IRSTI 58.33.37

Calculation of tritium release from driver fuels into primary coolant of research reactors

Hai Quan Ho and E.Ishitsuka*

Sector of Fast Reactor and Advanced Reactor Research and Development, Japan Atomic Energy Agency (JAEA), 4002 Narita-cho, Oarai-machi, Higashi Ibaraki-gun, Ibaraki-ken, 311-1393, Japan
**e-mail: ishitsuka.etsuo@jaea.go.jp*

Increasing of tritium concentration in the primary coolant of the research and test reactors during operation had been reported. To check the source for tritium release into the primary coolant during operation of the JMTR and the JRR-3M, the tritium release from the driver fuels was calculated by MCNP6 and PHITS. It is clear that the calculated values of tritium release from fuels are as about 10^7 and 10^6 Bq for the JMTR and JRR-3M, respectively, and that calculated values are about 4 order of magnitude smaller than that of the measured values. The JMTR is a tank type, and the JRR-3M is a pool type research reactor. The primary coolants are light water, in which the coolant temperature is lower than 50ºC. These results show that the tritium release from fuels is negligible for both the reactors. In the calculations of tritium release rates into the water by PHITS, a gaussian triton energy by ternary fissions of ^{235}U.

Key words: tritium release rate, driver fuels, primary coolant, JMTR, JRR-3M.
PACS numbers: 25.85.Ec, 28.41.Er.

1 Introduction

Tritium release into the primary coolant during operation of the JMTR (Japan Materials Testing Reactor) and the JRR-3M (Japan Research Reactor-3M) had been measured. As results, the amount of tritium release per operation cycle was reported as $1\sim2\times10^{11}$ Bq and $1\sim4\times10^{10}$ for the JMTR and JRR-3M, respectively [1-5]. The sources and mechanism of the tritium release had been studied [6-10], and it is clear that the beryllium components in core strongly affect the tritium release into the primary coolant. However, to get a scientific evidence, the other effects such as a ternary fission by the driver fuels should be checked [11-15]. Therefore, the calculation of tritium release from the driver fuels was carried out in this paper.

2 Calculations of tritium release from driver fuels

Outline of the JMTR and the JRR-3M are summarized in Table 1. The JMTR is a tank type, and the JRR-3M is a pool type research reactor. The primary coolants are light water, in which the coolant temperature is lower than 50ºC. Core configurations for both the reactors are shown in Figures 1 and 2 [1]. In this calculation, it was assumed that all fuels were the same as standard fuel. Size of standard fuel plates for both the reactors are shown in Table 2 [16, 17].

Table 1 – Outline of JMTR, JRR-3M

Items	JMTR	JRR-3M
Thermal power (MW)	50	20
Main purposes	Irradiation tests, RI productions, Training	Beam experiments, RI productions
Main core components	Be, Al	Be, D_2O tank
Operation	30d/cy, 6cy/y	25d/cy, 6cy/y

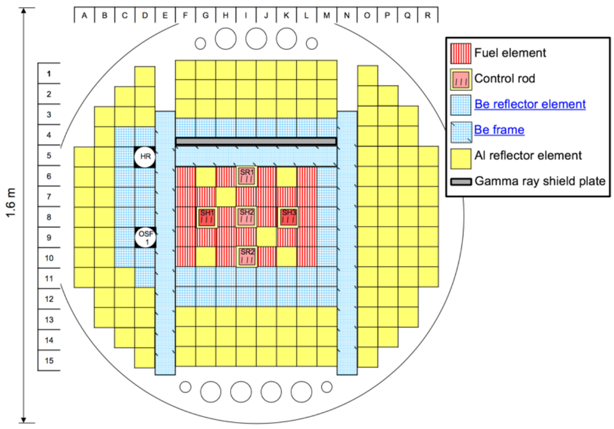


Figure 1 – Core of JMTR

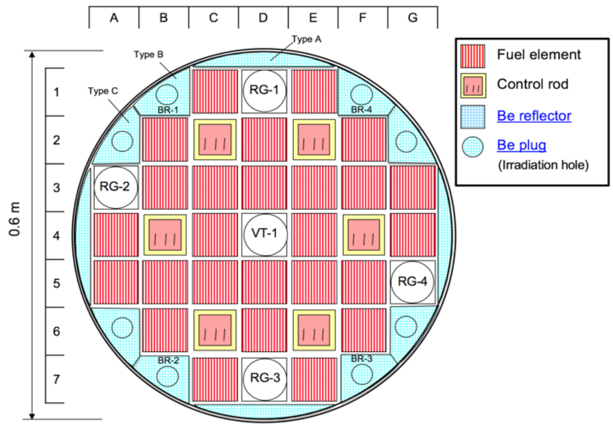


Figure 2 – Core of JRR-3M

Table 2 – Size of standard fuel plate

Items	JMTR	JRR-3M
Fuel meat thickness (mm)	0.51	0.51
Fuel meat width (mm)	62	62
Fuel meat length (mm)	760	750
Thickness of cladding (mm)	0.38	0.38
Fuel plate thickness (mm)	1.27	1.27
Fuel plate width (mm)	71	71
Fuel plate length (mm)	780	770

The difference in size of standard fuel plates between both the reactors is only the length. The cross-section of both fuel plates are the same size. Calculation model of the standard fuel plate is shown in Figure 3. Tritium productions by the ternary fissions and tritium release rates into the water for one operating cycle in both the reactors were calculated by MCNP6 [18] and PHITS [19], respectively. The calculation results of tritium production by MCNP are shown in Table 3.

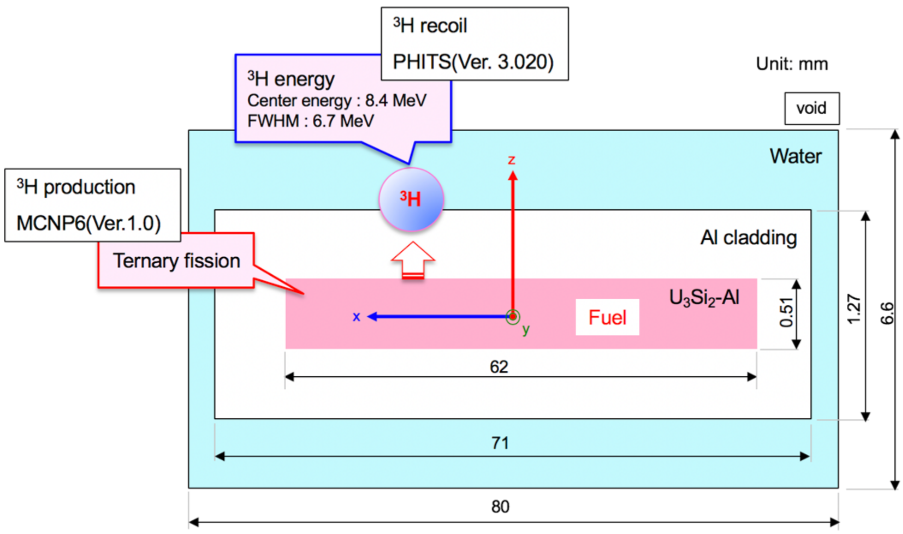
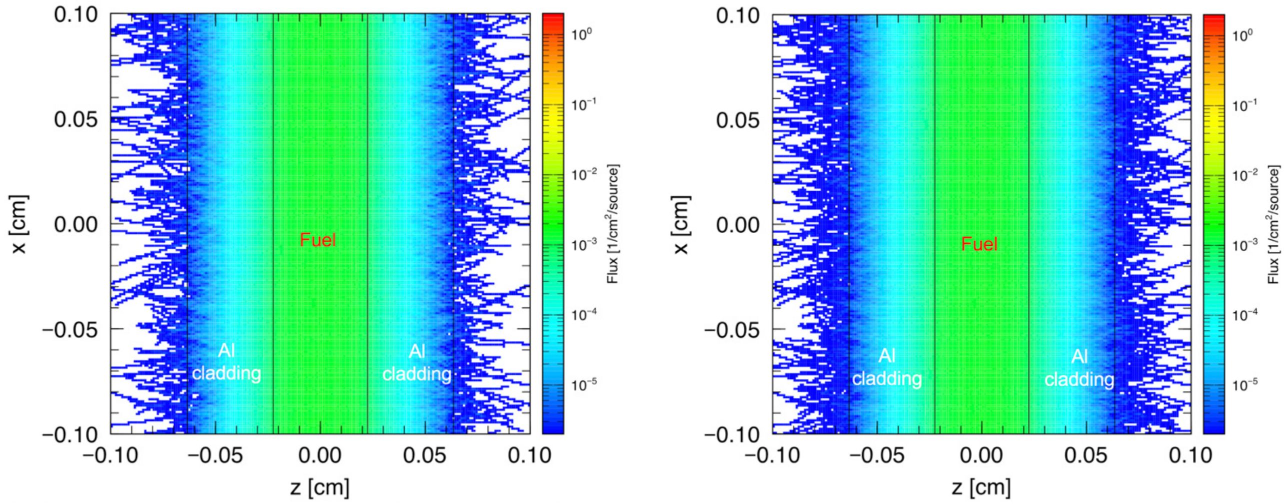
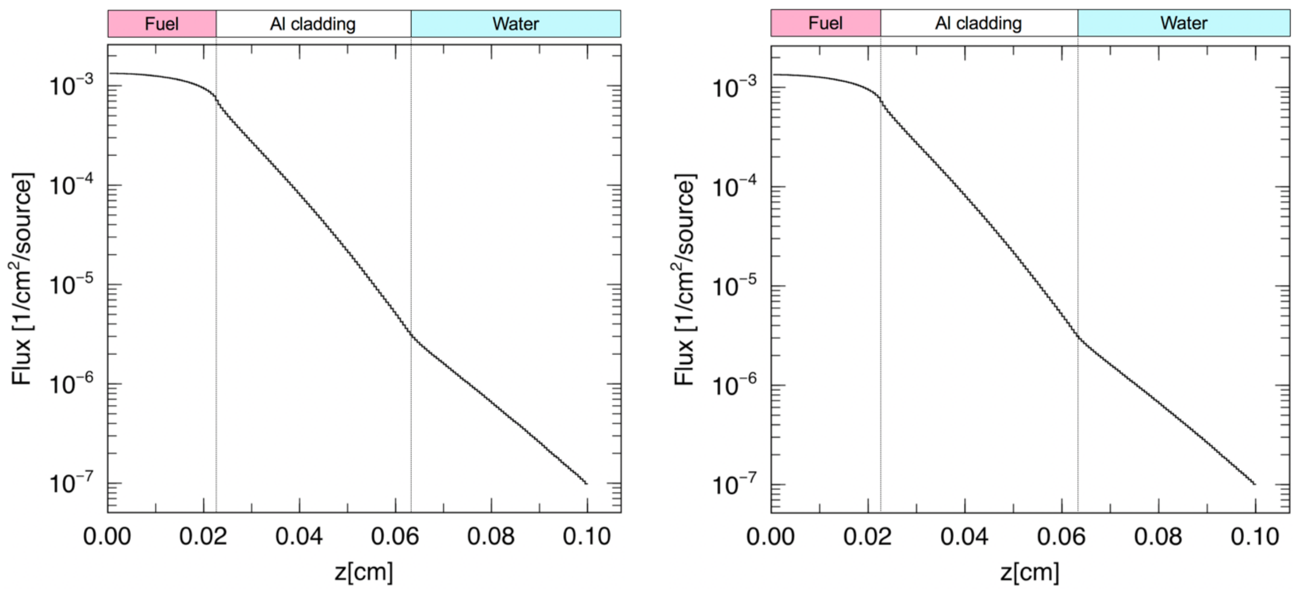


Figure 3 – Calculation model of standard fuel plate



(1) Standard fuel plate of JMTR (2) Standard fuel plate of JRR-3M

Figure 4 – Triton 2D distribution



(1) Standard fuel plate of JMTR (2) Standard fuel plate of JRR-3M

Figure 5 – Triton 1D distribution

Table 3 – Calculation results

Items	JMTR	JRR-3M
Tritium production (Bq)	2.7×10^{9}	2.4×10^{8}
Tritium release rate	2.8×10^{-3}	2.8×10^{-3}
Released tritium (Bq)	7.6×10^{6}	6.5×10^{5}
Calculated value / measured value	~10^{-4}	~10^{-4}

In the calculations of tritium release rates into the water by PHITS, a gaussian triton energy by ternary fissions of ^{235}U, as shown in Figure 3, was selected [20]. The calculation results for standard fuel plates by PHITS are shown in Figure 4, Figure 5, and Table 3. Tritium release from fuels is about 10^7 and 10^6 Bq for the JMTR and JRR-3M, respectively.

3 Discussion

From the above calculation results, the tritium release from fuels for both the reactors is about 4 order of magnitude smaller than that of the measured value

(JMTR: ~10^{11} Bq, JRR-3M: ~10^{10} Bq). Therefore, it is clear that the tritium release from fuels for both the reactors is negligible, and that it is not necessary to consider as the source of tritium release.

4 Conclusions

To check the source for tritium release into the primary coolant during operation of the JMTR and the JRR-3M, the tritium release from the driver fuels are calculated by MCNP6 and PHITS. The following results were obtained.

- The calculated amount of tritium release from fuels are about 10^7 and 10^6 Bq for the JMTR and JRR-3M, respectively.
- The calculated values are about 4 order of magnitude smaller than that of the measured value.
- The tritium release from fuels for both the reactors is negligible. It is not necessary to consider the fuels as the source of tritium release.

References

1 E. Ishitsuka, J. Motohashi, Y. Hanawa, M. Komeda, S. Watahiki, A. Mukanova, I. Kenzhina and Y. Chikhray. Study of origin on tritium release into primary coolant for research and testing reactors. Tritium release rate evaluated from JMTR, JRR-3M and JRR-4 operation data // JAEA-Technology 2014-025. – 2014

2 E. Ishitsuka, H. Kawamura, H. Sugai, M. Tanase, H. Nakata. Experiments on tritium behavior in beryllium (2), -tritium released by recoil and diffusion // JAERI-M 90-013. – 1990.

3 I. Kenzhina et al. Evaluation of curve for tritium release rate into primary coolant of research and testing reactors // 4th Asian Symposium on Material Testing Reactors, Hanoi, Vietnam, 3-4 March 2016.

4 E. Ishitsuka, I. Kenzhina, K. Okumura, N. Takemoto, Y. Chikhray. Calculation by PHITS code for recoil tritium release rate from beryllium under neutron irradiation // JAEA-Technology 2016-022. – 2016.

5 Ishitsuka E., Kenzhina I. E. Evaluation of tritium release curve in primary coolant of research reactors // Physical Sciences and Technology. – 2018. – Vol. 4. – №. 1. – P. 27-33.

6 Serp J. et al. The molten salt reactor (MSR) in generation IV: overview and perspectives // Progress in Nuclear Energy. – 2014. – Vol. 77. – P. 308-319.

7 Sinha R. K., Kakodkar A. Design and development of the AHWR—the Indian thorium fuelled innovative nuclear reactor //Nuclear Engineering and Design. – 2006. – Vol. 236. – №. 7-8. – P. 683-700.

8 Terrani K. A., Zinkle S. J., Snead L. L. Advanced oxidation-resistant iron-based alloys for LWR fuel cladding // Journal of Nuclear Materials. – 2014. – Vol. 448. – №. 1-3. – P. 420-435.

9 Şahin S. et al. Neutronics analysis of HYLIFE-II blanket for fissile fuel breeding in an inertial fusion energy reactor //Annals of Nuclear Energy. – 2003. – Vol. 30. – №. 6. – P. 669-683.

10 Hu X. et al. Hydrogen permeation in FeCrAl alloys for LWR cladding application //Journal of Nuclear Materials. – 2015. – Vol. 461. – P. 282-291.

11 Gainey B. W. Review of tritium behavior in HTGR systems. – General Atomic Co., San Diego, Calif.(USA), 1976. – №. GA-A-13461.

12 Şahin S., Übeyli M. Modified APEX reactor as a fusion breeder //Energy conversion and management. – 2004. – Vol. 45. – №. 9-10. – P. 1497-1512.

13 Maeda Y. et al. Distinguished achievements of a quarter-century operation and a promising project named MK-III in Joyo //Nuclear Technology. – 2005. – Vol. 150. – №. 1. – P. 16-36.

14 Zarchy A. S., Axtmann R. C. Limitations on tritium transport through fusion reactors //Nuclear Technology. – 1978. – Vol. 39. – №. 3. – P. 258-265.

15 Murata I. et al. Fusion-driven hybrid system with ITER model //Fusion Engineering and Design. – 2005. – Vol. 75. – P. 871-875.

16 E. Ishitsuka, T. Sato, H. Sakurai, M. Saito, Y. Hutamura. Thermohydrodynamic characteristic analysis on the steady state condition of JMTR LEU fuel core // JAERI-M 92-043. –1992.

17 M. Kaminaga. Steady-state thermal hydraulic analysis and flow channel blockage accident analysis of JRR-3 silicide core // JAERI-Tech 97-015. –1997.

18 T. Goorley et al. Initial MCNP6 Release Overview. Nucl. Technol. – 2012. – Vol. 180. – P.298-315.

19 T. Sato, K. Niita, N. Matsuda, S. Hashimoto, Y. Iwamoto, S. Noda, T. Ogawa, H. Iwase, H. Nakashima, T. Fukahori, K. Okumura, T. Kai, S. Chiba, T. Furuta, L. Sihver. Particle and heavy ion transport code system PHITS, Version 2.52 // J. Nucl. Sci. Technol. – 2013. – Vol. 50(9). –P. 913-923.

20 P.D'hundt, C.Wagemans, A.Declercq, G.Barreau, A.Deruytter. Energy distributions and absolute yields of the charged light particles emitter during the thermal neutron induced ternary fission of ^{235}U // Nucl. Phys. –1980. – Vol. A346. –P.461-472.