MSR Workshop at PSI

December 10, 2025

MSR Activity in Japan

1. Activity for Fluoride Salt MSR
2. Activity for Chloride Salt MSR
3. Regulatory Guides for MSR Safety

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International Thorium Molten-Salt Forum (ITMSF)

1. Activity for Fluoride Salt MSR

Concept of THORIMS-NES

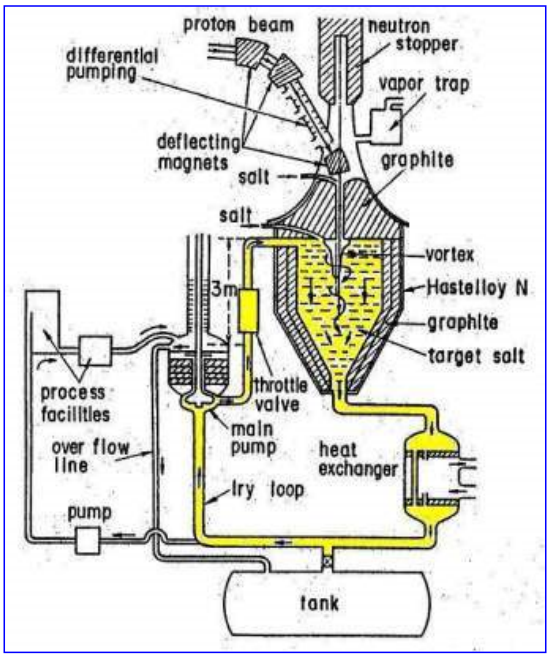
"THORIum Molten-Salt Nuclear Energy Synegetic system" was proposed by prof. Furukawa in 1990 [1].

THORIMS-NES is composed of

(1) MSR-FUJI, →See later.

(2) AMSB (★), and

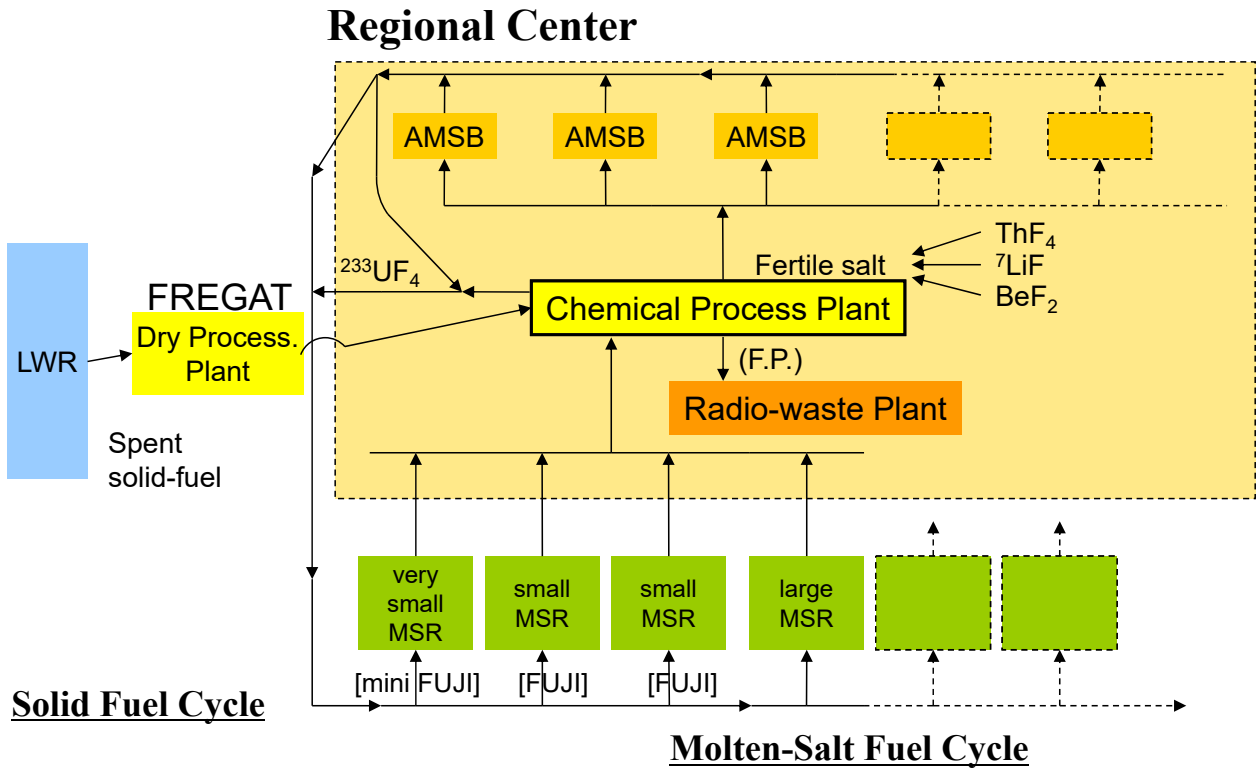
(3) Chemical processing plant.



★ **AMSB**(Accelerator Molten-Salt Breeding facility) is a kind of ADS (Accelerator Driven System), utilizing a proton accelerator to produce U233 at thorium molten salt target, by spallation reactions.

[1] K. Furukawa, et al., "Thorium Molten-Salt Nuclear Energy Synergetics", J. of Nuc. Sci. & Tech., Vol.27, No.12, 1990

Configuration of THORIMS-NES



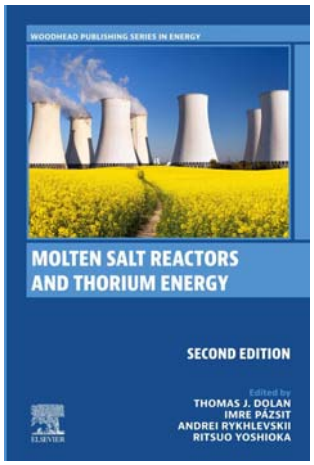
[2] R. Yoshioka, et al., "Accelerator-Driven Systems", Chapter-15 of the book "Molten Salt Reactors and Thorium Energy" by T. Dolan,et al, Elsevier, 2024

MSR-FUJI

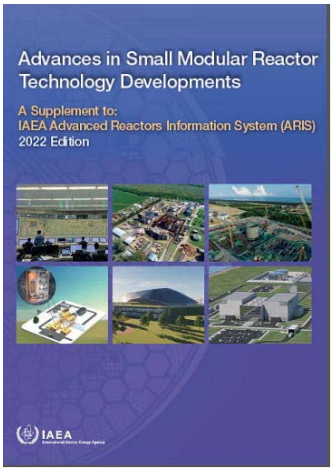
MSR-FUJI is based on the MSBR design at ORNL in 1960s to 70s, but there are several improvements.

(1) Small sized plant to deploy widely in the world.
(2) Remove online chemical reprocessing to simplify the plant.
(3) Achieve self-sustaining operation (Conversion Ratio=1.0).
(4) No graphite replacement within 30-years operation.

Information on MSR-FUJI is described in the following books [3][4].



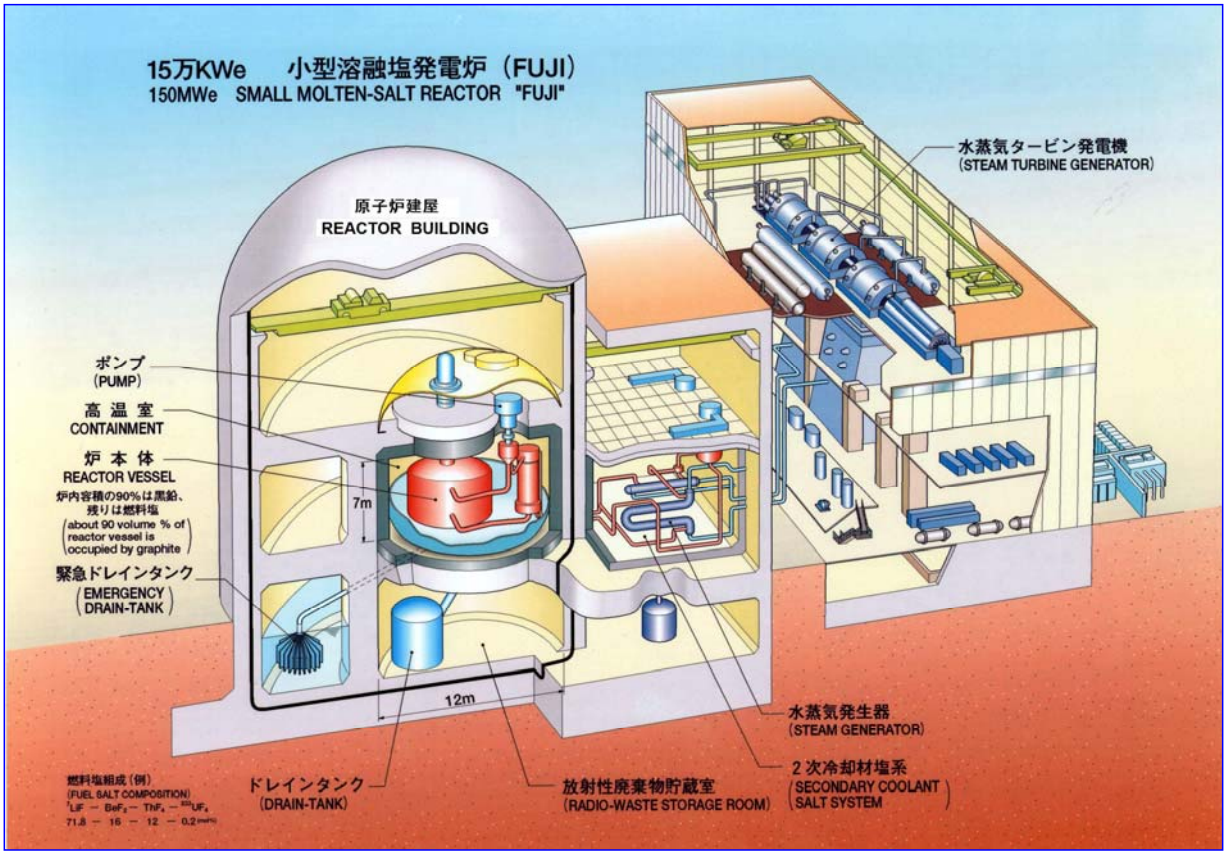
[3] "Molten Salt Reactors and Thorium Energy" , by T. Dolan,et al, Elsevier, 2024



[4] "Advances in Small Modular Reactor Technology Developments", by IAEA, 2022

Bird-eye View of MSR-FUJI

Its core is composed of fuel salt and graphite moderator, and fuel is fluoride salt such as FLiBe with Th and U233/Pu.



Molten Salt Loop Technology

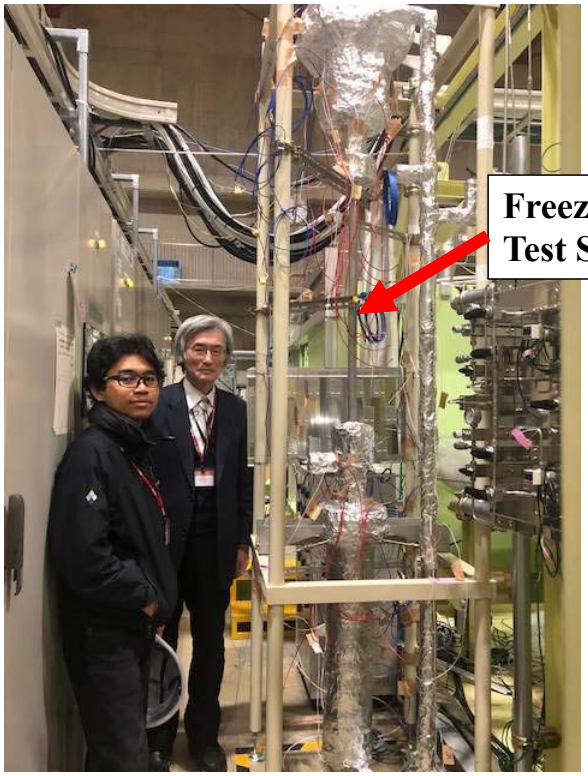
(1) FLiNaK loop (15L/min) is planned to acquire heat transfer data, which will be performed using a molten salt loop at Sukegawa Electric Co..

(2) FLiNaK (50L/min) loop at the fusion blanket system in NIFS (National Institute for Fusion Science) was used for freeze valve tests. (See next)

Freeze Valve Test at NIFS

Freeze valve is a key system for MSR safety.

Based on experimental studies, UEC (Univ. Elec. Comm.) patented freeze valve, which gives shorter opening time



Freeze valve test system at NIFS loop.

[5] I.K. Aji, et al., "An Experimental and Numerical Study of Wall Effect on Freeze Valve Performance in a Molten Salt Reactor", J. of Nuc. Eng. & Rad. Sci., 2020, Vol.6

Graphite and Hastelloy-N

Graphite and Hastelloy-N are key materials for MSR.

(1) Graphite for MSR can be provided by a Japanese maker, which was already provided to HTGRs both in Japan and China.

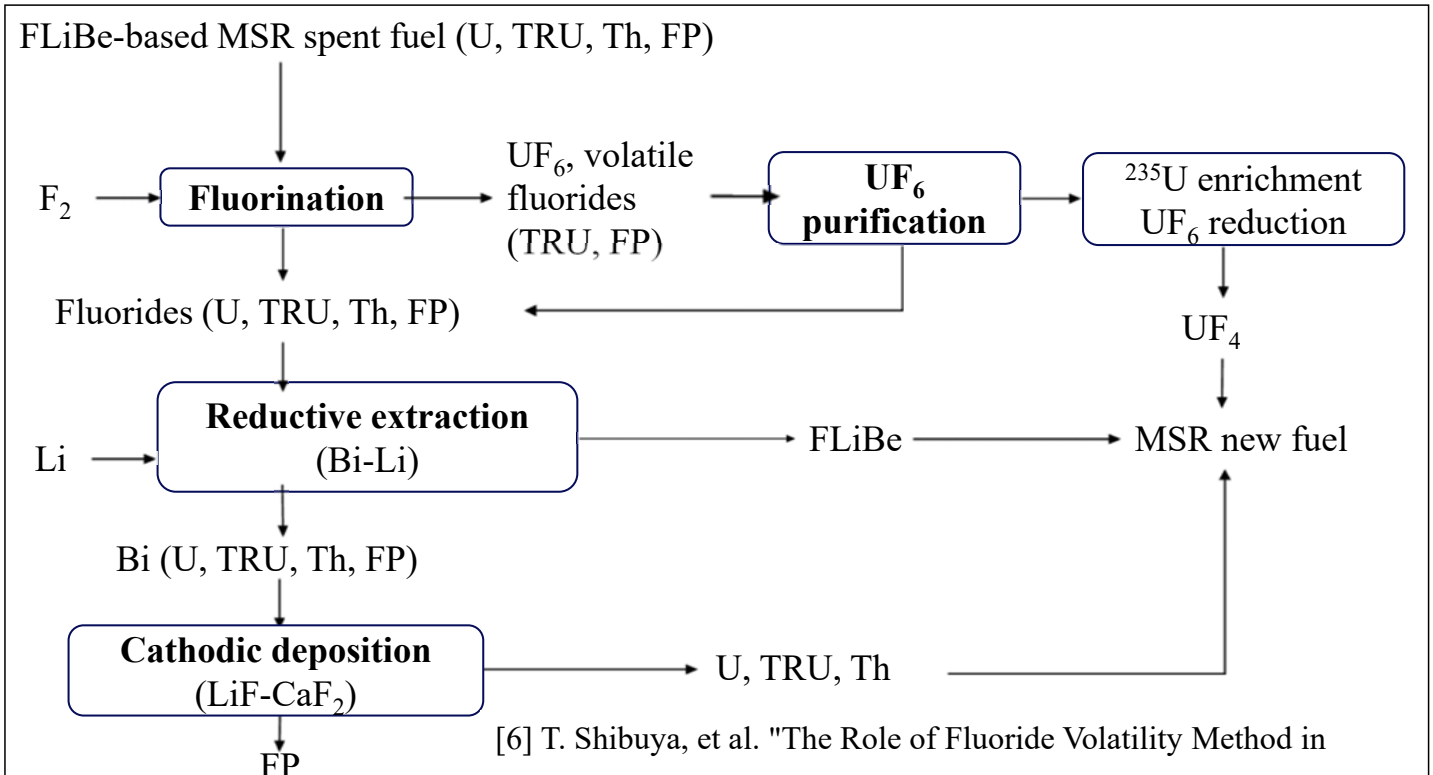
(2) Hastelloy-N is provided to industries by a Japanese maker, and there will be no concern to supply large amount.

Graphite for HTGR

Hastelloy-N sample

Reprocessing of Fluoride Fuel Salt

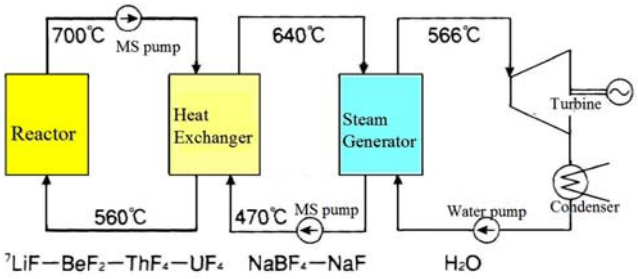
Online pyro-reprocessing was studied at ORNL in 1970s, but not demonstrated. The following off-line reprocessing is under consideration as feasible.

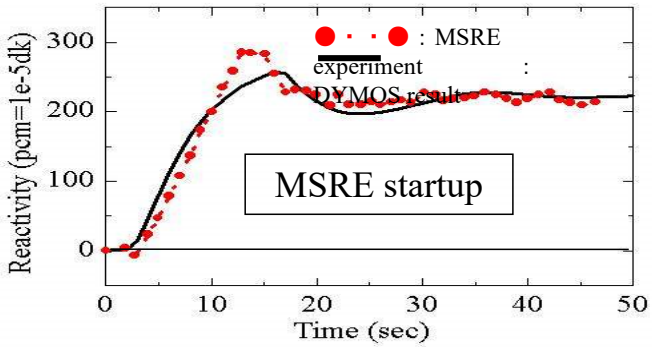


[6] T. Shibuya, et al. "The Role of Fluoride Volatility Method in Molten Salt Reactor Fuel Cycles", IAEA workshop, Nov. 2025

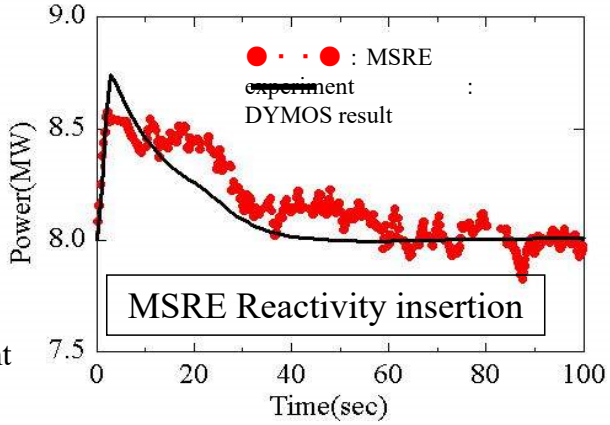
Safety Analysis Code “DYMOS”

We have performed verification study of a safety analysis code for MSR.
It can be used for transient & accident analysis, such as reactivity insertion accident, or pump trip accident, and so on.





Verification of DYMOS code for MSRE experiments shows very good agreement.



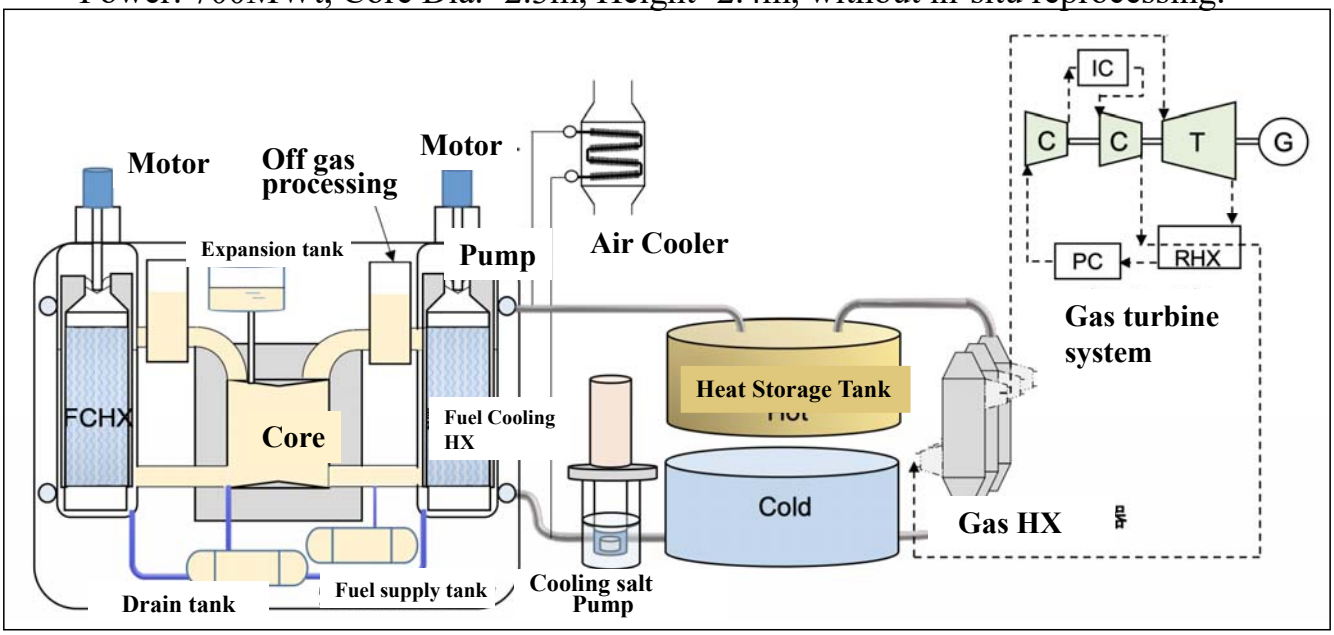
[7] Y. Shimazu, R. Yoshioka, K. Ogasawara, “Proposal of Application of a Simple Analysis Code DYMOS for Accident Analyses of Molten Salt Reactors”, Journal of Energy Research and Reviews, Vol.15, No. 4, 2023

2. Activity for Chloride Salt MSR

Chloride Salt MSR (BERD activity)

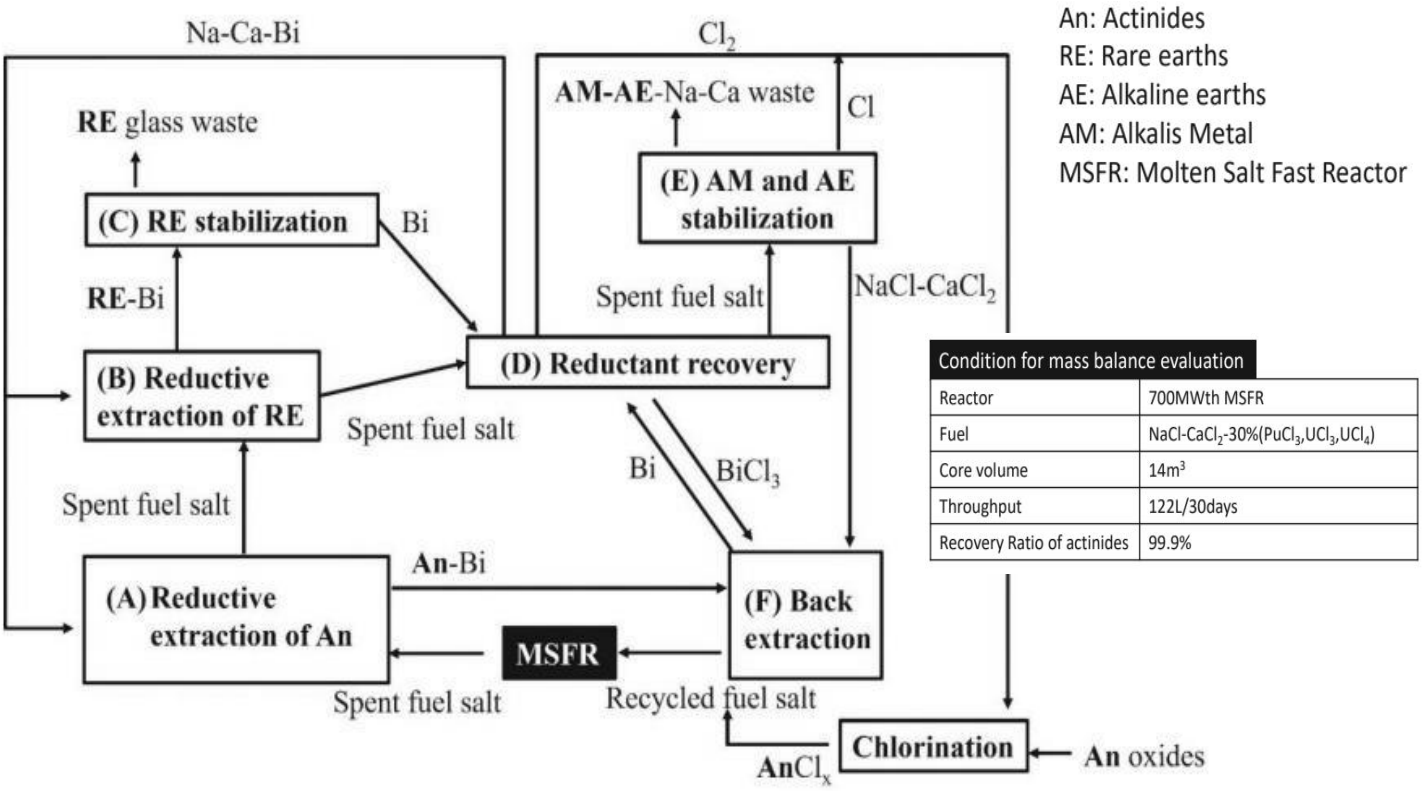
BERD is Japanese group for R&D of chloride salt MSR..
Member: Tokyo Inst. Tech., Fukui Univ. Doshisha Univ. CRIEPI
From 2019 till now, supported by NEXIP program of Japanese METI.

MSFR (Molten Salt Fast Reactor)
Power: 700MWt, Core Dia.=2.3m, Height=2.4m, without in-situ reprocessing.



[8] H. Mochizuki; Nucl. Eng. Design, 2024 Vol 428, November 2024, 113472

Reprocessing of Chloride Fuel Salt



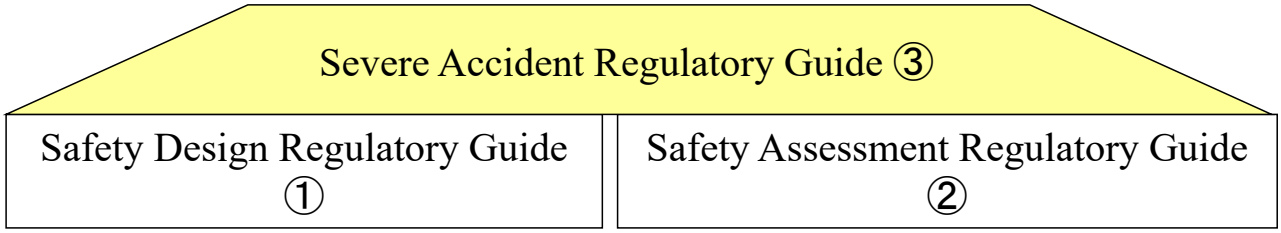
Condition for mass balance evaluation	
Reactor	700MWth MSFR
Fuel	$NaCl-CaCl_2$-30%($PuCl_3$,UCl_3,UCl_4)
Core volume	$14m^3$
Throughput	122L/30days
Recovery Ratio of actinides	99.9%

[9] T. Murakami, et al., "Development of Pyrochemical Treatment Process for Used Molten Salt Fast Reactor Fuels", IAEA workshop, Nov. 2025

3. Regulatory Guides for MSR Safety

Proposed Regulatory Guides for MSR Safety

Two-tiered structure:



No. 1 is **basic safety design guidelines** covering normal operations, Anticipated Operational Occurrences (AOO), and Design Basis Accidents (DBA) proposed by the authors [10], which is equivalent to ANSI/ANS-20.2-2023.

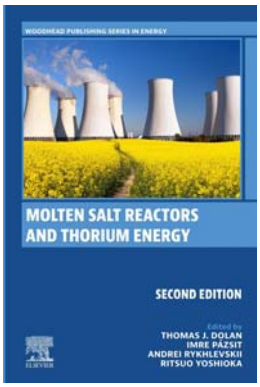
No.2 is **guidelines for safety analysis for AOO and DBA**, proposed by the authors [11], with reference to Japanese guidelines for light water reactors(LWRs).

No.3 is **Guidelines for events beyond-DBA (: severe accidents)**, also proposed by the authors [12], with reference to Japanese guidelines for LWRs.

Sources of Regulatory Guides for MSR Safety

[10] R. Yoshioka, M. Kinoshita, "**Regulatory guide for MSR safety design**", Section 11.6 in the book: "*Molten Salt Reactors and Thorium Energy*", Elsevier, 2024

[11] R. Yoshioka, M. Kinoshita, "**Regulatory guide for MSR safety assessment**", Section 11.7 of the book: "*Molten Salt Reactors and Thorium Energy*", Elsevier, 2024



[12] R. Yoshioka, T. Morita, K. Ogasawara, M. Kinoshita, Y. Shimazu, M. Furukawa, "**Regulatory Guide for MSR Severe Accident**", IAEA Technical Meeting on Severe Accident Analysis and Management for Non-Water Cooled Reactors", 14-17 October 2024.

Part of activity here was supported by NEXIP program of Japanese METI.

Thank you for your attention!

Any questions/comments?