Properties of Fission-Product Decay Heat from Minor-Actinide Fissioning Systems

Kazuhiro Oyamatsu* and Hideki Mori
Department of Energy Engineering and Science, Nagoya University
Furo-cho, Chikusa-ku, Nagoya, 464-8603, Japan
e-mail : oyak@asu.aasa.ac.jp

The aggregate Fission-Product (FP) decay heat after a pulse fission is examined for Minor Actinide (MA) fissiles ^{237}Np, ^{241}Am, ^{243}Am, ^{242}Cm and ^{244}Cm. We find that the MA decay heat is comparable but smaller than that of ^{235}U except for cooling times at about 10^8 s (≈3 y). At these cooling times, either the β or γ component of the FP decay heat for these MA's is substantially larger than the one for ^{235}U. This difference is found to originate from the cumulative fission yield of ^{106}Ru ($T_{1/2}$=3.2×10^7 s). This nuclide is the parent of ^{106}Rh ($T_{1/2}$=29.8 s) which is the dominant source of the decay heat at 10^8 s (≈3 y). The fission yield is nearly an increasing function of the fissile mass number so that the FP decay heat is the largest for ^{244}Cm among the MA's at the cooling time.

1. Introduction

The Fission-Product (FP) decay heat from Minor Actinide (MA) fissiles has growing importance to realize innovative MA burners such as accelerator driven nuclear reactors. In this paper, we examine the difference of the decay heat between MA fissiles and ^{235}U. The MA's studied here are ^{237}Np, ^{241}Am, ^{243}Am, ^{242}Cm and ^{244}Cm. For simplicity, we confine ourselves to the fast neutron induced fission because relatively hard spectra are expected in accelerator driven reactors. No neutron capture effects are taken into account as a natural consequence of a pulse fission.

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* present address : Faculty of Studies on Contemporary Society, Aichi Shukutoku University, 9 Katahira, Nagakute, Nagakute-cho, Aichi, 480-1197, Japan

2. Method of calculating FP decay heat

Input data required to calculate the FP decay heat are categorized into two. They are the fission-yield and decay data. The decay data consist of branching ratios (decay chains), half lives (decay constants) and average decay energy releases. These data are needed for about 1000 FP nuclides.

In this paper, the fission-yield and decay data are taken from ENDF/B-VI [1,2] because it is the only nuclear data library that has the fission-yield data for all the MA's of our interest.

The calculation of the decay heat power is straight forward in the summation method once the input database is prepared. In this paper, we use a handy computer code for personal computers [3] developed by one of the authors.

3. FP decay heat for MA fissiles

The FP decay heat power after a pulse fission of each MA is compared with that of ^{235}U as a function of cooling time.

Figure 1 shows the MA-to-^{235}U ratio of the aggregate FP decay heat after a pulse fission. The MA decay heat is comparable but smaller than that of ^{235}U except for cooling times at about 10^8 s (≈3 y). At these cooling times, either the β or γ component of the FP decay heat for each MA is substantially larger than that for ^{235}U.

In order to identify the source of the marked difference at 10^8 s, we examine decay energy releases from individual FP nuclides. Figure 2 shows the major sources of the decay heat at 7×10^7 s. The listed FP's in this figure cover 99% of the aggregate decay heat at the cooling time. It is clearly seen that the difference comes dominantly from ^{106}Rh. However, the half life of ^{106}Rh is only 29.8 s that is negligibly small compared with the cooling time. As shown in Fig. 3, at the cooling time ^{106}Rh is fed by its parent ^{106}Ru whose half-life is 3.2×10^7 s. Hence, the cumulative fission yield of ^{106}Ru is the dominant source of the difference between MA's and ^{235}U. Actually, we see from Fig. 4 that the ^{106}Ru yields from these MA's are substantially larger than that from ^{235}U. Moreover, the fission yield is nearly an increasing function of the fissile mass number. As a result, the FP decay heat is the largest for ^{244}Cm among the MA's as shown in Fig. 1.

4. Conclusion

We examine the aggregate FP decay heat after a pulse fission for ^{237}Np, ^{241}Am, ^{243}Am, ^{242}Cm and ^{244}Cm. We find that the MA decay heat is comparable but smaller than that of ^{235}U except for cooling times at about 10^8 s

(≈3 y). At these cooling times, either the β or γ component of the FP decay heat for these MA's is substantially larger than that for ^{235}U. This difference is found to originate from the cumulative fission yield of ^{106}Ru ($T_{1/2}$=3.2×10^7 s). This nuclide is the parent of ^{106}Rh ($T_{1/2}$=29.8 s), which the dominant source of the decay heat at 10^8 s (≈3 y). The fission yield is nearly an increasing function of the fissile mass number so that the FP decay heat is the largest for ^{244}Cm among the MA's.

References

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[2] T.R. ENGLAND, et al., "Decay Data Evaluation for ENDF/B-VI", Proc. Int. Sympo. on Nuclear Data Evaluation Methodology, Upton, 1992, pp. 611-22, 1993.
[3] K. OYAMATSU, Easy-to-use Application Programs to Calculate Aggregate Fission-Product Properties on Personal Computers, Proc. 1998 Sympo. on Nucl. Data, JAERI-Conf 99-002, pp. 234-239, 1999.

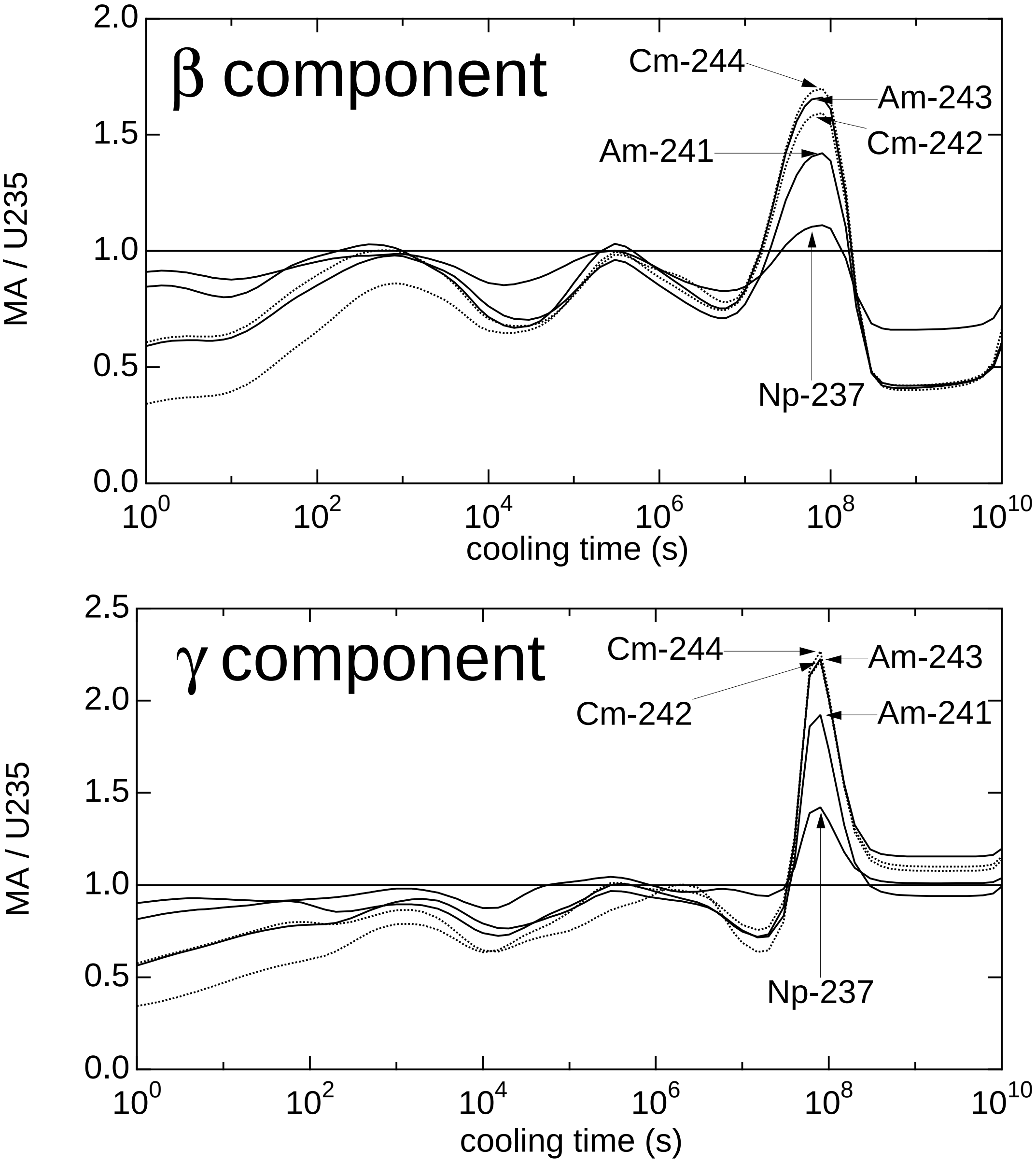
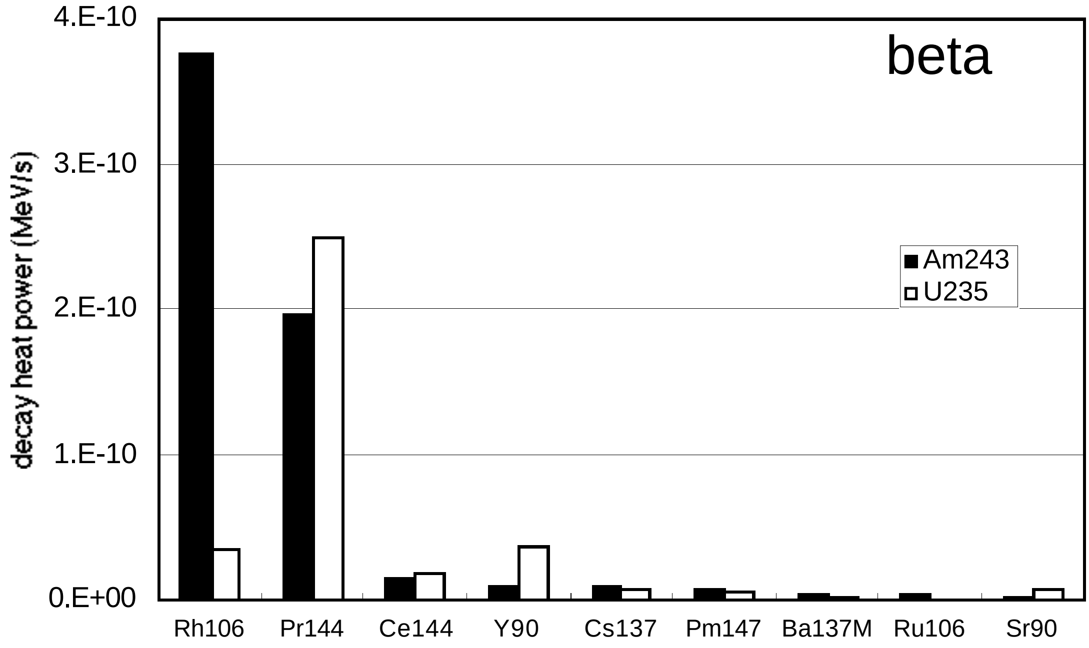


Fig. 1. The MA-to-^{235}U ratio of the aggregate FP decay heat after a pulse fission induced by a fast neutron.



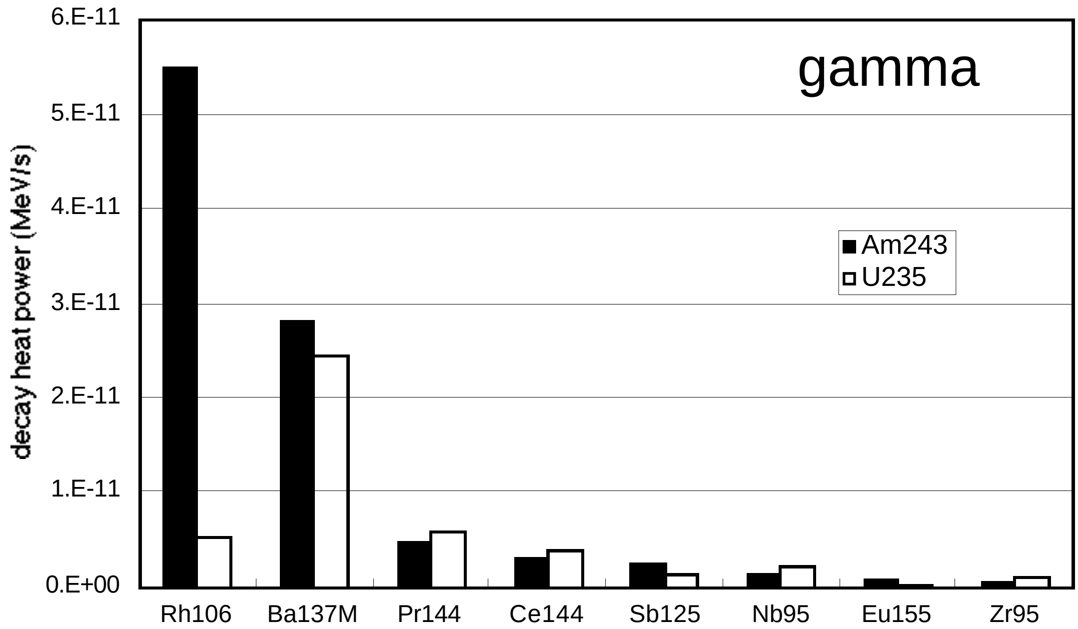


Fig. 2. The major sources of the FP decay heat at 7×10^{7} s.

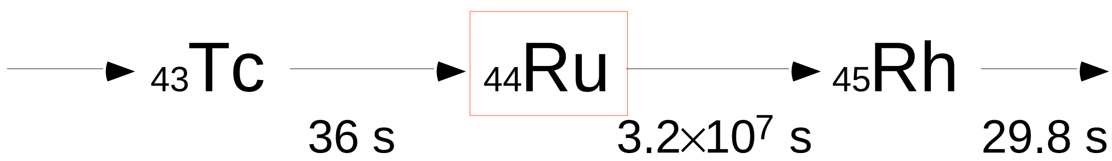


Fig. 3 The portion of A=106 decay chain relevant to ^{106}Rh decay at 10^{8} s.

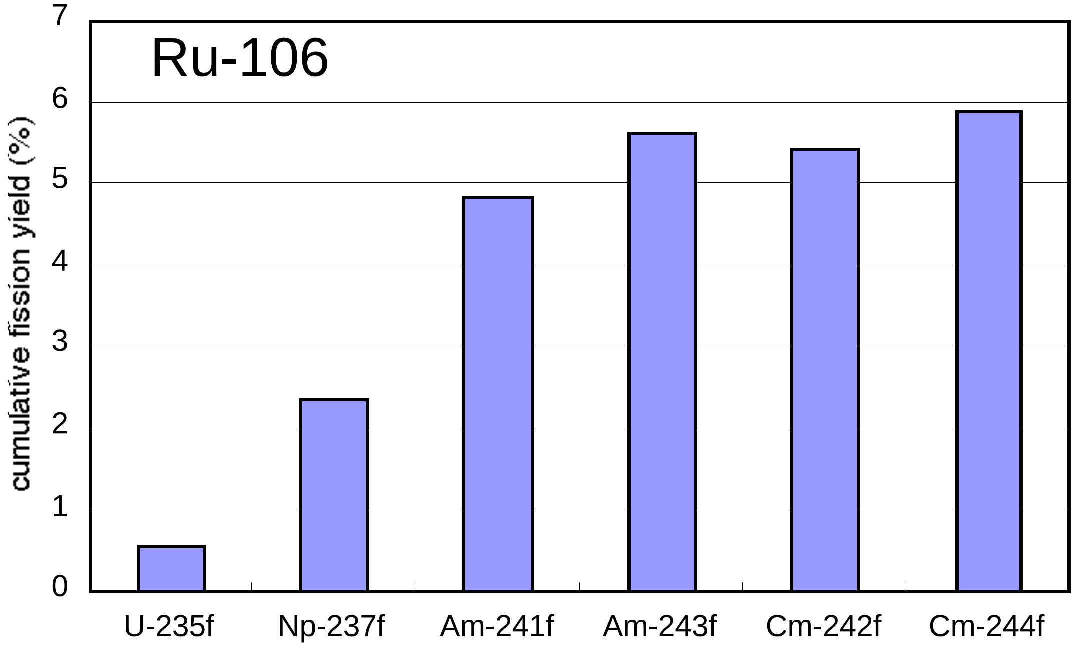


Fig. 4. The cumulative fission yield of ^{106}Ru for the fast neutron induced fission.