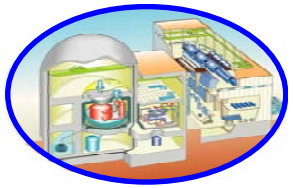


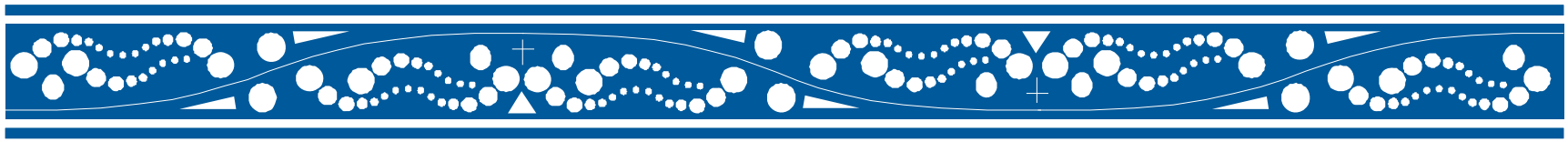
MSR Workshop at ORNL

October 11-12, 2022

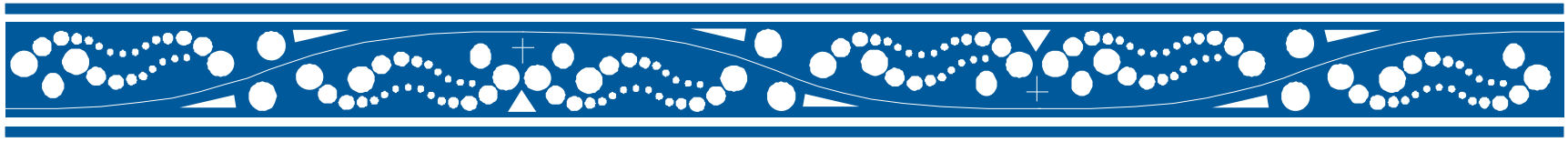
MSR Activity in Japan

1. Introduction
2. Transient Analysis Code
3. Regulatory Guides for MSR Safety
4. Proliferation Resistance and Physical Protection
5. Freeze Valve Experiment

Motoyasu Kinoshita, Kazuro Furukawa, Ritsuo Yoshioka
International Thorium Molten-Salt Forum (ITMSF)



1. Introduction



Our MSR Activity

International Thorium Molten-Salt Forum (ITMSF) is a Non-Profit-Organization, established in 2008 for basic study of MSR technology such as conceptual designs and safety analysis.

This Forum is an observer member of the GIF-MSR System Steering Committee from this Committee's beginning.

Besides that, **Thorium Tech Solution Inc. (TTS)** was established in 2010 for business application.

Both this Forum and TTS were established by Dr. Kazuo Furukawa, and there is an MOU between this Forum and TTS, for MSR-FUJI realization.
Recently, another MOU between this Form and **MOSTECH** Co. was signed, for mutual cooperation in MSR development.

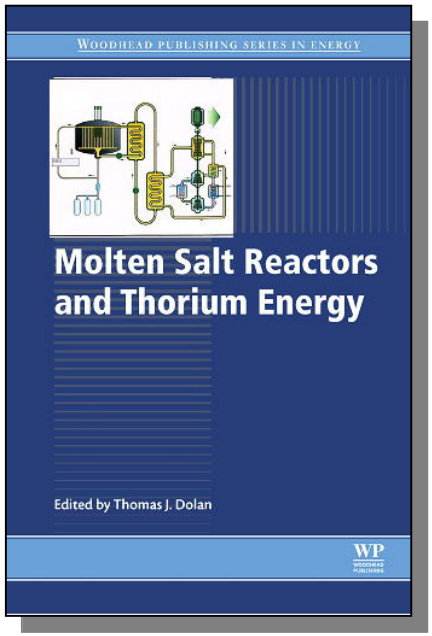
Japanese Government started to support startup companies

for MSR development from 2019.

MSR-FUJI

MSR-FUJI is based on the MSBR design at ORNL in 1960s to70s, 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.

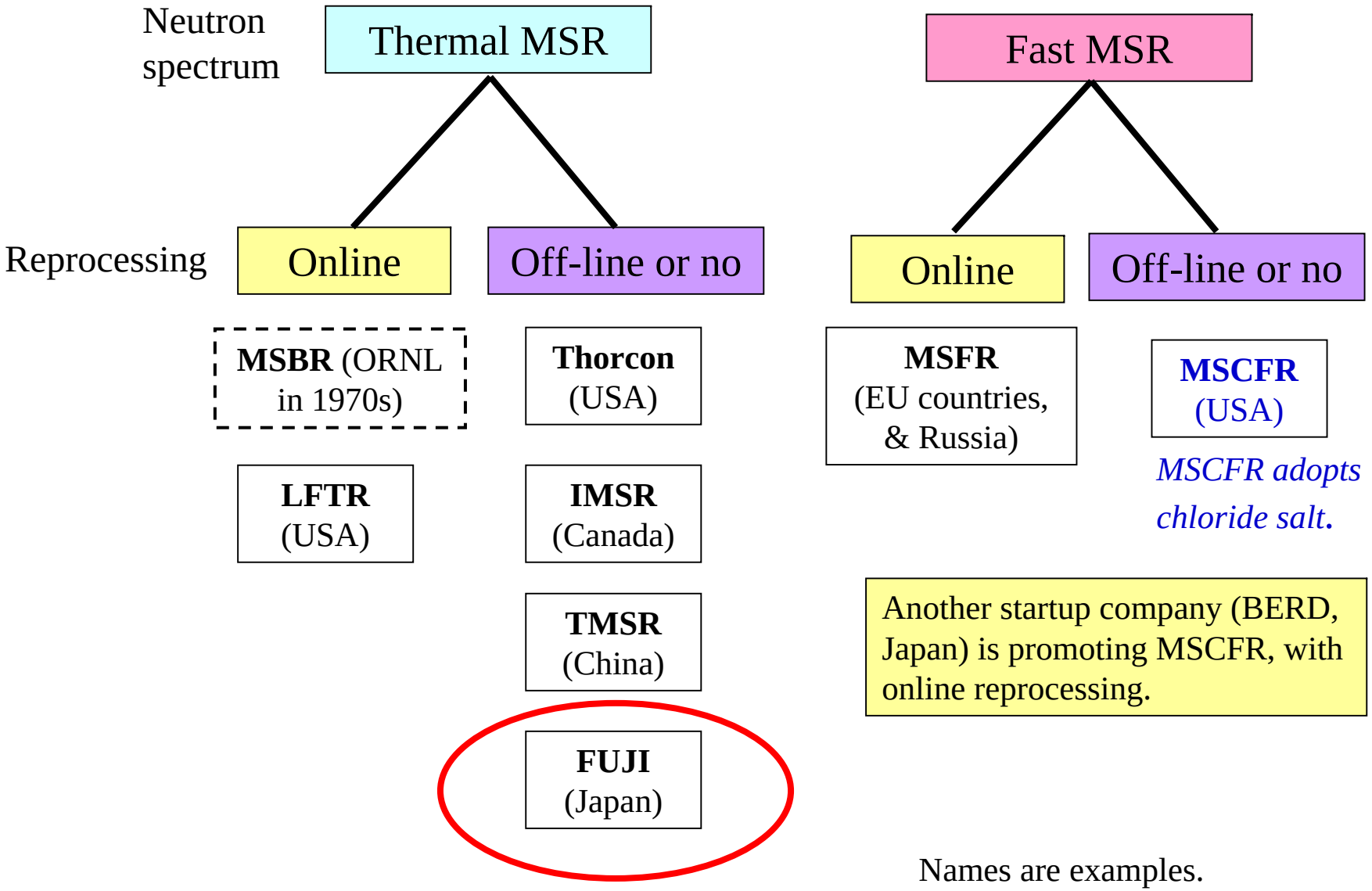
Information on MSR-FUJI is described in the following books [1][2].



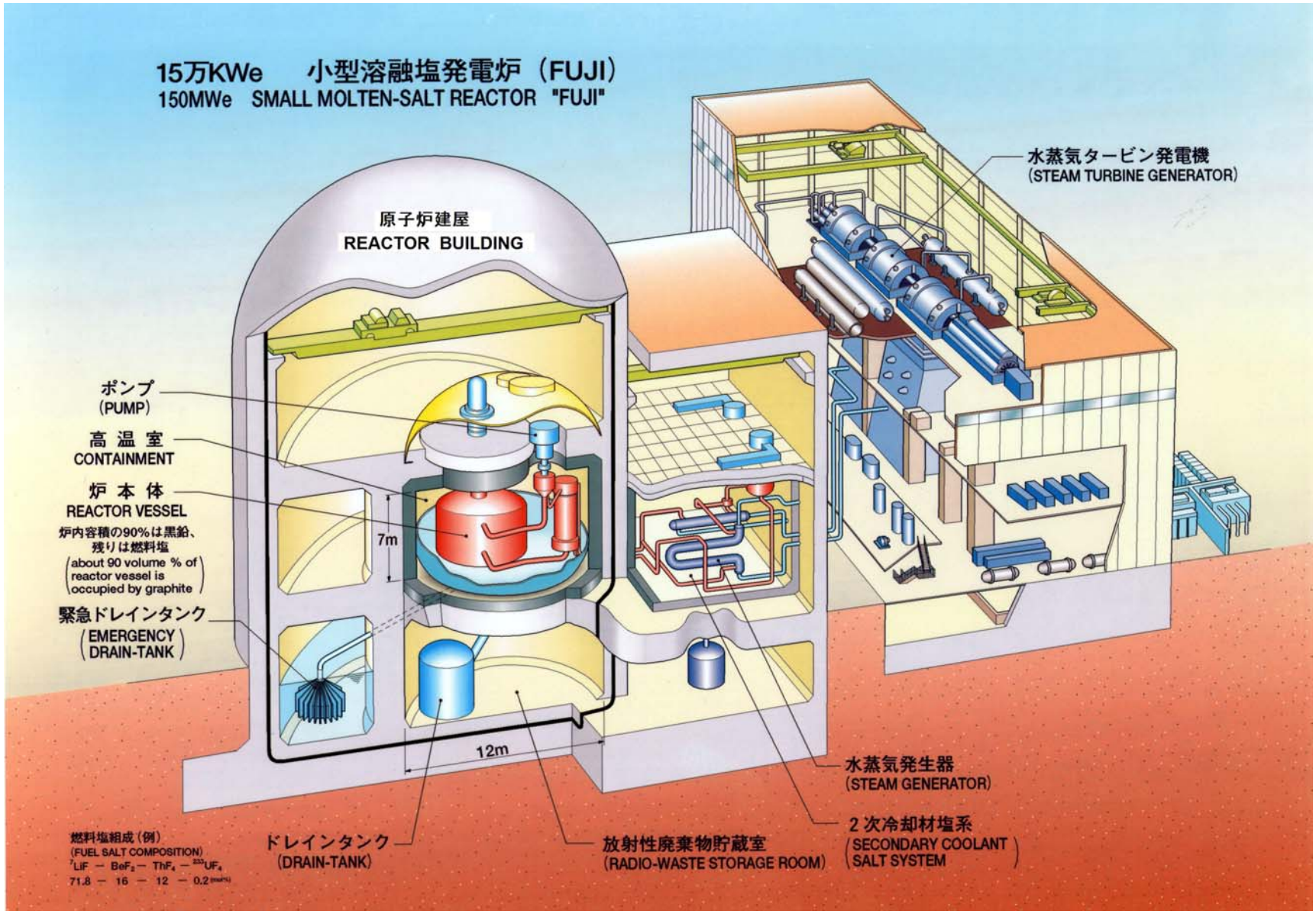
[1] “Molten Salt Reactors and Thorium Energy” , by T. Dolan, Elsevier, 2017

[2] “Advances in Small Modular Reactor Technology Development”, by IAEA, 2020

Various MSR Designs



Bird-eye View of MSR-FUJI



FUJI design was proposed in 1990 by Dr. Kazuo Furukawa.

Molten Salt Loop Technology

- FLiNaK loop (15L/min) is planned to acquire heat transfer data in 2023.
- Molten salt pump for FUJI is under designing.

●FLiNaK (50L/min) loop at the fusion blanket system in NIFS (National Institute for Fusion Science) is now preparing freeze valve test for MSR. (See Section.5.)

Graphite and Hastelloy-N

● Graphite for MSR can be provided by the Japanese maker, which provided to HTGRs both in Japan and China.

●Hastelloy-N is provided to industries by the Japanese maker, and there will be no concern for large amount supply.

Graphite for HTGR

Hastelloy-N sample

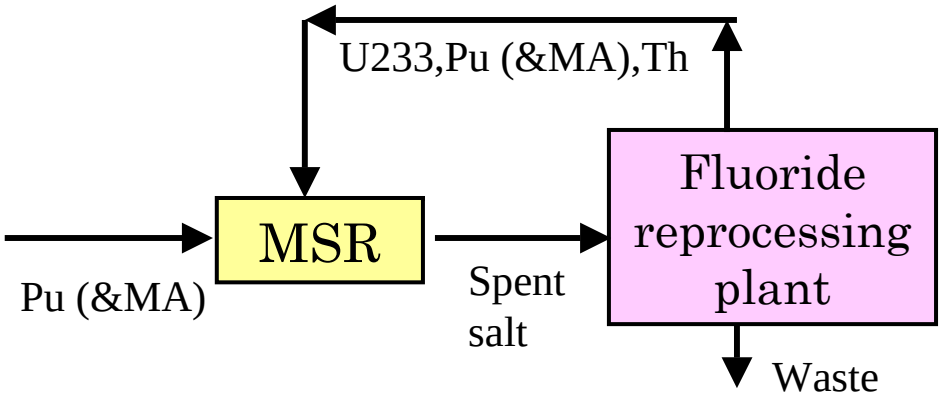
Fuel Cycle for MSR

TTS and CVR in Czech started a joint study to establish off-line reprocessing of spent fuel salt from MSR.

Online reprocessing was studied at ORNL in 1970s, but not demonstrated.

The following off-line reprocessing is under consideration, and considered feasible.

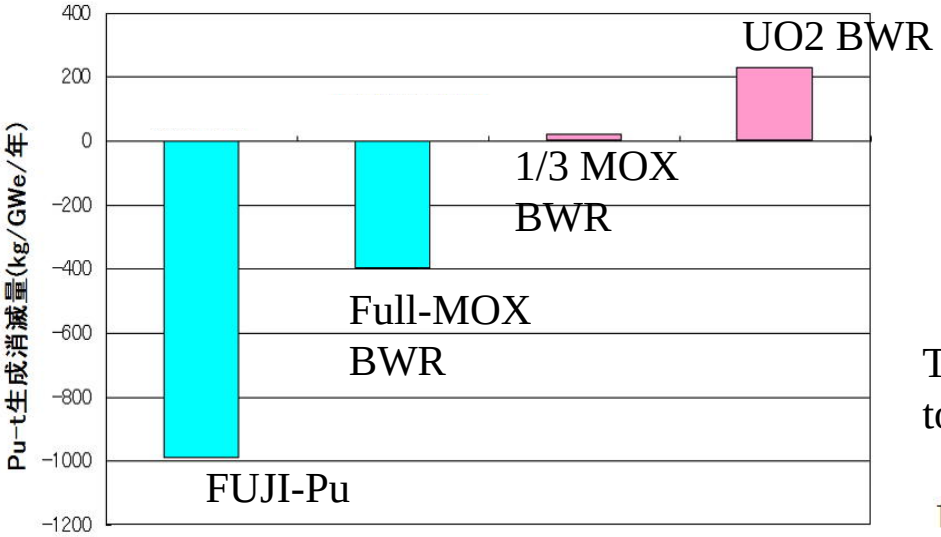
Off-line Reprocessing of MSR spent fuel salt



Czech's FREGAT facility

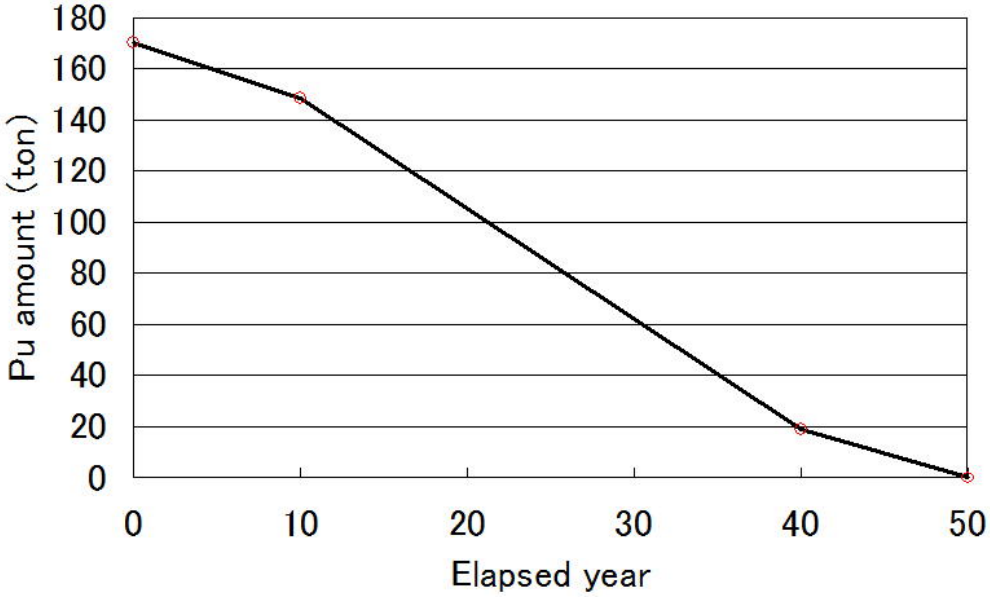
Pu Transmutation Study

Total Pu transmutation comparison (kg/GWe/year)



Normalized at 1-year operation of 1GWe plant size.

Total Pu amount in Japanese LWR spent fuel is 170 ton, which can be burned by 24 x 200MWe-FUJI-Pu.

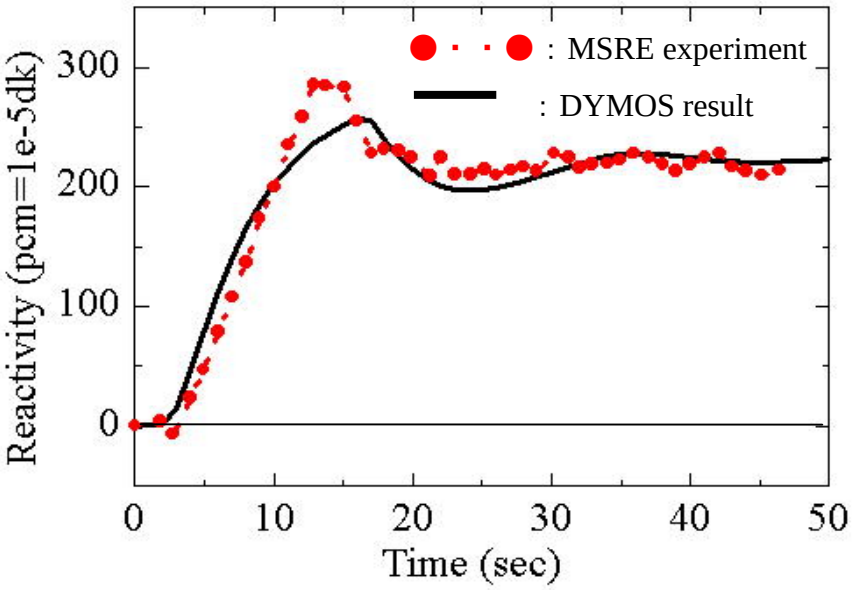


2. Transient Analysis Code

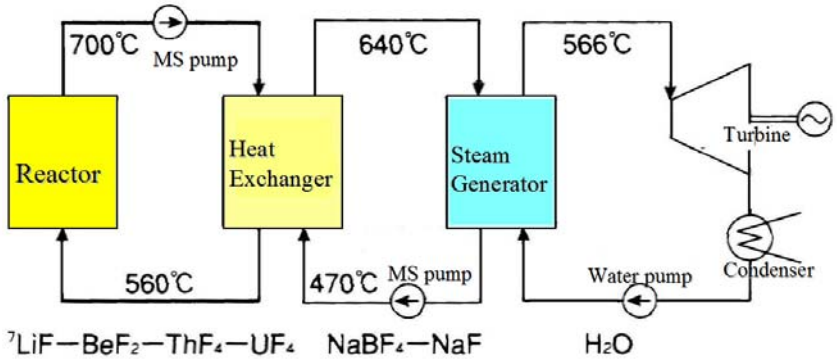
Y. Shimazu, R. Yoshioka, K. Ogasawara, M. Furukawa, "Transient Analysis Code for Molten Salt Reactor: DYMOS“, AESJ-2021-Sep-meeting (in Japanese)

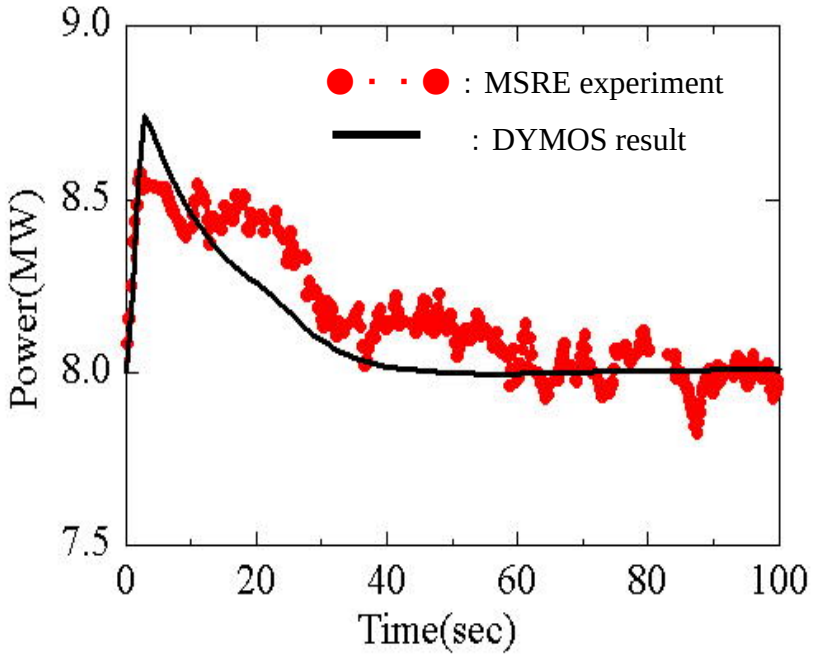
Transient Analysis Code (DYMOS)

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



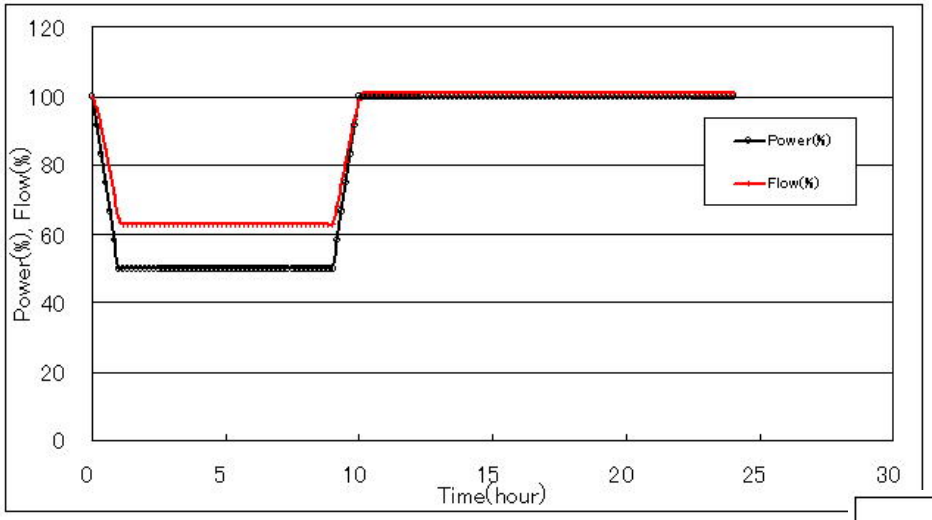
Verification of DYMOS code for MSRE experiments.





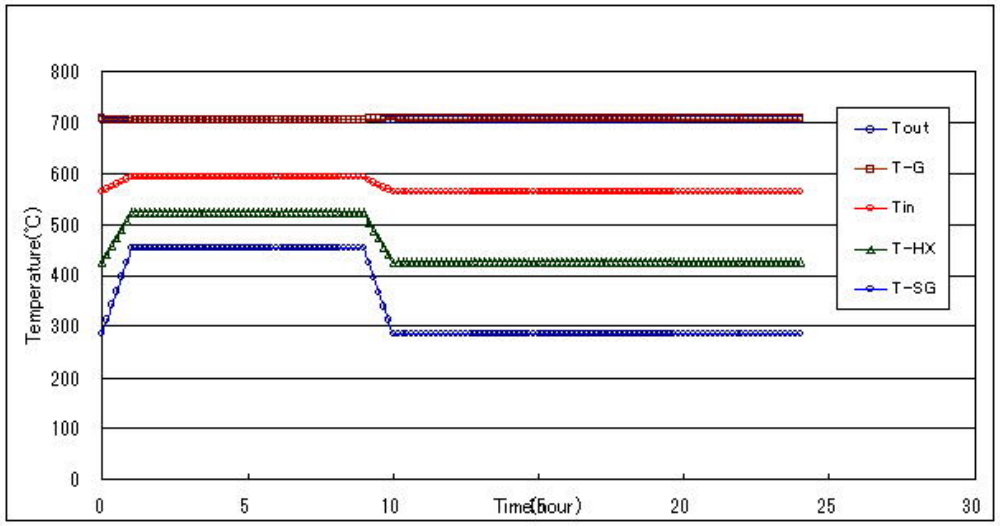
Load Following Capability

The above transient analysis code for MSR is applied to evaluate daily load following such as 14-1-8-1 (100%P⇔50%P) pattern.



MSR can maneuver daily load following only by changing core flow.

Different from LWR, peak temperature does not change, which is highest at the MSR core exit.



3. Regulatory Guides for MSR Safety

Two Safety Guides for MSR Safety

There are two important safety guides in current LWR licensing.

(1) **Regulatory guide for Reactor Safety Design**, which are used at reactor design stage.

(2) **Regulatory guide for Safety Assessment**, which are used to assess reactor safety based on accident analysis.

These 2 guides for MSR are proposed by the authors.

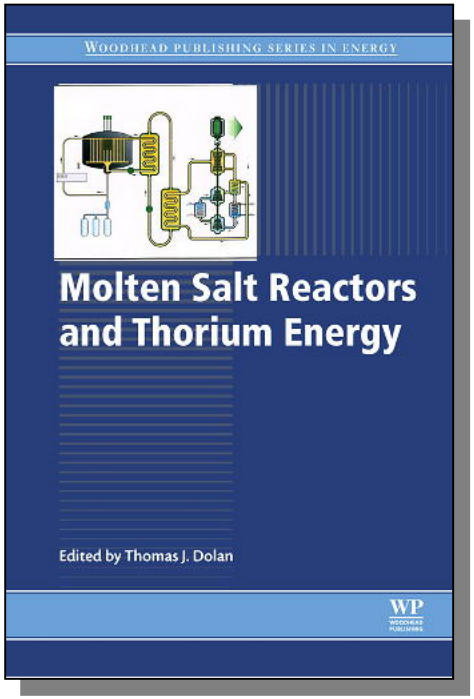
Regulatory Guide for Site Evaluation

(1) Regulatory Guide for MSR Safety Design

For reactor design

(2) Regulatory Guide for MSR Safety Assessment

For accident analysis



(1) is in 2017 edition.

(1)&(2) are in 2023 edition.

4. Proliferation Resistance and Physical Protection

Proliferation Resistance and Physical Protection

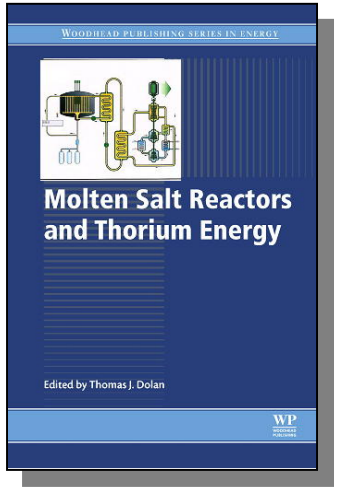
As for **Proliferation Resistance**, various MSR technologies are discussed, such as, Fuel type, Coolant type, Neutron spectrum, Fuel salt type, Fuel feeding after startup, Reprocessing type, Fissile & Fertile material, Blanket loop, Addition of Minor actinide, Purpose of MSR, and Core structure.

As a result, MSR fuel cycle has potential Proliferation Resistance, because of U-232 gamma radiation.

As for **Physical Protection**, design basis threat (DBT) for LWR is discussed at first. Then, DBT for MSR is proposed here, where loss of AC and DC power sources is already considered in designs.

It is concluded that MSR is appropriately protected against DBT.

Report is included in 2023 edition.

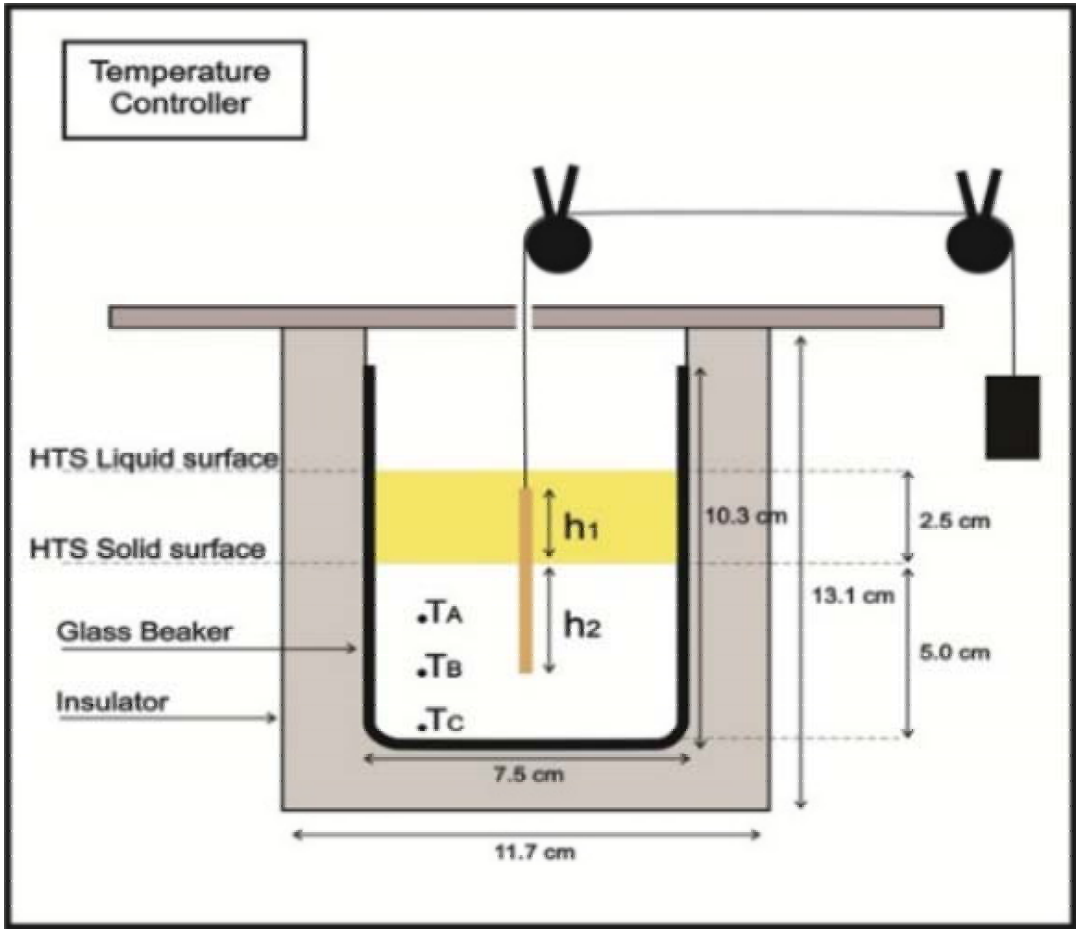


5. Freeze Valve Experiment

I. K. Aji, T. Tokushima, M. Kinoshita, T. Okawa, “An Experimental and Numerical Study of Wall Effect on Freeze Valve Performance in a Molten Salt Reactor”, J. of Nuclear Engineering and Radiation Science, 2020, Vol.6.

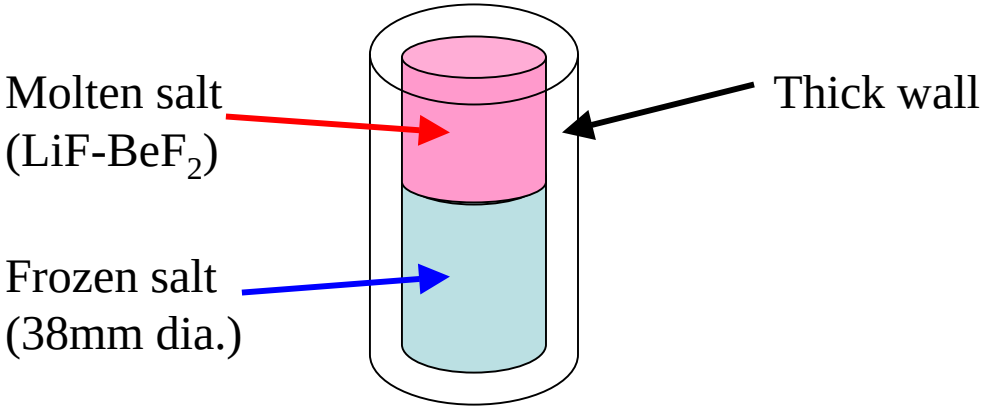
Basic Freeze Valve Experiment

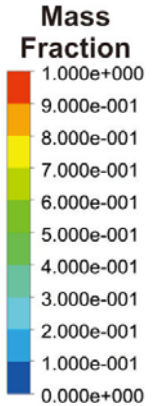
Using two-layered (molten salt over frozen salt) geometry, several parameters are investigated, such as salt temperatures, wall thickness, wall material, etc..



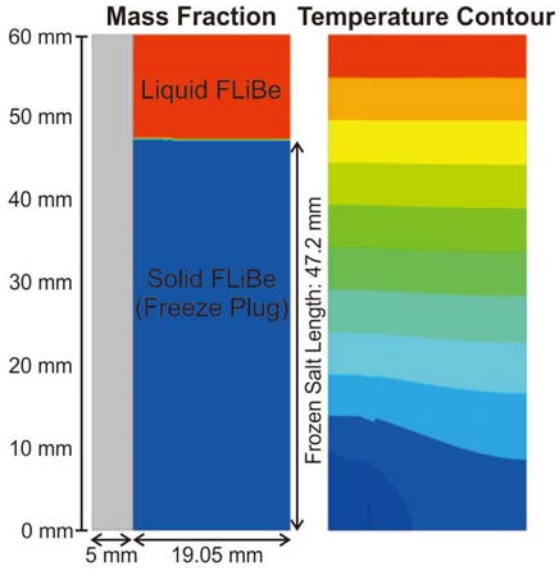
Freeze Valve Calculation in MSR

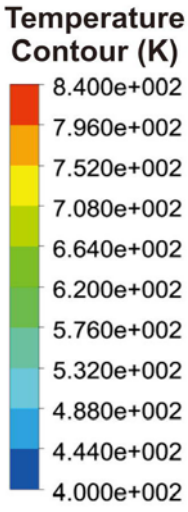
The following cylindrical freeze valve with thick wall is proposed for actual MSR.



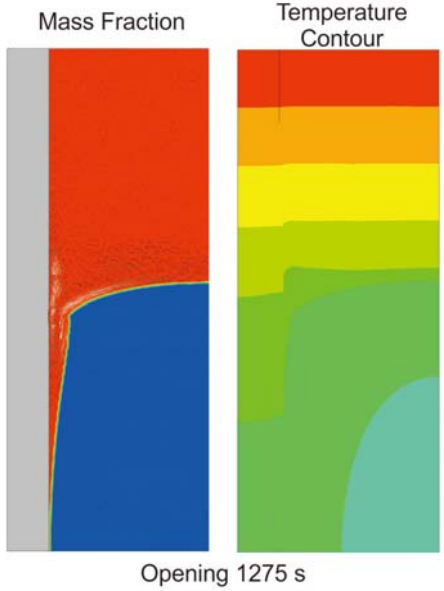


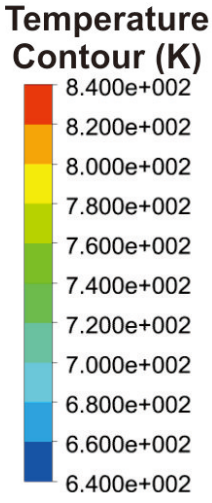
Owing to heat transfer at thick wall, opening time is shortened. (See next)





Freeze valve closed





Freeze valve opened

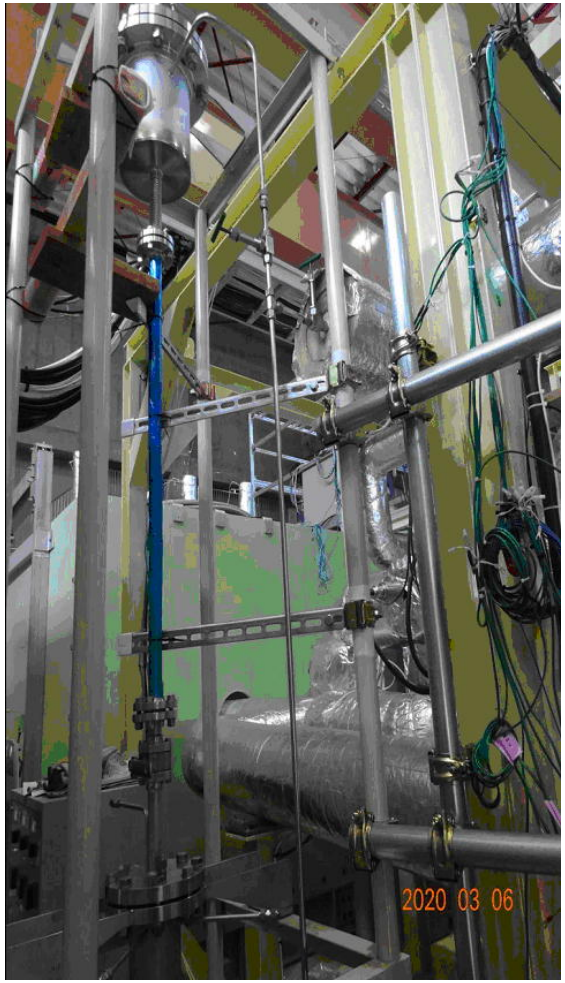
Conclusion on Freeze Valve

Based on our experimental study, thick wall made of copper is most effective to achieve shorter opening time, without using active system such as heater.

Temperature of frozen salt should be designed appropriately.

Based on the study here, we are doing freeze valve test at FLiNaK molten salt loop at National Institute of Fusion Science (NIFS).

Also, we will optimize freeze valve design for MSR.



Freeze valve test section at NIFS

Thank you for your attention!

Any questions/comments?