2nd Meeting of WPEC Subgroup 33 on
Methods and issues for the combined use of integral experiments and covariance data

November 24, 2009
NEA Headquarter, Issy-les-Moulineaux, France

Integral Experiments to be Included

Discussion Points

- **Name (Number) of integral experiments ?**
  - **Los Alamos Small Core (JEZEBEL, GODIVA),**
  - **ZPR6 (6A, 7),**
  - **ZPPR-9,**
  - **Others (SEFOR, JOYO, ZPR-9, IRMM, …..).**
- **Variety of core parameters ?**
  - **Criticality,**
  - **Reaction rate ratio (F8/F5, F9/F5, (C8/F9 ?)),**
  - **Control rod worth,**
  - **Sodium void reactivity,**
  - **Others (Doppler reactivity, Burnup reactivity, Sample reactivity, (power peak , or reaction rate distribution ?), …..).**
- **Level of analysis by benchmark participants ?**
  - **Cell heterogeneity model,**
  - **Pn-Sn transport calculation,**
  - **Ultra-fine energy group, or Continuous energy Monte-Carlo, …..**
- **Preparation and distribution of benchmarks?**
  - **ICSBEP or IRPhE handbooks? If needed, who? when? how?**
  - **How about sensitivity coefficients?**

Opinions on the Selection of Integral Experiments (1)

<u>Palmiotti</u> (June 24, 2009)

- Proposed list of experiments (**openly available**)
  - GODIVA: critical mass, spectral indices (F8/F5, F9/F5)
  - JEZEBEL: critical mass. spectral indices (F8/F5, F9/F5)
  - ZPR6 6A: critical mass
  - ZPR6 7: critical mass, critical mass high Pu240 content, spectral indices at center (TBD), sodium void (one configuration), control rods (one configuration)
  - ?
- Proposed list of integral parameters which uncertainty has to be calculated: Keff, power peak, sodium void, Doppler, control rod reactivity, ?

Opinions on the Selection of Integral Experiments (2)

<u>Ishikawa</u> (August 10, 2009)

(1) To attain the objective of this benchmark, we need a minimum variety and number of independent experimental cores and parameters in fast-reactor field, in order to test the validity and correctness of the methodology quantitatively, though I completely agree that we have to avoid giving too much burden to participants. (Imagine we use only one k-eff value of one experimental core for the adjustment. This would lead us to very dangerous conclusions.)

(2) From the viewpoint of the data independency and the core-size variety, I recommend to add the ZPPR-9 core, which has a clean core-structure and 600-MWe FBR-size. The quality of the ZPPR facility at ANL-West has been assured by the NEA/IRPhE project (ZPPR-LMFR-EXP-002). As the core parameters, I recommend 1) the criticality, 2) one control-rod worth (central position), and 3) one sodium-void reactivity (especially Step 3, that has a large reactivity value with small contribution of the neutron leakage which is mainly affected by the core neutron solver.) JAEA can supply a simplified benchmark model like homogeneous cell, and the correction values based on the detailed as-built model if needed.

(3) Doppler reactivity is one of the important parameters in the safety design. I recommend to add the SEFOR data in the benchmark. SEFOR is the only one experiment which measured the whole core Doppler reactivity, not the sample heating Doppler which has very complicated physics like the resonance-interference effect. The experimental data of SEFOR has been re-evaluated with high reliability (see ref: Taira Hazama and Jean Tommasi, "Re-Evaluation of SEFOR Doppler Experiments and Analyses with JNC and ERANOS systems", in proceedings of PHYSOR2004). Also, JAEA can supply a simplified benchmark model and the correction values based on the detailed as-built model.

(4) Besides the critical experiments, it is desirable to include some power-FBR core data in this benchmark from the viewpoint of the fuel pin-bundle configuration and the fuel composition with higher Pu-isotopes. The experimental fast reactor JOYO Mk-I data are available in the IRPhEP DVD (JOYO-LMFR-RESR-001). I recommend 1) the criticality, 2) one control-rod worth (Regulation Rod 1), and 3) one burnup reactivity (which will be included in the next-year's DVD). (Personally I have quite a confidence with the quality of the JOYO Mk-I data, since I made the measurement in my young age.)

Opinions on the Selection of Integral Experiments (3)

<u>Kodeli</u> (August 31, 2009)

The ZPR-9 series of experiments are distinct cases where very large discrepancies in k-eff are observed and are sensitive to the data of tungsten.

The most recent isotopic evaluations greatly reduce, but not remove the discrepancy. The sensitivity of the data is in the 100 KeV range. New evaluations include complete covariance data. Also, new data will be available when the analysis of the measurements at IRMM is complete. This seems a good case to study (and check) the methods.

<u>Manturov</u>

Also I agree with Dr.Ishikawa that to attain the objective we need a minimum variety and number of independent experimental cores and parameters for the integral experiments like GODIVA, JEZEBEL, ZPR6-6A and ZPR6-7.

But, I think, we need to include not only k-eff parameter in the adjustment, but spread the list to different kinds, like ratio of cross-sections and reactivities. There is, for example, very interesting issue how to use sample reactivity measurements in the cross-section adjustment. I believe there are another issues too.

Opinions on the Selection of Integral Experiments (4)

<u>De Saint Jean</u> (September 3, 2009)

11 isotopes with ~ 5 reactions in a 33 group structure give : 11 * 5 * 33 = 1815 parameters.

We have around 15 experimental results.

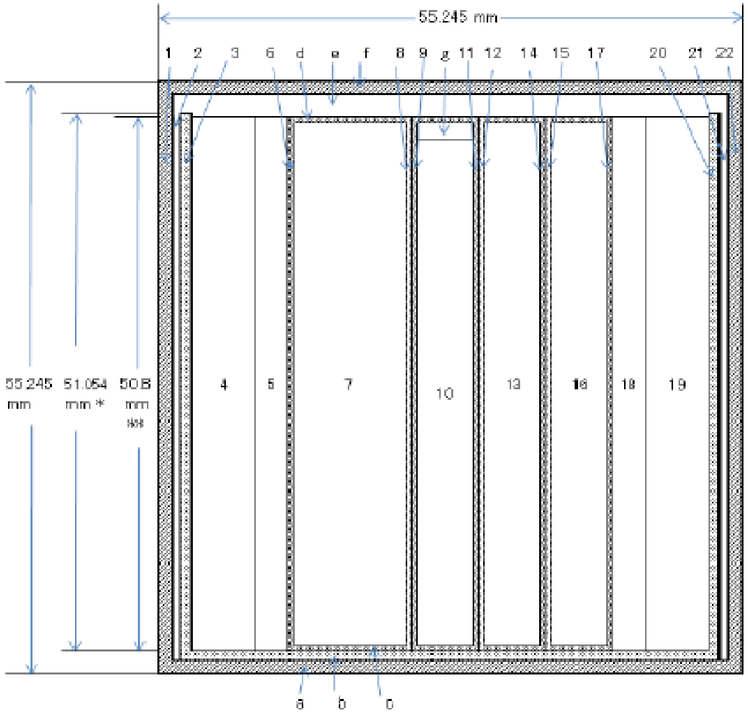
Perhaps, it is necessary in terms of mathematics/physics to lower the number of parameters and in the same time increase the number of experiment ?

This is for us an open question, but at first guess we think that simplifying the exercise is a better way : so less parameters with a limited set of integral experiments (those chosen in the proposal).

Besides the 5 basic reactions (capture, fission, nu-bar, elastic, inelastic), it would be interesting that participants able to deal with mu-bar and/or khi provide results with and without accounting for these two additional parameters (to check the impact of using them).

After the analysis of the exercise, we could then try to handle more complicated cases (more experiments + more parameters, etc ...) .

An Example of IRPhE Benchmarks (1)
- ZPPR-9 -

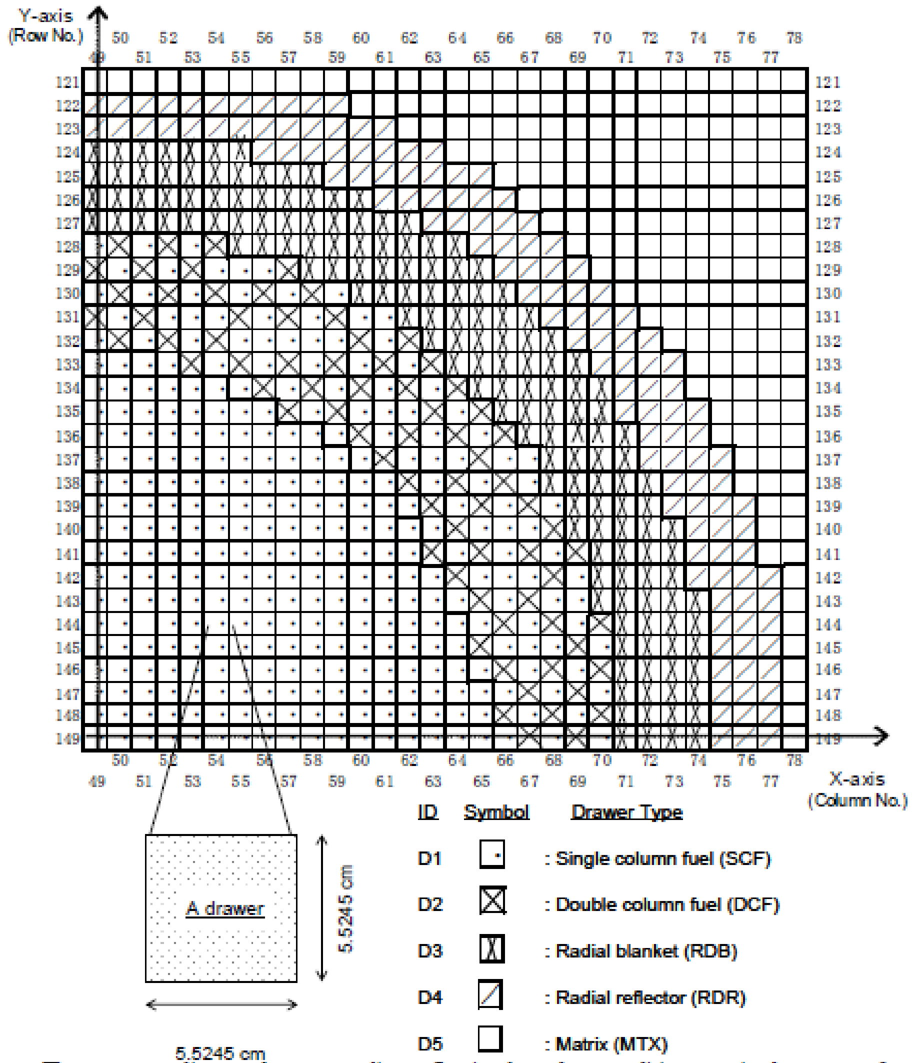


1 : Matrix tube (1.016 mm)
2 : Gap (0.4191 mm)
3 : Drawer (0.7874 mm)
4 : U_3O_8 plate (6.35 mm)
5 : Depleted uranium plate (3.175 mm)
6 : Can wall (0.381 mm)
7 : Sodium (11.938 mm)
8 : Can wall (0.381 mm)
9 : Can wall (0.381 mm)
10 : ZPPR-Pu fuel (5.588 mm)
11 : Can wall (0.381 mm)
12 : Can wall (0.381 mm)
13 : Sodium (5.588 mm)
14 : Can wall (0.381 mm)
15 : Can wall (0.381 mm)
16 : Na_2CO_3 (5.588 mm)
17 : Can wall (0.381 mm)
18 : Fe_2O_3 plate (3.175 mm)
19 : U_3O_8 plate (6.35 mm)
20 : Drawer (0.7874 mm)
21 : Gap (0.4191 mm)
22 : Matrix tube (1.016 mm)

a : Matrix tube (1.016 mm)
b : Drawer (0.7874 mm)
c : Can wall (0.381 mm)
d : Can wall (0.381 mm)
e : Gap (1.5256 mm)
f : Matrix wall (1.016 mm)
g : Gap (0.9144 mm)

* : Height of drawer side wall.
** : Height of plates.

Figure 3.1(2). As-built Cell Model of ZPPR-9 Single Column Fuel.



Note: The symmetry lines and corresponding reflecting boundary conditions are in the center of row 149 and column 49.

Figure 3.7. Two-dimensional XY Model of ZPPR-9 Benchmark Core for Criticality Evaluation.

An Example of IRPhE Benchmarks (2)
- ZPPR-9 -

Table 4.1. Analytical Results of ZPPR-9 Benchmark Model – Criticality.

Item		Values
Calculated k_{eff} [(a)]		0.99372
Correction by detailed model (Δk_{eff})	Transport theory	+0.00248
	Mesh-size effect	-0.00093
	Ultra-fine energy group effect	+0.00103
	Multi-drawer effect	+0.00047
	Cell asymmetry effect	-0.00052
Calculated k_{eff} after all corrections (C)		0.99625
Benchmark k_{eff} (E)		1.00080 +0.00153 -0.00154
C/E value		0.99545

(a) JENDL-3.2 library, "plate-stretch" model, current-weighted transport cross-section, Tone's background cross-section, three-dimensional XYZ model, 70-energy group, diffusion theory, Benoist's anisotropic diffusion constant, ~ 5-cm mesh size.

Table 4.5(1/2). Analytical Results of ZPPR-9 Benchmark Model.
(Zone Sodium Void Reactivity)

Voiding Step		Step 3		Step 5	
Non-leakage term or Leakage term		Non -leakage term	Leakage term	Non -leakage term	Leakage term
Calculated void reactivity (Cumulative) (cent) [(a)]		35.521	-2.374	59.944	-28.620
Correction by detailed model (multiplication factor)	Transport theory & Mesh-size effect	0.996	0.854	0.998	0.953
	Ultra-fine energy group effect	0.974	1.032	0.974	1.010
	Cell asymmetry effect	1.000	1.054	1.000	1.041
	Multi-drawer effect	negligible		negligible	
Calculated void reactivity after all corrections (cent)		34.433	-2.206	58.222	-28.682
	Total (C)	32.23		29.54	
Benchmark void reactivity (cent) (E)		29.18 +/-0.51		31.30 +/-0.53	
C/E value		1.104		0.944	

β_{eff} = 0.003550

(a) JENDL-3.2 library, "plate-stretch" model, current-weighted transport cross-section, Tone's background cross-section, three-dimensional XYZ model, 70-energy group, diffusion theory, Benoist's anisotropic diffusion constant. ~ 5-cm mesh size.