TAGS and FP Decay Heat Calculations(Ⅱ)
-Impact on the LOCA Condition Decay Heat-

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Introducing the TAGS (Total Absorption Gamma-ray Spectrometer) data, we calculated the FP decay heat for Pu-239, Pu-241, U-233 and U-235 after one-year irradiation. In order to see the impact of the introduction of the TAGS data on LOCA (Loss of Coolant Accident) analysis in LWRs, those results were compared with the calculations based on the original data libraries such as JENDL, JEF-2.2 and ENDF/B-VI which are widely used in the summation calculation of the FP decay heat. It was concluded that the decay heat calculation introducing TAGS data dose not exert any decisive impact on the LOCA analysis from the practical point of view. Further study is, however, required to validate the reliability of the TAGS data as the input of summation calculations.

1. Introduction

Summation calculations are widely used to evaluate the FP (fission product) decay heat after shutdown of power reactors. Those calculations, however, often suffer from the so-called "pandemonium problem"[1],[2]. Suppose that the β-transitions feed the very high energy levels of the daughter nuclide. These β-strengths are easily overlooked in the experimental or the evaluational procedure because of the weak and complicated nature of the γ-cascades which follow the β-transition. Then the calculation of the average β-decay energy (E_β) from this kind of data leads to overestimation and γ-decay energy (E_γ) to underestimation. In order to circumvent this problem[2], the gross theory of β-decay was applied in generating the JENDL[3] and the ENDF/B FP decay data files. As a result, the summation calculations based on JENDL and ENDF/B-VI are in very good agreement with measurements [4],[5].

In 1990's, a total absorption γ-ray spectrometer (TAGS) was developed and applied to the short-lived FP nuclides by the INEL (Idaho National Engineering Laboratory) group[6]. They measured the β-feeding as a function of the excitation energy of the daughter nuclide for 44 isotopes of 12 FP elements (Rb, Sr, Y, Cs, Ba, La, Ce, Pr, Nd, Pm, Sm and Eu) [7]. The TAGS data is, in principle, thought to be free from the pandemonium problem. In reality, however, the major libraries such as JENDL, ENDF/B and JEF have not adopted the TAGS data up to now. In this paper we try to see the impact of introducing the TAGS data on LOCA (Loss of Coolant Accident) analysis of LWRs by calculating the FP decay heat after one-year irradiation and comparing the results.

2. Total Absorption Gamma-ray Spectroscopy

The γ-ray detector used by the Greenwood group was a 25.4 cm diameter × 30.5 cm long NaI(Tl) scintillator installed at the INEL on-line mass separator [7]. In principle all of the γ-rays emitted in a cascade accompanied by a de-excitation of a certain level deposit all of their energies into the scintillator giving the level energy to which the β-transition takes place. In this way the TAGS gives the level energy as the pulse energy and the β-feeding rate as the pulse height at the same time. These are exactly the data required to calculate the average β- and γ- ray energies per one β-decay of the parent nucleus. Therefore, if the TAGS measurements are carried out in an ideal way, the average β- and γ- ray energies (E_β and E_γ) obtained from them are free from the pandemonium problem. In fact, however, there exist several difficulties which might make the TAGS data inadequate as the ideal source of information. These are the photon losses, the β-particle contamination, the finite energy resolution of the detector, the needs for the complicated theoretical corrections and so on. Partly because of these difficulties, JENDL, ENDF/B-VI and JEF had not adopted the TAGS data as the basis of the E_β and E_γ calculations.

3. Comparison with Integral Measurement

In the previous paper[9], FP decay heat calculations based on JENDL, ENDF/B-VI and JEF-2.2[8] were carried out introducing TAGS data and the results were compared with the integral experiment. Introduction of the TAGS data was carried out by replacing the original E_β and E_γ values with those calculated from the TAGS data for the 44 isotopes given in the previous section. Here we briefly review the effect of TAGS introduction taking Pu-239 as an example. As shown in Fig.1 and 2, the effect of introducing the TAGS data for the 44 isotopes is not remarkable for the β-ray component of the decay heat after a burst fission. Almost all the calculations keep fairly good consistency with the integral experiment at the Yayoi reactor[4] except JEF2.2 in the cooling-time range around several thousands seconds.

In case of the γ-ray component, the underestimation seen in the JEF-2.2 case is conspicuous (Fig.3.), where any theoretical correction was not applied for the pandemonium effect. On the other hand the improvement by introducing the TAGS data is remarkable in the JEF-2.2 calculation as one can see in Fig.4. In the cases of JENDL and ENDF/B-VI, where the correction applied on the basis on gross theory, the good agreement with the integral measurement (Fig.3) is no more maintained and overestimation appears in the cooling-time range from 20 to 200 s (Fig.4).

As for the total decay heat, or the β + γ, is concerned, almost all of the calculations agree with the Yayoi measurement within the error bars both before and after the TAGS-data introduction (Figs. 5 and 6).

4. Impact on the LOCA Condition Decay Heat

In the preceding section, the decay heat after a burst fission have been compared with the

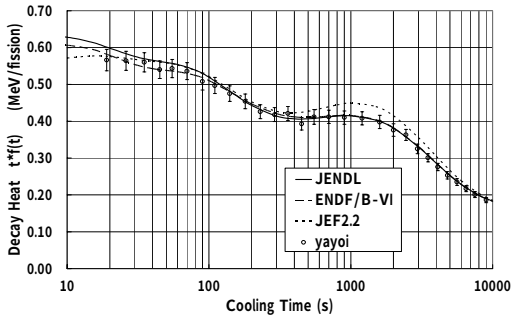

Fig.1 Decay Heat after a Burst Fission in Pu-239 before the TAGS Correction (β -ray Component)

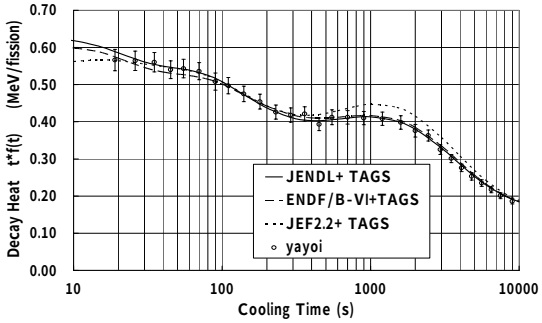

Fig.2 Decay Heat after a Burst Fission in Pu-239 after the TAGS Correction (β -ray Component)

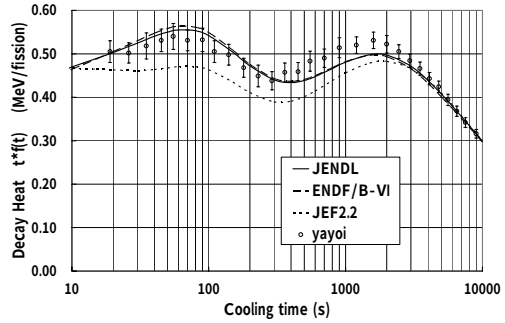

Fig.3 Decay Heat after a Burst Fission in Pu-239 before the TAGS Correction (γ -ray Component)

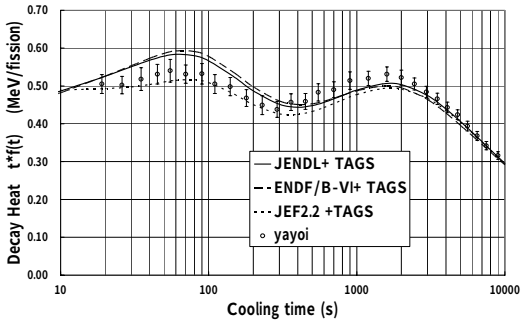

Fig.4 Decay Heat after a Burst fission in Pu-239 after the TAGS Correction (γ -ray Component)

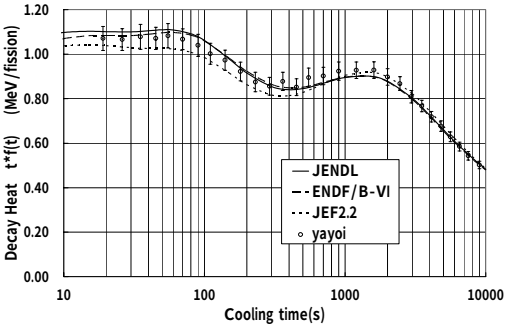

Fig.5 Decay Heat after a Burst Fission in Pu-239 before the TAGS Correction (Total)

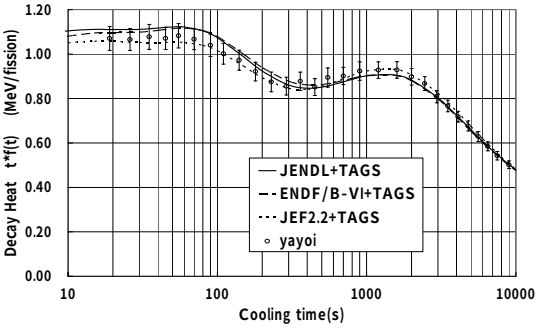

Fig.6 Decay Heat after a Burst Fission in Pu-239 after the TAGS Correction (Total)

integral measurement. In this section, the stress is put on the decay heat of cooling time range from 10 to 10000 seconds after one-year irradiation, which is very important in the LOCA analysis.

Shown in Fig. 7, 8 and 9 are the relative changes of the β- and γ-ray components and the total decay heat after one-year irradiation calculated for four major fissiles, or Pu-239, Pu-241, U-233 and U-235. As the summation calculations based on pre-JENDL have been recommended as a standard by the Atomic Energy Society of Japan (AESJ) [10], we are interested in the impact on the

JENDL calculations. Strictly speaking, the AESJ recommendation was calculated on the basis of the JNDC FP Decay Data File [11], which is the original form of the JENDL FP Decay Data File[3].

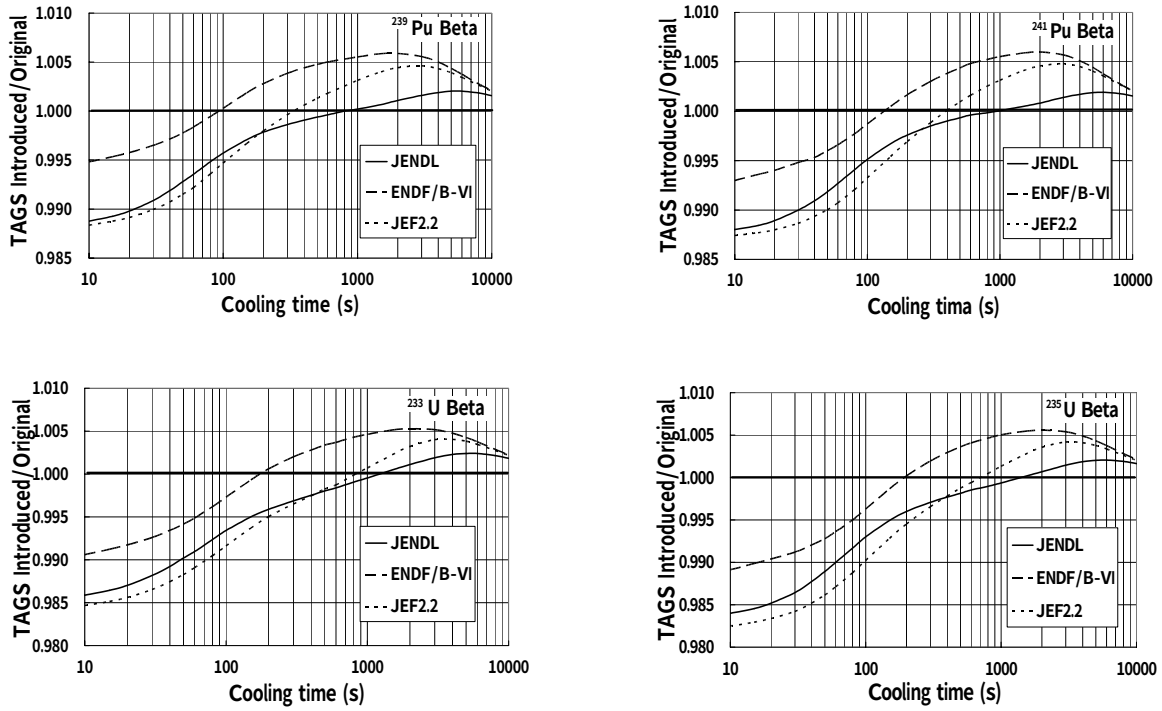

Fig. 7 Effect of Introduction of TAGS Energies into Summation Calculation (β -ray Component)

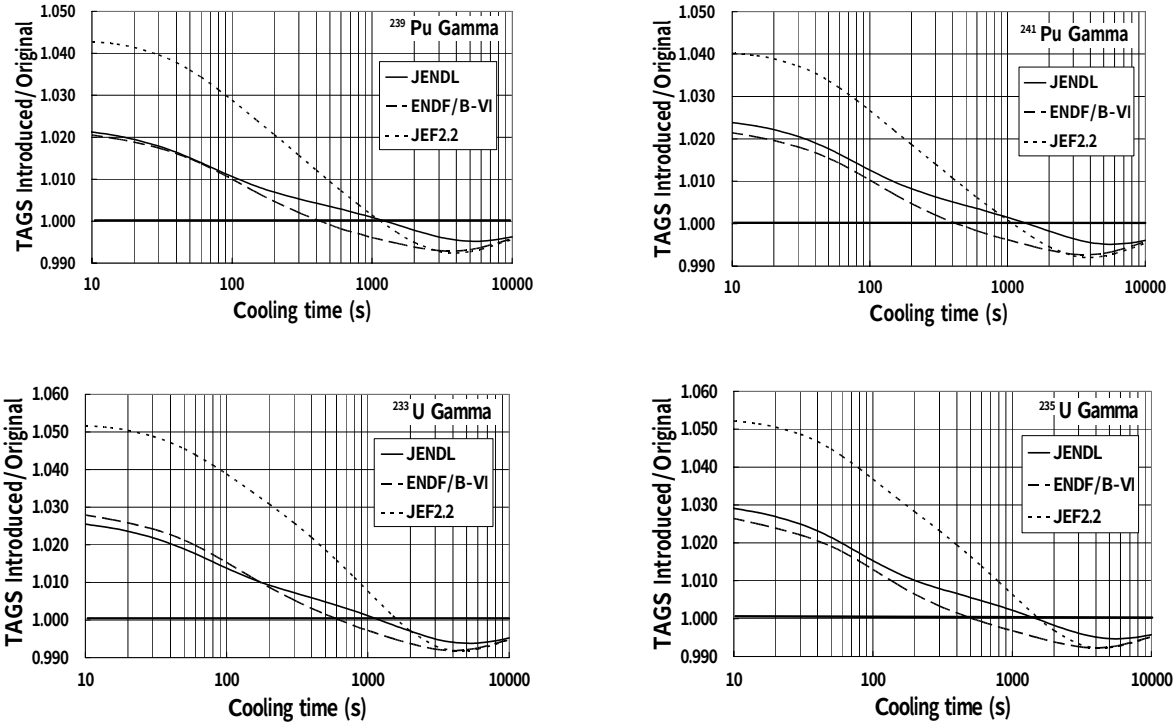

Fig.8 Effect of Introduction of TAGS Energies into Summation Calculation (γ -ray component)

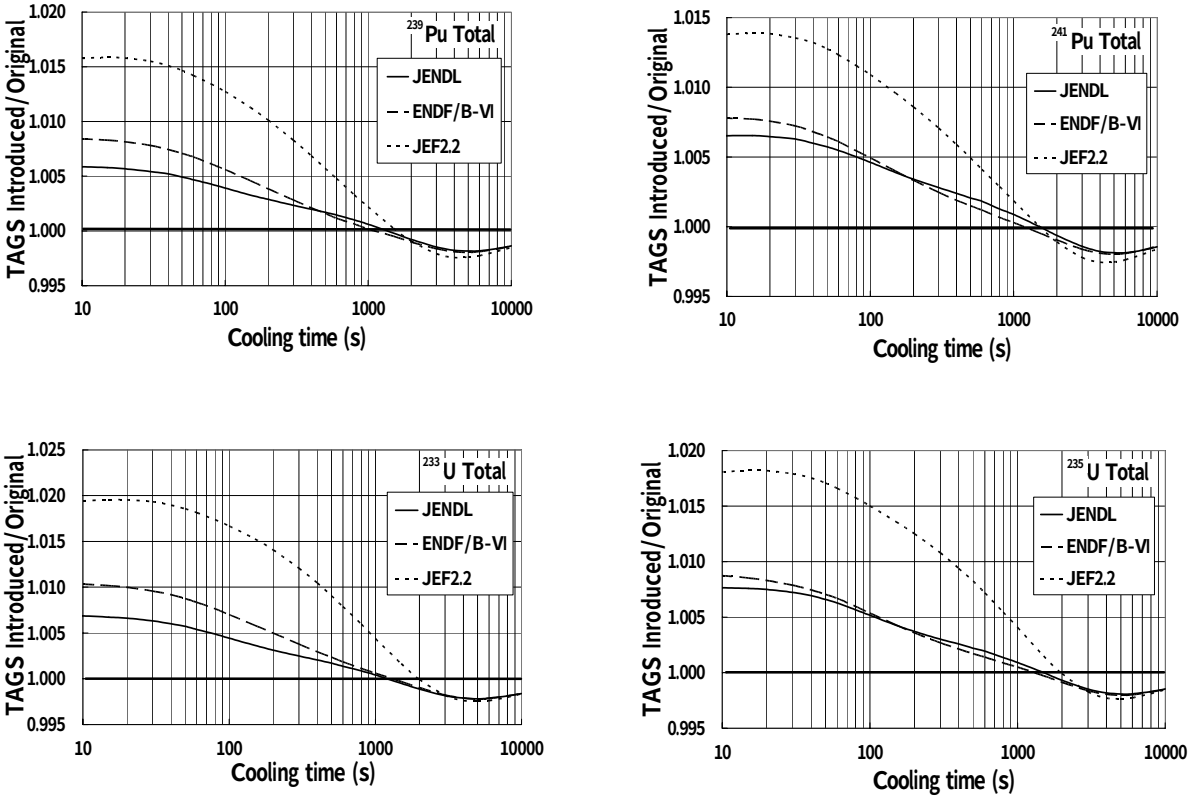

Fig.9 Effect of Introduction of TAGS Energies into Original Summation Calculation (Total or β + γ decay heat)

As far as the JENDL total decay heat in Pu-239 is concerned, the effect is smaller than 0.6 % even at the maximum as is seen in Fig.9. The estimated error of the total decay heat after an infinite irradiation is given in Ref. [10]. These errors vary from 0.8% to 1.1% for Pu-239 and for U-235, and from 1.2% to 1.7% for Pu-241 in the cooling-time range from 10 to 10000s. (The error values are not provided for U-233.) The impact of introduction of the TAGS data is smaller than these error values, which AESJ recommends, as far as the total decay heat is concerned. The γ-ray component, however, is overestimated by 2 ～3% for the cooling time range from 10 to 100 s.

5. Conclusion

In this paper, any decisive impact of introducing the TAGS data into JENDL in the LOCA condition was not found as far as the total, or the β + γ , decay heat is concerned. When we see the decay heat as component-wise, or the β-ray and the γ-ray components separately, the effects reach 2～3% even in the JENDL case (γ-ray component, Fig.8). In this sense the effect of introduction of the TAGS data should not be ignored. In addition an European group (spokesperson: A. Algora, Valencia) started a series of the TAGS experiments at Jyvaskyla on-line mass separator for several important FP nuclides [12]. Sooner or later we will have more TAGS data for the FP region nuclides.

Therefore, the further study is required to validate the reliability of the TAGS data as the input of the summation calculation.

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