

**Minutes of Post Experiment Meeting of  $\beta_{eff}$  Benchmarks in JAERI-Tokai  
May 12th - 14th 1998,**

On May 12-14 1998, the post experiment meeting of  $\beta_{eff}$  benchmarks was held at JAERI Tokai to compare the measurement technique and the measured  $\beta_{eff}$  values, to evaluate the experimental error and to finalize the experimental  $\beta_{eff}$  values in FCA XIX cores. Those who participated in the FCA  $\beta_{eff}$  experiments attended the meeting. Unfortunately, the IPPE group and the LANL group were absent from the meeting but they sent their results.

A list of the attendees is attached. A list of the documents distributed is also attached.

DR. NAKAGAWA, the director of the department of nuclear energy system of JAERI, welcomed the participants and surveyed the brief history of international benchmark experiments of  $\beta_{eff}$ .

The first day was devoted to the comparison of  $\beta_{eff}$  values measured by each participant in the FCA cores. The second day was devoted to the evaluation of experimental errors. The third day was devoted to the finalization of the measured  $\beta_{eff}$  values in FCA cores and the reporting to NEA-NSC-WPEC.

**1. Comparison of  $\beta_{eff}$  values in the FCA cores between participants**

T. SAKURAI presented a summary on measured results of the core characterization in FCA XIX cores.

- JAERI team provided the effective multiplication factors relevant to the XIX-core simplified geometries of two calculational models : the R-Z model and the X-Y-Z model.
- JAERI team measured the central fission rates of U-235, U-238 and Pu-239 and the distributions of the fission rates and of the fission importance.
- JAERI team estimated the heterogeneity correction factor which is necessary to deduce the cell averaged fission rates.
- JAERI team provided key parameters for  $\beta_{eff}$  determination: *Fission integral, Normalization integral,  $\nu$ , Importance ratio of Cf-252 neutrons to the core fission neutrons, Diven factor and a couple of spatial correction factors,  $g$  and  $g^*$ .*
- The final results for key parameters in XIX cores are shown in Table 4.2 in the distributed document (3).

A. D'ANGELO asked the uncertainty of the cell averaging factors on the central fission

rate. The answer was that these factors were determined from the measurement with fission foils and/or the Monte Carlo calculations and that the uncertainty was adopted the statistical error in the measurement and the calculation. A. D'ANGELO commented that the heterogeneity corrections were sufficiently performed.

#### MASURCA Team

J. F. LEBRAT showed the central fission rates obtained by CEA absolute fission chambers and the measured  $\beta_{\text{eff}}$  values in FCA XIX-1 and -3 cores by using the Cross Power Spectral Density (CPSD) measurement technique.

- The calibrated fission chambers of CEA were used to measure the central fission rates. The central fission rates were measured with the experimental errors of 1.7% and showed an excellent agreement within the experimental errors with those measured by the JAERI fission chambers.
- The  $\beta_{\text{eff}}$  value was determined from the CPSD, the reactivity level, the integral fission rate and the calculated Diven factor. The  $\beta_{\text{eff}}$  values are  $743 \pm 19$  (pcm) in the XIX-1 core and  $247 \pm 6$  (pcm) in the XIX-3 core when the key parameters calculated by CEA team were used.

A. D'ANGELO commented that the uncertainty of the Diven factor should be divided into two parts: Nuclear data part and spatial part.

#### IPPE Team

S. OKAJIMA presented the experimental results measured by joint of IPPE team and JAERI team. In their measurements, JAERI's experimental systems were used.

- They used two measurement techniques to measure  $\beta_{\text{eff}}$  values : one is Rossi- $\alpha$  technique, and the other Cf source technique. The former method was used in the XIX-1 core and the latter was used in all of three cores.
- In the Rossi- $\alpha$  technique, the  $\beta_{\text{eff}}$  value was obtained from the ratio between the correlated and background parts in Rossi- $\alpha$  spectrum. The measurement was carried out at two different subcritical conditions. The  $\beta_{\text{eff}}$  value was adopted the mean values of the measurements,  $771 \pm 23$  (pcm).
- In the Cf source technique, they measured the change of fission rate due to the introduction of the Cf-252 source into the core center under a certain subcritical condition of the core. The  $\beta_{\text{eff}}$  value is determined from the measured results, the calculated  $\nu$  value and the calculated importance ratio between Cf-252 and core fission neutrons. The values were  $733 \pm 33$  (pcm),  $355 \pm 10$  (pcm) and  $251 \pm 7$  (pcm) in XIX-1, XIX-2 and XIX-3 cores, respectively.

When the calculated key parameters for the determination of  $\beta_{\text{eff}}$  were compared

between IPPE and JAERI, the large discrepancy was found in some of those parameters. Before the re-evaluation of  $\beta_{\text{eff}}$  values with the key parameters given by the JAERI team, the definition of the key parameters and those values should be carefully compared between IPPE and JAERI.

#### JAERI / KAERI Team

T. SAKURAI showed the measured  $\beta_{\text{eff}}$  values by using the Cf source technique. The measurements were carried out by the joint of the KAERI team and the JAERI team.

- They measured the pseudo-reactivity worths due to the introduction of the Cf-252 source into the core center at several subcritical states. The  $\beta_{\text{eff}}$  value is determined from the measured results of the pseudo-reactivity worth, the measured central fission rates, the calculated  $\nu$  value and the calculated importance ratio between Cf-252 and core fission neutrons. The values were  $733 \pm 17$  (pcm),  $358 \pm 10$  (pcm) and  $253 \pm 7$  (pcm) in XIX-1, XIX-2 and XIX-3 cores, respectively.

#### JAERI Team

T. SAKURAI showed the measured  $\beta_{\text{eff}}$  values in the XIX-1 and -3 cores by using the covariance-to-mean ratio technique.

- They took the covariance data between a couple of BF<sub>3</sub> detectors which were placed at the symmetrical positions in the soft blanket region of XIX cores. The covariance-to-mean ratio was fitted on the theoretical formula to obtain the amplitude of the correlated part by the least squares method. The  $\beta_{\text{eff}}$  value is determined from the amplitude of the correlated part, the measured central fission rates, the calculated Diven factor and the spatial correction factor,  $g$ . The values were  $723 \pm 18$  (pcm) and  $251 \pm 6$  (pcm) in XIX-1 and XIX-3 cores, respectively. In the evaluation of the uncertainties, the uncertainty of Diven factor was not taken into account.

#### LANL Team

S. OKAJIMA presented the LANL team's results.

- They measured the correlation function using a Cf-252 neutron source at several subcritical ( $\$0.1$  to  $\$1$ ) states and derived the Nelson number from the correlation function. The  $\beta_{\text{eff}}$  value was derived from the Nelson number and the subcriticality.
- They obtained the  $\beta_{\text{eff}}$  values of  $726 \pm 18$  (pcm) in the XIX-1 core. The measurement in other cores were failed because of the noise in the experimental systems.

#### NAGOYA UNIV. Team

T. IMAI reviewed the Bennett's covariance method and showed their results.

- They measured the covariance between two detectors.
- The  $\beta_{eff}$  value was derived from the combination of the covariance data, the integral fission rate and the calculated Diven factor.
- The results of the  $\beta_{eff}$  in the XIX-1, XIX-2 and XIX-3 cores were  $782 \pm 8$  (pcm),  $368 \pm 3$  (pcm) and  $252 \pm 3$  (pcm), respectively.

The experimental error in their values were discussed. In their estimation, the error was only considered the statistical error. When the error of Diven factor ( $\pm 4\%$ ) is taken into account, for instance, the value of the error becomes larger such as  $\pm 20$  (pcm) for the XIX-1 core,  $\pm 9$  (pcm) for the XIX-2 core,  $\pm 6$  (pcm) for the XIX-3 core.

### **2. Evaluation of Experimental Errors**

T. SAKURAI presented a breakdown of the uncertainties for key parameters in the  $\beta_{eff}$  determination and sensitivity analysis for each measurement technique. The reasonable uncertainty for each parameter was discussed based on T. Sakurai's analysis, CEA evaluations, IPPE's results and LANL results. A. D'ANGELO presented the evaluation method of uncertainties for the measured and corrected parameters of the obtained  $\beta_{eff}$  value.

- The uncertainties of key parameters in the  $\beta_{eff}$  determination in each core were fixed through the discussion and summarized in Table 1.
- JAERI team will evaluate sensitivity matrix and correlation matrix and will evaluate the experimental errors.

### **3. Finalization of Measured $\beta_{eff}$ values**

Before the finalization of the measured  $\beta_{eff}$  value in each core, the total fission rates in each core were discussed and finalized.

- The central fission rates in each core obtained by CEA absolute fission chambers were compared with those by JAERI absolute fission chambers. From the comparison in Table 2, an excellent agreement between them was found within the experimental error. The total fission rates which obtained from the central fission rates were also shown good agreement between CEA and JAERI. The total fission rate in each core finalized to be average value of the CEAs and JAERIs.

The measured  $\beta_{eff}$  values by each group are summarized in Table 3. To finalized the  $\beta_{eff}$  value in each core, the discussion was held and the following conclusion was drawn.

- To finalize the  $\beta_{eff}$  value, all of participants re-evaluate the  $\beta_{eff}$  values with using the key parameters provided by the JAERI team.
- All of participants will send the re-evaluated value to the JAERI team by May 30th, 1998.
- JAERI team will finalize the measured  $\beta_{eff}$  value in each core and will distribute the results to all of participants.

#### **4. Summary of the $\beta_{eff}$ Benchmark Experiments in MASURCA and FCA cores and Reporting to OECD/NEA/NSC-WPEC**

The JAERI team proposed that following the MASURCA experiments, as a common paper, the experimental results will be presented in International Conference on the Physics of Nuclear Science and Technology which will be held in Long-Island, New York, USA in October, 1998. All of participants accepted this proposal. To complete the full paper, the following schedule was fixed:

- May 30, 1998 : Dead line for re-evaluation of  $\beta_{eff}$
- June 5, 1998 : JAERI team will send the paper drafted to all of participants
- June 15, 1998 : Dead line for comments on the paper drafted
- June 30, 1998 : Dead line for Full paper

A. D'ANGELO demanded that a summary paper for both of MASURCA and FCA benchmark experiments should be written to report to Sub Group 6 of OECD/NEA/NSC-WPEC.

#### **5. Others**

A. D'ANGELO showed the recent activities in Sub Group 6 of OECD/NEA/NSC/WPEC.

**Table 1 Uncertainties of key parameters for  $\beta_{eff}$  determination in the FCA Cores**

Parameters		XIX-1	XIX-2	XIX-3
Rf		<1%	<1%	<1%
Fr or Fi	Eq.(3.1) or (3.2)	1 - 1.1%	1 - 1.1%	1 - 1.4%
Dv	Eq. (3.7)	2%	2%	2%
g	Eq. (3.8)	1%	1%	1%
g*	Eq. (3.6)	1%	-	-
v	Eq.(3.3) or (3.4)	0.5%	0.5%	0.5%
$\rho_0$ (\$)	Sub-criticality	2%	2%	2%
CPSD		3%	-	3%
A0	Bennett method	3%	3%	3%
Ap	Cov. to mean	2.5%	-	2.5%
S/N	Rossi- $\alpha$	3.5% ?	-	-
M	Nelson #	0.2%	-	-
S <sub>cr</sub>	Source Intensity	0.7%	0.7%	0.7%

\* The detail equation of Parameter is shown in Document No. 3.

**Table 2 Comparison of Central Fission Rates between CEA and JAERI in the FCA Cores**

U-235	Team	XIX-1	XIX-2	XIX-3
	CEA	(1.72E-15±1.6%	-	3.01E-15±1.6%)*
		1.69E-15±1.6%	-	3.02E-15±1.6%
	JAERI	1.71E-15±0.7%	1.44E-15±0.8%	3.04E-15±0.8%
U-238	Team	XIX-1	XIX-2	XIX-3
	CEA	(6.54E-17±1.7%	-	1.03E-17±1.7%)*
		6.73E-17±1.7%	-	1.06E-17±1.7%
	JAERI	6.77E-17±1.1%	5.87E-17±1.1%	1.07E-17±1.0%
Pu-239	Team	XIX-1	XIX-2	XIX-3
	CEA	(-	-	3.26E-15±1.5%)*
		-	-	3.29E-15±1.5%
	JAERI	-	1.52E-15±1.0%	3.28E-15±1.0%

\*: Raw data given by Absolute Fission Chamber

The values in last two rows in each nuclide are cell averaged ones.

Total Fission	Team	XIX-1	XIX-2	XIX-3
	CEA	3.83E6±1.7%	-	7.10E6±1.5%
	JAERI	3.87E6±1.0%	3.79E6±1.0%	7.08E6±1.1%
	Average	3.86E6±0.9%	3.79E6±1.0%	7.09E6±0.9%

**Table 3 a Comparison of measured  $\beta_{eff}$  values between participants in the FCA cores**

Team	Method	XIX-1 (pcm)	XIX-2 (pcm)	XIX-3 (pcm)	Remarks *
CEA	CPSD	743±19	-	247±6	(CEA)
IPPE	Cf source	733±30	355±10	251±7	(IPPE)
	Rossi- $\alpha$	771±23	-	-	(IPPE)
JAERI / KAERI	Cf source	733±17	358±10	253±7	(JAERI)
JAERI	Cov. to Mean	723±18	-	251±6	(JAERI)
LANL	Nelson Number	726±18	-	-	(LANL)
Nagoya univ.	Bennett	782±20	368±9	252±6	(JAERI)

\* : Key parameters calculation

**Table 3 b Comparison of measured  $\beta_{eff}$  values between participants in the FCA cores**

(Key parameters provided by JAERI were used to determine the  $\beta_{eff}$  values)

Team	Method	XIX-1	XIX-2	XIX-3	Remarks
CEA	CPSD	733±19*	-	248±6*	(JAERI)
IPPE	Cf source	?	?	?	(JAERI)
	Rossi- $\alpha$	?	-	-	
JAERI / KAERI	Cf source	733±17	358±10	253±7	(JAERI)
JAERI	Cov. to Mean	723±18	-	251±6	(JAERI)
LANL	Nelson Number	737±18*	-	-	(JAERI)
Nagoya univ.	Bennett	782±20*	368±9*	252±6*	(JAERI)

\* : Preliminary results which were obtained during the meeting

Attachment 1

List of attendees

Post Experiment Meeting of Beff Benchmarks in JAERI-Tokai

12th - 14th May, 1998

Roland SOULE	CEA/Cadarache	France	
Jean-Francois LEBRAT	CEA/Cadarache	France	
Antonio D'ANGELO	ENEA	Italy	
KIM, Young In	KAERI/Taejon	Korea	
Yoshihiro YAMANE	Nagoya Univ.	Japan	(2nd & 3rd days only)
Tomiyasu IMAI	Nagoya Univ.	Japan	(1st & 2nd days only)
Masayuki NAKAGAWA	JAERI	Japan	(1st day only)
Hajime NAKAJIMA	JAERI	Japan	(1st day only)
Toshitaka OSUGI	JAERI	Japan	Chairman of the
meeting			
Susumu IJIMA	JAERI	Japan	(1st & 2nd days only)
Fujiyoshi AKINO	JAERI	Japan	(2nd day only)
Shigeaki OKAJIMA	JAERI	Japan	Secretary of the meeting
Tsuyoshi YAMANE	JAERI	Japan	
Hiroyuki OIGAWA	JAERI	Japan	(2nd & 3rd days only)
Takeshi SAKURAI	JAERI	Japan	
Masaki ANDOH	JAERI	Japan	(1st day only)
Hideaki WATANABE	JAERI	Japan	(1st & 2nd days only)
Hiroshi SODEYAMA	JAERI	Japan	(2nd day only)
Junichi KATAKURA	JAERI	Japan	

Attachment 2

List of documents distributed  
Post Experiment Meeting of  $\beta_{eff}$  Benchmarks in JAERI-Tokai  
12th - 14th May, 1998

- (1) Agenda
- (2) List of Participants
- (3) T. Sakurai, S. Okajima : "International Benchmark Experiment of Effective Delayed neutron Fraction  $\beta_{eff}$  at FCA, JAERI - Core Characterization of FCA XIX Assemblies"
- (4) J.F. Lebrat, M. Martini, P. Chaussonnet, H. Philibert : " $\beta_{eff}$  Measurements in FCA by CEA Team"
- (5) P. Chaussonnet, M. Martini, H. Philibert : "International  $\beta_{eff}$  Benchmark Experiment in FCA -CEA Results-"
- (6) V. A. Doulin, G. Mikhailov : "The  $\beta_{eff}$  Measurement Results on FCA-XIX Cores Obtained by Joint FCA and BFS Team."
- (7) T. Sakurai, S. Okajima, H. Song, H. Sodeyama, Y. Kim : "International Benchmark Experiment of Effective Delayed neutron Fraction  $\beta_{eff}$  at FCA, JAERI - Measurements of the  $\beta_{eff}$  by Cf Source Method in FCA XIX Assemblies - "
- (8) T. Sakurai, H Sodeyama, S. Okajima : "International Benchmark Experiment of Effective Delayed neutron Fraction  $\beta_{eff}$  at FCA, JAERI - Measurements of the  $\beta_{eff}$  by Modified Variance to Mean Method in FCA XIX Assemblies"
- (9) G. D. Spriggs, T. Sakurai, S. Okajima : "Rossi- $\alpha$  and  $\beta_{eff}$  Measurements in the Japanese Atomic Energy Research Institute's FCA XIX-1 Assembly"
- (10) Y. Yamane, Y. Takemoto, T. Imai, S. Okajima, T. Sakurai : "Effective Delayed Neutron Fraction Measurements in FCA-XIX cores - Measurements in XIX-1(Uranium) core, XIX-2(Plutonium/Natural Uranium) core, and XIX-3(Plutonium) core"
- (11) P. Bertrand et al. : "BERNICE - Inter Laboratory Comparison of  $\beta_{eff}$  Measurement Techniques at MASURCA"
- (12) Copy of E-mail message between IPPE team and S. Okajima
- (13) Okajima : "Typical example for Re-evaluation of LANL's  $\beta_{eff}$  values with JAERI's key parameters"
- (14) T. Sakurai : "Summary of Uncertainty of Experimental  $\beta_{eff}$ "
- (15) A. D'Angelo : "How to take into account common corrections"
- (16) V. A. Doulin, A. L. Kotchetkov : "The  $\beta_{eff}$  Measurement Results on FCA-XIX-1

Core”

- (17) T. Sakurai et al. : “An International Benchmark Experiment of Effective Delayed neutron Fraction  $\beta_{eff}$  in FCA, JAERI,” Abstract for Int. Conf. on the Physics of Nuclear Science and Technology (Long Island, NW, 1998)
- (18) A. D’Angelo : “OECD/NEA/WPEC Subgroup 6 Status Report”
- (19) A. D’Angelo : “Status Report of the WPEC Subgroup 6 activities”
- (20) T. Parish, et al. : “Status of Six Group Delayed Neutron Data and Relationships between Delayed Neutron Parameters from the Macroscopic and Microscopic Approaches”
- (21) J. L. Rowlands : “Delayed Neutron Data Requirements for Reactor Technology”
- (22) A. D’Angelo, A. Filip : “Problems in Fitting Together Total Delayed Neutron Yield Data and in-Pile Integral Measurement Results”
- (23) E. Fort et al. : “Preliminary evaluation of the LENDEL et al model to calculate the delayed neutron yield as a function of energy. -First results of the JEF2.2 data validation-”
- (24) V. G. Pronyaev, V. M. Piksaikin : “Factors Determining the Energy Dependence of Delayed Neutron Yields in Neutron Induced Fission”

## Distribution

R. SOULE	CEA/Cadarache	France
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T. OSUGI	JAERI	Japan
S. IJIMA	JAERI	Japan
F. AKINO	JAERI	Japan
S. OKAJIMA	JAERI	Japan
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G. D. SPRIGGS	LANL	USA
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