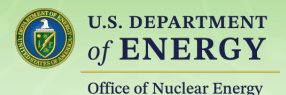


Molten Salt Reactor
P R O G R A M

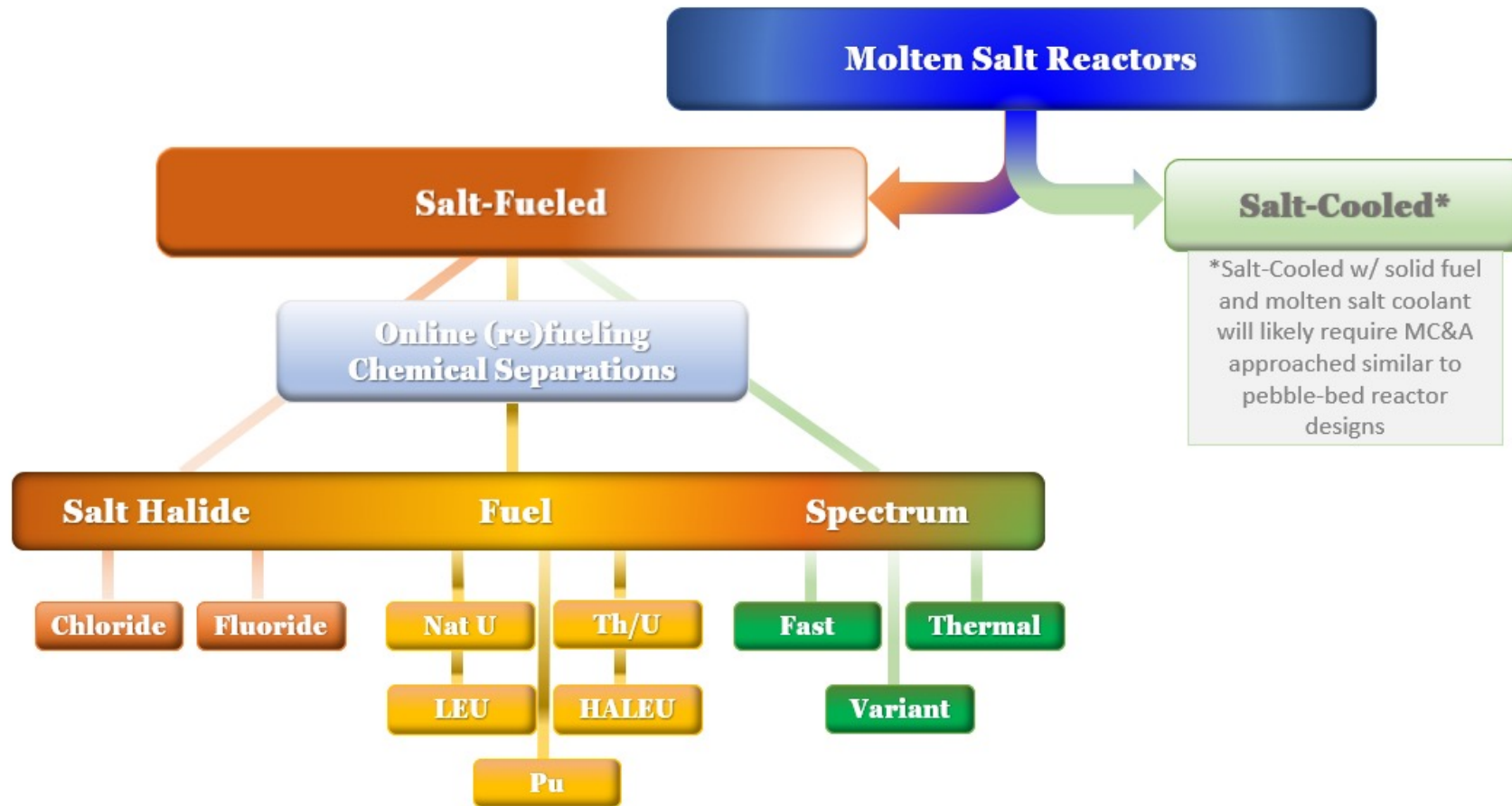
Molten Salt Reactors and Fuels

ICTP-IAEA Workshop on Physics and Technology of Innovative Nuclear Systems
Trieste Italy, July 13-17, 2026.

Melissa A. Rose, Argonne National Laboratory



MSRs are a Class of Reactors in which a Molten Salt performs a Significant Function in Core



- Liquid- and solid-fueled variants
- Chloride-, fluoride-, and mixed halide-based fuel salts
- Salt and liquid-metal coolants
- Thermal, fast, time-variant, and spatially-variant neutron spectra
- Wide range of power scales
- Intensive, minimal, or inherent fuel processing
- Multiple different primary system configurations
- Nearly all fuel cycles



Molten Salt Reactor
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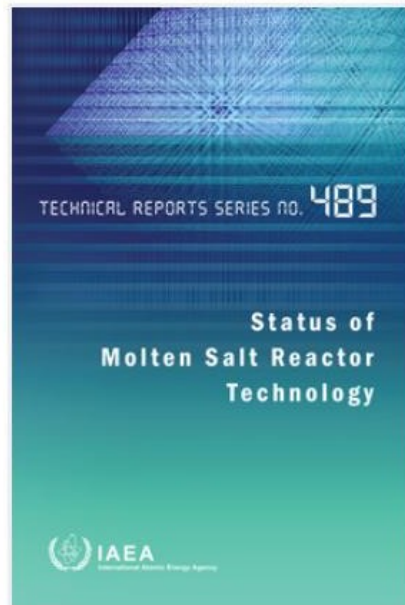


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Slide Courtesy Patricia Paviet, PNNL, USA

MSR Taxonomy from the IAEA TRS No. 489

Status of Molten Salt Reactor Technology



Technical Reports Series No. 489

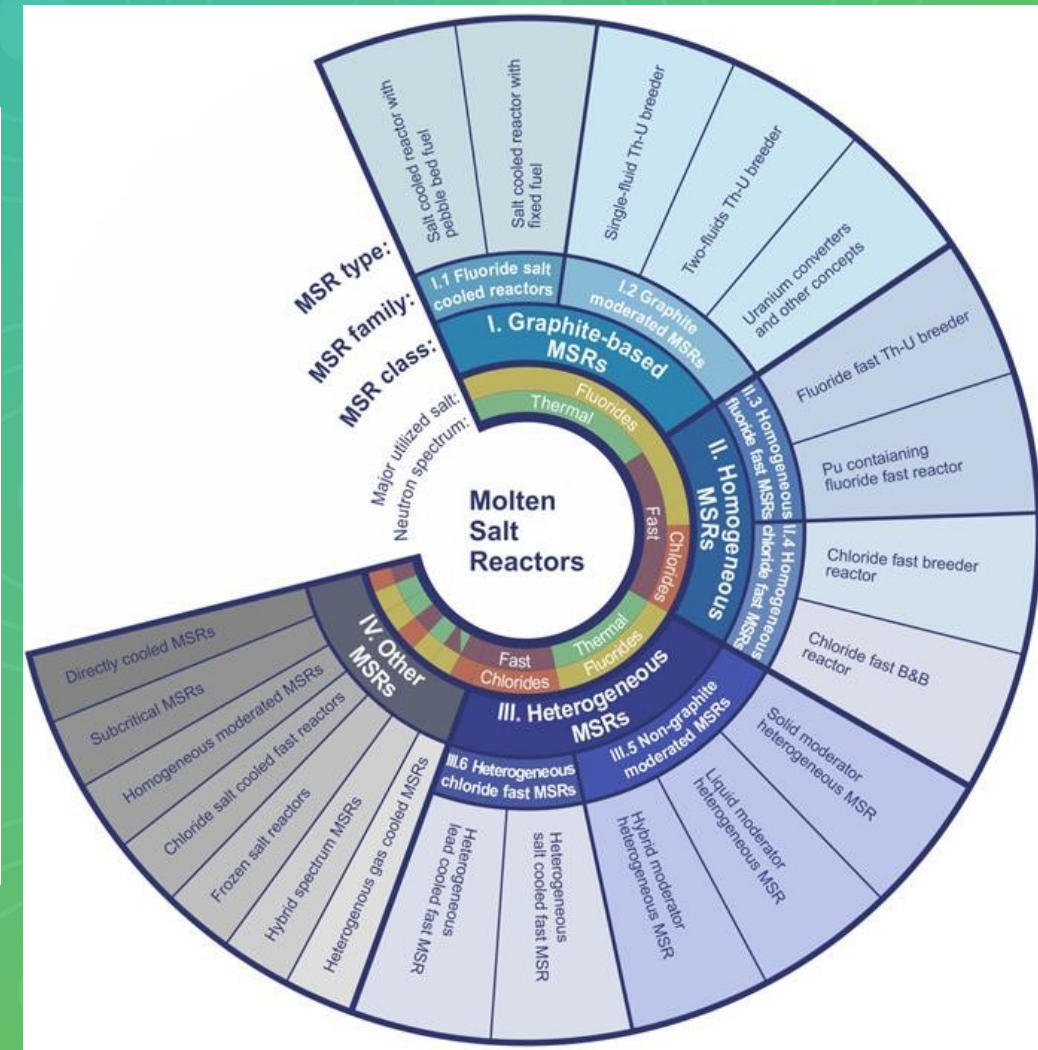
English STI/DOC/010/489 | 978-92-0-140522-7

315 pages | 110 figures | € 86.00 | Date published: 2023

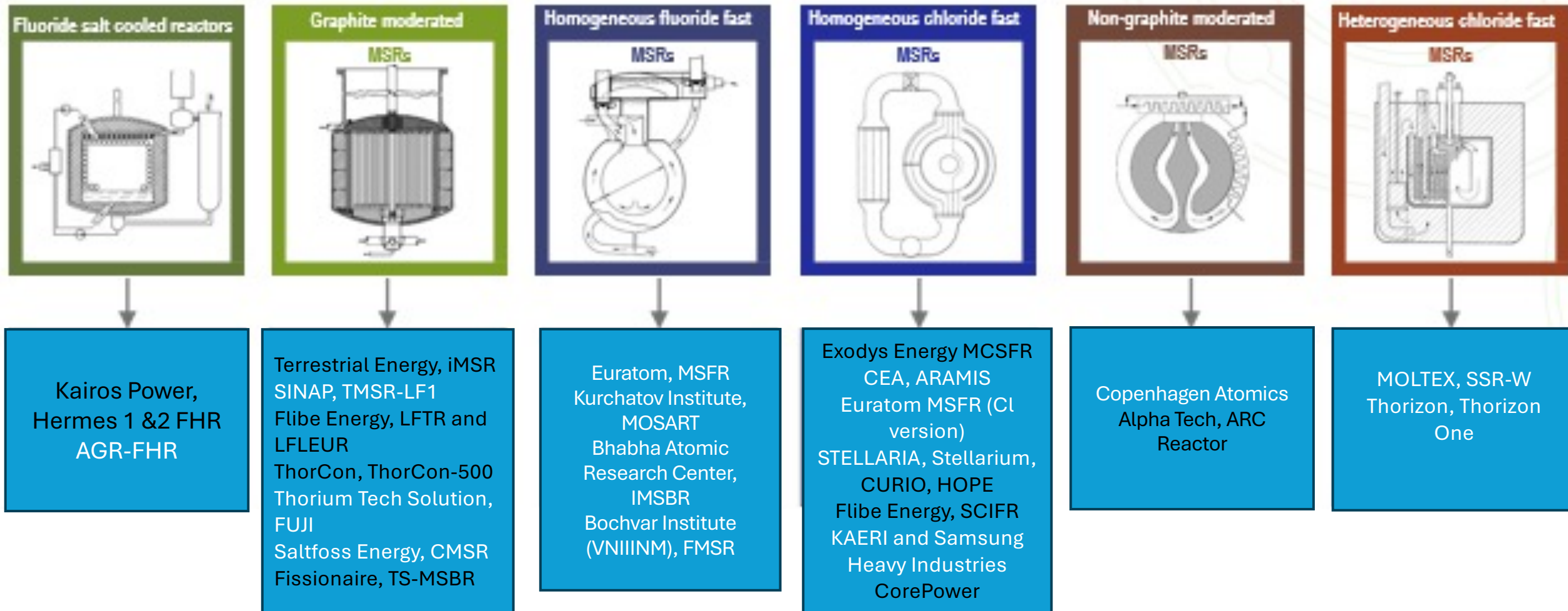
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EPUB format available (68.77 MB)

Get citation details



Molten Salt Reactor Concept(s) ... so many



Deployment Status

☒ Operated in the past ☒ Operating today ☐ Operating at commercial scale

- The first MSR was the Aircraft Reactor Experiment Reactor, US, 1954
- One MSR is currently operating in China: TMSR-LF1
- More than 15 MSR designs are under development globally. Two are under construction in the U.S.: Hermes and MSR-1 (MSRR)



Courtesy NRC, Greg Oberson and Raj Iyengar

*TRISO
fuel

MSR Fuel Synthesis Considerations

For molten salt systems where the fuel is dissolved in the salt many sources of actinides are being considered.

- LEU
- HALEU
- UNF
- Legacy Pu

Generally, fast reactors will utilize chloride fuels while thermal reactors will utilize fluoride fuels.

All fuels will require purification, salts obtained from commercial suppliers routinely contain significant impurities (Oxides, metals, oxyhalides)

^7Li can be used in MSRs instead of ^6Li to mitigate tritium formation

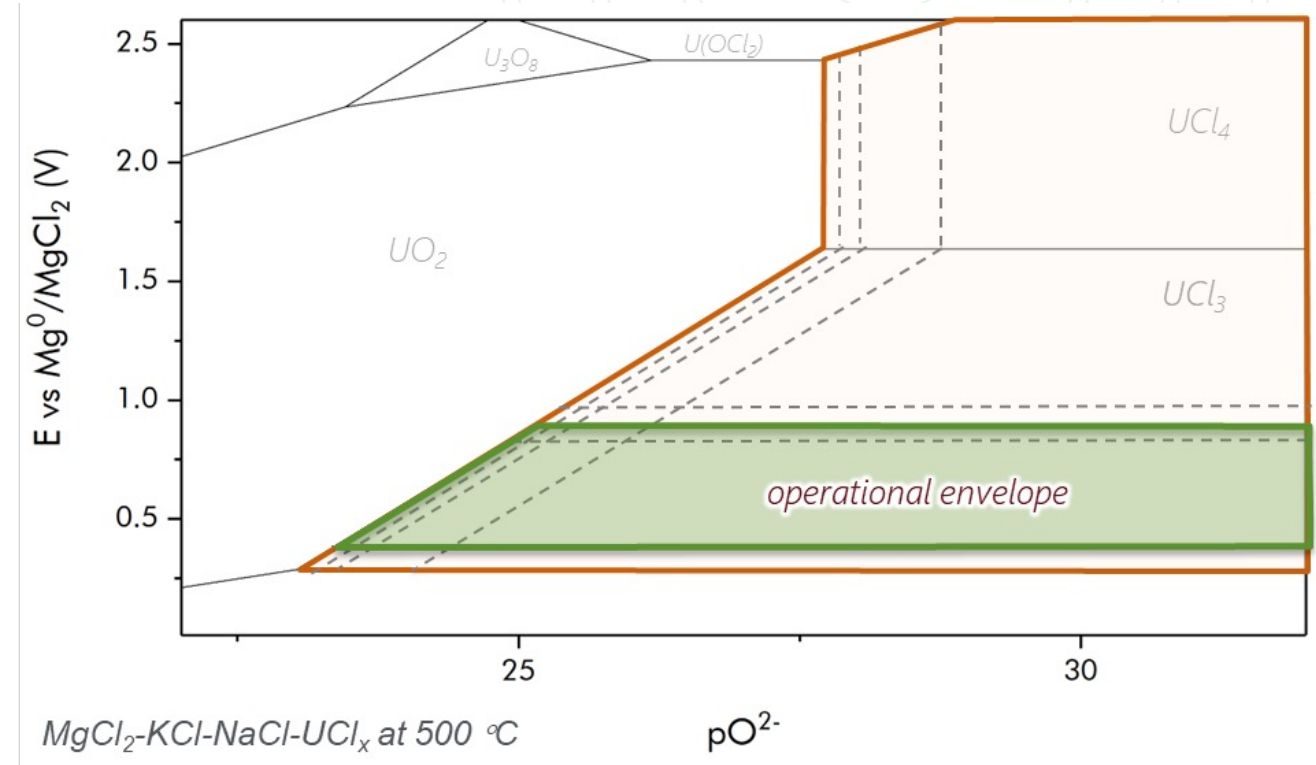
^{37}Cl will be needed for fast reactors to prevent neutron absorption by ^{35}Cl and to avoid generating long-lived ^{36}Cl , which will be a disposal challenge.

Molten salt fuels prepared from UNF will contain FPs which will impact salt behavior and reactor operation

Evolution with Use

-

Establish a fuel composition envelope and ensure an adequate operational window by knowing the range of the fuel property values



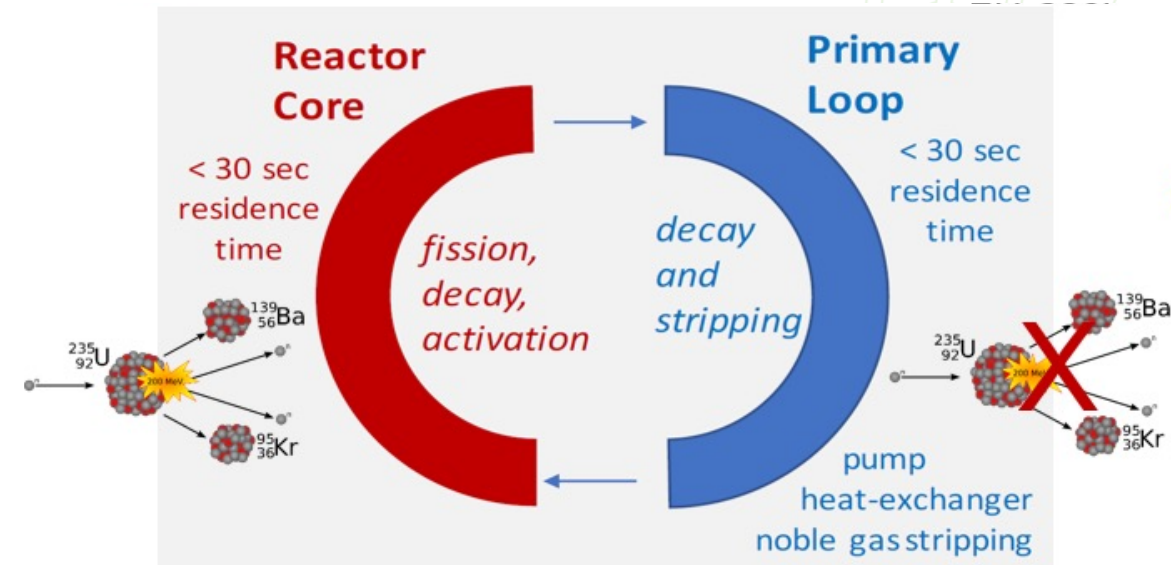
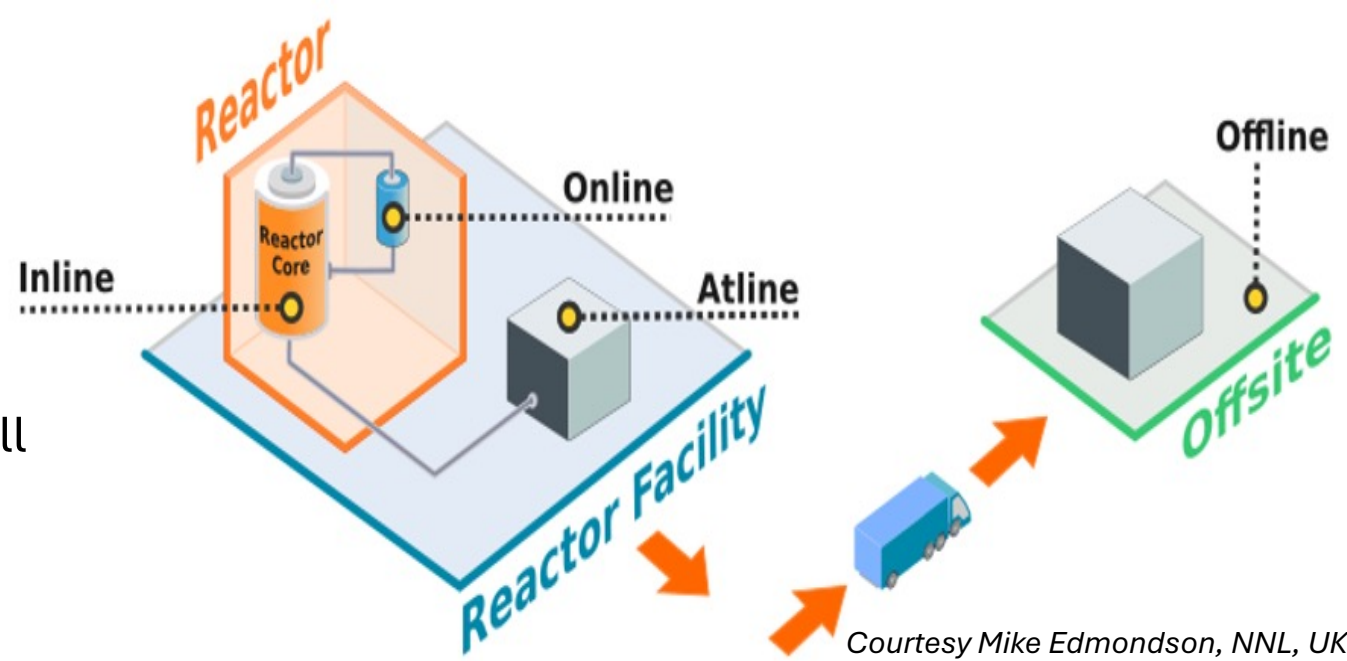
MSR Operation – In Operando Conditioning

Continuous operation with a liquid fuel will require in-operation conditioning of fuel, including:

- Gaseous fission products must be managed with an off-gas system
- Redox control to prevent corrosion of structural materials and components

Lifetime of fuel may be lengthened with additional conditioning:

- Soluble neutron poisons may need to be removed
- Filtration of particulate



Molten Salt Reactor
PROGRAM



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MSR fuels are uniquely suited for advanced fuel cycles:

- Enable on-line fuel conditioning or purification
- On-line fuel additions
- Online, at-line, in-line and offline processing options are all possible.

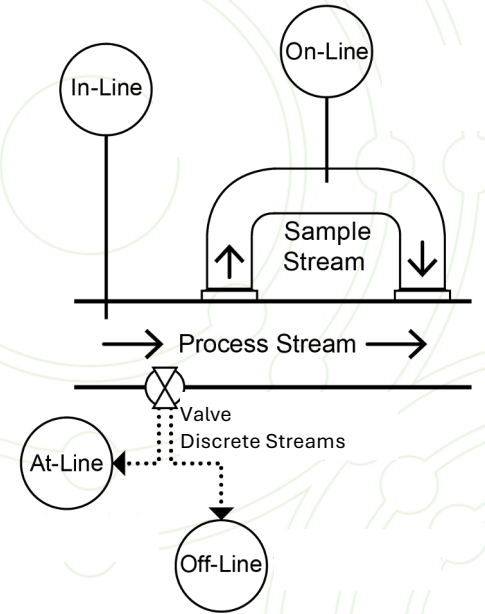
Fuel cycles can be customized to fit the reactor design and/or the developer motivations

Limited conditioning to prolong the life of fuels could include:

- Removal of oxides
- Recovery of FP and noble gases
- Recovery of noble metals
- Removal of soluble neutron poison FPs

Full recycling could include all of the above and:

- Actinide recovery
- Rare earth element extraction
- Recycling of the ^{37}Cl or ^7Li
- Repurification and reuse of the base salts



Molten Salt Reactor
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Argonne
NATIONAL LABORATORY

Molten Salt Fuel Management

Fuel salt considerations throughout operational lifetime



Fuel synthesis, purification and delivery

- Sources of fuel and purity requirements
- Production of stable isotopes
- Packaging of fuel for delivery



Liquid fuel allows on-line chemistry control

- Control of chemistry to lengthen fuel lifetime
- Online purification and refueling
- Material control and accountability challenges



Back-end of fuel cycle

- Salt purification and recycle reduces waste volume and improves resource utilization
- Waste forms for disposal

MSR Fuel Cycle Discussions

- MSR Fuel Cycle Chemistry Workshop Held at Argonne, September 2023
- IAEA/NEA International Workshop on the Chemistry of Fuel Cycles for Molten Salt Reactor Technologies Held in Vienna, October 2023
- IAEA/NEA/EC-JR Workshop on the Taxonomy and Related Terminology of Fuel Cycles for Molten Salt Reactors Held in Vienna, November 2025

Recent workshops on MSR fuel cycle chemistry have discussed technical issues, terminology and knowledge gaps

Work under the United States Department of Energy Office of Nuclear Energy have been addressing aspects of these knowledge gaps.



DOE - Office of Nuclear Energy supports seven national laboratories to efficiently and effectively address, in partnership with other stakeholders, the technology challenges for MSRs to enter the commercial market.

SALT and FUEL SALT CHEMISTRY

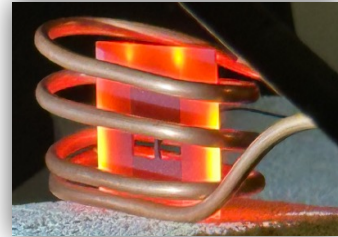
Thermophysical and Thermochemical Properties of Molten Salts –
Experimental and Computational
Salt purification and synthesis
UF₃, UF₄, UCl₃, PuCl₃, AmCl₃
Databases
ASTM Standard Method Development

MODELING & SIMULATION FOR MSR SAFETY

NEAMS Tools & MELCOR used for
Species Tracking
MSR Safety
Accident Scenario
Mechanistic Source Term....

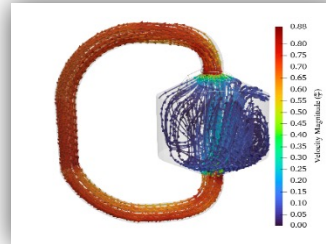
MATERIALS

Development of materials surveillance technology
Graphite/Salt Interaction
Corrosion studies (SS316H, Alloy 709, Alloy 625, Haynes 244) in F and Cl salts
Under AMMT and GCR programs



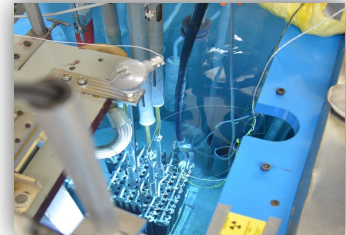
TECHNOLOGY DEVELOPMENT

Off-Gas Integrated System
Salt Chemistry Monitoring Tools
Radionuclide Release Monitoring
MSR Gas and Particles Transport Phenomena



SALT IRRADIATION

Fuel salt irradiation and post irradiation examination capabilities
NRAD, ATR, HFIR
Under AFC



ENGINEERING SCALE FACILITY

LSTL- FLiNaK loop - ORNL
FASTR –NaCl/ MgCl₂/ KCl loop-ORNL
MSTTE – Molten Salt Tritium Transport Experiment - INL
SAAF- Salt Accident Analysis Facility - ANL
ASL – Actinide Salt Loop - ANL
CLESF – Chlorine Enrichment & Separation Facility - PNNL

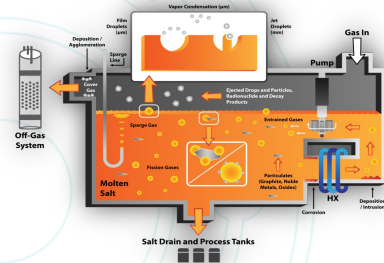
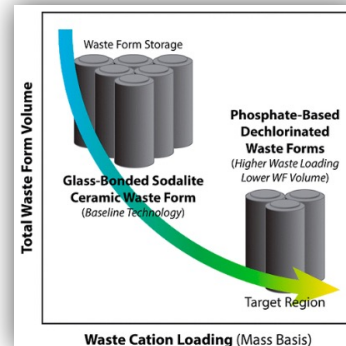


MSR RADIOISOTOPES

Developing new Technologies to separate Radioisotopes of Interest to the MSR Community.

WASTE FORM DEVELOPMENT

Off-gas waste-form development (Iodine)
Dehalogenation process for chloride and fluoride salt waste treatment
Under MRWFD Program



MSR Program Website:

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

The breadth of the MSR design space presents a substantial challenge to the completeness and broad applicability of any technology development planning activity. Dozens of design concepts are currently in some state of development, nearly all have been introduced in the past decade, and it is not currently possible to reasonably evaluate which designs will eventually be successful. Nevertheless, MSRs have common characteristics and many technology development issues are broadly applicable to most MSRs

Contacts

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MSR Annual Campaign Review

- [April 22-24, 2025](#)
- [April 16-18, 2024](#)
- [May 2-4, 2023](#)
- [April 26-27, 2022](#)
- [June 17, 2021](#)

MSR Course



Announcements

Molten Salt Reactor Reports

CHEMISTRY

Search

Title	Link	Report Number	Year	# of Pages
Synthesis and Thermophysical Property Determination of NaCl-PuCl3 Salts	Link	INL/RPT-22-69181	2022	34
Engineering-Scale Batch Purification of Ternary MgCl2-KCl-NaCl Salt Using Thermal and Magnesium Contact Treatment	Link	ORNL/TM-2022/2554	2022	31
An Overview of the Molten Salt Thermal Properties Database□Thermophysical, Version 2.1.1 (MSTDB-TP v.2.1.1)	Link	ORNL/TM-2023/2955	2023	25
FY23 Progress Report on Viscosity and Thermal Conductivity Measurements of Molten Salts	Link	ORNL/TM-2023/3048	2023	31
Experimental Plan for Synthesis of an Americium- and Plutonium-Containing Salt	Link	INL/RPT-24-80052	2024	18

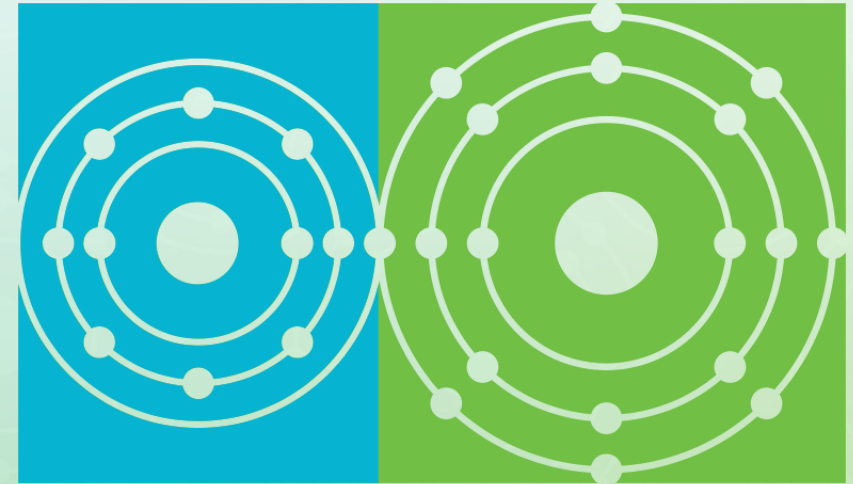
Thank you
Teresa Krynicki, INL
Slide Courtesy Patricia Paviet, PNNL, USA

Acknowledgements

- Financial support provided by U.S. Department of Energy, Office of Nuclear Energy
- Government License Notice -the manuscript has been created by UChicagoArgonne, LLC, Operator of Argonne National Laboratory (“Argonne”). Argonne, a U.S. Department of Energy Office of Science laboratory, is operated under Contract No. DE-AC02-06CH11357.

Questions

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