<u>Consultants' Meeting on Beta-decay and decay heat</u>

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Background prepared by A.L. Nichols, IAEA Nuclear Data Section

β-Decay Data Requirements for Reactor Decay Heat Calculations

1. Preamble

Somewhat significant developments in mid/late 2004 and establishment of experimental facilities and expertise in Europe (particularly ISOLDE and University of Jyvaskyla, Finland) have resulted in a situation in which a Consultants' Meeting at IAEA Headquarters, is highly desirable. The current situation merits such an approach, and suitable monies are judged to be available through the 2005 funding process.

2. Scientific Background

Neutron-induced fission is a complex form of nuclear decay in which a controlled neutron flux induces scission of a target nucleus to produce lower mass nuclides (fission products (FP)) and prompt- and delayed-neutron emissions. More than 500 FPs are produced with wide variations in their internal excitation, kinetic energy, mass and charge. The released energy is shared between the following phenomena:

(a) kinetic energy of FPs and neutrons;
(b) prompt γ radiation from highly-excited fission fragments;
(c) β and γ decay energy released through the natural decay of the FPs.

The last source of energy amounts to ~ 7% of the total energy generated during the fission process, and is called *decay heat*.

The prompt sources of energy decline rapidly after a reactor is shutdown, but radioactive decay remains to maintain a moderate level of heating in the reactor core. Thus, the energy released from this particular source increases from 7% of the total released energy to 100% after reactor shutdown, and the reactor coolant has to be maintained after the fission process has been terminated to an extent determined by means of *decay-heat calculations*. Decay heat varies as a function of the cooling time, and can be determined from known nuclear data based on the core inventory (principally FPs and actinides) and their radioactive decay characteristics.

The correct assessment of the decay heat is an important factor in the design of a safe nuclear power facility. This ever-changing parameter is also important for the design of shielding for fuel discharges, fuel storage and transport flasks, and the management of the resulting radioactive waste. Obviously, this type of calculation has economic, legislative, and important safety implications. Such studies require large amounts of cross-section, fission-yield and decay data (nuclides, half-lives, mean β and γ energy releases in the overall decay process, neutron-capture cross sections, etc), and correct estimates of the data uncertainties.

3. Experimental Facilities

Appropriate experimental facilities exist at the University of Jyvaskyla, Finland, and a new total absorption spectrometer (Lucrecia) has been installed at ISOLDE. Previous experiments at such facilities have been based on the study of nuclear species from the proton-rich side of the line of stability. A primary aim of the proposed consultants' meeting would be to determine the FPs on which to focus attention, and to assess the feasibility of undertaking equivalent experiments on the neutron-rich side of the line.

4. Conflict between Decay Heat Predictions and Benchmark Experiments

Figure 1 depicts a comparison between the calculated decay heat after an instantaneous fission event in ^{239}Pu and measurements performed at the YAYOI reactor, at ORNL, and at Lowell University. Calculations were undertaken with JNDC-V2, JEF-2.2 and ENDF/B-VI. All calculations consistently underestimate the experiments from 300 to 3000 s, as identified by Yoshida *et al.*, while even more recent calculations reveal that the γ-ray component may be overestimated in the cooling time range of 3 to 300 s.

Four possible sources for these discrepancies have been considered:

(a) underestimation of E_γ for some FP nuclei;
(b) underestimation of half-lives;
(c) overestimation of half-lives;
(d) underestimation of $N_i(t)$.

All of these possibilities have been considered for nuclei with half-lives of about 1000 s, and for nuclei with half-lives shorted than 1000 s that are situated just after a precursor with a half-life of approximately 1000 s in a β-decay chain. The simplest explanation for the γ-ray discrepancy would be the first assumption. The decaying radionuclide should have a half-life of ~ 1000 s, or should be β-fed by a precursor with a half-life of about 1000 s. An additional β-decay chain has been artificially inserted into the JNDC-V2 database to give the improved fit depicted in Figure 2. This form of conjecture needs to be proven, or replaced by a suitable explanation based on valid experimental observations.

5. Out-of-cycle Proposal

A Consultants' Meeting would prove extremely timely and highly important in considering the various alternative explanations for the disagreements between the decay-heat calculations and available experimental benchmarks. Such an informed debate would provide significant guidelines in the subsequent design of appropriate experimental studies.

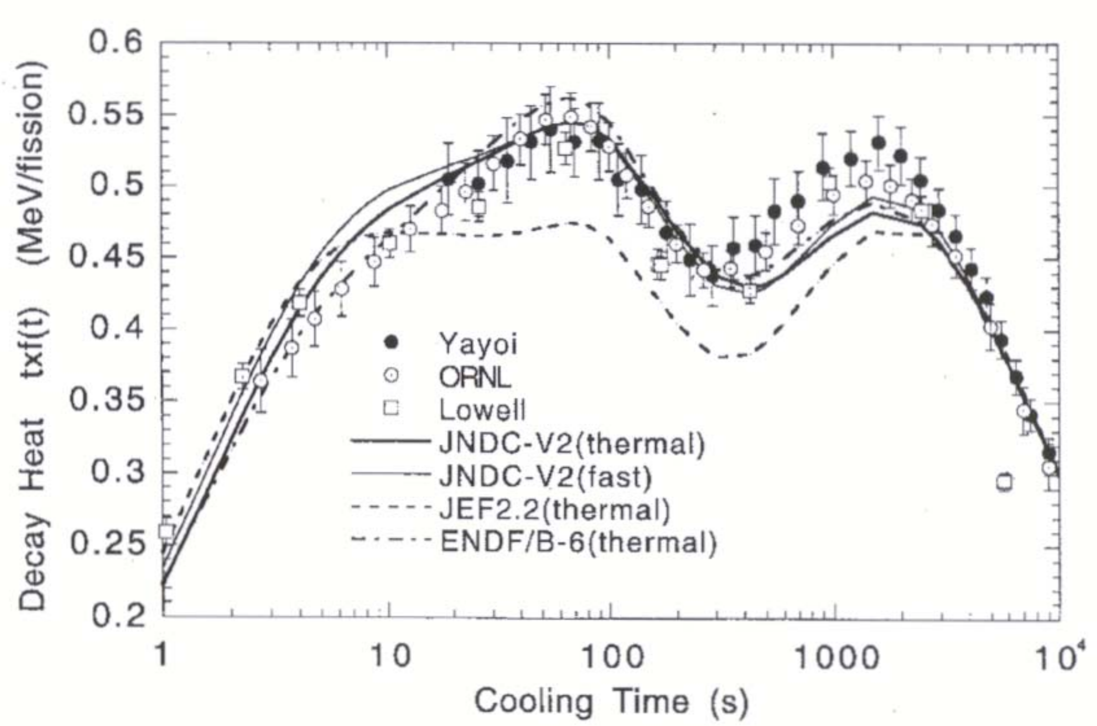
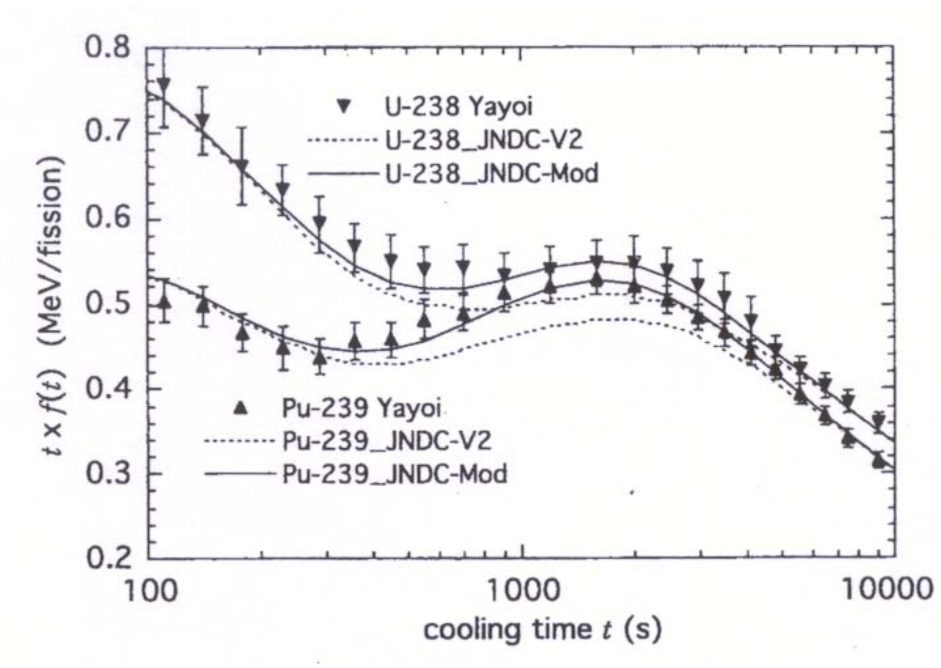
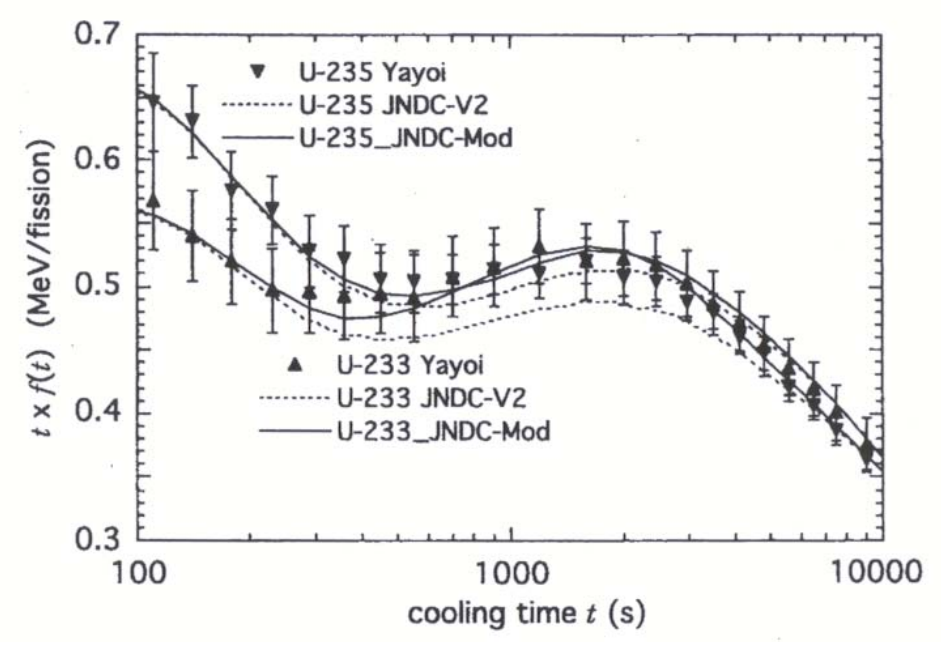


Figure 1.
Gamma-ray discrepancies seen in ^{239}Pu decay heat after a fission burst. Lines represent results of summation calculations using different databases, and points are experimental results.



a) Additional fission yields required are 6% for ^{239}Pu and 5% for ^{238}U.



b) Additional fission yields required are 2% for ^{235}U and 6% for ^{233}U.

Figure 2.
Possible remedy of γ-ray discrepancy by adding chain-X with a 1.5 MeV γ-emitter. Dotted line represents the results of summation calculations using JNDC-V2 database, while the continuous line represents the results obtained by adding the chain-X with the 1.5 MeV γ-emitter to the JNDC-V2 database (JNDC-Mod); Yayoi are experimental results.