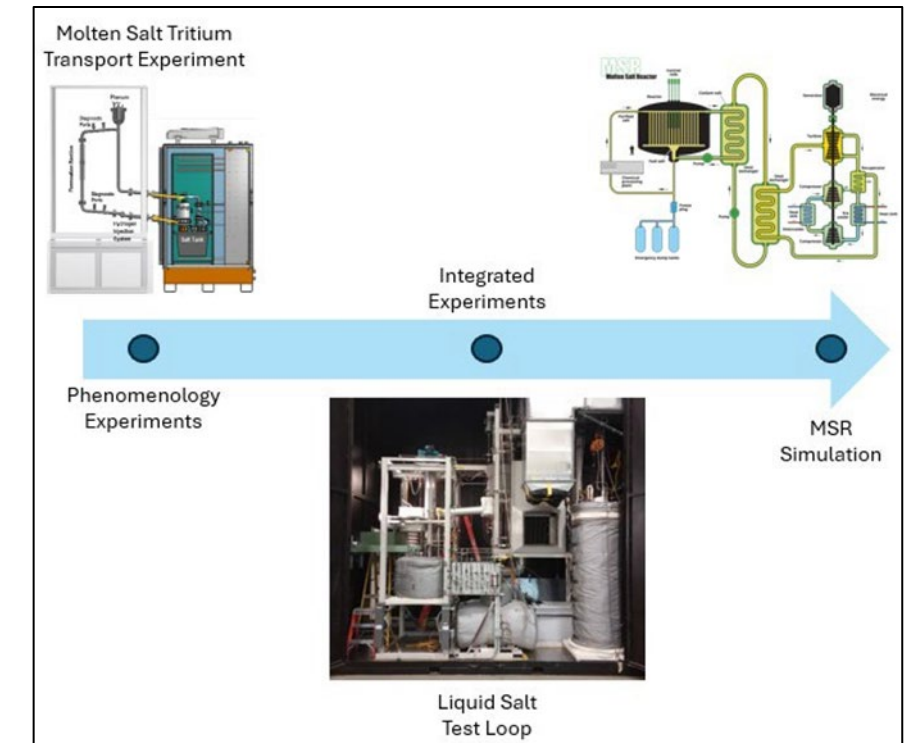
Speed of sound measurements in chloride salts (D. Orea)

Figure from Henning and Rautenberg Ultrasonics 2006



Visualization/PIV to give data on bubble behavior and aerosol generation.

Daniel Orea et al. ANS 2026



MELCOR will use data from integrated experiments to develop models for aerosol transport.

Matt Christian et al.



# *In the US, the goal is to demo an integrated off-gas system in 5 years.*

FY 26

Roadmap and start design

FY 27

start building the integrated off gas system

FY 28

Start cold test Analyze cold test results

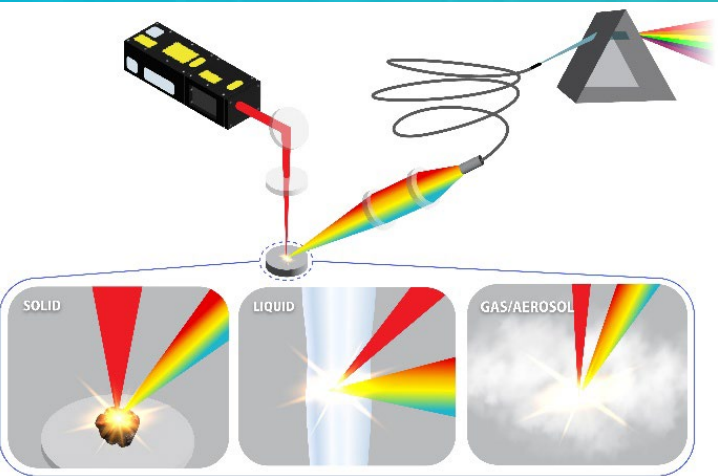
FY29

modify design if necessary and start building system for hot test

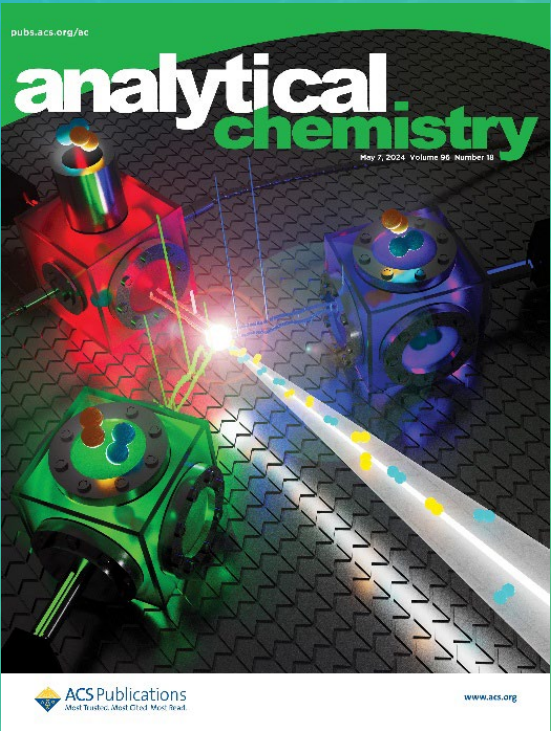
FY 30

Start hot test – Analyze result

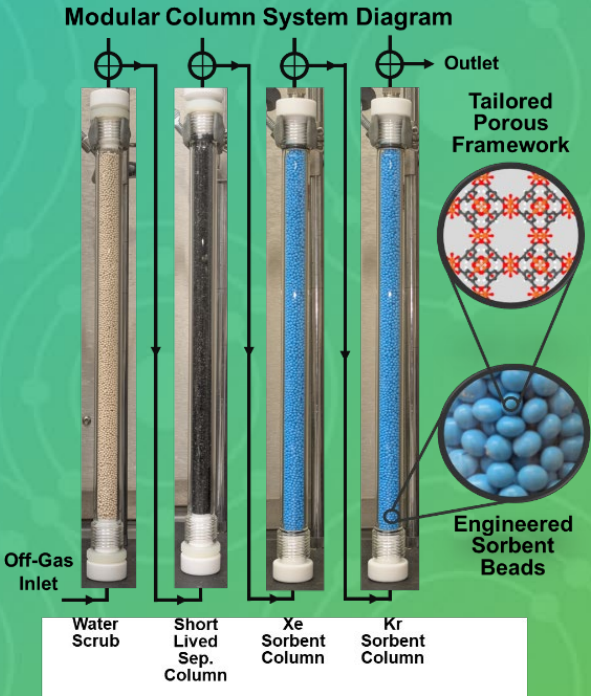
Off gas system ready for testing in MSRR and MCRE



Radionuclide sensors



& transport, vapor pressures, chemistry



Capture technologies



Testing in large loops

Deployment in MSRs



Molten Salt Reactor  
PROGRAM

U.S. DEPARTMENT OF  
**ENERGY**

Office of  
NUCLEAR ENERGY

# Reports and publications in 2025/26

## INL

T. Fuerst et al. (2025) “Experimental Design and Details of the Molten Salt Tritium Transport Experiment”, Annals of Nuclear Energy 223, <https://doi.org/10.1016/j.anucene.2025.111659>

T. Fuerst et al. “Computational fluid dynamics analysis of the molten salt tritium transport experiment test section”. (2026) Fusion Science and Technology 82, 431-448.

## SNL

M. Christian et al. (2025) “MELCOR deposition models applied to noble metals”, SAND-2025-12380, <https://doi.org/10.2172/2999088>

## ANL

S. Thomas, A. O’Brien (2025) “Real-time characterization of salt aerosols generated from static and sparged molten salt.” Argonne National Laboratory Report ANL/CFCT-25/18.

S. Thomas (2025) “Preliminary design of engineering-scale salt accident analysis facility to support molten salt reactor licensing, Argonne National Laboratory Report ANL/CFCT-25/1.

## PNNL

H.M. Felmy et al. (2025) “Demonstration of optical spectroscopic flow cell design for molten salt reactor off-gas streams”, Pacific Northwest National Laboratory Report, PNNL-38277



# Publications continued - ORNL

D. Orea et al., “Comparative study between experimental measurements and model predictions of bubble rise velocity in molten LiCl-KCl”, (2025) Nucl. Eng. & Design (443) 114247

D. Orea et al. “Optical and Neutron Imaging Measurements of Gas Bubble Rise Velocity in Molten Salt” Transactions of the American Nuclear Society 2025

H. Andrews et al. “Real-time monitoring of trace noble gases using LIBS- An investigation on the impact of bulk gas on plasma properties and sensitivity” (2025), Spectrochimica Acta Part B: Atomic Spectroscopy (230), 107237, 10.1016/j.sab.2025.107237.

Z. Kitzhaber et al. “Spurge sampling of molten salts for online monitoring via laser-induced breakdown spectroscopy”, (2025) ACS Omega (10), 37889-37897

H. Andrews et al. (2025) “Analysis of off-gas streams from small- and large-scale sparging salt vessels using laser-induced breakdown spectroscopy”, ORNL/TM-2025/4115

H. Andrews et al., “Real-time elemental and isotopic measurements of molten salt systems through laser induced breakdown spectroscopy, JACS, 147(1), 910-917, 2025, 10.1021/jacs.4c13684

H. Andrews et al. “Quantification of trace iodine using laser-induced breakdown spectroscopy for real-time monitoring of nuclear off-gas streams” (2025) J Analytical Atomic Spectroscopy 41(3), 953-961, 10.1039/D5JA00481K

H. Andrews et al. “Design of a molten salt flow cell for combined absorbance and laser-induced breakdown spectroscopy for online measurements” (2026) Applied Spectroscopy, 1-12, DOI: 10.1177/00037028261436815

# Speaker line up for off-gas and radionuclide transport

| Time        | Title                                                                                       | Speaker/Lab                            |
|-------------|---------------------------------------------------------------------------------------------|----------------------------------------|
| 8:20-8:50   | Salt Loop and Capability for Testing Sensors and Off Gas components                         | Kevin Robb/ORNL                        |
| 8:50-9:20   | Bubble Behavior in Molten Salts Relevant to MSRs                                            | Daniel Orea/ORNL                       |
| 9:20-9:50   | Actinide Salt Loop and Sensors Development at ANL                                           | Nora Shaheen/ANL                       |
| 9:50-10:20  | On-line Monitoring for MSR Off-Gas Treatment: Molecular approach                            | Heather Felmy/PNNL                     |
| 10:20-10:30 | Break                                                                                       |                                        |
| 10:30-11:00 | Laser Induced Breakdown Spectroscopy (LIBS) for elemental monitoring of MSR off-gas streams | Hunter Andrews/ORNL                    |
| 11:00-11:30 | Update on Radiation Exposure Measurements of Metal Organic Framework at PNNL                | Praveen Thallapally & Mark Murphy/PNNL |
| 11:30-12:00 | Experiment and Modeling Liquid Salt Test Loop (LSTL)                                        | Bob Salko/ORNL                         |
| 12:00-12:30 | Tritium Transport                                                                           | Anthony Bowers/INL                     |

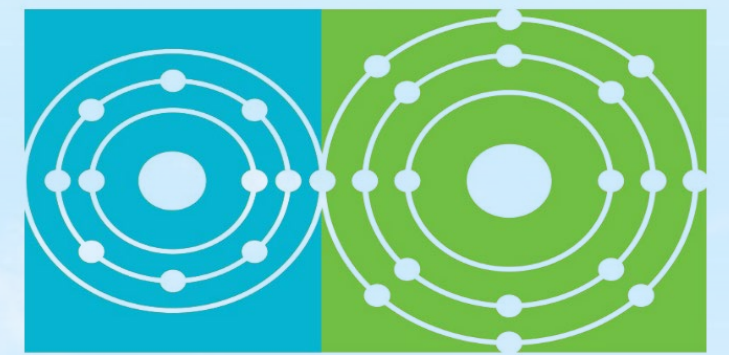


# Thank-you

[mcfarlanej@ornl.gov](mailto:mcfarlanej@ornl.gov),

[Patricia.Paviet@pnnl.gov](mailto:Patricia.Paviet@pnnl.gov)

<https://gain.inl.gov/doe-molten-salt-reactor-program/>



**Molten Salt Reactor**  
P R O G R A M

Hunter Andrews  
Anthony Bowers  
Sam Bryan  
Matt Christian  
Paulina Guerrero-  
Almaraz  
Tommy Fuerst  
Heather Felmy  
Nathanial Hoyt  
Katie Johnson

Amanda Lines  
Bruce McNamara  
Daniel Orea  
Kevin Robb  
Bob Salko  
Sara Thomas  
Praveen Thallapally  
Zechariah Kitzhaber

**Funding provided by the DOE-NE-5  
Advanced Reactor Technology,  
Molten Salt Reactor Campaign**