U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Overview of the Molten Salt Reactor Program

Dr. Patricia PAVIET

November 29th, 2023

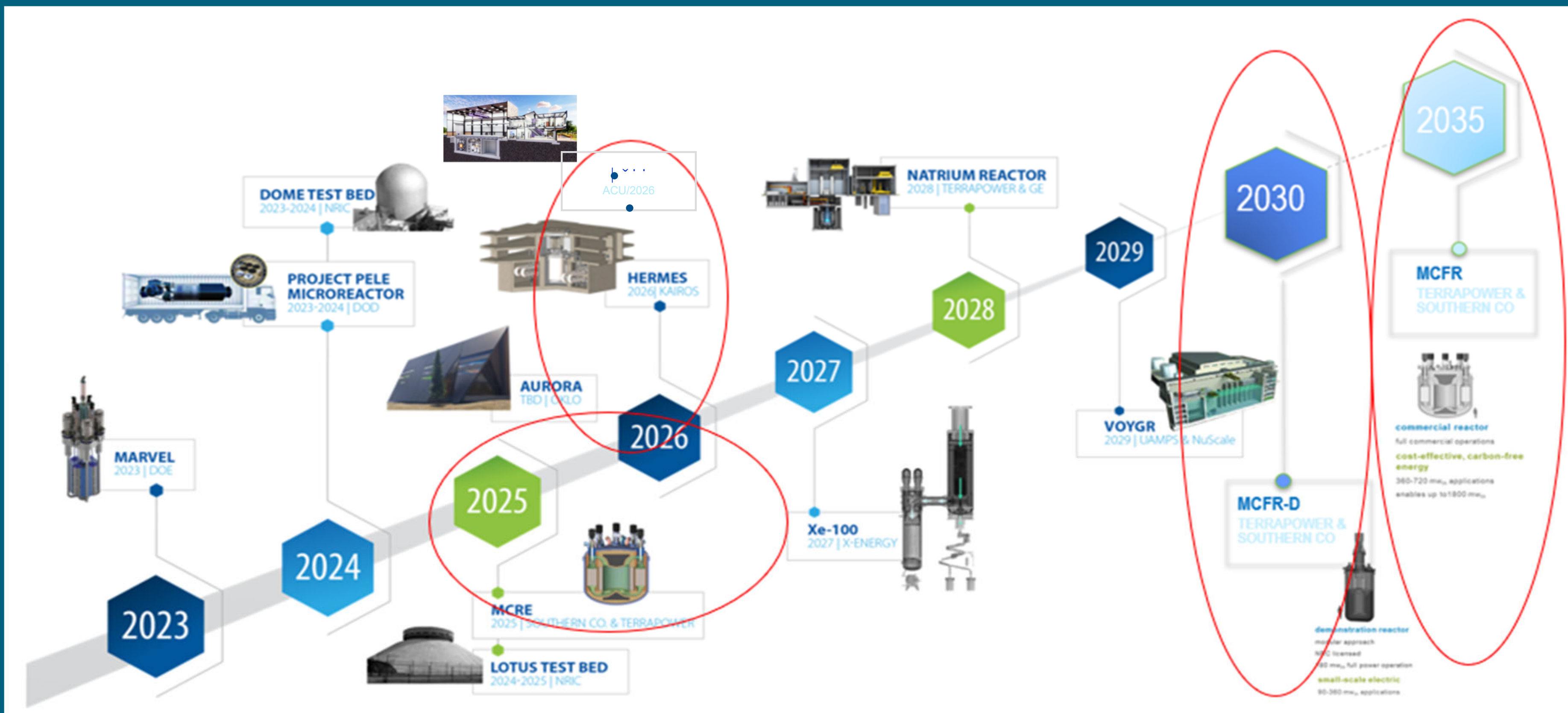
Avignon, France

SAMOSAFER final meeting

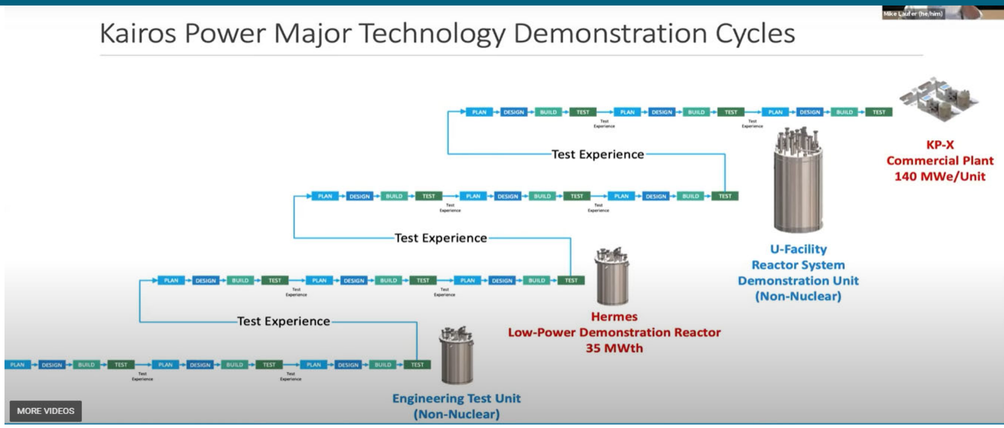
Molten Salt Reactor PROGRAM

PNNL-SA-192514

THIS IS A MOTIVATING TIME



Two Advanced Reactor Designs Received DOE-NE Risk Reduction Award

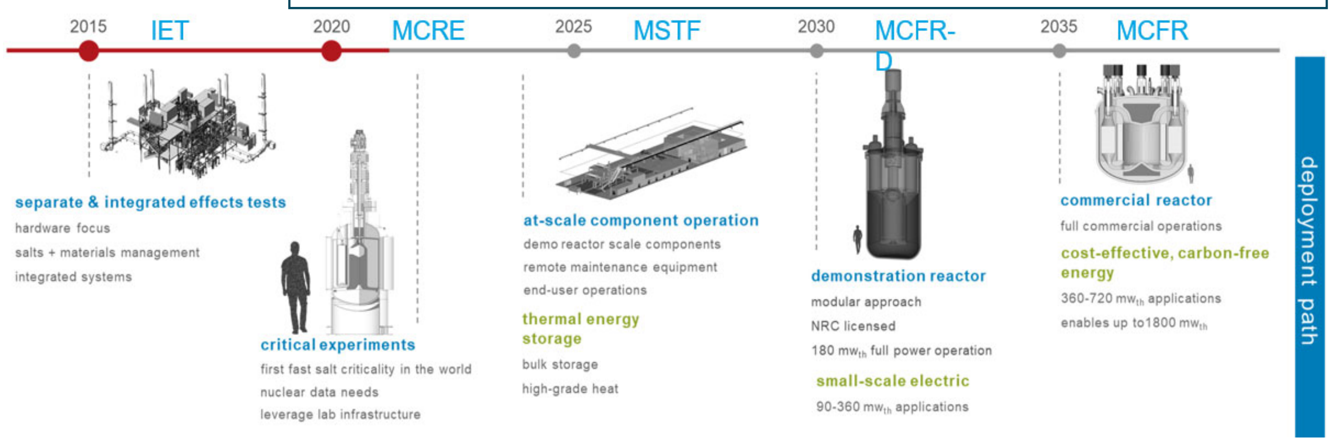


Hermes Reduced-Scale Test Reactor

Siting at the East Tennessee Technology Park in Oak Ridge, TN. Hermes is expected to lead to the development of Kairos Power's commercial-scale KP-FHR which uses TRISO fuel form combined with a low-pressure fluoride salt coolant. Total award for 7 years :$629 M (DOE share: $303M)

Southern Molten Chloride Reactor Experiment

Southern Company Services, based in Birmingham AL, is designing, constructing and operating the Molten Chloride Reactor Experiment to demonstrate the high-burnup capabilities of Southern' s liquid salt-fueled Molten Salt Reactor. Total award over 7 years: $113M (DOE Share: $90.4M)



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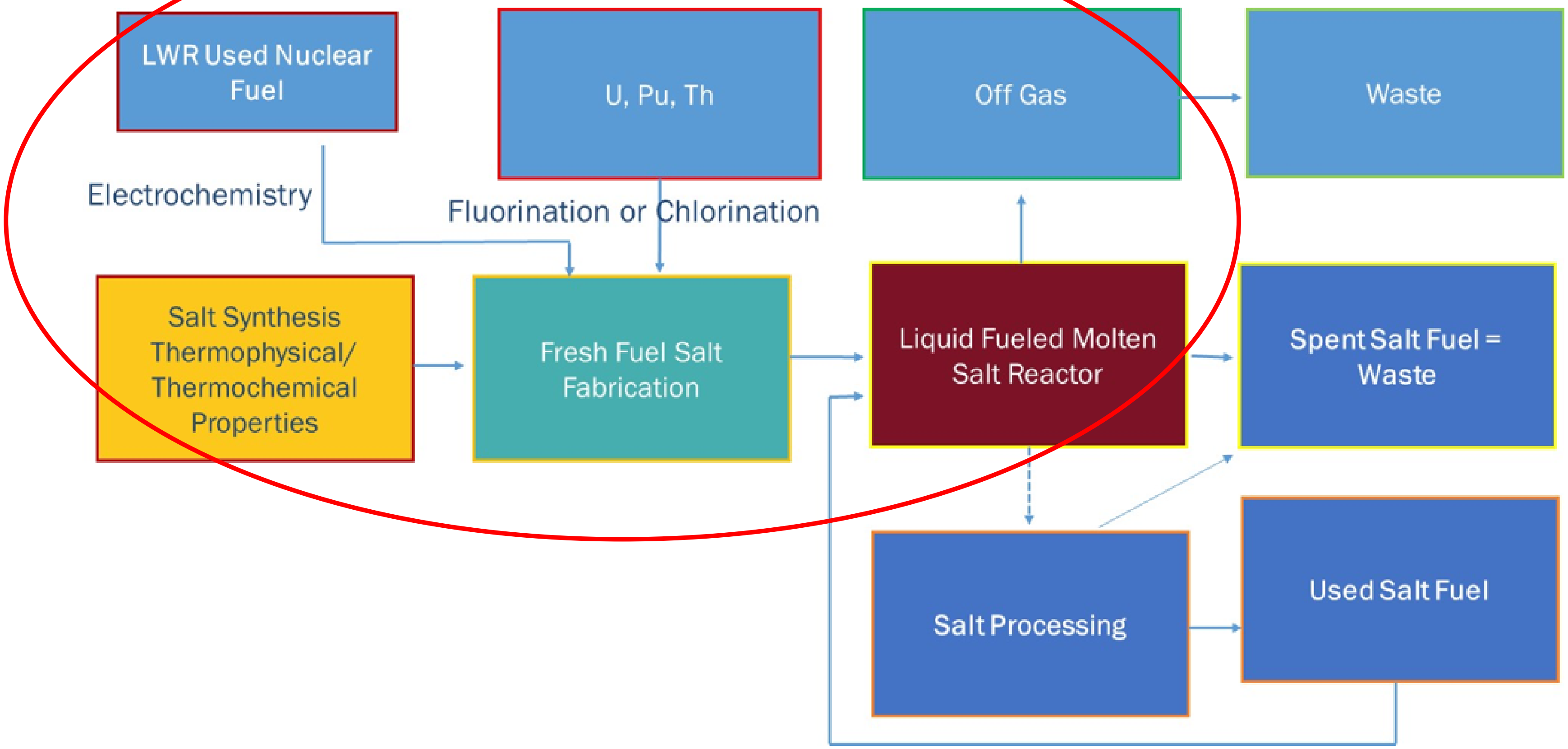
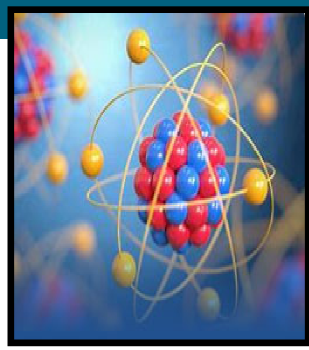
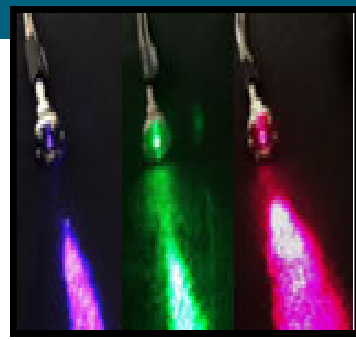
Liquid Fueled MSR – Generic Fuel Cycle

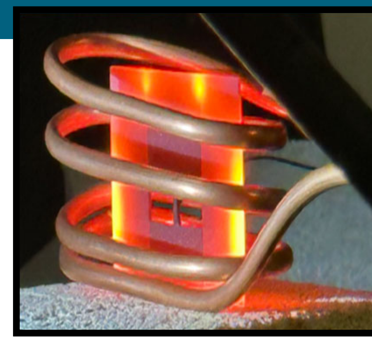


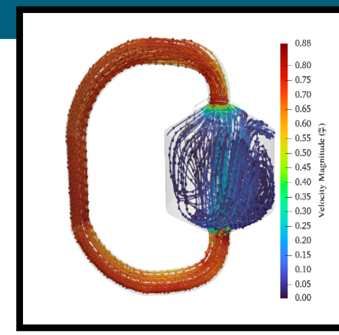
Mission

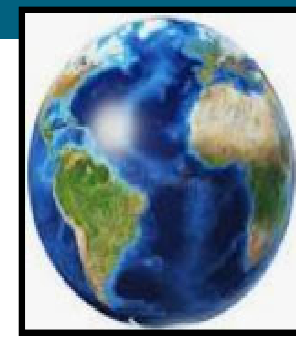
Vision: The DOE-NE MSR campaign serves as the hub for efficiently and effectively addressing, in partnership with other stakeholders, the technology challenges for MSRs to enter the commercial market.











Salt Chemistry

Determination of the Thermophysical and Thermochemical Properties of Molten Salts – Experimentally and Computationally

MSR Radioisotopes

Developing new technologies to separate radioisotopes of interest to the MSR community

Technology Development and Demonstration – Radionuclide Release

Radionuclide Release Monitoring, Sensors & Instrumentation, Liquid Salt Test Loop

Advanced Materials

Development of materials surveillance technology
Graphite/Salt Interaction
De-risk the transition from 316H to higher performance alloy 709

Mod & Sim
Resolve technical gaps related to mechanistic source term (MST) modeling and simulation tools.
Modeling radionuclide transport from a molten salt to different regions of an operating MSR plant

International Activities

GEN IV International Forum
IAEA International Atomic Energy Agency
NEA Nuclear Energy Agency

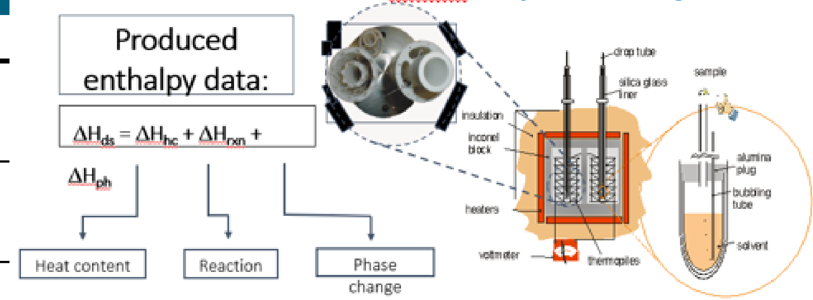
Mission: Develop the technological foundations to enable MSRs for safe and economical operations while maintaining a high level of proliferation resistance.

Argonne National Laboratory · INL Idaho National Laboratory · Oak Ridge National Laboratory · Los Alamos National Laboratory · Pacific Northwest National Laboratory · Sandia National Laboratories · U.S. Department of Energy | Office of Nuclear Energy

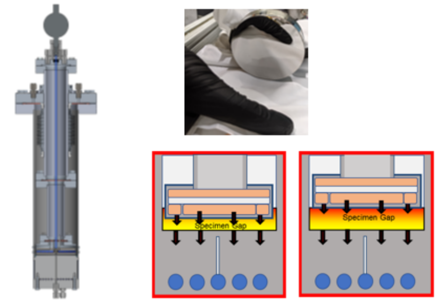
Thermophysical Properties of Molten Salts

Property					
Phase Transition Temperatures	Differential Scanning Calorimeter				
Heat Capacity	DSC (Ratio and Modulated techniques	Drop Calorimeter			
Solubility of FPs	Saturation Method	Press. Drop Method			
Vapor Pressure	Transpiration	TGA/DTA			
Density / Volume Expansion Coefficients	Hydrostatic Method	X-ray dilatometer	Neutron Radiography	Pycnometer	Push Rod Dilatometry
Viscosity	Rotating Spindle	X-ray Falling Ball	Dynamic Neutron Radiography	Rheometer	
Thermal Conductivity/ Diffusivity	Laser Flash Analysis	Variable Gap			
Emissivity	Pyrometer				
Surface Tension	Hydrostatic Method	Contact Angle			
Enthalpy of Fusion	DSC	Drop Calorimeter			
Melting Point	DSC	Thermomechanical Analysis			

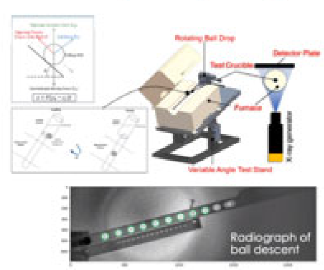
Twin Calvet Drop Calorimetry



Thermal Conductivity System



Viscosity: X-Ray Falling Ball



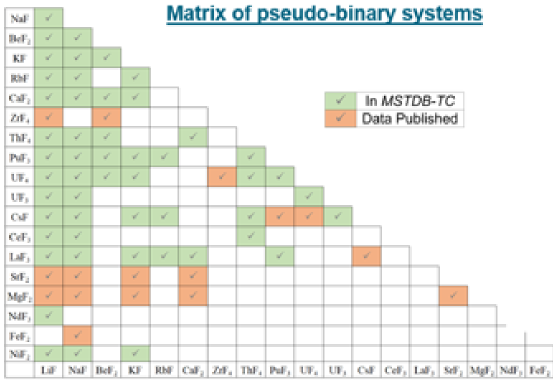
Molten Salt Thermal Properties Database

MSTDB-TC Fluoride Systems Content: Be-Ca-Ce-Cs-K-La-Li-Na-Ni-Nd-Pu-Rb-Th-U-F

Pseudo-ternary and higher order systems

- BeF2-LiF-NaF
- BeF2-LiF-PuF3
- BeF2-LiF-ThF4
- BeF2-LiF-UF4
- BeF2-NaF-PuF3
- BeF2-NaF-ThF4
- BeF2-NaF-UF4
- BeF2-ThF4-UF4
- CaF2-KF-NaF
- CaF2-LaF3-LiF
- CaF2-LaF3-NaF
- CaF2-LiF-KF
- CaF2-LiF-ThF4
- CeF3-LiF-ThF4
- CsF-LaF3-LiF
- CsF-LiF-KF
- CsF-LiF-PuF3
- LaF3-LiF-NaF
- LiF-KF-NaF
- LiF-KF-RbF
- LiF-NaF-CeF3
- LiF-NaF-PuF3
- LiF-NaF-RbF
- LiF-NaF-ThF4
- LiF-NaF-UF4
- LiF-PuF3-ThF4
- LiF-PuF3-UF4
- LiF-ThF4-CaF2
- LiF-NaF-BeF2-ThF4-PuF3-UF4
- LiF-NaF-BeF2-KF-PuF3-UF4
- LiF-NaF-KF-

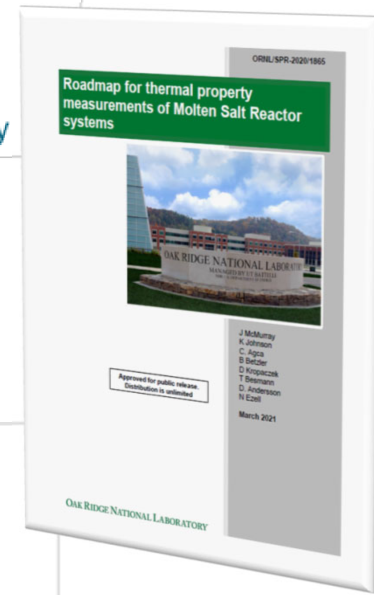
Matrix of pseudo-binary systems



MSDTB- TP for Fluoride Salts

KF	B						
LiF	A, B, D	A, B, C, D					
NaF	A, B	A, B, C	A, B, C, D				
ThF4		A, B	A, B, D	A, B			
UF3							
UF4		A, B	A, B	A, B			
ZrF4			A	A, B, D			
	BeF2	KF	LiF	NaF	ThF4	UF3	UF4

Key
A: Density
B: Viscosity
C: Thermal conductivity
D: Heat capacity

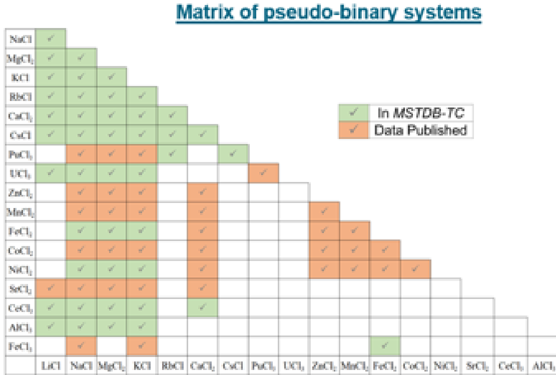


MSTDB-TC Chloride Systems Content: Al-Ca-Ce-Cs-Fe-K-Li-Mg-Na-Ni-Pu-Rb-U-Cl

Pseudo-ternary and higher order systems

- CeCl3-KCl-LiCl
- CeCl3-KCl-MgCl2
- CeCl3-KCl-NaCl
- CeCl3-LiCl-MgCl2
- KCl-LiCl-UCl3
- LiCl-NaCl-MgCl2-KCl-PuCl3-UCl3
- LiCl-NaCl-MgCl2-KCl-CeCl3

Matrix of pseudo-binary systems



MSDTB- TP for Chloride Salts

KCl	A, B								
LiCl	A	A, B, D							
MgCl2		A, B, D	A, B						
NaCl	A, B	A, B, D	A, D	A, B					
PuCl3									
ThCl4		A			A				
UCl3		A, B	A		A, B				
UCl4		A, B	A	A	A, B				
ZrCl4		A							
	AlCl3	KCl	LiCl	MgCl2	NaCl	PuCl3	ThCl4	UCl3	UCl4

Key
A: Density
B: Viscosity
C: Thermal conductivity
D: Heat capacity

NERGY

MSTDB-TP Expansion Efforts

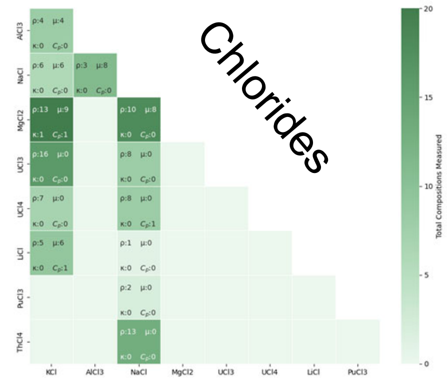
Available @ mstdb.ornl.gov

- **MSTDB-TP has undergone 2 major expansion efforts:**
  - 1.0 to 2.0 (68 entries to 273 entries)
  - 2.0 to 2.1 (273 entries to 448 entries)
- **These expansions incorporate replacements of old datasets as well**
  - E.g. recent literature has suggested UCl3 and relevant mixtures has a lower thermal expansion coefficient than previously understood
- **MSTDB-TP is being expanded for later releases**
  - This includes new pseudo-binary and higher order system data that exist in literature and need evaluated
  - MSTDB-TP will also include new data of new systems as it is published
- **MSTDB-TP is intending on including surface tension data in the future**
  - There is a significant body of literature already evaluated and tabulated

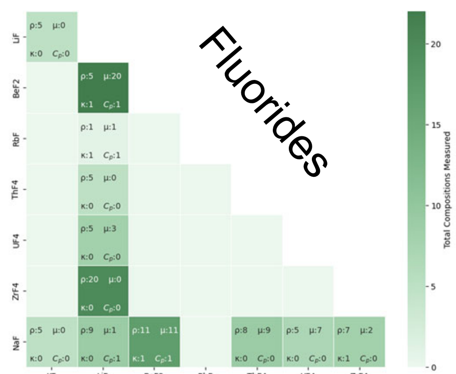
Pure:

Salt	Measurements			
	ρ	μ	κ	c_p
AlCl3	1	1	0	1
BeCl2	1	0	0	0
BeF2	1	1	1	1
CaCl2	1	1	1	1
CaF2	1	1	1	1
GdCl3	1	1	0	0
GdF3	0	0	0	0
KCl	1	1	1	1
KF	1	1	1	1
LaCl3	1	1	0	0
LaF3	1	0	0	1
LiCl	1	1	1	1
LiF	1	1	1	1
MgCl2	1	1	1	1
MgF2	1	1	1	0
NaCl	1	1	1	1
NaF	1	1	1	1
NdCl3	1	1	0	0
NdF3	0	0	0	1
NpCl3	0	0	0	0
NpF3	0	0	0	0
PuCl3	0	0	0	1
PuF3	0	0	0	1
SrCl2	1	1	1	0
SrF2	1	1	1	0
ThCl4	1	0	0	0
ThF4	1	0	0	0
UCl3	1	0	0	1
UCl4	1	0	0	0
UF3	0	0	0	1
UF4	1	1	0	1
ZrCl4	1	1	0	0
ZrF4	1	0	0	0

Binary:



Living database



Ternary:

Salt	Measurements			
	ρ	μ	κ	c_p
KCl-LiCl-NaCl	4	0	0	0
LiCl-NaCl-AlCl3	10	10	0	0
LiF-BeF2-ThF4	3	2	0	0
LiF-BeF2-ZrF4	1	0	0	0
LiF-NaF-BeF2	1	1	0	0
LiF-NaF-KF	1	1	1	1
LiF-BeF2-UF4	36	36	0	0
NaF-BeF2-UF4	79	71	0	0
NaF-KF-BeF2	1	1	0	0
NaF-KF-MgCl2	1	0	0	0
NaF-KF-UF4	1	1	1	1
NaF-KF-ZrF4	1	1	0	0
NaF-LiF-BeF2	4	4	0	0
NaF-LiF-ZrF4	10	1	0	1
NaF-ZrF4-UF4	5	3	2	3
RbF-ZrF4-UF4	2	2	1	1

Quaternary:

Salt	Measurements			
	ρ	μ	κ	c_p
LiF-BeF2-UF4-ThF4	1	1	0	0
LiF-BeF2-ZrF4-UF4	1	0	0	0
NaF-LiF-BeF2-UF4	1	1	0	0
NaF-LiF-KF-UF4	2	2	1	1
NaF-LiF-ZrF4-UF4	1	1	0	1

Courtesy Dianne Ezell and Tony Birri, ORNL

MSTDB-TC Ver. 3 Released in May 2023

- **Significant increase in content plus a number of systems revised/updated**
- **New values/models generated from our measurements together with reported properties**

New additions for Ver. 3 over Ver. 2 in **bold**

	Fluorides	**Chloride**	**Iodides**
Alkali metals	LiF, NaF, KF, RbF, CsF	LiCl, NaCl, KCl, RbCl, CsCl	LiI, NaI, KI, CsI
Alkaline earth metal	BeF_2, CaF_2, **SrF_2, BaF_2**	$MgCl_2$, $CaCl_2$	BeI_2, MgI_2
Transition metals	NiF_2, **CrF_3**	$CrCl_2$, $CrCl_3$, $FeCl_2$, $FeCl_3$, $NiCl_2$	-
Other metals	**YF_3, ZrF_4**	$AlCl_3$	-
Lanthanides	LaF_3, CeF_3, NdF_3, **PrF_3**	$CeCl_3$, **$LaCl_3$**	-
Actinides	ThF_4,UF_3, UF_4	UCl_3, UCl_4, **$PuCl_3$**	UI_3, UI_4
Pseudo-binary	53 systems (v.2) **70 systems (v.3)**	60 systems (v.2) **70 systems (v.3)**	10 systems (v.2) **30 systems (v.3)**
Pseudo-ternary	25 systems (v.2) **30 systems (v.3)**	22 systems (v.2) **27 systems (v.3)**	None (v.2) **15 systems (v.3)**

New Content

BeF_2 and ZrF_4

- LiF-BeF_2
- NaF-BeF_2
- KF-BeF_2
- CsF-BeF_2
- BeF_2-UF_4
- BeF_2-ThF_4
- BeF_2-ZrF_4
- LiF-ZrF_4
- CsF-ZrF_4

Reciprocal

- LiF-CsI
- LiF-KI
- LiF-NaI
- KI-CsF
- KF-CsI
- NaF-KI
- KF-NaI
- NaF-CsI

Iodides

- KI-CsI
- NaI-LiI
- LiI-KI
- NaI-KI
- NaI-CsI
- LiI-CsI

Higher Order

- LiF-LiI-CsI
- LiF-LiI-NaI
- LiF-LiI-KI
- LiF-CsF-CsI
- LiF-KF-KI
- LiF-NaF-NaI
- LiF-NaF-NaI
- NaI-NaF-KF
- KF-KI-NaF
- NaF-NaI-KF
- LiF-NaF-CsI
- LiF-KF-CsI
- LiF-KF-CsI
- NaF-KF-CsI
- LiF-KF-CsF-CsI
- CsI-LiF-NaF-KF
- $MgCl_2$-NaCl-$UCl_{3,4}$
- $MgCl_2$-KCl-$UCl_{3,4}$

Courtesy Prof. Ted Besmann, USC

MSTDB-TC Thermochemical (Experimental) Data Needs for the MSR Program

- **Selective data needs for current system assessments**
  - **LiF-NiF_2** system: Need enthalpy of mixing, Cp for intermediate compound
  - **NaF-NiF_2** system: Need enthalpy of mixing, Cp for intermediate compounds
  - **KF--NiF_2** system: Need enthalpy of mixing, Cp for intermediate compounds
  - **$PuCl_3$** systems with **LiCl, NaCl, KCl, $MgCl_2$**: MSTDB-TC improved with phase equilibria, enthalpies of mixing, Cp for the intermediate compounds
- **System information and/or assessments needed for new reciprocal salt models**
  - **UI-$UF_{3,4}$**
  - **UI-$UCl_{3,4}$**
  - **BeI-BeF_2**
- **Phase Equilibria for Be-containing Systems Requiring Experimental Determination**
  - **BeF_2-CrF_2, BeF_2-FeF_2**, and **BeF_2-NiF_2**
  - **LiF-BeF_2-CrF_2, LiF-BeF_2-FeF_2**, and **LiF-BeF_2-NiF_2**

Courtesy Prof. Ted Besmann, USC
MSR Campaign Review Meeting 2-4 May 2023

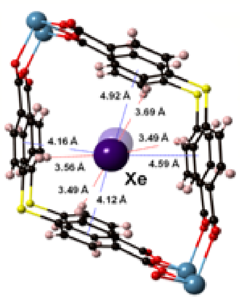
Technology Development and Demonstration

Multi-faceted approach to investigation of technologies for MSR off-gas systems

Component testing

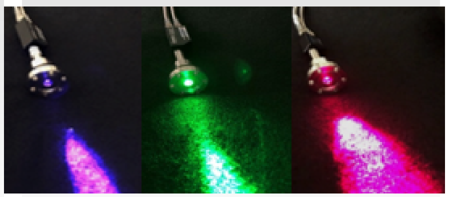
- Large Scale Test Loop

- Xe/Kr separation in MOF



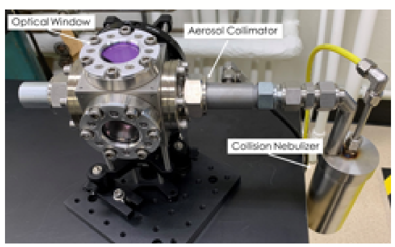
Radionuclide identification/speciation

Raman



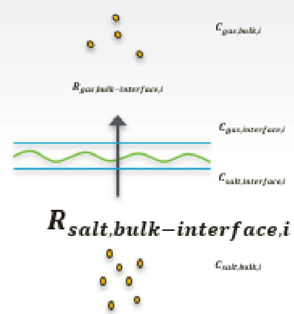
405 nm 532 nm 671

LIBS



Source term modeling

- Gas-liquid interface
- Provides source term to off-gas

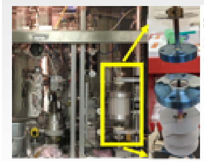


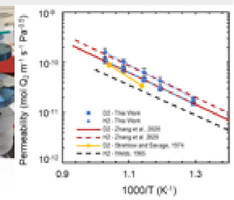
Removal Rate

$$\frac{d(m_i)}{dt} = kA(C_{gas,interface,i} - C_{gas,bulk,i})$$

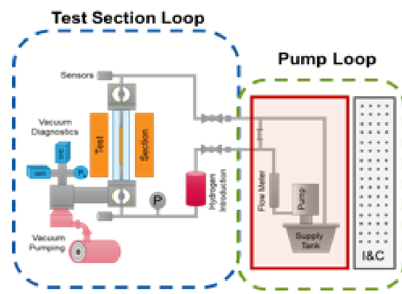
Tritium permeation

- Hydrogen isotope permeability in Hastelloy N





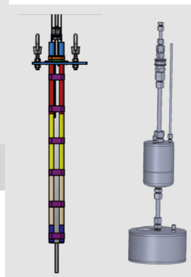
- Tritium transport salt loop



Sensors/ salt chemistry

- Salt composition
- Redox state
- Salt level

Particulate Monitoring



Automated Salt Sampling

Monitoring of Molten Salt Systems

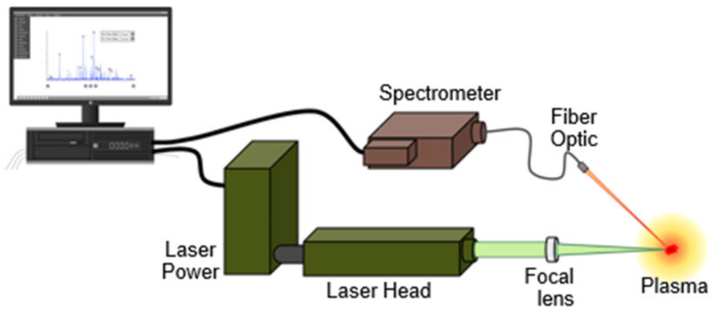
Measurement Type	Sensor Type
Salt Composition (species concentrations)	Salt Sampler Electrochemical Raman UV Vis LIBS
Isotopics Radiation	Gamma spectroscopy Alpha spectroscopy
Isotopic Ratio	LIBS QQQ-ICPMS
Pressure	Pressure Transducer (NaK filled etc...)
Flow Rate	Thermal flow meter Ultrasonic flow meter Activation flow meter
Corrosion/Structural materials	Magnetic susceptibility Meter Ultrasound UV Vis/Raman (Cr, Fe, Ni)
Temperature	Thermocouples Fiber optics

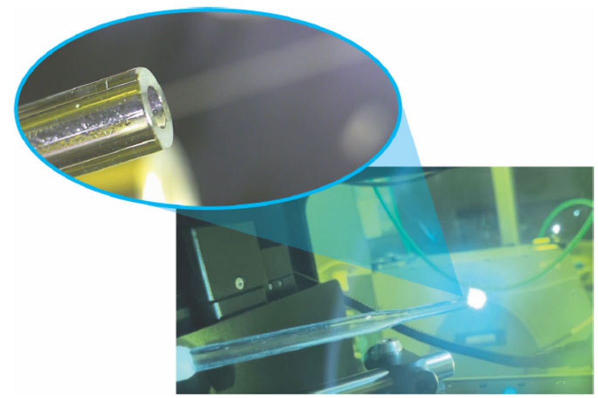
Measurement Type	Sensor Type
Salt Redox Potential	Dynamic reference electrode Optical Spectroscopy (UV Vis, raman Thermodynamic reference electrodes)
Volume (Liquid/Level)	Tracer dilution Ultrasound Contact Depth sensor Radar
Particulate Monitoring	Electrical Resistance Tomography Ultrasonics
Off gas monitoring	Optical LIBS
Under salt viewing	Ultrasound Video
Vibrations/accelerations	accelerometers
Valve position monitoring	Position monitoring
In reactor video monitoring	Camera (CCD, CMOS…)

Adapted from N. Hoyt presentation, “Fuel Salt Characterization and Qualification”
MSR fuel Cycle Workshop 19-21 SEP 2023, ANL

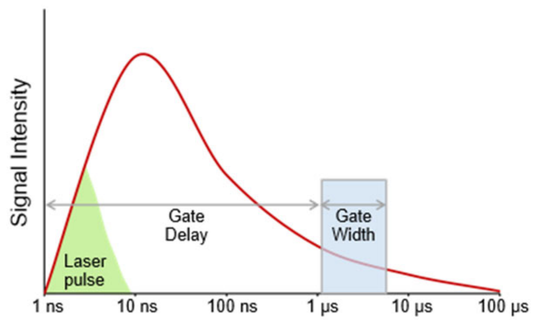
Laser-induced breakdown spectroscopy (LIBS) can provide an elemental fingerprint in real-time

A high energy density laser pulse ablates a sample to form a micro plasma at T~10,000 K

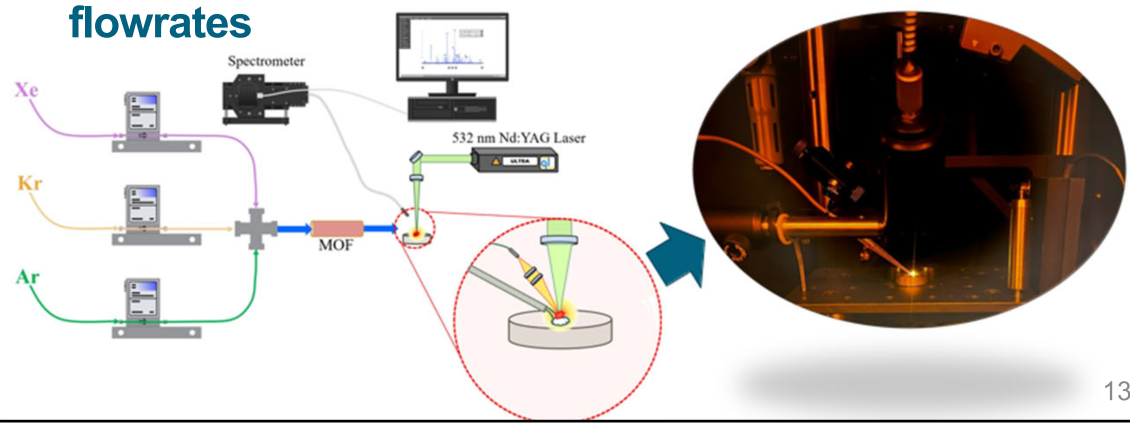




The plasma light is collected with a gated spectrometer to measure an elemental signature



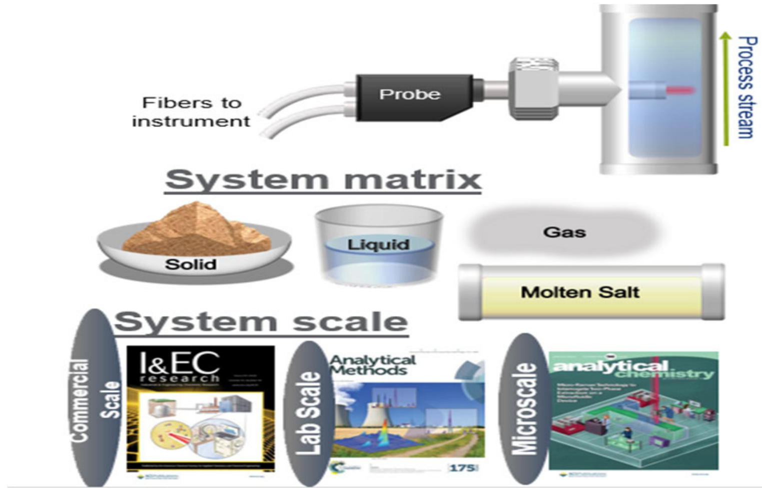
New LIBS setup needed to facilitate MOF size and flowrates



Courtesy Hunter Andrews, ORNL

In- On-line Monitoring – Molecular Approach

Sensors directly in or on the process
In situ and real-time analysis of a given process or system



Optical Spectroscopy:

Provides chemical information
Highly mature technology
Simplistic integration
Versatile

Fundamental characterization

Efficient process design

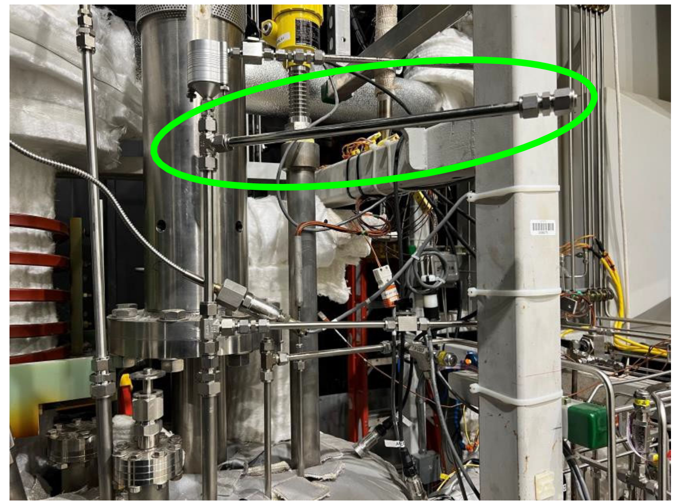
Safe and cost-effective deployment

Courtesy Amanda Lines and Sam Bryan, PNNL

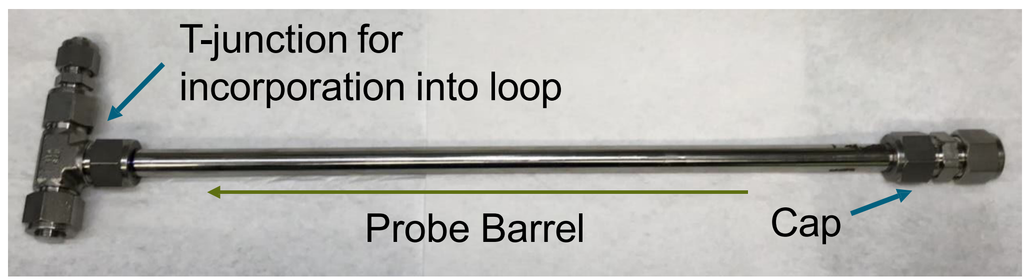
Testing Probe Materials in LSTL

Before incorporation into salt loop

- **Salt loop testing**
  - Probe barrel swaged into loop
  - No visual degradation after testing



After incorporation into salt loop

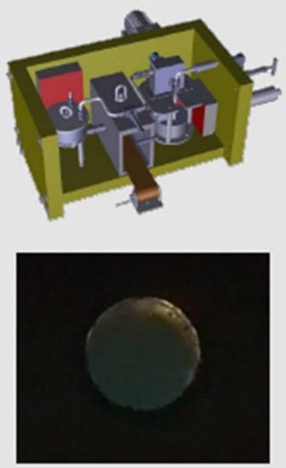


Courtesy Amanda Lines and Sam Bryan, PNNL

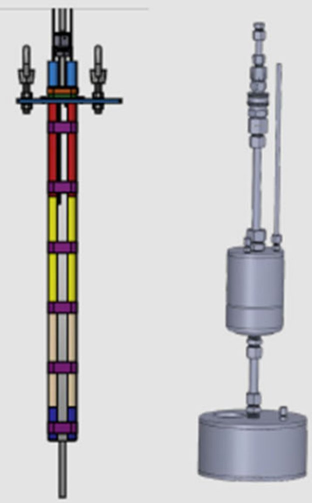
Online monitoring of molten salt chemistry

Argonne has demonstrated several monitoring technologies with sensors development for salt composition, redox state, salt level, etc.

Electrochemical Monitoring of Salt Composition



Windowless Optical Monitoring of Composition



Automated Salt Sampling

Particulate Monitoring

Courtesy N. Hoyt, ANL

What is the Liquid Salt Test Loop? (LSTL) at ORNL

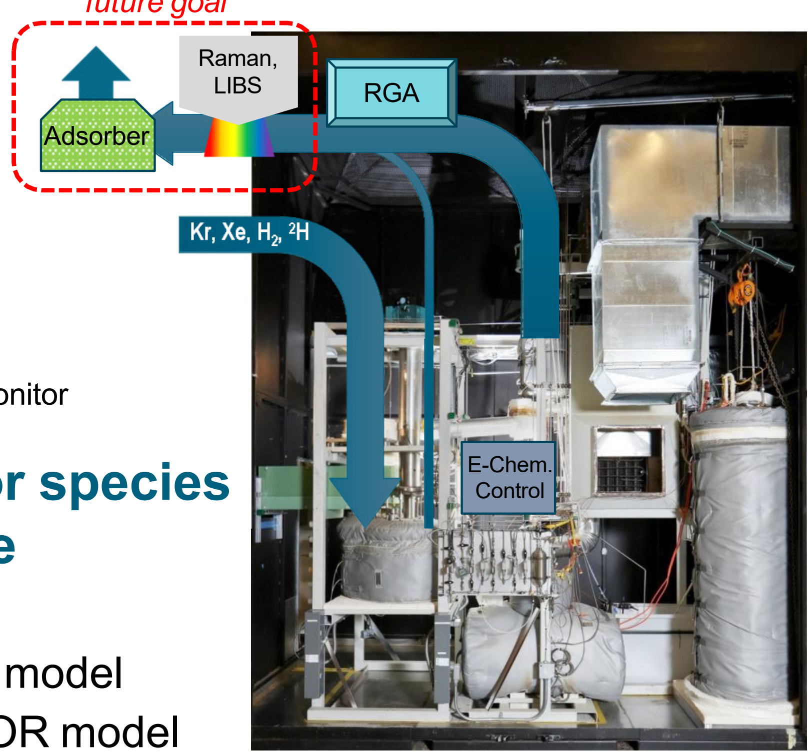
Largest F salt loop in DOE

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

- PNNL Raman probe exposure
- ANL E-Chem sensors operation
- ORNL gas-space particle capture
- Thermal hydraulic system performance

- Specie transport test
  - He, 4% H_2, and Kr injection
  - Monitoring of off-gas

- NEUP Virginia Tech: flow meter
- Small business: system PLC monitor



Data output for species transport code modelling:

- ORNL SAM model
- SNL MELCOR model

Courtesy Robb, ORNL

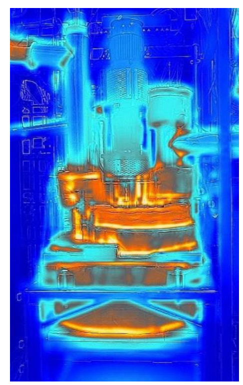
Facility to Alleviate Salt Technology Risks (FASTR)

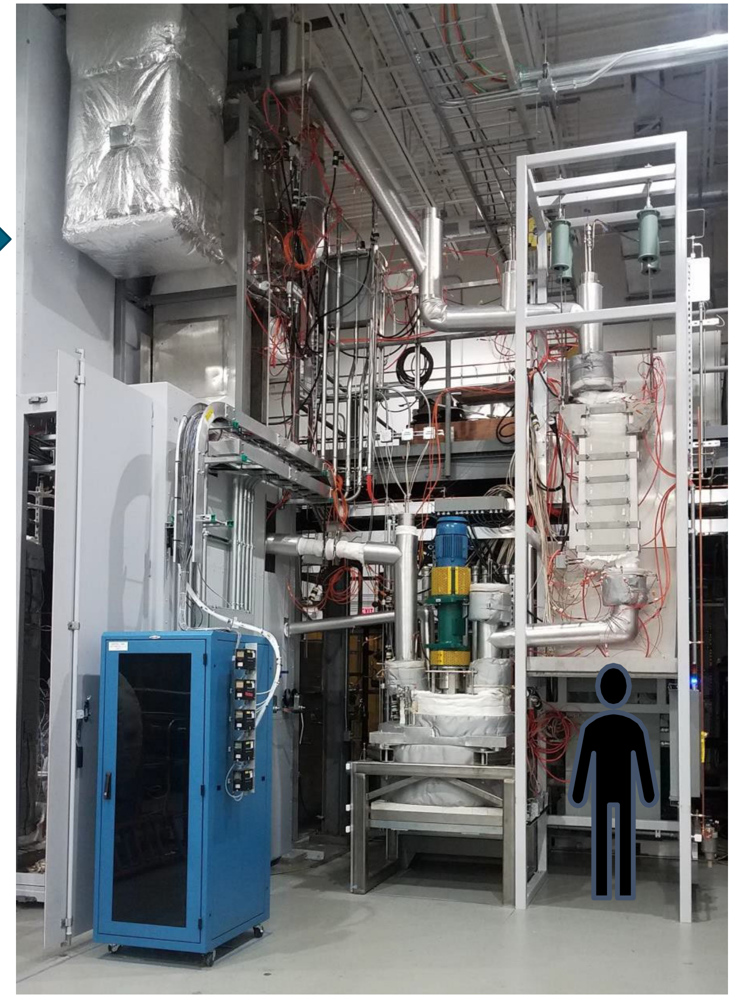
Largest Cl salt loop in DOE

Salt	$NaCl\text{-}KCl\text{-}MgCl_2$
Operating Temp.	725^{o}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 2023

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.

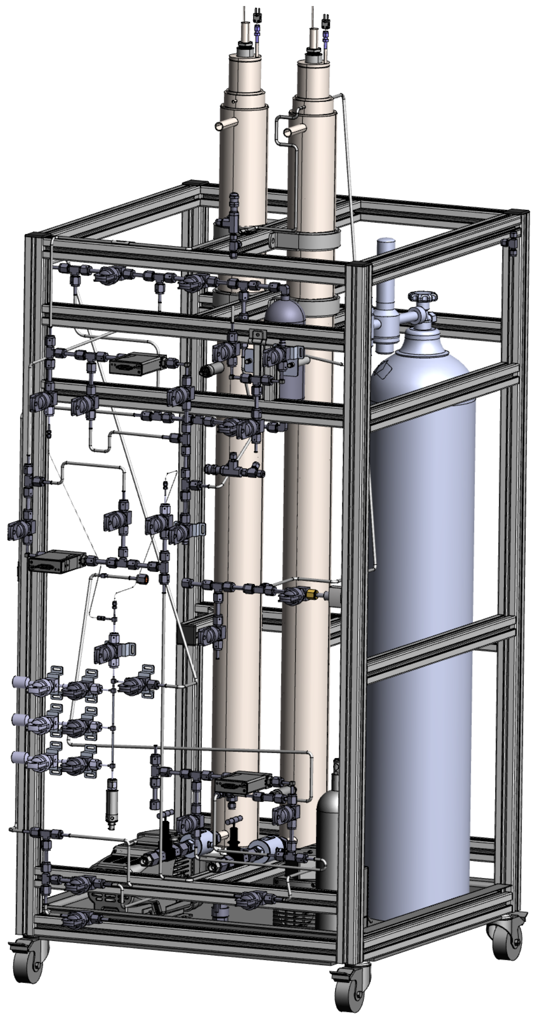
Chlorine Isotopes Separation System for Chloride MSR

WHY

- ^{35}Cl (76% of natural chlorine) has large neutron capture cross section
- ^{36}Cl activation product is long-lived (301,000 years) and energetic (709 keV) beta emitter
- Highly soluble in water

CAPABILITIES DEVELOPMENT at PNNL

- Thermal diffusion isotope separation system for enrichment of ^{37}Cl. FY24 will upgrade to produce >99% ^{37}Cl enrichment
- Multi-physics model exists to optimize and inform facility designs at multiple scales
- Precise Cl isotope QQQ-ICP-MS method with $HCl_{(L)}$ – no chemistry needed and >1% accuracy on $^{37}Cl/^{35}Cl$ ratio



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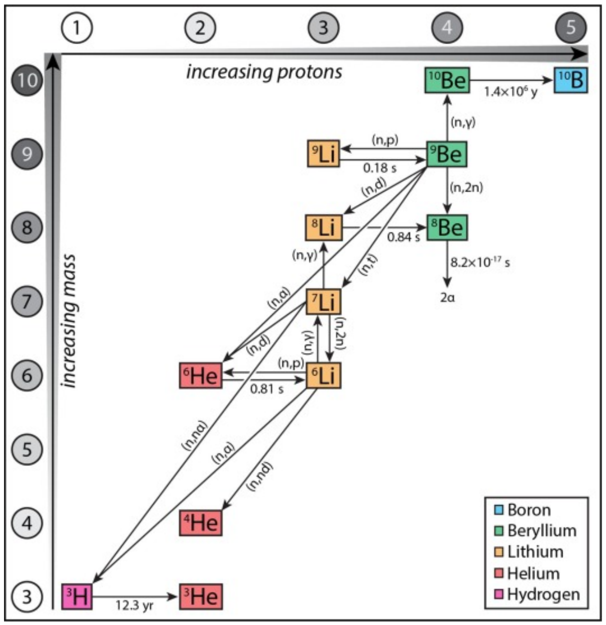
Courtesy Bruce McNamara, PNNL

Tritium Generation in MSRs

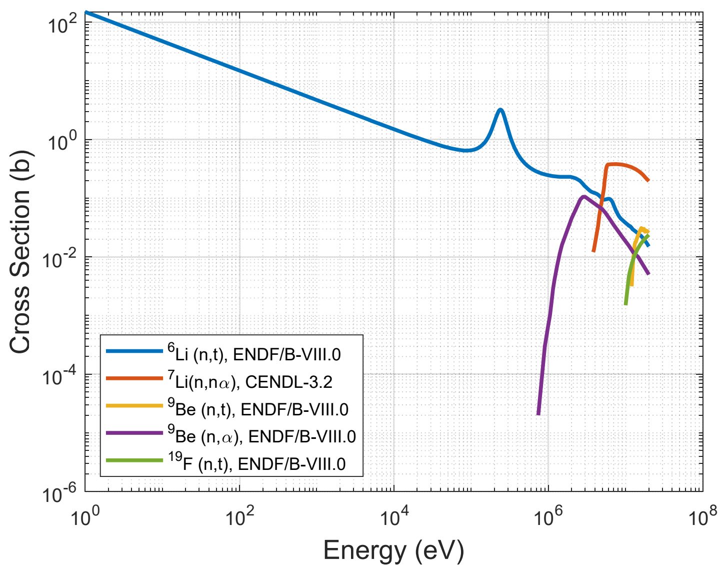
Tritium generated by neutron reactions with Li, Be, and F.



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

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

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



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

CANDUs produce world's supply of tritium for peaceful purposes.

Tritium is a potential valuable byproduct of MSRs.

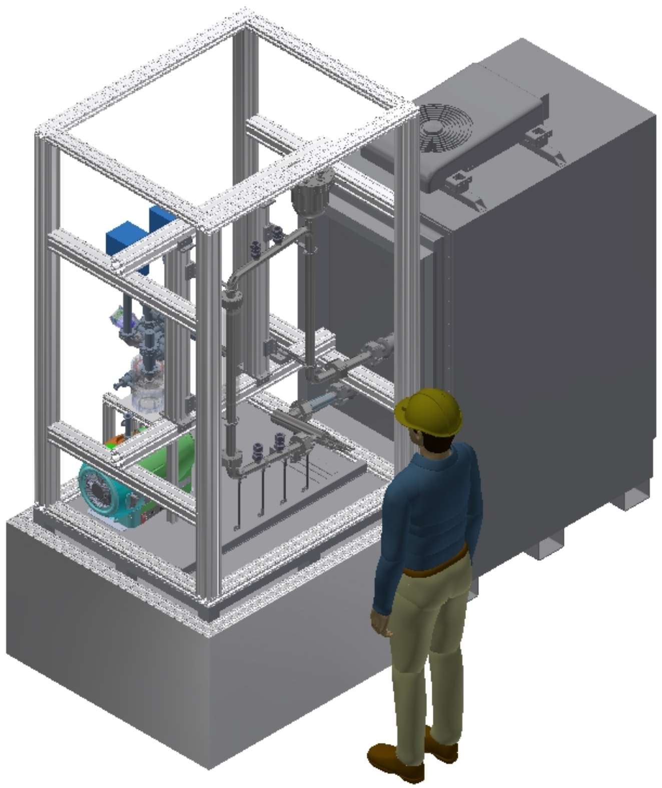
Reactor Type	Tritium Formation Rate 1000 MWe (Ci/day) [1]
MSR	2400*
CANDU	2700
HTGR	50
PWR	2

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

Sabharwall, P.; Schmutz, H.; Stoots, C.; Griffith, G. Tritium Production and Permeation in High-Temperature Reactor Systems;, 2013. https://doi.org/10.1115/HT2013-17036.
Andrews, Hunter B., et al. "Review of molten salt reactor off-gas management considerations." Nucl. Eng. Des. 385 (2021): 111529.

Molten Salt Tritium Transport Experiment

- ***MSTTE is a semi-integral tritium transport experiment for flowing fluoride salt systems.***
- **Location: S**afety and **T**ritium **A**pplied **R**esearch facility
- **Objectives:**
  (1) Safety code validation data.
  (2) Test stand for tritium control technology.
- ***Major Equipment:***
  - **Copenhagen Atomics Salt Loop**: salt tank, pump, & flow meter
  - **External Test Section:** hydrogen injection, permeation, & plenum
- ***Phased approach***
  - **Phase I:** FLiNaK and D_2
  - **Phase II:** FLiBe and D_2
  - **Phase III:** FLiBe and T_2



Courtesy Thomas Fuerst, INL

Molten Salt Spill Accident Research at ANL and SNL

Spreading and Heat Transfer Tests

- Leading edge vs. time
- Covered area vs. time
- Temperature of steel and salt surfaces vs. time

Flowing and Freezing in Tubing Tests

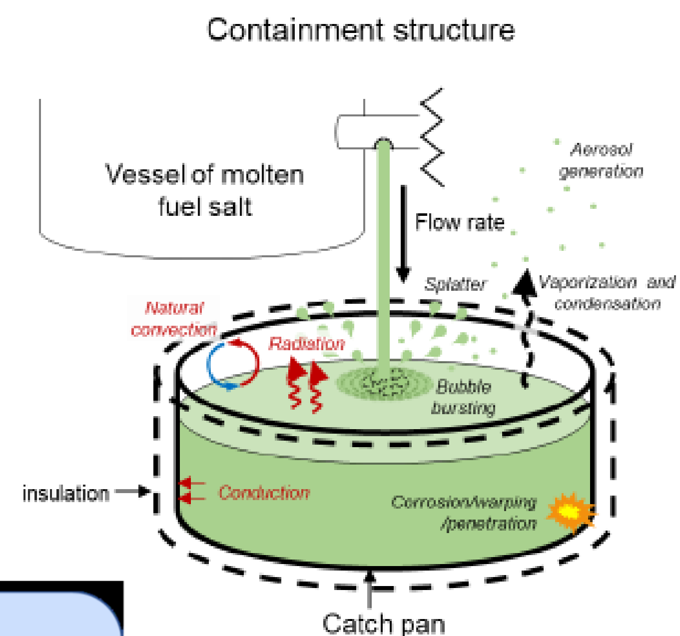
- Temperature of tubing surface during salt draining
- Locations where tubes of different diameter plug with salt

Splashing and Aerosol Generation Tests

- Compositions and sizes of splatter and aerosols generated by splashing

Corrosion Tests in Molten Salt

- Electrochemical corrosion rates at fixed redox, salt chemistry, and temperature



Interaction with stakeholders

(model developers and MSR vendors)

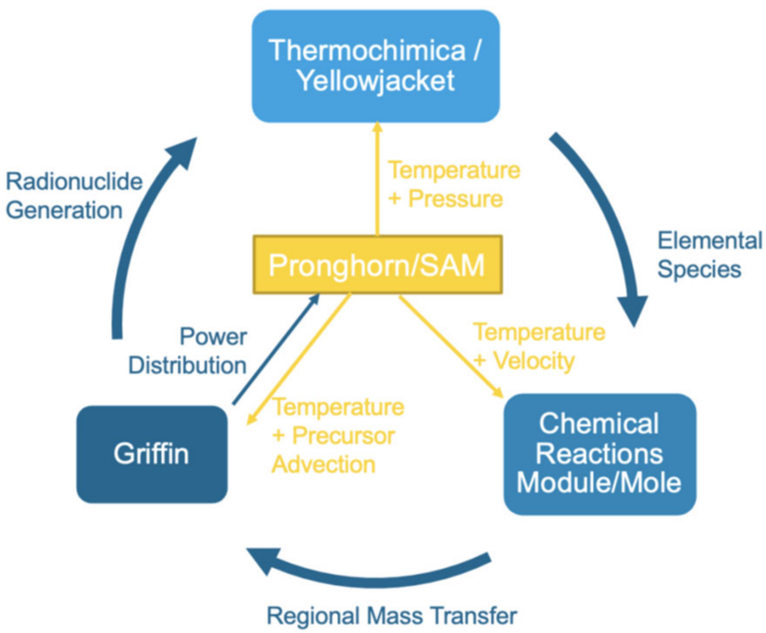
1. Conduct individual process tests at laboratory scale — **initiated**
2. Conduct integrated process tests at laboratory scale — **initiated**
3. Design engineering-scale tests — **initiated**
4. Build apparatus and conduct engineering-scale tests

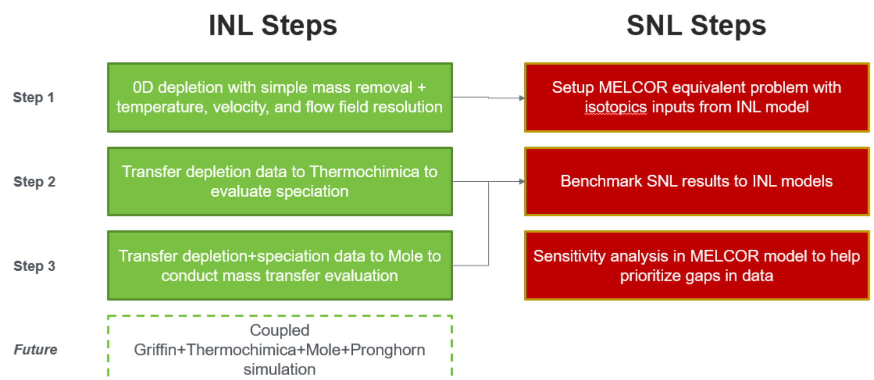
Modeling and Simulation

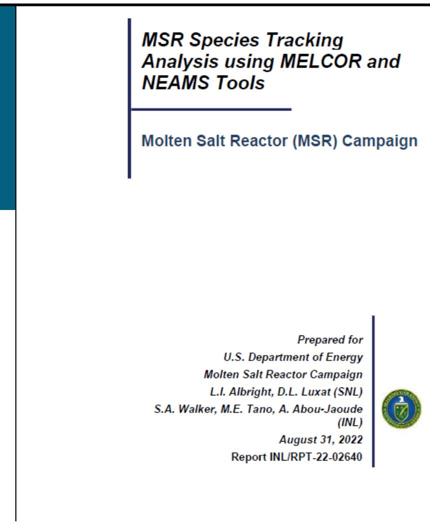
MSR SPECIES TRACKING ANALYSIS USING MELCOR AND NEAMS TOOLS

- NEAMS toolkit used to accurately resolve multiphysics analysis in MSRs for gaseous speciation and corrosion of structural materials due to thermochemical changes in the fuel-salt.

- Support MSR campaign missions through MELCOR modeling and analysis
- Identify and collaboratively resolve MSR mechanistic source term knowledge gaps
- Develop engineering level models for mechanistic source term capability gaps







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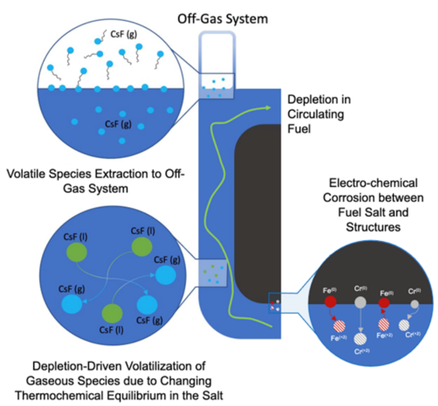
Advanced Materials

Salt and Materials Interaction

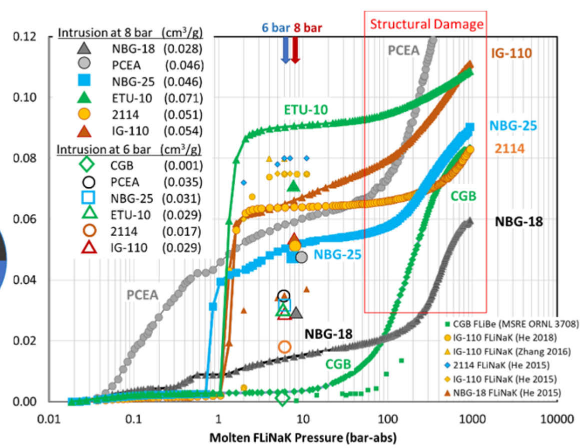
Supporting MSR development by studying 316H flowing salt compatibility at high temperature (off-normal)

2021 ORNL FLiBe TCL

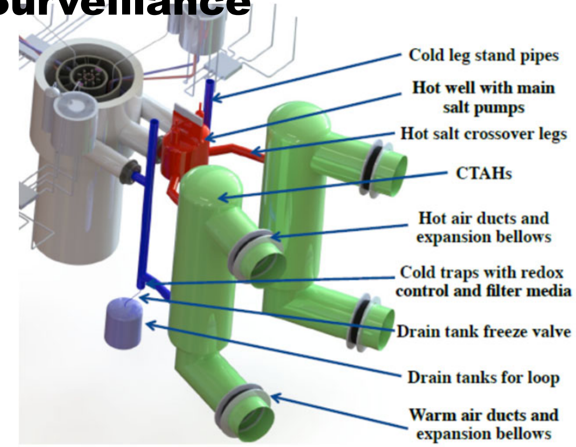


Graphite-Salt Study

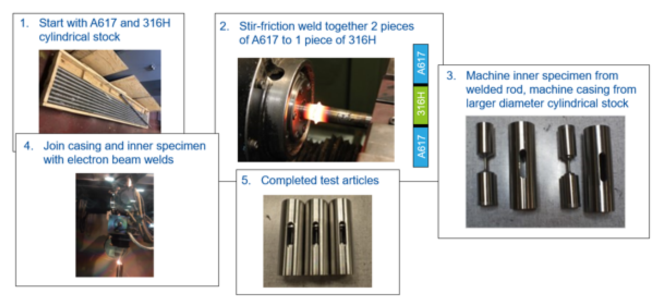
Study of salt intrusion in graphite and chemical interactions that may affect graphite's structural or physical properties



Development of Test Articles for Surrogate Materials Surveillance



Test Articles Fabrication Completed – Both Types Follow the Same Basic Process



MSR Campaign Reports

- Melissa Rose et al., “Effect of Cs and I on Thermophysical Properties of Molten Salts “, M3AT-23AN0705011M3AT, SEP 2023
- Melissa Rose et al. “Workshop-Uncertainty in MS Property Measurements and Predictions: Sent milestone report ANL/CFCT-23/32 t”, M3AT-23AN0705013, SEP 2023
- Trou Askin et al “Progress Report on Identification and Resolution of Gaps in Mechanistic Source Term Modeling for Molten Salt Reactors”, SAND-2023-10090, SEP 2023
- Bruce McNamara, “Chlorine isotopes separations, mid-year report, *M4AT-23PN1101043, PNNL -34297, May 2023*
- *Bruce Pint, et al. “The Dissolution of Cr and Fe at 850C in FLiNaK and FLiBe,* M3RD-23OR0603032, ORNL/SPR-2023/3170, SEP 2023
- Bruce Pint et al., “Measuring the Dissolution of Cr and Fe at 550°C-750°C in FLiNaK and FLiBe, ORNL/SPR-2023/3169, SEP 2023
- Ting-Leung Sam et al, “ Development of Surveillance Test Articles with Reduced Dimensions and Material Volumes to Support MSR Materials Degradation Management , INL /RPT-23-74540 , SEP 2023
- Mark Messner, “Modeling support for the development of material surveillance specimens and procedures”, NL-ART-268, SEP 2023
- Thomas Hartmann, , “Modeling of Austenitic MSR Alloys with Supporting Experimental Data-Part 2: Diffusion controlled corrosion in austenitic MSR containment alloys ,PNNL-34802, SEP 2023
- Sara Thomas “ Integrated Process Testing of MSR Salt Spill Accidents , ANL/CFCT-23/25 SEP 2023
- Hunter Andrews, “Establishing Isotopic Measurement Capabilities using Laser-Induced Breakdown Spectroscopy for the Molten Salt Reactor Campaign” (ORNL/TM-2023/3067. SEP 2023
- Kevin Robb et al. “*Molten Salt Loop testing of Sensors and Off-Gas Components: FY23 Progress”,* ORNL/LTR-2023/3087 *, SEP 2023*
- Nathaniel Hoyt, Assessment of salt sensor Performance, , M3RD-23AN0602061 , SEP 2023
- Danny Bottenus et al, “Molten Salt Reactor Radioisotopes Separation by Isotachophoresis”, PNNL-34997, SEP 2023
- Anne Campbell, “ Be2C synthesis, properties, and ion-beam irradiation damage characterization “, ORNL/TM-2023/3011 , AUG 2023
- Joanna McFarlane et al., Design of Instrumentation for Noble Gas Transport in LSTL Needed for Model Development “, ORNL/TM-2023/3138, SEP 2023
- Walker et al., “Application of NEAMS Multiphysics Framework for Species Tracking in Molten Salt Reactors”, INL/RPT-23-74376, (2023).

New MSR Program Website

Information on:

MSTDB

MSR Campaign Review Meeting

Publications/Reports

GIF webinars

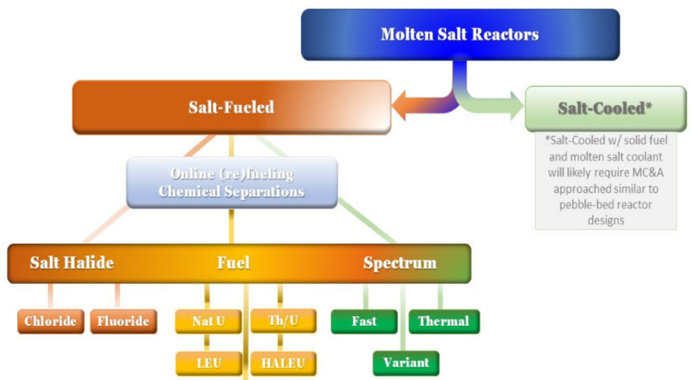
Molten Salt Reactor
PROGRAM

The DOE-NE MSR program serves as the hub for addressing the technology challenges for MSRs to enter the commercial market.

Mission: Develop the technological foundations to enable MSRs for safe and economical operations while maintaining a high level of proliferati
1) MSRs can provide a substantial portion of the energy needed for the US to achieve net zero carbon emissions by 2050 and

A molten salt reactor (MSR) is any nuclear reactor that employs liquid halide salt to perform a significant function in-core. MSRs include a broad spectrum of design options including:

- liquid- and solid-fueled variants,
- chloride- and fluoride-based fuel salts,
- thermal, fast, time variant, and spatially varying neutron spectra,
- wide range of reactor power scales,
- intensive, minimal, or inherent fuel processing,
- multiple different primary system configurations, and compatibility with
- nearly all fuel cycles.



FY2022 Integrated Research Projects Awards

- Reduction, Mitigation, and Disposal Strategies for the Graphite Waste of High Tempe
- Bridging the gap between experiments and modeling to improve design of molten s

NRL Projects Awarded CINR FY22 Funding

- Integrated Effects of Irradiation and Flibe Salt on Fuel Pebble and Structural Graphite Reactors

FY 2022 CINR MSR AWARDS

- A Molten Salt Community Framework for Predictive Modeling of Critical Characterist
- Understanding the Interfacial Structure of the Molten Chloride Salts by in-situ Electro Soft X-ray Scattering (RSoXS)
- Nuclear Material Accountancy During Disposal and Reprocessing of Molten Salt Reac
- Optical Basicity Determination of MoltenFluoride Salts and its Influence on Structural

FY22 SciDAC Award

- Los Alamos National Laboratory to lead study of molten-salt nuclear reactor material

MSR Annual Campaign Review

- May 2-4, 2023
- 2022
- 2021

MSR Course

Molten Salt Thermal Properties Database (MSTDB)

- University of South Carolina - College of Engineering and Computing -- MSTDB
- Oak Ridge National Laboratory -- MSTDB

https://gain.inl.gov/SitePages/MSR_Program.aspx

Gen IV International Forum - Webinars

Series 8: Fluoride-Cooled High-Temperature Reactors (FHR)

- 27 April 2017
  Presenter: Prof. Per Peterson, UC Berkeley, USA
  Watch WEBCAST | DOWNLOAD PRESENTATION | VIDEO

Series 9: Molten Salt Reactors (MSR)

- 23 May 2017
  Presenter: Dr. Elsa Merle, CNRS, France
  Watch WEBCAST | DOWNLOAD PRESENTATION | VIDEO

Series 44: Molten Salt Reactor Safety Evaluation - A US Perspective

- 26 August 2020
  Presenter: Dr. David Holcomb, ORNL, USA
  Watch WEBCAST | DOWNLOAD PRESENTATION

Series 79: Off-gas Xenon Detection and Management in Support of Molten Salt Reactors

26 July 2023
Presenters: Hunter Andrews, ORNL, USA and Praveen Thallapally PNNL, USA
Watch WEBCAST | DOWNLOAD PRESENTATION

Series 21: Molten Salt Actinide Recycler and Transforming System with and Without Th-U support: MOSART

- 07 June 2018
  Presenter: Dr. Victor Ignatiev, Kurchatov Institute, Russia
  Watch WEBCAST | DOWNLOAD PRESENTATION | VIDEO

Series 73: Molten Salt Reactors taxonomy and fuel cycle performance

25 January 2023
Presenter: Dr. Jiri Krepel, Paul Scherrer Institute, Switzerland
Watch WEBCAST | DOWNLOAD PRESENTATION

Series 66: Nuclear Waste Management Strategy for Molten Salt Reactor Systems

15 June 2022
Presenter: Dr. John Vienna and Dr. Brian Riley, PNNL, USA
Watch WEBCAST | DOWNLOAD PRESENTATION

https://www.gen-4.org/gif/jcms/c_84279/webinars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Thank you

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