

**For Official Use**

**NEA/NSC/DOC(2013)2**



Organisation de Coopération et de Développement Économiques  
Organisation for Economic Co-operation and Development

**English - Or. English**

**NUCLEAR ENERGY AGENCY  
NUCLEAR SCIENCE COMMITTEE**

NEA/NSC/DOC(2013)2  
For Official Use

**EVALUATION GUIDE FOR THE INTERNATIONAL REACTOR PHYSICS EXPERIMENTS  
EVALUATION PROJECT (IRPhEP)**

Akifumi Yamaji  
akifumi.yamaji@oecd.org  
+33 1 45 24 10 83

Complete document available on OLIS in its original format

*This document and any map included herein are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.*

English - Or. English

**EVALUATION GUIDE FOR THE  
INTERNATIONAL REACTOR PHYSICS EXPERIMENTS  
EVALUATION PROJECT (IRPhEP)**

**Table of Contents**

Summary Information Guide.....	3
Status Sheet.....	5
Format Guide.....	8
Nuclear Constants.....	23
Commonly Used Symbols and Terms.....	26
References.....	28

## Summary Information

(To be used for the report containing inventory of experiments and linked to the first page of the evaluation)

- 1.0 Experiment identification number
- 2.0 Date
- 3.0 Name of experiment
  - 3.1. Purpose of experiment
  - 3.2. Phenomena measured and scope
- 4.0 Name or designation of experimental programme
- 5.0 Description of facility
- 6.0 Description of test or experiment
  - 6.1 Experimental configuration
    - 6.1.1 Type of assemblies
      - Zoned assembly
      - Clean benchmark assembly
      - Engineering benchmark assembly / engineering mockup core
      - Special purpose assemblies
    - 6.1.2 Assembly details
      - 6.1.2.1 Type
      - 6.1.2.2 Fuel
      - 6.1.2.3 Moderator
      - 6.1.2.4 Absorbers
      - 6.1.2.5 Critical mass
      - 6.1.2.6 Core volume
      - 6.1.2.7 Blanket
      - 6.1.2.8 Reflectors
      - 6.1.2.9 Reactivity adjustment
      - 6.1.2.10 Other
    - 6.1.3 Assembly variants
  - 6.2 Core life cycle
    - BOL
    - EOL
    - Other
  - 6.3 Experimental limitations or shortcomings

7.0 Phenomena measured

7.1 Description of results and analysis (values and evaluated uncertainties)

7.1.1 Reactivity control for criticality

7.1.2 Reaction rates / ratios

- Capture
- Fission
- Other

7.1.3 Reactivity worth

- Of samples
- Expansion worth
- Voided zone
- Reflector worth
- Other

7.1.4 Sample Doppler reactivity

7.1.5 Temperature coefficients

7.1.6 Control rod or rod-bank worths

7.1.7 Soluble boron worth

7.1.8 Gamma heating distributions

7.1.9 Neutron spectrum

7.1.10 Kinetic parameters

7.1.11 Reactor power distributions

7.1.12 Isotopic measurements

7.2 Special features and characteristics of experiment

7.2.1 Moderator/fuel ratio

7.2.2 Measured spectral indices

7.3 Measurement systems (methods) and uncertainties

8.0 Duplicate or complementary experiments / other related experiments

9.0 Status of completion of the evaluation

10.0 References (pointer to evaluation, archive if available, otherwise generic bibliographic reference)

11.0 Authors/ organisers

11.1 Establishment

11.2 Staff involved in experiment

11.3 Contact information

11.4 Reviewers of compiled data

12.0 Material available

12.1 Data and Format

**Status of Compilation / Evaluation / Peer Review**

<b>Section 1</b>	<b>Compiled</b>	<b>Independent Review</b>	<b>Working Group Review</b>	<b>Approved</b>
1.0 DETAILED DESCRIPTION				
1.1 Description of the Critical and / or Subcritical Configuration				
1.2 Description of Buckling and Extrapolation Length Measurements				
1.3 Description of Spectral Characteristics Measurements				
1.4 Description of Reactivity Effects Measurements				
1.5 Description of Reactivity Coefficient Measurements				
1.6 Description of Kinetics Measurements				
1.7 Description of Reaction-Rate Distribution Measurements				
1.8 Description of Power Distribution Measurements				
1.9 Description of Isotopic Measurements				
1.10 Description of Other Miscellaneous Types of Measurements				
<b>Section 2</b>	<b>Evaluated</b>	<b>Independent Review</b>	<b>Working Group Review</b>	<b>Approved</b>
2.0 EVALUATION OF EXPERIMENTAL DATA				
2.1 Evaluation of Critical and / or Subcritical Configuration Data				
2.2 Evaluation of Buckling and Extrapolation Length Data				
2.3 Evaluation of Spectral Characteristics Data				
2.4 Evaluation of Reactivity Effects Data				
2.5 Evaluation of Reactivity Coefficient Data				
2.6 Evaluation of Kinetics Measurements Data				
2.7 Evaluation of Reaction Rate Distributions				
2.8 Evaluation of Power Distribution Data				
2.9 Evaluation of Isotopic Measurements				
2.10 Evaluation of Other Miscellaneous Types of Measurements				

<b>Section 3</b>	<b>Compiled</b>	<b>Independent Review</b>	<b>Working Group Review</b>	<b>Approved</b>
<b>3.0 BENCHMARK SPECIFICATIONS</b>				
3.1 Benchmark-Model Specifications for Critical and / or Subcritical Measurements				
3.2 Benchmark-Model Specifications for Buckling and Extrapolation Length Measurements				
3.3 Benchmark-Model Specifications for Spectral Characteristics Measurements				
3.4 Benchmark-Model Specifications for Reactivity Effects Measurements				
3.5 Benchmark-Model Specifications for Reactivity Coefficient Measurements				
3.6 Benchmark-Model Specifications for Kinetics Measurements				
3.7 Benchmark-Model Specifications for Reaction-Rate Distribution Measurements				
3.8 Benchmark-Model Specifications for Power Distribution Measurements				
3.9 Benchmark-Model Specifications for Isotopic Measurements				
3.10 Benchmark-Model Specifications of Other Miscellaneous Types of Measurements				
<b>Section 4</b>	<b>Compiled</b>	<b>Independent Review</b>	<b>Working Group Review</b>	<b>Approved</b>
<b>4.0 RESULTS OF SAMPLE CALCULATIONS</b>				
4.1 Results of Calculations of the Critical or Subcritical Configurations				
4.2 Results of Buckling and Extrapolation Length Calculations				
4.3 Results of Spectral Characteristics Calculations				
4.4 Results of Reactivity Effect Calculations				
4.5 Results of Reactivity Coefficient Calculations				
4.6 Results of Kinetics Parameter Calculations				
4.7 Results of Reaction-Rate Distribution Calculations				
4.8 Results of Power Distribution Calculations				
4.9 Results of Isotopic Calculations				
4.10 Results of Calculations of Other Miscellaneous Types of Measurements				
<b>Section 5</b>	<b>Compiled</b>	<b>Independent Review</b>	<b>Working Group Review</b>	<b>Approved</b>
<b>5.0 REFERENCES</b>				
Appendix A: Computer Codes, Cross Sections, and Typical Input Listings				

## **Evaluation Guide for the International Reactor Physics Experiments Evaluation Project (IRPhEP)**

### ***General Format Guidelines***

*Final formatting, in terms of the document, including text, table and graphics, will be done by the publication staff. Evaluators are encouraged to follow the standard formatting guidelines outlined below, but should allow the publication staff to perform final formatting, to ensure consistency in evaluations contained within the Handbook. Publication templates will be used to ensure this consistency. Evaluations containing special/individual formatting functions, such as auto table/figure numbering, may interfere with the template styles and capabilities. Such special formatting functions should be avoided.*

*Note: Although final formatting will be done by the publication staff, evaluators should number tables and figures sequentially within sections (e.g., For Section 2 tables/figures, label as Table/Figure 2.1, 2.2, etc.). Authors of evaluations with unusually large numbers of figures and tables may, at their discretion, use additional levels of Table/Figure numbering (e.g., For Section 2 tables/figures, label as Table/Figure 2.1.1, 2.1.2, etc. or Table 2.1.1.1, 2.1.1.2, etc.); however numbering must be consistent throughout the evaluation and in no case should more than four levels be used.*

*General presentation guidelines that evaluators should follow are given below:*

- *Paper size should be “A4”.*
- *Use 11-point, Times New Roman font for main text.*
- *Main text should be left-justified.*
- *Margins should be set as follows: top and bottom margins - .3 inches; left-hand margins – 1 inch; and right-hand margins - .8 inches.*

## DOCUMENT FORMAT GUIDE

### EXPERIMENT TITLE

#### IDENTIFICATION NUMBER:

Each experiment has a unique identifier that consists of two parts. Part 1 consists of the Reactor Name, Reactor Type, Facility Type and a Three Digit Numerical Identifier. Part 2 of the identifier begins on a separate line and includes the Measurement Type(s). Identifiers take the following form:

(Reactor Name)-(Reactor Type)-(Facility Type)-(Three-Digit Numerical Identifier)  
(Measurement Type(s))

REACTOR TYPE		FACILITY TYPE		MEASUREMENT TYPE	
Pressurized Water Reactor	PWR	Experimental Facility <sup>(1)</sup>	EXP	Critical Configuration	CRIT
VVER Reactors	VVER	Power Reactor	POWER	Subcritical Configuration	SUB
Boiling Water Reactor	BWR	Research Reactor	RESR	Buckling & Extrapolation Length	BUCK
Liquid Metal Fast Reactor	LMFR			Spectral Characteristics	SPEC
Gas Cooled (Thermal) Reactor	GCR			Reactivity Effects	REAC
Gas Cooled (Fast) Reactor	GCFR			Reactivity Coefficients	COEF
Light Water Moderated Reactor	LWR			Kinetics Measurements	KIN
Heavy Water Moderated Reactor	HWR			Reaction-Rate Distributions	RRATE
Molten Salt Reactor	MSR			Power Distributions	POWDIS
RBMK Reactor	RBMK			Isotopic Composition	ISO
Space Reactor	SPACE			Other Miscellaneous Types of Measurements	MISC
Fundamental <sup>(2)</sup>	FUND				

(1) Generally, experimental facilities are easily modified to represent a wide variety of core configurations and often criticality is achieved by a means other than control rod position (control rods are typically fully withdrawn). Facilities for which the primary focus is the production of integral-experiment data that support ex-core activities such as handling and storage of fissile material are also categorized as experimental facilities.

(2) Reactors or assemblies that are intended primarily to make fundamental physics measurements and do not support the design of a particular reactor type are categorized as Fundamental.



Examples of identifiers are:

ZPR-LMFR-EXP-001  
CRIT-SPEC-REAC-COEF-KIN-RRATE

This identifier corresponds to the first evaluation of measurements made on the ZPR liquid metal fast reactor experimental facility. The critical configuration, spectral measurements, reactivity measurements and coefficients, kinetics parameters, and reaction rates were measured and the data are provided.

VENUS-PWR-EXP-001  
BUCK-RRATE-POWDIS

This identifier corresponds to the first evaluation of measurements made on the VENUS pressurized water reactor experimental facility. Buckling and extrapolation length, reaction rate, and power distributions were measured and the data are provided.

ZR6-VVER-EXP-001  
CRIT-BUCK-SPEC-REAC-COEF-RRATE

This identifier corresponds to the first evaluation of measurements made on the ZR-6 VVER experimental facility. The critical configuration, buckling and extrapolation length, reaction rate, spectral measurements, reactivity measurements and coefficients, and reaction rates were measured and the data are provided.

#### **KEY WORDS:**

A list of words that describe key features of the experiment is provided. Keywords include the fissile material of the reactor as well as moderator and reflector materials (e.g., low-enriched uranium, light-water-moderated, graphite-reflected, unreflected).

#### **Section 1 General Guidelines**

*A detailed description of the experiments and all relevant experimental data are provided in the appropriate subsections within this section. The detailed description includes the measurement methods used and the results obtained for the parameters of interest, as well as methods used to obtain the experimental data. Experimental data are values of parameters that are needed to completely describe the experiment and that have been directly measured. Examples are dimensions obtained from tightly controlled specifications or with calibrated measuring devices, masses obtained from weighing, and temperatures from thermometer readings. It is recommended that only experimental data, taken directly from the references, be included in Section 1. However, values derived from experimental data, such as density derived from masses and dimensions, or compositions normalized to 100 wt.%, may be included if clearly noted as derived with the method of derivation given.*

*In order to clarify the description of the experiment and to not prejudge the evaluation, there should be no mention of models, calculated results, or evaluative statements in this section. Only the physical description of the actual experiment is given.*

*Uncertainties in the data that were assigned by the experimenters, either in published or unpublished (e.g., logbook) sources, should be given. How the uncertainties were determined and what they represent (e.g., standard deviation, specification tolerance, measured bounds), if known, should be noted.*

*Any inconsistencies in the data from different sources are mentioned. In addition to enough information that the derivation of benchmark-model specifications in Section 3 is evident, it is recommended that more experimental data, which might be useful for more detailed modelling or for justification of sufficiency of the model, be provided.*

*The source of each datum should be clear. Sources of data include published reports, logbooks, chemical-laboratory analyses, handbooks or standards of material compositions, photographs, memos or other records provided by experimenters, and discussions with experimenters.*

*Details of the main features of an experiment given in Section 1.1 for the critical and / or subcritical configurations are often the same for all other types of measurements. It is not necessary to repeat this information in each subsequent section. However, additions and modifications to the geometry and additional materials that are introduced for each particular measurement type must be described in detail in the appropriate subsections, following the recommendations exemplified in the details given for Sections 1.1.X, below.*

*In general, modelling (idealization, simplification) of the experiment is not discussed here. However, if the exact experimental configuration is unknown (e.g., perhaps it was not reported because it was thought to be too complicated to describe in detail) and an idealization was provided by the experimenters, then the idealized experiment may be described here. Evaluation (Sections 2 and 3.1) of an idealized experiment includes an explanation of the assumptions used in going from the real experimental configuration to the idealization.*

## **1.0 DETAILED DESCRIPTION**

This section should start with a brief description of the scope and objectives of the experiment carried out. A short general description of the reactor or experimental facility is given, with a more detailed description optionally provided in an appendix. The types of evaluated experiments acceptable as benchmarks are summarized.

### **1.1 Description of the Critical and / or Subcritical Configuration**

#### **1.1.1 Overview of Experiment**

The overview of the experiment should include the name of the facility, when the experiments were performed, the organization that performed the experiments, and perhaps the names of the experimenters if available. The conclusions of the Evaluation of Experimental Data section, Section 2.1, should be briefly stated. (e.g., “Twenty experiments were evaluated, but only 12 were judged to be acceptable for use as critical benchmark experiments.”)

#### **1.1.2 Geometry of the Experiment Configuration and Measurement Procedure**

This section contains the detailed description of the physical arrangement and dimensions of the experiment. The method of determining the critical condition and, if applicable, the measured reactivity are stated. For ease of accurate transcription and checking, data and uncertainties are simply copied from the references, in their original units and to the precision that was recorded. However, if original units are not SI, evaluators are encouraged to parenthetically provide SI units immediately following the original units.

Subcritical measurements may require more detailed information about the neutron source and detectors than is typically required for critical assemblies.

#### **1.1.3 Material Data**

This section contains the detailed description of all materials used in the experiment as well as significant materials in the surroundings. Whether compositions are from physical or chemical analyses of the materials actually used in the experiments or are from material handbooks when only the type of material

was specified (e.g., stainless steel 304L) should be clear. Details of the methods of analysis and uncertainties, if known, are also given. When isotopic buildup and decay are important, relevant dates should be provided.

#### **1.1.4 Temperature Data**

The temperature at which the experiments were performed should be given and discussed in this section.

#### **1.1.5 Additional Information Relevant to Critical and Subcritical Measurements**

Additional information that is relevant to critical and subcritical measurements, such as reactivity measurements of components, is presented in this section. Subcritical measurement description must include the measurement technology and a discussion on the interpretation of the measurements as well as the measured data.

### **1.2 Description of Buckling and Extrapolation Length Measurements**

This section contains a detailed description of any buckling and/or extrapolation length measurements. Uncertainties in the measurements assigned by the experimentalists, either in published or unpublished (e.g., logbooks) sources, should be included. Subsections 1.2.1 through 1.2.5 should contain, respectively, an overview of the measurements, the configuration geometry and measurement procedure, material data, temperature data, and additional information relevant to the buckling and extrapolation measurements. Detailed descriptions of the methods used to obtain the data should be included in the appropriate subsections. Values of the parameters that were directly measured should be given, as well as other data (e.g., constants) used in the data-reduction process. Clear distinction should be made between measured values, derived values, and data used to process measurements to obtain the experimental results. Subheadings for Sections 1.2.1 through 1.2.5 are fixed and, with the exception of Section 1.2.5, are the same as those heading listed in Section 1.1. The subheading for Section 1.2.5 is: **Additional Information Relevant to Buckling and Extrapolation Measurements.**

### **1.3 Description of Spectral Characteristics Measurements**

This section contains a detailed description of any measurements made to determine spectral characteristics such as neutron spectra or  $^{238}\text{U}/^{235}\text{U}_f$  ratios. Uncertainties in the measurements that were assigned by the experimentalists, either in published or unpublished (e.g. logbooks) sources, should be included. Subsections 1.3.1 through 1.3.5 should contain, respectively, an overview of the measurements, the configuration geometry and measurement procedure, material data, temperature data, and additional information relevant to the spectral characteristics measurements. Detailed descriptions of the methods used to obtain the data should be included in the appropriate subsections. Values of the parameters that were directly measured should be given, as well as other data (e.g., constants) used in the data-reduction process. Clear distinction should be made between measured values, derived values, and data used to process measurements to obtain the experimental results. Subheadings for Sections 1.3.1 through 1.3.5 are fixed and, with the exception of Section 1.3.5, are the same as those heading listed in Section 1.1. The subheading for Section 1.3.5 is: **Additional Information Relevant to Spectral Characteristics Measurements.**

#### **1.4 Description of Reactivity Effects Measurements**

This section contains a detailed description of measurements such as control-rod worth, void effects, small-sample worth, fuel substitution, and xenon effects. Uncertainties in the measurements that were assigned by the experimentalists, either in published or unpublished (e.g., logbooks) sources, should be included. Subsections 1.4.1 through 1.4.5 should contain, respectively, an overview of the measurements, the configuration geometry and measurement procedure, material data, temperature data, and additional information relevant to the reactivity-effect measurements. Detailed descriptions of the methods used to obtain the data should be included in the appropriate subsections. Values of the parameters that were directly measured should be given, as well as other data (e.g., group constants of delayed neutrons) used in the data-reduction process. Clear distinction should be made between measured values, derived values, and data used to process measurements to obtain the experimental results. Subheadings for Sections 1.4.1 through 1.4.5 are fixed and, with the exception of Section 1.4.5, are the same as those heading listed in Section 1.1. The subheading for Section 1.4.5 is: **Additional Information Relevant to Reactivity Effects Measurements.**

#### **1.5 Description of Reactivity Coefficient Measurements**

This section contains a detailed description of measurements such as the temperature coefficient of reactivity,  $\partial\rho/\partial T$ ; the moderator-height coefficient of reactivity,  $\partial\rho/\partial H$ ; and soluble boron worth,  $\partial\rho/\partial C_B$ . Uncertainties in the measurements that were assigned by the experimentalists, either in published or unpublished (e.g. logbooks) sources, should be included. Subsections 1.5.1 through 1.5.5 should contain, respectively, an overview of the measurements, the configuration geometry and measurement procedure, material data, temperature data, and additional information relevant to the reactivity-coefficient measurements. Detailed descriptions of the methods used to obtain the data should be included in the appropriate subsections. Values of the parameters that were directly measured should be given, as well as other data (e.g., constants) used in the data-reduction process. Clear distinction should be made between measured values, derived values, and data used to process measurements to obtain the experimental results. Subheadings for Sections 1.5.1 through 1.5.5 are fixed and, with the exception of Section 1.5.5, are the same as those heading listed in Section 1.1. The subheading for Section 1.5.5 is: **Additional Information Relevant to Reactivity Coefficient Measurements.**

#### **1.6 Description of Kinetics Measurements**

This section contains a detailed description of measurements such as decay constants,  $\beta_{\text{eff}}$ , or prompt neutron lifetime. Uncertainties in the measurements that were assigned by the experimentalists, either in published or unpublished (e.g., logbooks) sources, should be included. Subsections 1.6.1 through 1.6.5 should contain, respectively, an overview of the measurements, the configuration geometry and measurement procedure, material data, temperature data, and additional information relevant to the kinetics measurements. Detailed descriptions of the methods used to obtain the data should be included in the appropriate subsections. Values of the parameters that were directly measured should be given, as well as other data (e.g., constants) used in the data-reduction process. Clear distinction should be made between measured values, derived values, and data used to process measurements to obtain the experimental results. Subheadings for Sections 1.6.1 through 1.6.5 are fixed and, with the exception of Section 1.6.5, are the same as those heading listed in Section 1.1. The subheading for Section 1.6.5 is: **Additional Information Relevant to Kinetics Measurements.**



































