March 7, 2006

WPEC Subgroup Proposal

Title:

Prompt Photon Production from Fission Products

Short Justification for a Subgroup:

In a typical nuclear reactor some 10-12% of heating comes from the energy deposited by gamma rays. The major photon production sources (equal proportions) are :- prompt neutron induced fission, capture of prompt neutrons, and the decay of fission plus activation daughter products. The photons penetrate some distance from their birth and can cause some 80-90% of heating in non-fissile regions. This can lead to distortion of control rods and chemical damage in moderators, e.g. enhancing graphite erosion rate.

There is considerable interest in extending fuel life (deep burn) and this in turn leads to more higher actinides and more FISSION PRODUCTS (nuclides with Z=35-70).

A survey (of JEFF3.0, ENDF/B-VIr8 and JENDL3.3) in 2003 indicated very few modern evaluations in the mass range of fission products contain gamma source data. Where data are present they are often old and incomplete.

At the completion of WPEC sub-group 23, a comprehensive and validated file of neutron cross sections will be ready for inclusion in modern libraries. This would form an ideal base that could be extended to include source information for production of prompt gammas.

Subgroup Monitor:

JEFF/JENDL

Subgroup Chairman:

ENDF

List of Subgroup Participants:

ENDF
JEFF C J Dean
JENDL
BROND

Definition of the Project:

The first stage of the project will review sources of prompt gammas from neutron interaction with fission products. Typical sources are:-

1. The Thermal Neutron Capture Gamma-rays database (Capgam) at BNL,
2. The IAEA CRP on Prompt Gamma-ray Neutron Activation Analysis,
3. ENDF/B-VIr8 files for lighter nuclides
4. Models for short lived fission products e.g Xe-135.

It will consider the variation of the energy and intensity of prompt gamma rays from neutron capture and inelastic reactions as a function of incident neutron energies below ~10MeV. It will consider if these data are adequate for thermal and fast fission reactor applications. If necessary, it will recommend how further data should be generated. It will NOT instigate immediate generation.

The second stage will be to add the relevant data to existing files produced by WPEC sub-group 23. Fission products will be ordered by absorption rate in 0.25, 0.5, 0.75 and fully irradiated fuel from a typical fast and a typical thermal reactor. Data will be added either to file 6 or, more probably to files 12, 14, 15. Use of file 13 (photon production cross sections) should be avoided so that later enhancement to neutron cross sections can be applied more easily. File assembly will be undertaken using OECD NEA quality procedures that include processing with the BNL codes CHECKR, FIZCON, and PSYCHE.

The third stage of the project will assess the results of sum up and discrepant point checks from FIZCON and make best efforts to remove as many comments as reasonably possible within the limitation of scientific knowledge. It will also assess other comments from the checking codes and take action to remove as many of these as deemed practical.

Justification of the Project:

In a typical civil nuclear reactor some 10-12% of heating comes from the energy deposited by gamma rays. The major photon production sources (equal proportions) are:- prompt neutron induced fission, capture of prompt neutrons, and the decay of fission plus activation daughter products. The photons penetrate some distance from their birth and can cause some 80-90% of heating in non-fissile regions. This can lead to distortion of control rods and chemical damage in moderators, e.g. enhancing graphite erosion rate.

A modern analysis of the contribution of gamma heating can be found on page 12 of Anton Lüthi's thesis(1). It notes in-core and control rod contributions of ~10% but up to 90% in radial reflectors.

It is important to note the need to model transport of the gammas from their birth in say fuel during fission, to their death in say a control rod or breeder element, where the energy is deposited. However, applicable gamma interaction data are already available. Being elemental data it is better to keep them separate from the isotopic gamma source

data. In the authors view, current gamma interaction data are “fit for purpose” in gamma transport calculations and need NOT be considered by this sub-group.

There is considerable interest in extending the life of fuel (deep burn) and this in turn leads to more higher actinides and more FISSION PRODUCTS (nuclides with Z=35-70).

Enriched fuels and MOX fuels are being employed to reduce reload and generally extend fuel life. There are hence more neutrons captured and more neutron induced fission leading to the production of higher actinides and fission products. These will also absorb neutrons and produce gamma rays.

A survey in 2003 indicated very few modern evaluations in the mass range of fission products contain gamma source data. Where data are present they are often old and incomplete. Considering the fission product range (Z=35-70), it found:-

Library	No. of Nuclides	Nuclides with γ Source Data	Fission Products with γ Source data
JEFF3.0	340	83	4
JENDL3.3	337	114	31
ENDF/B-VI-R8	329	98	15

In JENDL3.3 the fission products are natural isotopes of Zr (+Zr93), Mo, Ag, Cd, Eu and Er. It is noticeable that other databases contain thermal neutron gamma source data for significant numbers of naturally occurring isotopes. These could be introduced for appropriate fission products. A similar exercise has been performed to introduce data for light elements into ENDF/B-VIr8 (2).

Relevance to Evaluated Data Files:

At the completion of WPEC sub-group 23, a comprehensive and validated file of neutron cross sections will be ready for inclusion in modern libraries. This would form an ideal base that could be extended to include source information for production of prompt gammas.

Deliverables:

Stage 1 - Review

- Lists of current documents and databases containing gamma source data for fission products.
- Assessment of the current data.
- Possible recommendation of future needs.

Stage 2 -Assembly

- A list of fission products ordered by importance to neutron absorption

- Inclusion of current data in prioritised fission product evaluations.
- Output from BNL checking codes for the new evaluations.

Stage 3 - Delivery

- Improved evaluations following assessment of the comments from the BNL codes.

Time-Schedule and Milestones:

- 2007: Stage 1 - Review sources.
- 2008: Stage 2 - Assemble initial evaluations.
- 2009: Stage 3 - Assemble final evaluations and issue final report

References

1 Anton Lüthi
Development and Validation of Gamma-Heating Calculational Methods for Plutonium-Burning Fast Reactors.
These No 1854 (1998)
École Polytechnique Fédérale de Lusanne

2 Stephanie C. Frankle, Robert C Reedy, Phillip G. Young
Improved Photon-Production Data for Thermal Neutron Capture in ENDF/B-VI Evaluations
LA-13812
June 2001