Summary Record of the 2nd Meeting of the WPEC Subgroup 33 on

Methods and issues for the combined use of integral experiments and covariance data

NEA, Issy-les-Moulineaux, France

24 November 2009

1. Introduction

The subgroup co-coordinator, M. Salvatores, opened the meeting and welcomed the participants from France (CEA), Japan (JAEA), The Netherlands (NRG), Slovenia (IJS), USA (INL), EC-JRC-IRMM, and OECD-NEA. Only part of the subgroup members could be present or represented (cf. list in Appendix 1). R. Jacqmin confirmed that C. de Saint Jean (CEA) will contribute to the subgroup, although one of his PhD student defense prevent him participating to this meeting. ANL could not send any representative. R. Xu, H. Wu (CAEA, China), and G. Manturov (IPPE, Russia) could not attend the meeting for administrative or funding reasons. M. Salvatores ask the NEA secretariat to send again invitations to CAEA and IPPE representatives for the next meeting.

The proposed agenda was accepted with minor practical changes (cf. final agenda in appendix 2). M. Salvatores reviewed the minutes and actions from the last meeting. Action 1 (*all participants: to answer the list of 6 questions*) is completed. Action 2 (*all participants: to write papers on the different adjustment methodologies*) is on-going and deadline has been extended to March 2010. However, action 3 (*Report on the critical review on the different adjustment methodologies*) deadline should not be moved. Indeed, this report is the first subgroup deliverable, which should be available by June 2010.

2. Updated proposal

G. Palmiotti presented an updated proposal for data adjustment method evaluation, revised with the comments he had received so far. G. Palmiotti highlighted a few issues that should be discussed during this meeting:

- Integral experiments to be used in the adjustment,
- Isotopes and reactions to be adjusted,
- Energy group structure,
- Covariance data,
- Choice of an actual reactor design example.

3. Presentations

D. Rochman presented the work planned at NRG. Two approaches will be used, both based on MCNP simulations using TALYS data. In the first method (MCNP+SUSD), TENDL-2009 data and covariances (MF31,32,33 only) are used to calculate the integral value and its uncertainty, which is obtained by perturbation using SUSD sensitivity coefficients. In the second method (MCNP+TMC[1]), TALYS microscopic nuclear parameters and uncertainties are directly propagated

[1] TMC stands for Total Monte Carlo

through the TALYS calculation and MCNP simulation by performing thousands of runs with different nuclear parameters sampling. However, NRG has no experience in nuclear data adjustment on integral data and would welcome some collaboration in the framework of this subgroup.

R. Jacqmin presented motivations and methods for CEA, which already performed nuclear data adjustment in the past to improve fast reactor calculations. It was stressed that the subgroup should concentrate on methodologies, not specific experiments or evaluated files.

G. Palmiotti presented the work planned at INL in collaboration with BNL/ORNL/LANL (for the covariances). Integral experiments will be analyzed, whenever possible, with MCNP and ENDF/B-VII data. The perturbation methods implemented in the ERANOS code will be used for sensitivity analysis. The covariances produced within the AFCI framework will be used. The adjustment code implements a statistical method with maximum likelihood function and Lagrange multipliers.

M. Ishikawa presented the adjustment studies performed at JAEA since the 90's. The last adjusted data set (ADJ2000) performs very well for various core parameters (critical mass, power distribution, Doppler and Na-void reactivity) and is being used at JAEA to design a 600MWe FBR. The next adjusted data set (ADJ2010) is expected to be released quite soon. Hundreds of integral data have been used for the whole library adjustment. For the present benchmark exercise, a few integral data from ZPPR9, JUPITER, and JOYO experiments could be made available. In addition, a simplified model of the JAEA 600MWe FBR could be provided as an actual reactor design example.

I. Kodeli presented the sensitivity and uncertainty analysis tools used at the Jozef Stefan Institute. The GANDR system makes a link between differential and integral databases *via* sensitivity and uncertainty analysis tools, such as SEMOVE (derivatives of groupwise cross sections with respect to nuclear parameters), and ZOTTVL (minimization program based on partitioned least-squares). Covariance data have been produced using the GANDR system for IAEA evaluations of Th and W. The SUSD3D code calculates sensitivity coefficients (first order) to propagate nuclear data covariances in multi-dimensional transport problems. The ANGELO-LAMBDA codes are usefull to interpolate on any arbitrary energy group structure and for mathematical verification of covariance matrices. Conversion between the BOXR (NJOY) and the COVERX (PUFF) formats is also possible. It was stressed that a recent NJOY update is available to process MF35 and that ERRORJ should allow the processing of MF34 in both center-of-mass and laboratory frames to avoid a loss of accuracy due to the change of frame.

A. Plompen presented WPEC subgroup 26[2] follow-up activities in Europe. Both WPEC subgroup 33 and subgroup 31[3] are established on the basis of subgroup 26 recommendations. A. Plompen gave an overview of nuclear data activities in Europe at national (Gedepeon, Thorea), international (JEFF, IAEA-CRP), and European Commission levels (Eurotrans, Efnudat, Eufrat, Candide, Andes, and EMRP). The ANDES project is part of the 7th EC Framework Program and support the production of Accurate Nuclear Data for nuclear Energy long term Sustainability (ANDES). The project is organized in work packages (measurement, evaluation and covariances, integral experiments, high energy model). The work package WP3 on "Integral experiments for validation and constraints of nuclear data" coordinated by CEA/Cadarache was considered as highly relevant to the subgroup 33 activities.

[2] See WPEC Subgroup 26 report on *"Uncertainty and Target Accuracy Assessment for Innovative Systems Using Recent Covariance Data Evaluations"*, available on the NEA website at http://www.nea.fr/html/science/wpec/

[3] WPEC Subgroup 31 on *"Meeting Nuclear Data Needs for Advanced Reactor Systems"*, to be started in 2010.

4. Discussions

The afternoon was devoted to discussions on reaching agreement on the remaining issues.

M. Ishikawa led the discusion on which integral experiments could be used in the exercise.
R. Jacqmin led the discussion on which isotopes and reactions could be included.
M. Ishikawa presented arguments in favor of the adjustment of Mu-bar.
G. Palmiotti made some proposals relative to the energy group structure issue.
G. Palmiotti led the discussion on which covariance data could be used.

The next section is a summary of these discussions and of the following wrap up session (led by M. Salvatores).

5. Conclusions

Benchmark proposal

A "benchmark" exercise is proposed. It is agreed that the main objective of this benchmark is to test different methods of nuclear data adjustment/assimilation and different sets of covariance data, for the purpose of reducing the design uncertainties of a particular type of sodium-cooled fast reactor. The benchmark will make use of a single, limited set of integral experiments and measurements. The final results will be tested on a model of the Advanced burner reactor (ABR) with plutonium oxyde fuel or/and a model of the JAEA FBR core. As a by product of this exercise, feedback will be sent to the evaluation projects if consistent and unambiguous nuclear data trends can be found.

To facilitate comparisons, a common 33 group structure (available on the subgroup webpage) is adopted for the benchmark input/output. Every participant is responsible for the conversion of its own data into the adopted group structure. The ANGELO code can be used to convert covariance matrices from one group structure to another (cf. presentation by I. Kodeli). For what concerns cross sections, these can be smoothed out (e.g. using lethargy width) on the 33 energy group structure. All data, especially covariance matrices, should be provided in a "human readable" (ASCII) tabular format. The coordinators and the NEA secretariat will send format specification to the participants. All benchmark input/output will be available on the subgroup webpage.

Benchmark input

Isotopes

^{10}B	for cross correlation testing,
^{16}O	as part of oxyde fuel,
^{23}Na	as coolant,
^{56}Fe, ^{52}Cr, ^{58}Ni	as major structural materials,
^{235}U	as fuel and for cross correlation testing,
^{238}U	as fuel and for indirect spectra effect (inelastic transfer matrix[4]),
^{239}Pu	as fuel and for cross correlation testing,
^{240}Pu, ^{241}Pu	as fuel and for testing Pu isotopic vector.

[4] See WPEC Subgroup 4 report on *"^{238}U Capture and Inelastic Cross-sections"*, available on the NEA website at http://www.nea.fr/html/science/wpec/

Nuclear data

Elastic scattering infinite-dilution cross section,
Total inelastic scattering infinite-dilution cross section,
Capture infinite-dilution cross section (this includes $^{10}B(n,\alpha)$ reaction),
Fission infinite-dilution cross section,
Average prompt fission neutron multiplicity (Nu-bar),
Normalized prompt fission neutron spectrum,
Average cosine of elasticaly scattered neutrons (Mu-bar).

Following post-meeting email exchanges between the participants, it was proposed to add the

Average delayed fission neutron multiplicity (Nu-d),

as an optional adjustable parameter (on a voluntary basis). This proposal was driven by consideration on the impact of Nu-d on the integral C/E ratio value and uncertainty for Na void reactivity (measured in dollars). When not adjusting Nu-d, the participants should add the corresponding uncertainty to the C/E value of Na void reactivity in order to reduce their statistical weight.

The spectra of inelasticaly scattered neutron is not part of the benchmark exercise. However, every participant should provide the $^{238}U(n,n')$ energy transfer matrix used in the exercise.

Nuclear data covariances

Every participant will use its own nuclear data covariances (step 1, see below). However, in step 2 of the exercise, for comparison purpose and to disentangle effects from different *a priori* cross sections or covariances, it was decided that one common set of covariance data would be used by all the participants, in addition to their own specific sets. The 33-group AFCI-1.2 covariance matrices will be used, if available. If not, the 44-group SCALE6.0 matrices (ZZ-SCALE6.0/COVA-44G package) or the 15-group ANL matrices will be considered.

Integral data

Jezebel	^{239}Pu configuration: 1 critical mass, 3 spectral indices: F28/F25, F49/F25, F37/F25,
	^{240}Pu configuration: 1 critical mass,
Flattop	Pu configuration: 1 critical mass, 2 spectral indice: F28/F25, F37/F25,
ZPR6-7	Standard configuration: 1 critical mass, 3 spectral indices: F28/F25, F49/F25, C28/F25,
	High ^{240}Pu content: 1 critical mass,
ZPPR9	1 critical mass, 3 spectral indices: F28/F25, F49/F25, C28/F25,
	2 Na voids: central void and leakage-dominated configurations,
Joyo	1 critical mass.

Other integral experiments (e.g. ZPR9, MOZART/ZEBRA, SEFOR, ZPR6-6A, Godiva, Flattop-U) can be considered for the verification of the adjustment procedure (i.e. they are not part of the adjustment).

The participants in close cooperation with the coordinators will provide simplified models of these configurations (homogenized composition) together with prescriptions for meshing and quadrature corrections relevant to 33-group S4-P1 transport calculations. All participants should make sure that their own code system give a reasonable integral C/E value before starting the benchmark exercise.

Integral data covariance

The subgroup coordinators will provide the participants with an integral data correlation matrix for testing purpose.

Sensitivity coefficients

Every participant to the benchmark exercise will use its own sensitivity coefficients. Some comparisons of sensitivity profiles will be performed on a case by case basis.

Benchmark exercise

Every participant to the benchmark exercise will use the same integral experiment values (E) and uncertainties, but their own calculated value (C), sensitivity coefficients, and adjustment/assimilation method.

The benchmark will consist of a three-step exercise using:

1. own initial cross sections, own nuclear data covariances, w/wo integral correlation
2. own initial cross sections, same nuclear data covariances, w/wo integral correlation
3. same initial cross sections, same nuclear data covariances, w/wo integral correlation

Benchmark output

The main benchmark results relevant for comparison are,

- Adjusted nuclear data,
- Final nuclear data covariances,
- Initial and final integral C/E values and associated uncertainties,
- Initial and final results of reactor project calculations including uncertainties.

The initial/final nuclear data and covariance matrices will be tested on the ABR (start up) configuration. In order to test the ability to extrapolate the results, it has been suggested to consider also a different target design. As possible candidates: ABR at equilibrium, JAEA FBR.

All results should be provided in a simple, consistent tabular form, to facilitate comparisons and post-processing (format to be specified).

The non-linearity issue will be considered in a further step only (e.g. by doing the same exercise again).

6. Next meeting

It was discussed whether the next meeting of the subgroup could be held in April 2010 during the ND2010 conference. It was agreed that preliminary results could not be available by April 2010 and to hold the next meeting in Port-Jefferson, NY, USA, in June 2010. The following meeting could be held in November 2010 in Europe.

7. Actions

NEA (E. Dupont)	Update the subgroup web page with materials from this meeting and other participant contributions.
CEA/Cadarache	To provide, before the end of the year 2009, INL with the ENDF/B-VII.0 33-group data library for the ERANOS code.
CEA/Cadarache	To consider providing a fast reactor core concept for testing.
G. Palmiotti E. Dupont	To provide, before the end of January 2010, the participants with format specification for the benchmark input/output.
All participants	To provide, before the end of February 2010, the coordinators (copy NEA) with the simplified integral experiment models and associated specifications to be used in the benchmark exercise.
All participants	To provide, before the end of March 2010, the coordinators (copy NEA) with a paper describing the adjustment methodology to be used in the exercise.
G. Palmiotti C. de Saint-Jean M. Ishikawa	To critically review the participants papers describing the adjustment methodology and to write a report of the findings by June 2010. This is the first deliverable requested to the subgroup.
All participants	To start the benchmarking of adjustment methodologies in April/May 2010 the latest. The preliminary results should be discussed at the next SG33 meeting in June 2010.

Appendix 1

Participants to the 2nd meeting of WPEC subgroup 33

NEA, Issy-les-Moulineaux, France

24 November 2009

M. Salvatores	INL, USA – CEA, France	(Co-coordinator)
G. Palmiotti	INL, USA	(Co-coordinator)
E. Dupont	NEA	(Secretary)
M. Ishikawa	JAEA, Japan	
R. Jacqmin	CEA, France	
I. Kodeli	IJS, Slovenia	
A. Plompen	IRMM	
D. Rochman	NRG, Netherlands	
Y. Rugama	NEA	

Appendix 2

Agenda of the 2nd meeting of WPEC subgroup 33

NEA, Issy-les-Moulineaux, France

24 November 2009

8.30 – 9.00 Welcome and review of minutes and actions from last June meeting (M. Salvatores)
9.00 – 9.30 Updated proposal for common adjustment exercise, including comments received so far (G. Palmiotti)

Short presentations will follow, from each participant to the exercise, on methods and data that will be used. Please, indicate cross section data files to be used, methods and codes used for experiment analysis, methods and codes for sensitivity coefficient computation, covariance data to be used, and methodology for adjustment. Please, plan 15 minutes presentation plus 5 minutes for discussion.

9.30 – 9.50 NRG (D. Rochman)
9.50 – 10.20 CEA (R. Jacqmin)
10.20 – 10.40 CAEA (no CAEA representative could attend the meeting)
10.40 – 11.00 Coffee break
11.00 – 11.20 INL (G. Palmiotti)
11.20 – 11.40 IPPE (no IPPE representative could attend the meeting)
11.40 – 12.00 JAEA (M. Ishikawa)
12.00 – 12.20 Jozef Stefan Institute (I. Kodeli)
12.20 – 12.40 Follow up activities in Europe for SG-26 (A. Plompen)

Afternoon will be devoted to discussions on reaching agreement on the different issues that are still open. Each issue will have a discussion leader.

14.00 – 14.45 Integral experiments to be used (discussion leader: M. Ishikawa)
14.45 – 15.30 Isotopes and reactions, including mubar and fission spectrum, to be considered (discussion leaders: R. Jacqmin, M. Ishikawa)
15.30 – 15.45 Coffee break
15.45 – 16.30 Energy group structure (discussion leader: G. Palmiotti)
16.30 – 17.15 Covariance data (discussion leader: G. Palmiotti)
17.15 – 18.00 Wrap up, next steps, and final conclusions (M. Salvatores)