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The International Reactor Physics Experiment Evaluation Project (IRPhEP)

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The International Reactor Physics Experiment Evaluation Project (IRPhEP)

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Abstract

Since the beginning of the Nuclear Power industry, numerous experiments concerned with nuclear energy and technology have been performed at different research laboratories, worldwide. These experiments required a large investment in terms of infrastructure, expertise, and cost; however, many were performed without a high degree of attention to archival of results for future use. The degree and quality of documentation varies greatly. There is an urgent need to preserve integral reactor physics experimental data, including measurement methods, techniques, and separate or special effects data for nuclear energy and technology applications and the knowledge and competence contained therein. If the data are compromised, it is unlikely that any of these experiments will be repeated again in the future. The International Reactor Physics Evaluation Project (IRPhEP) was initiated, as a pilot activity in 1999 by the by the Organization of Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC). The project was endorsed as an official activity of the NSC in June of 2003. The purpose of the IRPhEP is to provide an extensively peer reviewed set of reactor physics related integral benchmark data that can be used by reactor designers and safety analysts to validate the analytical tools used to design next generation reactors and establish the safety basis for operation of these reactors. A short history of the IRPhEP is presented and its purposes are discussed in this paper. Accomplishments of the IRPhEP, including the first publication of the IRPhEP Handbook, are highlighted and the future of the project outlined.

KEYWORDS: benchmarks, integral measurements, reactor physics

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1. Introduction

Since the beginning of the Nuclear Power industry, numerous experiments concerned with nuclear energy and technology have been performed at different research laboratories, worldwide. These experiments required a large investment in terms of infrastructure, expertise, and cost; however, many were performed without a high degree of attention to archival of results for future use. The degree and quality of documentation varies greatly. Often a comprehensive and detailed report was prepared, but in many cases, the results may appear only in a series of internal reports (e.g., progress reports), or in logbooks. There is an urgent need to preserve integral reactor physics experimental data, including measurement methods, techniques, and separate or special effects data for nuclear energy and technology applications and the knowledge and competence contained therein. If the data are compromised, it is unlikely that any of these experiments will be repeated again in the future.

The International Reactor Physics Evaluation Project (IRPhEP) was initiated, as a pilot activity in 1999 by the by the Organization of Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Nuclear Science Committee (NSC). The project was endorsed as an official activity of the NSC in June of 2003. The IRPhEP is patterned after its predecessor, the International Criticality Safety Benchmark Evaluation Project, (ICSBEP), but focuses on other integral measurements such as buckling, spectral characteristics, reactivity effects, reactivity coefficients, kinetics measurements, reaction-rate and power distributions, nuclide compositions and other miscellaneous types of measurements in addition to the critical configuration. The two projects are closely coordinated to avoid duplication of effort and to leverage limited resources to achieve a common goal.

2. Purpose

The purpose of the IRPhEP is to provide an extensively peer reviewed set of reactor physics related integral benchmark data that can be used by reactor designers and safety analysts to validate the analytical tools used to design next generation reactors and establish the safety basis for operation of these reactors. While coordination and administration of the IRPhEP takes place at an international level, each participating country is responsible for the administration, technical direction, and priorities of the project within their respective countries.

3. Evaluation Process

The evaluation process entails the following steps: (1) Identification of experimental reactor physics related data; (2) Verification of data, to the extent possible, by reviewing original and subsequently revised documentation and by talking with experimenters or individuals who were associated with the experiments or the experimental facility; (3) Evaluation of the data and quantification of overall uncertainties through various types of sensitivity/uncertainty analyses; (4) Compilation of the data into a standardized format; (5) Performance of sample calculations of each experiment with standardized reactor physics neutronics codes; and (6) Formal

documentation of the work into a single source of verified and extensively peer reviewed benchmark reactor physics data.

4. IRPhEP Handbook

The work of the IRPhEP is documented in an OECD NEA Handbook entitled, "International Handbook of Evaluated Reactor Physics Benchmark Experiments." The first edition of this Handbook, the 2006 Edition (See Fig. 1) spans over 4400 pages and contains data from 16 different experimental series that were performed at 12 different reactor facilities. Included are evaluated data from five liquid metal fast reactors (JOYO, BFS-1, BFS-2, ZPPR, and ZEBRA), one gas cooled reactor (HRT-10), one heavy water reactor (DCA), one light water reactor (CROCUS), two pressurized water reactors (VENUS and DIMPLE), and two VVER reactors (ZR6 and PFACILITY).

Figure 1: OECD NEA "International Handbook of Evaluated Reactor Physics Benchmark Experiments"— Published on DVD.

Seven of the 16 evaluations are published as, approved benchmarks. The remaining nine evaluations are published as DRAFT documents only. Draft documents have been reviewed by the IRPhEP Technical Review Group (TRG); however, all action items could not be completed or reviewed in time for the final publication or, in most cases, the TRG requested the opportunity to review the revised evaluations, one last time, before giving final approval.

The Handbook is organized in a manner that allows easy inclusion of additional evaluations, as they become available. Annual publications are anticipated. The 2007 Edition of the Handbook is expected to include additional data from ZPPR, VENUS, and ZEBRA and new data from the VHTRC, PROTEUS, and ASTRA gas cooled reactor facilities; the KRITZ pressurized water reactor facility; the STEK liquid metal fast reactor facility; and the TCA and MB-01 light water reactor facilities. The information and data included in this Handbook are available to OECD member countries, to all contributing countries, and to others on a case by case basis.

5. Contents of an IRPhEP Evaluation

5.1 Identification and Types of Measurements

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 includes the Measurement Type(s). Identifiers take the following form:

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

Identifier elements and their meanings are given in Table 1.

5.2 Format

The format for IRPhEP evaluations is patterned after the format used by the ICSBEP. The general format is: (1) describe the experiments, (2) evaluate the experiments, (3) derive benchmark specifications, and (4) provide results from sample calculations. Code and cross section information, including typical input lists, are provided in Appendix A. Additional information may be provided in subsequent appendices. The format is the same for all evaluations. Seldom, if ever, are all types of measurements made in a particular series of experiments. However, sections for all measurement types are retained in the format, and it is simply stated, when applicable, that no such measurements were made. A detailed IRPhEP Evaluation Guide [2] can be obtained on the following two Internet Sites: http://nuclear.inl.gov/irphep/ and http://www.nea.fr/lists/irphe/. The guide is also published as part of the IRPhEP Handbook.

The ICSBEP format [3] for critical or subcritical measurements is very well known. Except for the expansion to include other types of measurements, there is only one minor difference between the two formats, a specific section for temperature has been added to Section 1.

The types of information and format presentation are essentially the same for each measurement type. Therefore, the details of each subsection are only stated once.

Table 1. Identifier Elements and Their Meanings.

REACTOR TYPE		FACILITY TYPE		MEASUREMENT TYPE	
Pressurized Water Reactor	PWR	Experimental Facility	EXP	Critical Configuration	CRIT
VVER Reactor	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			Nuclide Composition	ISO
Fundamental	FUND			Other Miscellaneous Types of Measurements	MISC

6. Archival of Primary Documentation

Since the inception of the IRPhEP, the NEA has been collecting primary documentation and has been transforming those documents into electronic form to facilitate data retrieval and dissemination. An archive of those documents has been established at the NEA and contains the following:

- IRPHE/B&W-SS-LATTICE, Spectral Shift Reactor Lattice Experiments
- IRPHE/ZEBRA, AEEW Fast Reactor Experiments
- IRPHE/JOYO MK-II, core management and characteristics database
- IRPHE/JAPAN, Reactor Physics Experiments carried out in Japan
- IRPhE/HTR-ARCH-01, Archive of HTR Primary Documents
- IRPHE-SNEAK, KFK SNEAK Fast Reactor Experiments
- IRPhE/STEK, Experiments from Fast-Thermal Coupled Facility
- IRPhE-DRAGON-DPR, OECD High Temperature Reactor Dragon Project
- IRPhE/RRR-SEG, Experiments from Fast-Thermal Coupled Facility
- Experiments in VENUS- Project on the Physics of Plutonium Recycling
- IRPHE/AVR, AVR – Experimental High Temperature Reactor
- IRPHE-KNK-II-ARCHIVE, KNK-II fast reactor documents, power history and measured parameters
- IRPHE/BERENICE, effective delayed neutron fraction measurements
- IRPHE-TAPIRO-ARCHIVE, TAPIRO fast-neutron source reactor experiments

7. Conclusions

The activities of the IRPhEP systematically: (1) consolidate and preserve the international reactor physics information base, (2) identify areas where more data is needed, (3) draw upon the resources of the international reactor physics community to help fill those needs, and (4) identify discrepancies between calculations and experiments. The project is expected to eliminate a large portion of the tedious and redundant research and processing of experimental data and will greatly streamlined the validation process. Benchmarks produced by the IRPhEP will provide new dimension to validation efforts and will greatly expand the collection of available integral benchmarks for nuclear data testing and uncertainty determination. The International Handbook of Evaluated Reactor Physics Benchmark Experiments is expected to be a valuable resource to the reactor physics, criticality safety, and nuclear data communities for decades.

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