Initial Efforts Organizing WPNCS SG-8: Preservation of Expert Knowledge and Judgement Applied to Criticality Benchmarks

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INTRODUCTION

The Working Party on Nuclear Criticality Safety (WPNCS) under the guidance of the Organization for Economic Co-operation and Development (OECD) Nuclear Energy Agency (NEA) has over 20 years of experience addressing concerns related to static and transient configurations encountered within the nuclear fuel cycle: fuel fabrication, transportation, reprocessing, storage, and geological disposal [1]. One of the cornerstone activities of the WPNCS is the International Criticality Safety Benchmark Evaluation Project (ICSBEP) [2], which was established to identify a comprehensive set of criticality benchmark data, evaluate the data, including quantification of overall uncertainties; compile the data into a standardized format, perform sample calculations utilizing modern nuclear data sets and codes utilized in nuclear criticality safety, and formally document the work into a single source of verified benchmark data. Annually, members of the ICSBEP Technical Review Group (TRG) contribute evaluated benchmark data that undergoes comprehensive technical review prior to publication in the ICSBEP Handbook [3].

In the years since the ICSBEP was established, there has been much work to prepare benchmark data to support validation activities in nuclear criticality safety. The 2020 edition of the ICSBEP Handbook contains acceptable benchmark specifications for 5,053 critical, subcritical, or near-critical configurations in 582 benchmark evaluations [4]. Modern benchmark development benefits from decades of experienced international participants, a well-established handbook format, supplementary guides to deal with uncertainty quantification, and a comprehensive review process based upon independent reviews from international experts [5]. The ICSBEP Handbook also contains 838 configurations deemed unacceptable to support criticality safety efforts. They are recorded, with the reasoning for their rejection, to preserve the experimental data, prevent reevaluation of data that are incomplete or contain known errors, and/or to potentially allow future reevaluation of the experiment pending the identification of sufficient data to resolve identified inconsistencies and errors.

Users of the ICSBEP Handbook today might notice that the rigor and quality of modern criticality safety benchmarks is much greater than those prepared within the initial decade of the project. Benchmarks with 1σ uncertainties in k_{eff} greater than 1% were traditionally rejected unless they were identified as unique experiment types that encompassed materials, fuels, or designs not available from other benchmark experiments. However, benchmarks developed using modern experimental techniques and practices typically have uncertainties on the order of a few tenths of a percent. There have been ongoing efforts to improve the overall quality of previously published benchmark evaluations. Seventy-eight evaluations, containing approximately 600 configurations, have been revised just within the past decade. An additional eleven benchmarks are under revision for updated release in the 2020 edition of the ICSBEP Handbook.

If some of the historic benchmarks were resubmitted in their current form to the TRG today, they would be rejected due to lack of data, missing components in the uncertainty analysis, or incomplete benchmark model development. The use of historic criticality safety benchmarks that underestimate the total uncertainty, lack properly quantified biases, or provide inadequate benchmark specifications do not sufficiently support modern criticality safety and nuclear data efforts. Although the ICSBEP Handbook is recognized by regulating bodies to support criticality safety, users are required to justify their reasons to ignore historic benchmark data and include additional safety margins within their designs.

Discussions were held at the WPNCS 23rd Annual Meeting in September 2019 [6] regarding the aforementioned issues. The resultant decision was to establish Subgroup 8 (SG-8): Preservation of Expert Knowledge and Judgement Applied to Criticality Benchmarks. The current activities of SG-8 are discussed herein.

DESCRIPTION OF THE ACTUAL WORK

A proposal to establish SG-8 was presented to the WPNCS in September 2019 and was then officially accepted, and a Chair was elected: Will Wieselquist from

Oak Ridge National Laboratory (ORNL). Numerous international participants in the subgroup were also identified. The official scope of this activity is the following:

> "Over twenty-five years of benchmarking activity, the expectations and review rigor required for ICSBEP has evolved, the benchmarks are being used for unanticipated scenarios, tools and computational power exist to solve more complex problems, and new practitioners are entering the field. A need has been recognized to preserve expert knowledge and judgement regarding the suitability of ICSBEP evaluations to common uses such as modern code validation, nuclear data evaluation, and nuclear data adjustment. This activity will develop a methodology for collecting and disseminating feedback on evaluations from qualified experts to better serve users of the ICSBEP benchmarks."

The purpose of this subgroup is estimated to be completed within a two-year timeframe, with the following two expected results:

1. "Identify benchmarks for evaluation and collect feedback from experts, such as completeness of uncertainty representation, specificity of dimensions/conditions of the benchmark model, oversimplification, etc.
2. Prepare a report outlining a methodology for collecting and disseminating feedback on evaluations from qualified experts to better serve users of the ICSBEP benchmarks."

The identified technical significance of this work driving this effort is as follows:

> "With the increasing rigor of the ICSBEP review process, there exists a disparity between earlier and modern benchmarks in terms of uncertainty quantification and more realistic modelling of the configurations. For example, earlier benchmarks may quote unrealistic uncertainties that are then used to set safety limits or assess nuclear data evaluations."

RESULTS

The initial year of activity since SG-8 was established has included efforts to develop a strategy for professionals to assign their perceived quality of a benchmark evaluation to support validation efforts, including annotation of what limitations have been identified for the benchmark in its current state. Comments should include recommendations for what revisions would be necessary to improve the overall quality of the benchmark. A ranking strategy will be implemented for participants to identify high-quality benchmarks suitable for criticality safety and nuclear data efforts, those identified as needing minor or major revision to improve the confidence in their use, and those recommended for rejection and deemed unacceptable for modern validation efforts unless new data are found. The ranking strategy will be discussed at the July 2020 WPNCS meetings and presented at the October 2020 ICSBEP TRG meeting.

An approved ranking structure will be distributed to all interested international criticality safety users to provide their input. It is recognized that each criticality safety expert will have different levels of engagement with the ICSBEP Handbook data and may have only utilized specific benchmark(s) relative to their areas of work. The expertise of different criticality safety practitioners also means that their rankings and reasonings for improvement can and will vary, providing a range of results that can be utilized to best identify benchmarks in need of revision. All users of the ICSBEP Handbook are strongly encouraged to contribute to the success of this project.

Results from the collection of expert knowledge and judgment regarding the quality of existing benchmark data will be compiled and supplied to the ICSBEP TRG. Recommendations for improvement of lower-quality evaluations and a strategy for their revision or rejection will also be proposed. The ICSBEP TRG, under the auspices of the OECD NEA, will then be responsible to utilize the results from the SG-8 efforts to further improve the quality of the ICSBEP Handbook for all international users. The final report generated from SG-8 could be utilized by nuclear criticality safety practitioners in their current efforts to support validation practices in regard to limitations of some current benchmark evaluations. The report can also facilitate the identification and prioritization of new critical benchmark experiments. Moreover, it could be used by people of the nuclear data community, who often do not have expertise in criticality experiments, to identify the most accurate benchmarks that are well adapted for their validation. Results from this effort may also provide feedback into possible improvement of the ICSBEP uncertainty guides.

The results of the ranking strategy will be presented at the ANS 2020 Winter Meeting. Members of the nuclear criticality safety community will be invited to participate in the evaluation strategy activities. Ultimately a draft report will be prepared and presented to WPNCS in July 2021 prior to its finalization shortly thereafter. Those interested in participating in this effort should contact the primary author of this paper for further information.

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