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

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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 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 235U.

Key words: tritium release rate, driver fuels, primary coolant, JMTR, JRR-3M.
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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 1~2×10^11 Bq and 1~4×10^10 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].

| 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, D2O tank |
| Operation             | 30d/cy, 6cy/y | 25d/cy, 6cy/y |
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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.
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Figure 4 – Triton 2D distribution

Figure 5 – Triton 1D distribution

Table 3 – Calculation results

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

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.
Calculation of tritium release from driver fuels. (JMTR: $\sim 10^{11}$ Bq, JRR-3M: $\sim 10^{10}$ 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.

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