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Molten Salt Reactor PROGRAM

Tritium Transport

Update on the Molten Salt Tritium Transport Experiment

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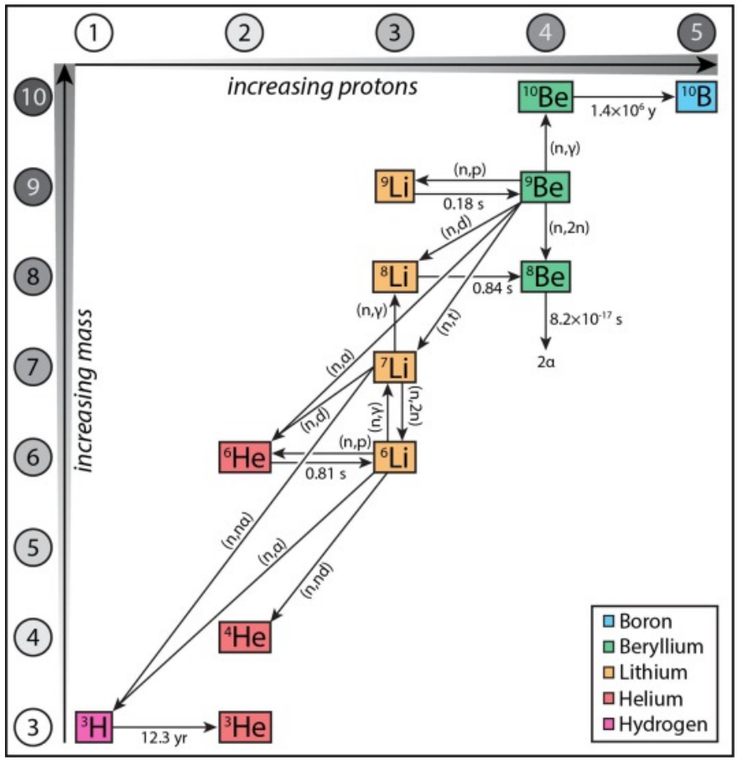
Sandia National Laboratories
U.S. DEPARTMENT of ENERGY Office of Nuclear Energy

Outline

- Tritium Transport Background
  - Generation in MSRs
  - Transport in MSRs
- **M**olten **S**alt **T**ritium **T**ransport **E**xperiment (MSTTE)
  - Overview
  - Status Update

Tritium Generation in MSRs

Tritium generated by neutron reactions with Li, Be, and F.

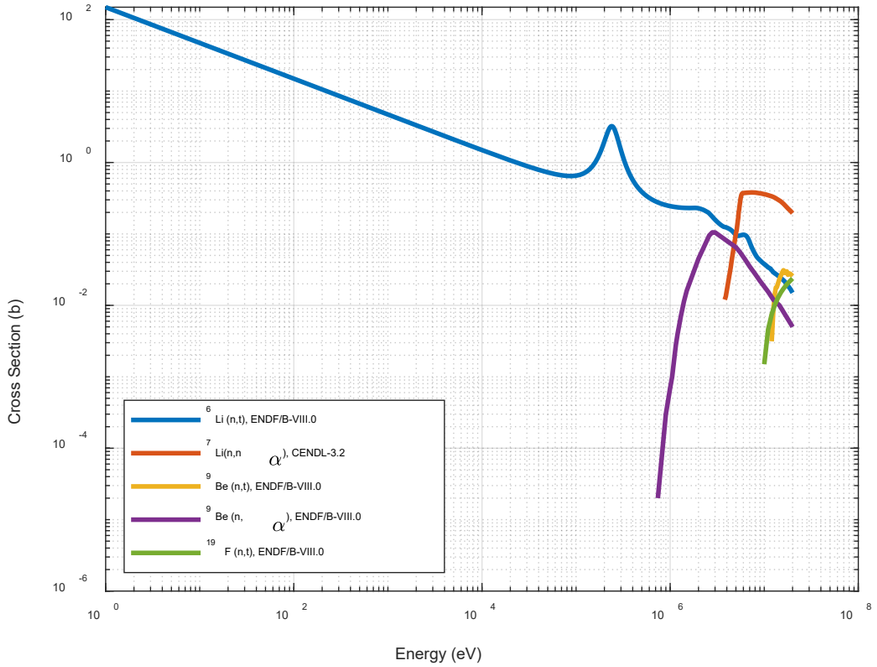


Andrews, Hunter B., et al. "Review of molten salt reactor off-gas management considerations." Nucl. Eng. Des. 385 (2021): 111529.

^{6}Li (7.5%) large thermal cross-section.

^{7}Li (92.5%) moderate cross-section in fast-spectrum.

^{9}Be and ^{19}F in fast-spectrum.



Tritium generation rates in *fluoride* salt reactors are similar to CANDU reactors.

CANDUs produce world's commercial supply of tritium.

Tritium is a valuable byproduct of MSRs.

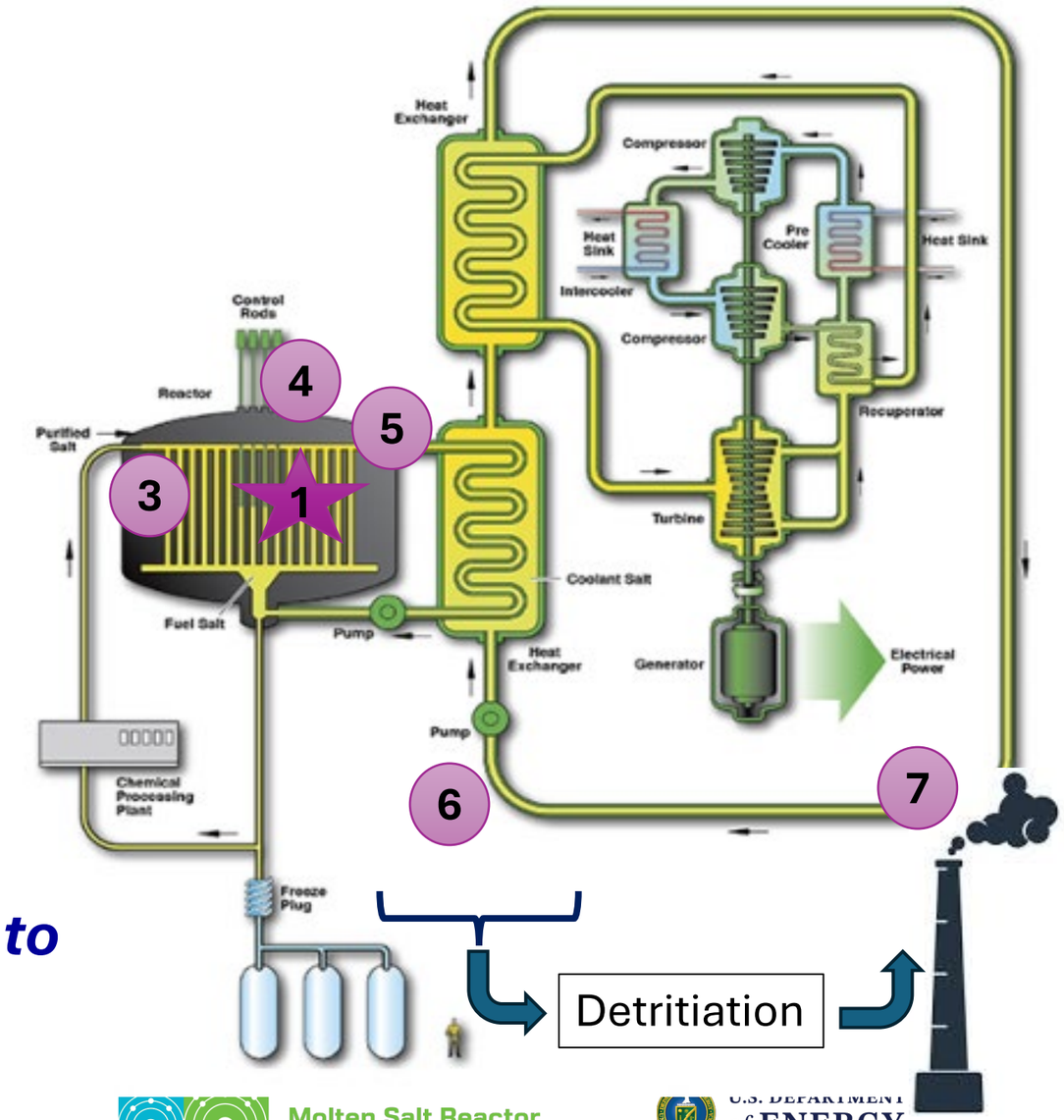
Reactor Type	Tritium Formation Rate 1000 MWe (Ci/day) [1]
MSR	2400*
CANDU	2700
HTGR	50
PWR	2

*MSBR enriched in ^{7}Li (99.992%).

Tritium Transport in MSRs

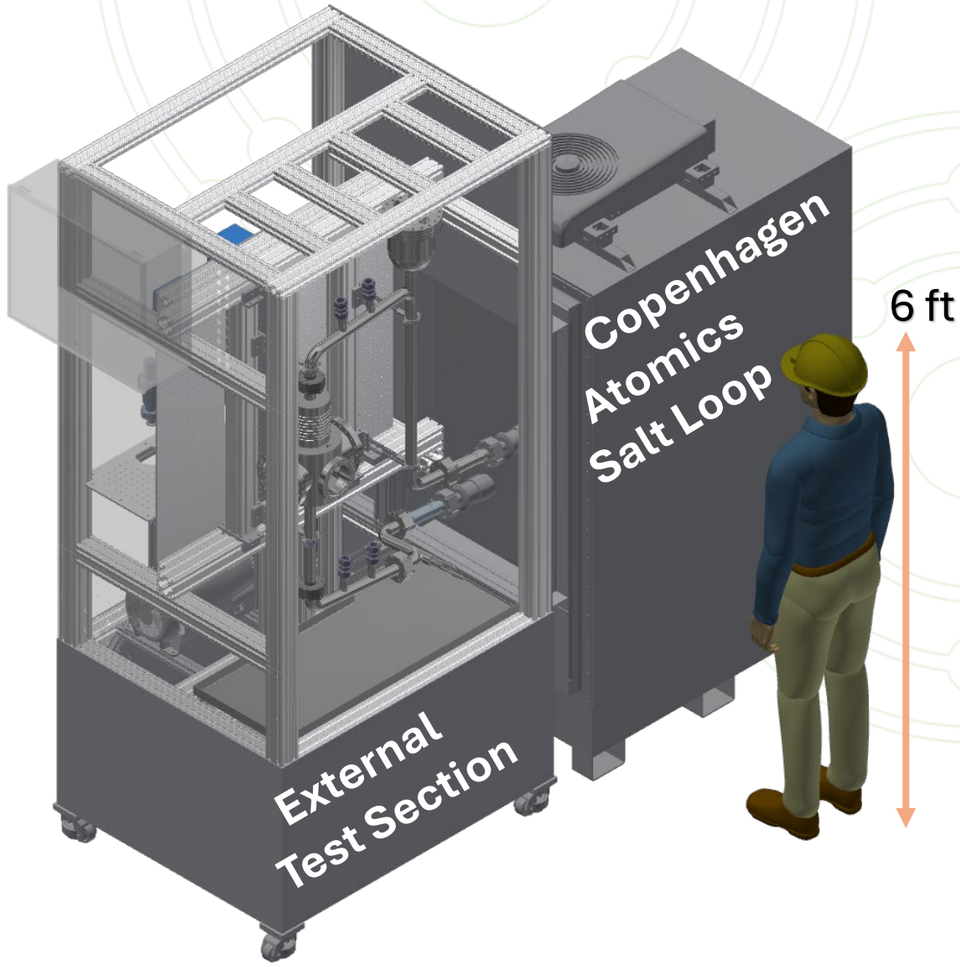
1. Production (neutrons + Li, Be, F)
2. *Speciation (TF vs. T_2)*
3. *Graphite*
4. Evolution into off-gas system
5. *Diffusion through materials*
6. Secondary system off-gas system
7. Onwards to detritiation/stack

Can we predict tritium transport in order to develop required control technology?



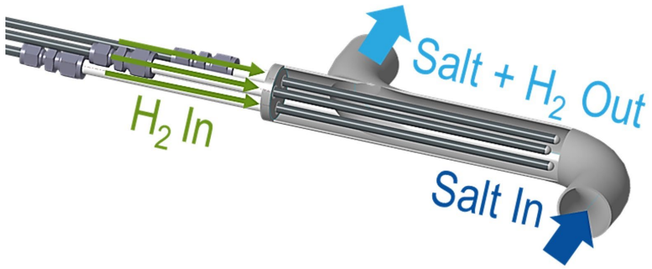
Molten Salt Tritium Transport Experiment

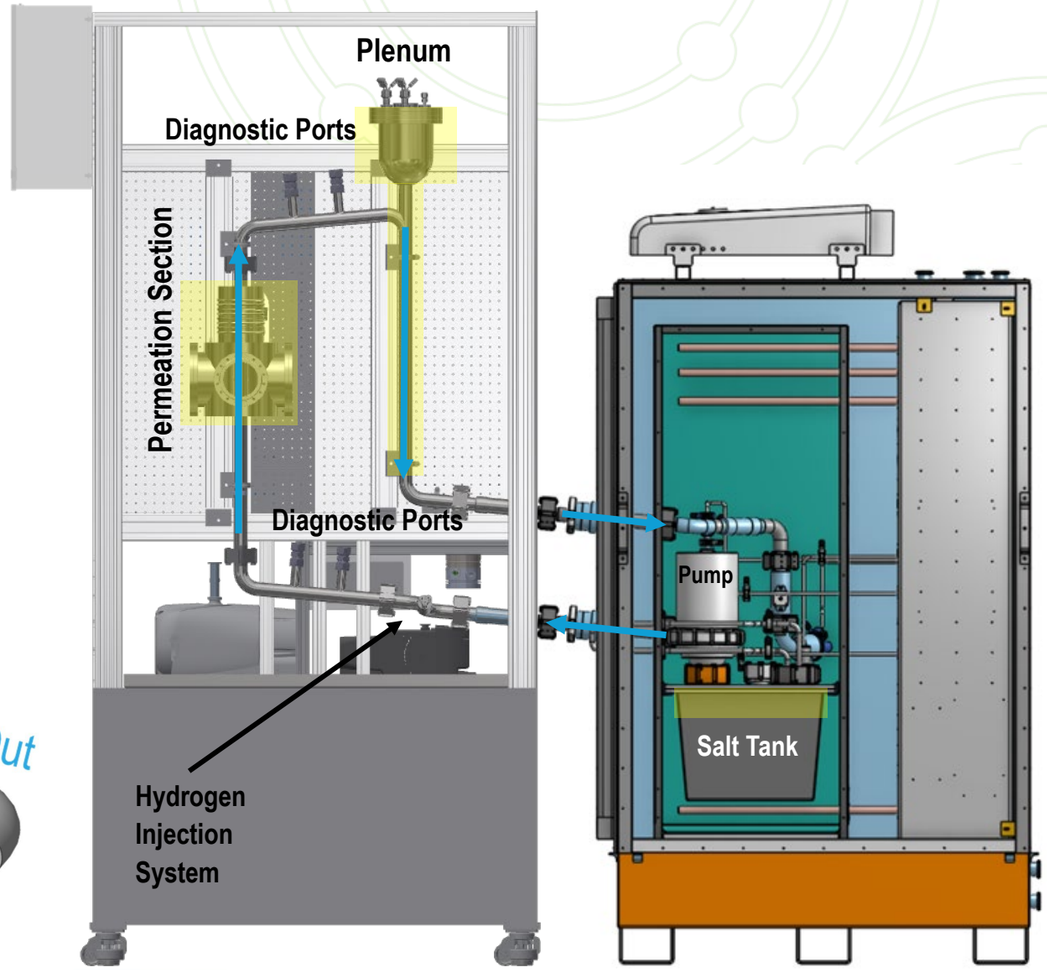
- *MSTTE is a semi-integral tritium transport experiment for flowing fluoride salt systems.*
- Location: Safety and Tritium Applied Research facility at Idaho National Laboratory
- **Objectives:**
  - **(1) Safety code validation data.**
  - **(2) Test stand for tritium control technology.**
- *Major Equipment:*
  - **Copenhagen Atomics Salt Loop**: salt tank, pump, flow meter, instrumentation and control
  - **External Test Section:** hydrogen injection, permeation, plenum, salt diagnostics, gas systems, controls, salt exchange tank, and *versatile*



MSTTE Transport Phenomena

- Permeation through structural materials: *permeation test section:*
  - **316 SS – 1 ½ in OD – 0.120 in WT – ASTM A269**
    - 15,000 < **Re**$_{FLiNaK}$ < 90,000
    - 7,000 < **Re**$_{FLiBe}$ < 40,000
- Evolution to off-gas: *plenum* and *salt tank*
  - Argon Cover Gas





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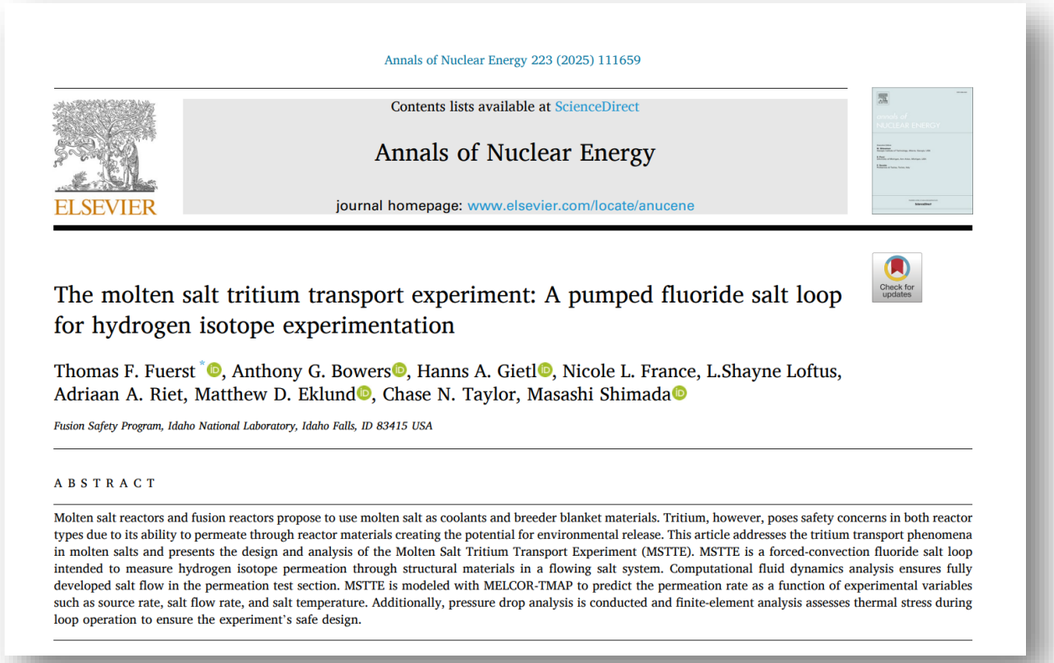
MSTTE Design Paper Published!



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The molten salt tritium transport experiment: A pumped fluoride salt loop for hydrogen isotope experimentation

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ABSTRACT

Molten salt reactors and fusion reactors propose to use molten salt as coolants and breeder blanket materials. Tritium, however, poses safety concerns in both reactor types due to its ability to permeate through reactor materials creating the potential for environmental release. This article addresses the tritium transport phenomena in molten salts and presents the design and analysis of the Molten Salt Tritium Transport Experiment (MSTTE). MSTTE is a forced-convection fluoride salt loop intended to measure hydrogen isotope permeation through structural materials in a flowing salt system. Computational fluid dynamics analysis ensures fully developed salt flow in the permeation test section. MSTTE is modeled with MELCOR-TMAP to predict the permeation rate as a function of experimental variables such as source rate, salt flow rate, and salt temperature. Additionally, pressure drop analysis is conducted and finite-element analysis assesses thermal stress during loop operation to ensure the experiment's safe design.

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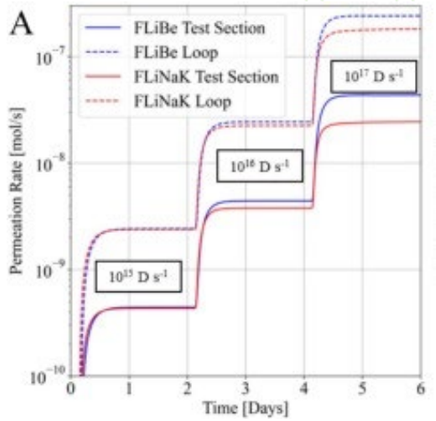

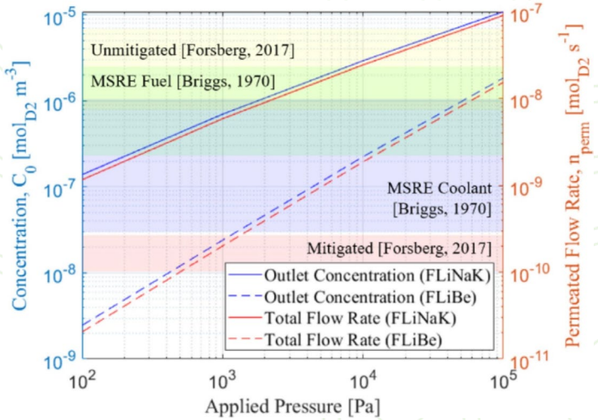

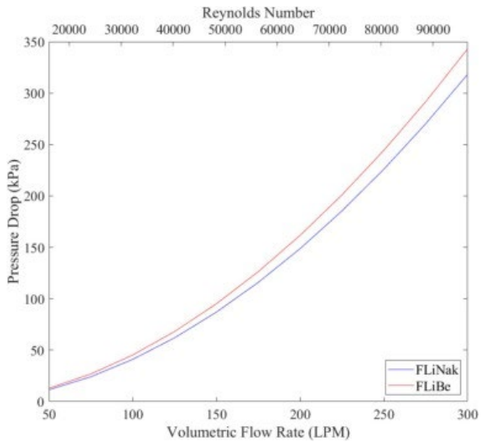

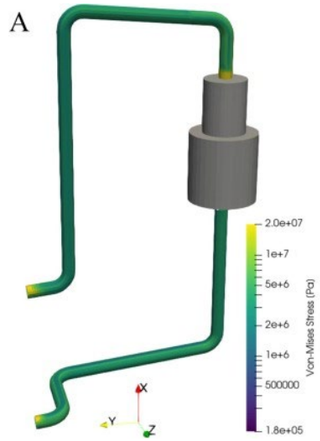

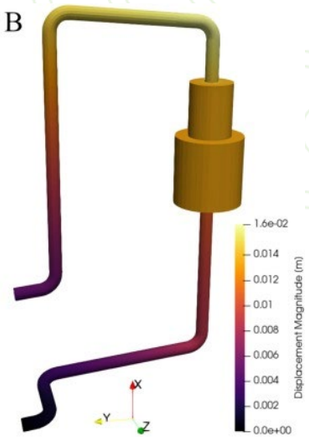

MSTTE CFD Paper Published!

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ANS

Check for updates

Computational Fluid Dynamics Analysis of the Molten Salt Tritium Transport Experiment Test Section

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Abstract — *Tritium, a radionuclide produced through neutron capture by lithium and other elements (beryllium and fluoride) in molten salts, presents unique challenges to radionuclide release. This is true for both fusion energy breeder blankets and molten salt fission reactors. The fundamental understanding of tritium transport is crucial to the safe design and operation of these reactors.*

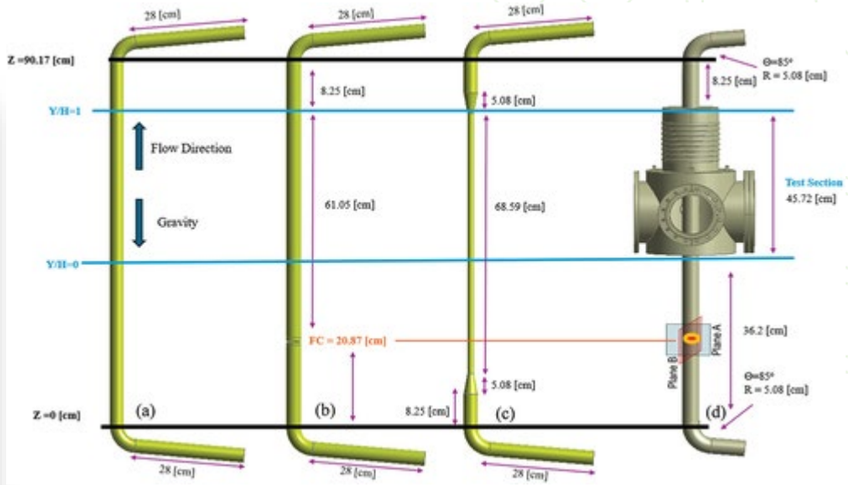
The Molten Salt Tritium Transport Experiment (MSTTE), currently under construction at Idaho National Laboratory, aims to investigate tritium transport phenomena using a forced-convection fluoride salt loop. This loop is designed to study various transport mechanisms, such as permeation through metals and gas-liquid interactions, and is intended to support future research on tritium extraction units.

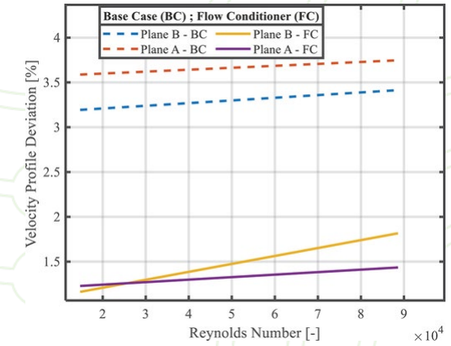
A critical aspect of the MSTTE loop design is ensuring a fully developed velocity profile before the fluid reaches the permeation test section where measurements are made. This study employs computational fluid dynamics to model the salt flow behavior within the MSTTE permeation test section. A realizable k-ε turbulent model with enhanced wall treatment is used to simulate the single-phase, vertical upward flow of molten salt FLiNaK under isothermal conditions.

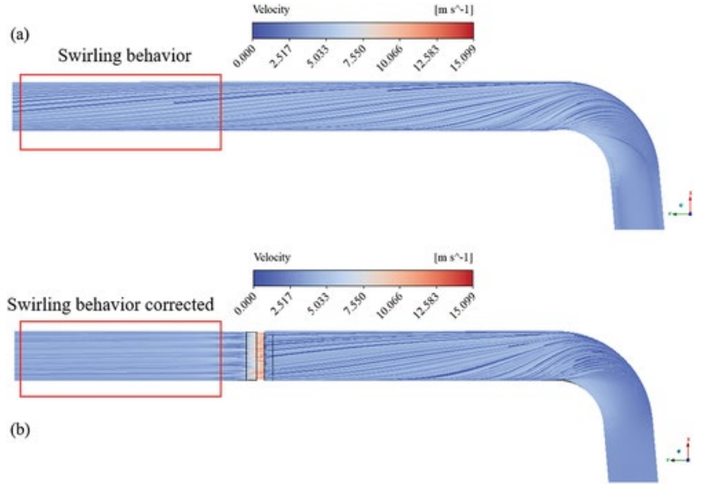
The simulation results indicated flow distortion and underdeveloped profiles at all planned flow rates within the test section due to the 85-deg sharp bend. To address this issue, a reduced diameter with a reducer and expander and a flow conditioner are investigated to achieve fully developed flow. The analysis showed that the flow conditioner successfully corrected the flow profile, achieving fully developed behavior at a flow rate of 50 liters per minute (LPM). This research enhances our understanding of flow dynamics in molten salt systems and contributes to optimizing tritium transport control technologies.

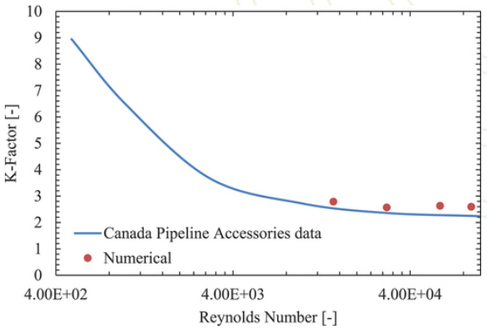
Keywords — *Molten salt, FLiNaK, computational fluid dynamics, turbulence, tritium transport.*

https://doi.org/10.1080/15361055.2025.2549608









Copenhagen Atomics Loop Status

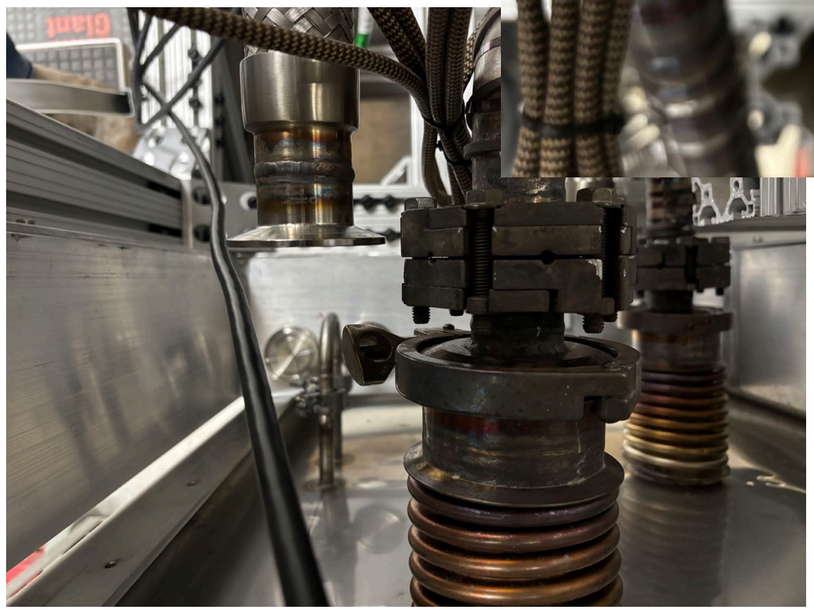
- Communication Established
- Facilities Setup
- Commissioning Scheduled for May 11-14.

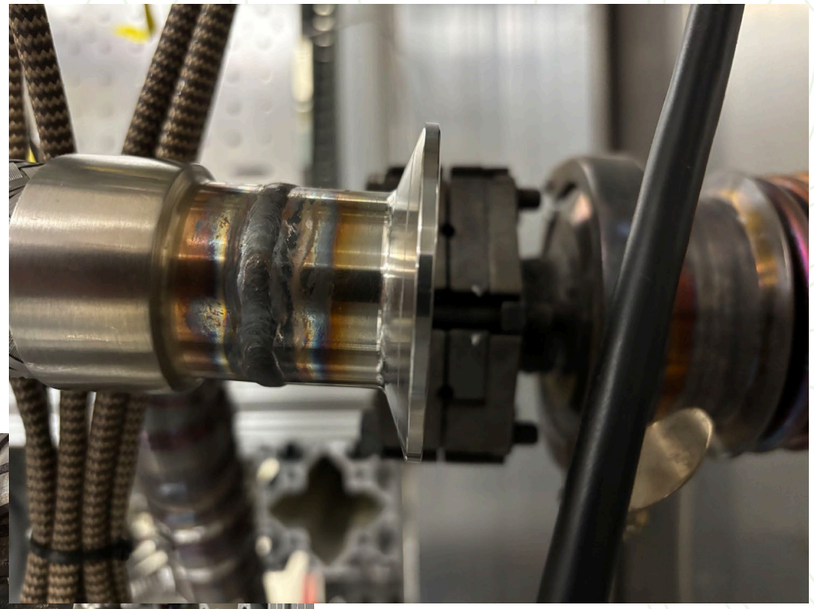
External Test Section Fabrication

- Fabrication delay of 6-months
- Fabricated Oct 2025
- Installed Nov 2025

External Test Section Aligned

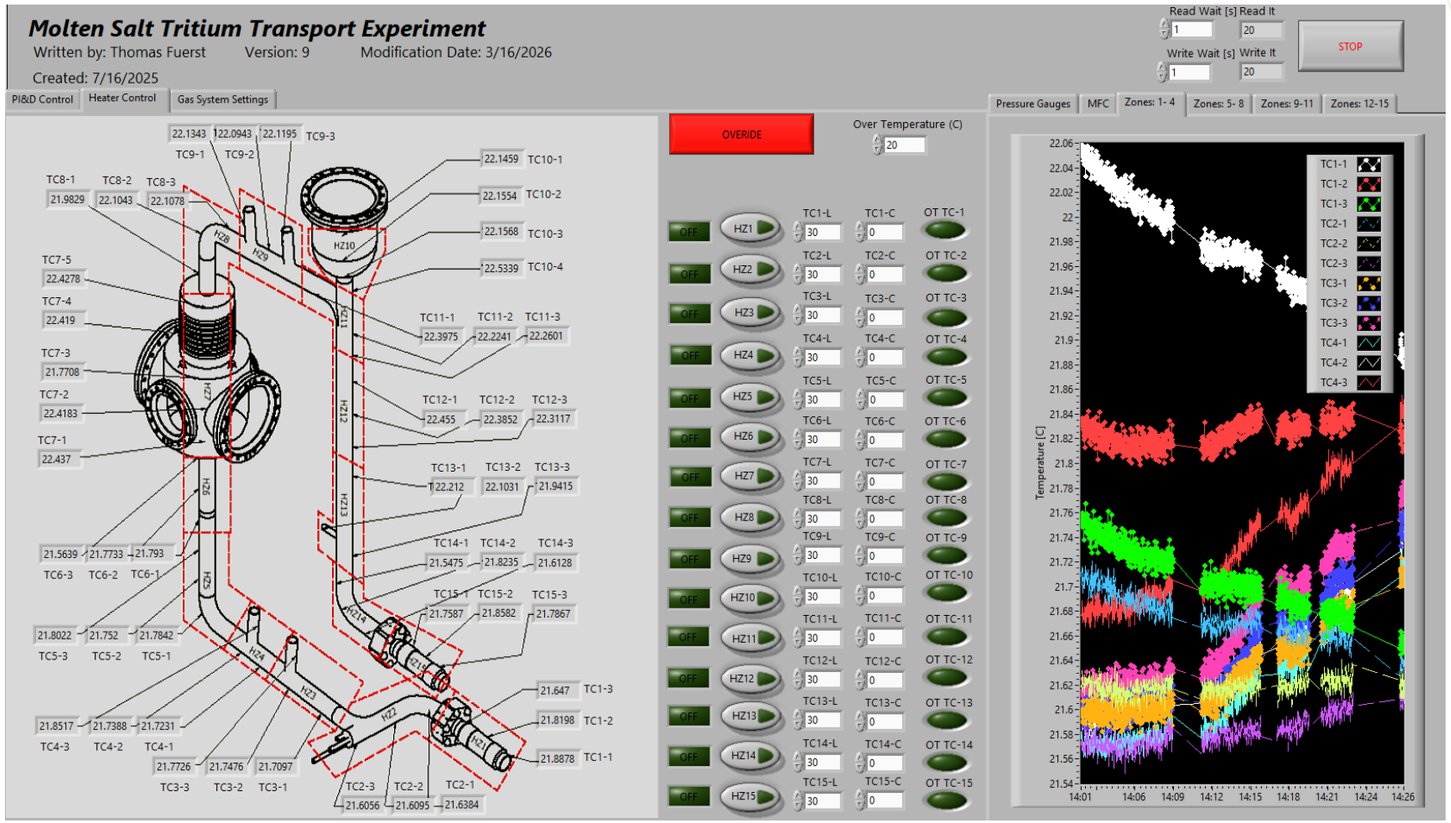
Top View



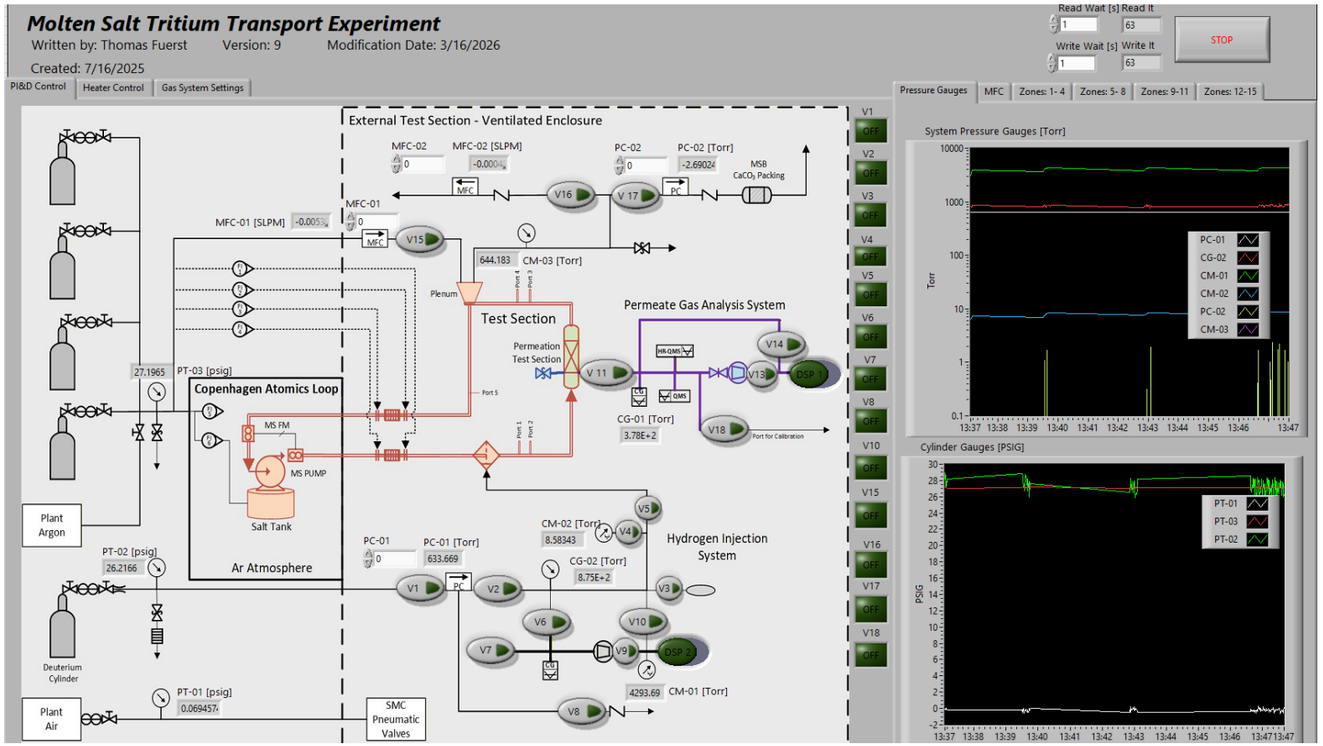


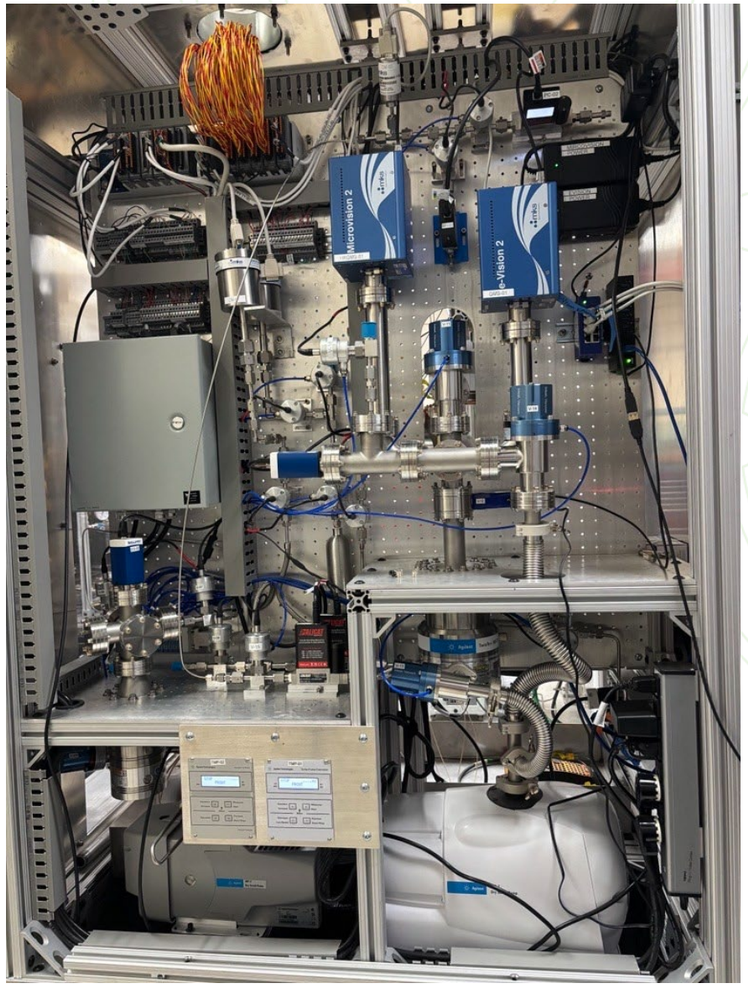
Side View

External Test Section Trace Heat



External Test Section Control System





Other Salt Work at the STAR Facility

FLiBe-Tritium Experiment for Solubility and Diffusivity Measurements

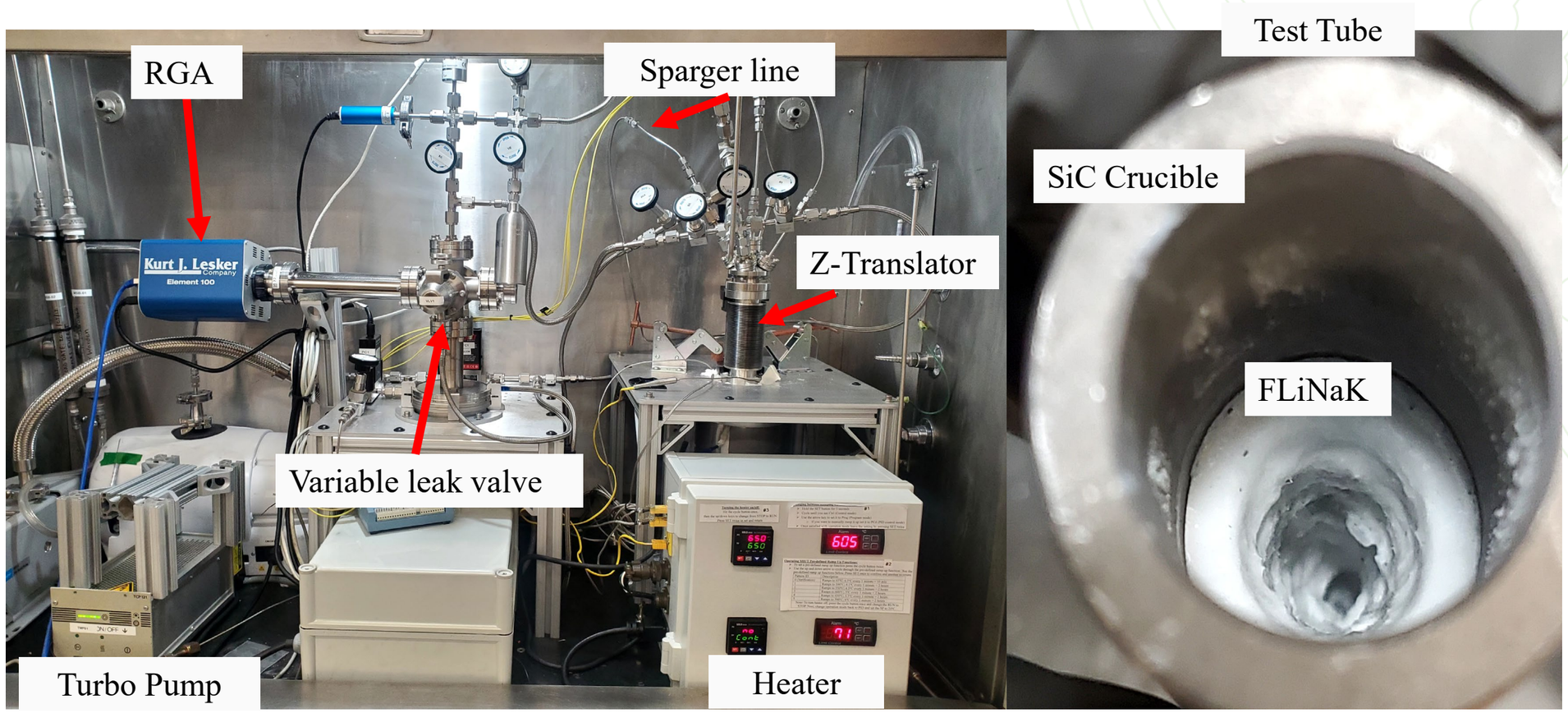
- The STAR facility began tritium solubility measurements in molten FLiBe (LiF-BeF_2) using 43.25 g of high-purity salt provided by Kairos Power (KP), marking INL's first FLiBe experiment in 20 years and the first use of the newly commissioned TGAP (Tritium Gas Absorption Permeation) system.
- Tritium control remains a key challenge for FHRs (Fluoride-salt-cooled High-temperature Reactors), where uncertainties in tritium generation, transport, solubility, and capture drive the need for improved data and mitigation strategies.
- Under ***Kairos's ARDP project*** INL is conducting scaled experiments at the STAR facility to validate tritium transport models and demonstrate tritium capture and extraction technologies across multiple KP-FHR relevant systems and release pathways.

Top Left: Newly commissioned TGAP (Tritium Gas Absorption Permeation) glovebox. Bottom Left: FLiBe (LiF–BeF_2) salt used in the first tritium solubility measurements. Right: TGAP permeation test section loaded with 43.25 g of FLiBe.

Contact: Masashi.Shimada@inl.gov

Other Salt Work at the STAR Facility

Experiment for testing hydrogen sensors in FLiNaK in operation

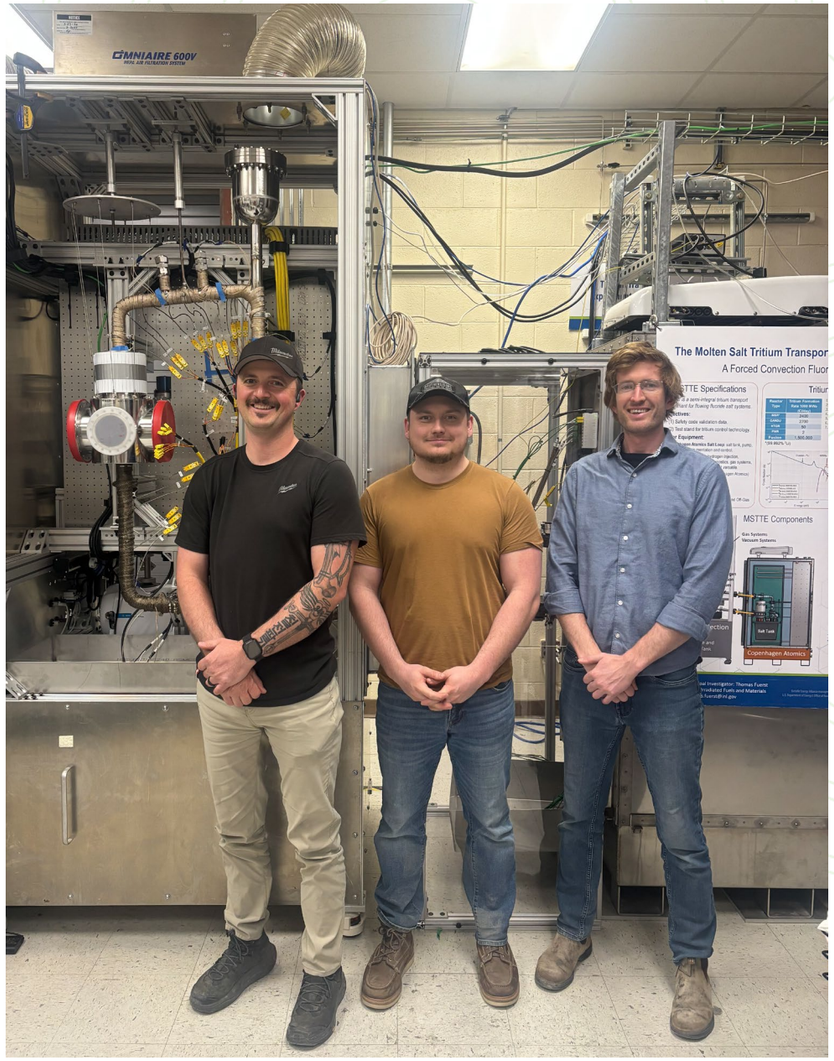


Summary

- Molten Salt Tritium Transport Experiment is versatile capability designed to provide tritium transport data and test control technology related to Molten Salt Reactors
- Will be running this summer!!

- Sensors and Diagnostics
- Modeling and Simulation

Connect with us!



Contributions/Collaborations

Safety and Tritium Applied Research Facility

- ***Joseph Redmond (MSU)***
- ***Tucker Warden (CSM)***
- ***Andrew Hutsell (VCU)***
- Chase Taylor
- Anthony Bowers
- Shayne Loftus
- Bob Pawelko
- Taylor Hill
- Casey White
- Travis Neuman
- Jacob Abbott
- Rowdie Shepherd
- Randel Paulsen
- Megan Laing
- Tony Wease
- Nikki France

Modeling and Simulation

- Ad Riet
- Matt Eklund
- Sam Walker

***Student Interns**

Thank you

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