Preliminary Study for Radioactivity Evaluation of MSR compared with LWR

Geun Hyeong Lee* and Hee Reyoung Kim
Ulsan National Institute of Science and Technology, Ulsan 689-798, Republic of Korea
**Corresponding author: studiousgh@unist.ac.kr*

1. Introduction

One of the most important things in nuclear engineering is safety respect to radiation. When huge accidents occur, nuclear fission substances are emitted outside with radiation and high level radioactive wastes leak. LWR uses fuel as ^{235}U and fissile material as solid (enriched uranium). Those cannot control its component artificially and hard to change fuel frequently. Therefore this fuel remains as much as possible. That makes risk of high radiation leakage because of long neutron irradiation time. On the other hand, MSR (Molten Salt Reactor) uses fuel as thorium-uranium; fissile ^{233}U when ^{232}Th absorbs one neutron, and fissile material as liquid (molten salt). It has plenty of benefits respect to radioactive safety. It leads nuclear fuel dump when accident happens, diminishes basic fission substances' radiation and even the cost (Th exist 3~4 times more on the earth compared with natural uranium). Those features excludes disperse of radiation to nature.

2. Radiation Characteristic of MSR

In this section, basic concept of radioactivity evaluation of Molten Salt reactor is written which are source term, volatile fission products, and radioactive waste.

2.1 Source Term

Source term means that amount of radioactivity available to an accident for dispersal and for impact on the environment.

LWR uses enriched uranium which is contained solid. When fuel assembly is loaded once, its components could not control artificially, and fuel could not be changed frequently during the operation. Therefore fuels remain long time. It causes high leakage of radioactive source when accident happens. On the other hand, in case of MSR, fuels remain short time compared to LWR because it uses liquid fuels. It can be easily replaced during the operation. MSR's processing time is assumed about 1~10 days while typical LWR's about 300~1000 days.

For isotopes with short half-life compared with processing time ($T_m \ll P$), isotopes rapidly build up to their equilibrium level of F/λ where F is production rate. MSR have much smaller kind of those than LWR because MSR has low processing time about 1/100. This short half-life isotope's λ is up to a few days. In order to this source term significantly diminished by time, it has not seriousness when accident is occurred.

For isotopes with long half-life compared with processing time ($T_m > P$), The quantity of these isotopes is limited to $F * P$. This group is important because it released to environment long remaining radiation when accident happens including prominent members as strontium and cesium with half-lives of decades. In the case of MSR has lower quantity than LWR proportional to its processing time. Thus it is lots of safer than LWR.

Shielding is simple because of those properties. MSR has just 3 wall compared to LWR has 5. As shown to Table I, MSR has not pellet and cladding walls.

Table I: LWR and MSR's wall segment

Wall number	LWR	MSR
1	Pellet	None (liquid fuel)
2	Cladding	None (liquid fuel)
3	Pressure vessel, pipes	Reactor vessel, pipes
4	Containment	High temperature confinement
5	Reactor building	Reactor building

2.2 Volatile Fission Products

When nuclear reactor accident happen, diffused volatile fission products leak, for example, Kr, I, Br, and Xe. In the MSR those volatile fission products are continuously removed from fuel salt minimizing their leakage. For instance AMBIDEXTER (Advanced Molten-salt Break-even Inherently-safe Dual-mission Experimental and Test Reactor) which is experimentation about concept planning, can be seen Table II and Fig.1, leak just 3% (without on-line reprocessing) and 1.6% (with on-line reprocessing). Therefore exposing to radiation is negligibly small when severe accidents happen.

Table II: Comparison of fuel burn-up properties of AMBIDXTER and PWR

	Radioactivity ($Ci \cdot MW_{th}^{-1}$)	Volatile FPs ($Ci \cdot MW_{th}^{-1}$)	Minor actinides ($g \cdot MW_{th}^{-1}$)
AMBI (+)[a]	$1.06*10^5$	$3.6*10^4$	13.6
AMBI (-)[b]	$1.83*10^5$	$7.6*10^4$	17.6
PWR	$5.90*10^6$	$2.0*10^6$	142.0

[a] AMBIDEXTER with on-line reprocessing.
[b] AMBIDEXTER without on-line reprocessing.

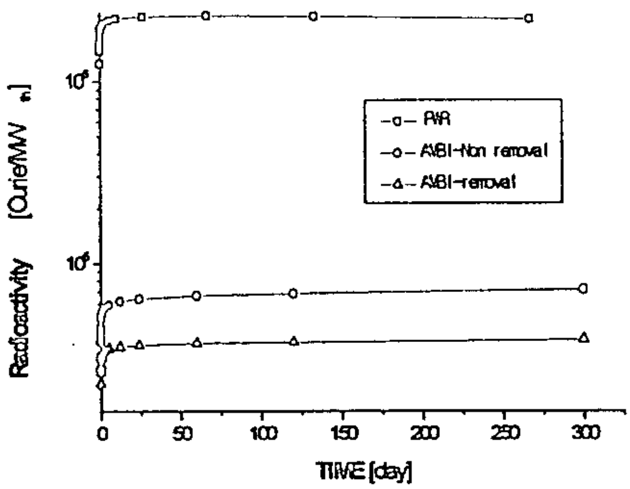

Fig. 1. Volatile releasable inventory in nuclear reactor

2.3 Radioactive Waste

In LWR, there are uncertainties in predicting long-term behaviors of the α-emmiting transuranic isotopes which half-life is more than 5 years. Fission products such as ^{99}Tc, ^{137}Cs, ^{129}I, and ^{79}Se remain too large to be implemented in the engineering design verification. On the other hand MSR, ^{7}LiF-BeF_2 which is base salt material restrains transmutation probability of Th to transuranic actinides by multiple captures of neutrons. So it makes low quantity of high-level radioactive waste.

Next is about minor actinide inventory in reactor. Minor actinide is actinides excluding ^{233}Th, ^{233}Pa, ^{233}U, ^{235}U, ^{238}U, ^{239}Np, and all Pu isotopes. In the case of AMBIDEXTER, can be seen in Fig.2 and Table II, there is 2% quantity minor actinide compared with PWR. It also makes low quantity waste. Therefore high-level waste treatment is safer than that of LWR.

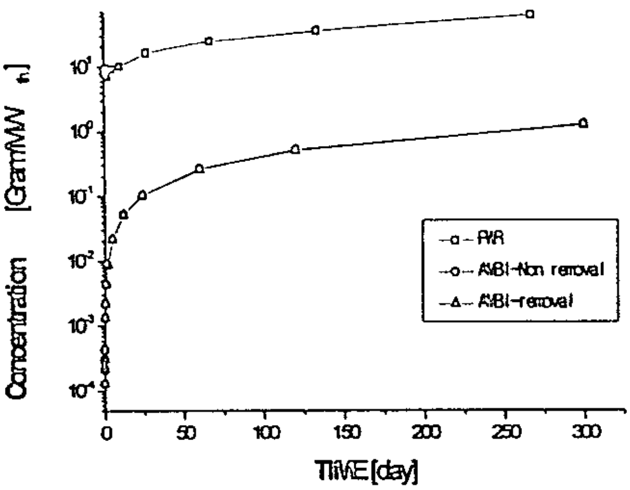

Fig. 2. Quantity of remained minor actinide in reactor

3. Conclusions

It was understood that MSR had inherent safety in the aspect of radioactivity in spite of its tritium production. Source term is much lower than conventional LWR in order to processing time. Radiation exposure from volatile fission products in severe accidents is thought to be negligible due to the continuous removal mechanism. The generation of high level radioactive wastes from MSR is estimated to be much smaller than that of conventional LWR because of its less converting probability of thorium to minor actinides. It was thought the fundamental approach to MSR would make it possible to realize the safety of reactor when considering the severe accidents affecting on nuclear power plants due to natural disaster.

REFERENCES

[1] J. S. Yoon, N. B. Jang, and S. G. Oh, Assessment of the AMBIDEXTER Radioactivity Behaviors with Respect to Operational Safety, Ajou University, Korea, 2000.

[2] S. K. Oh, and K. Chung, AMBIDEXTER nuclear energy complex: a practicable approach for rekindling nuclear energy application, Nuclear Engineering and Design, Jul, 2001.

[3] Badawy M. Elsheikh, Safety assessment of molten salt reactors in comparison with light water reactors, Egyptian Nuclear and Radiological Regulatory Authority, August 17, 2013.

[4] H. L. Dodds, The Source Term and Waste Optimization of Molten Salt Reactors with Processing, June 14, 1993.d