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INTERNATIONAL HANDBOOK OF EVALUATED CRITICALITY SAFETY BENCHMARK EXPERIMENTS

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EVALUATED CRITICALITY SAFETY BENCHMARK EXPERIMENTS

INTRODUCTION

Criticality safety organizations, worldwide, are often required to compare results obtained from their calculational techniques with experimental data. Common practice includes the tedious process of researching critical-experiment data reported in journals, transactions, or reports. This process is repeated over and over at non-reactor nuclear facilities throughout the world in order to ensure that calculated criticality safety margins are accurate.

Since the beginning of the nuclear industry, thousands of critical experiments have been performed. Many of these critical experiments can be used as benchmarks for validation of calculational techniques. However, many were performed without a high degree of quality assurance and were not well documented.

The International Criticality Safety Benchmark Evaluation Project (ICSBEP) Working Group was formed to:

1. Identify and evaluate a comprehensive set of benchmark critical experiment data.

2. Verify the data, to the extent possible, by reviewing original and subsequently revised documentation and by talking with experimenters or individuals who were associated with the experimenters or the experimental facility.

3. Compile the data into a standardized format.

4. Perform sample calculations of each experiment with standardized criticality safety neutronics codes.

5. Formally document the work into a single source of verified benchmark critical data.

The primary purpose of this effort is to compile benchmark critical experiment data into a standardized format that allows criticality safety analysts to easily use the data to validate calculational techniques and cross sections. **This work does not constitute a validation of codes or cross section data**. Results of calculations with standardized criticality safety neutronics codes are presented in this document because the information is useful as a comparative tool for those who are using similar calculational methods and cross section data. Within most code systems, there are numerous options available that, if used properly, can each accurately model the same problem. Only a limited number of options have been exercised for this work. The user of any code system has the responsibility to ensure that the calculational tools and options used to solve a particular problem are properly validated.

Sample input listings are not intended to be used directly for validation efforts and should be verified by the user. Since it is not practical to describe in detail the code input used to model each benchmark critical experiment, computer input listings are given for typical reported calculations of accepted benchmark configurations. From these listings, a user can identify which options were used to obtain the reported results. This is the sole purpose for inclusion of the input listings. It is the responsibility of the user to ensure that use of these listings for any other purpose is consistent with proper criticality safety practices.

Criteria for acceptance of critical and subcritical experiments as benchmarks were recently established by the Physics Criteria for Benchmarks Working Group as part of the United States Department of Energy sponsored Nuclear Criticality Technology and Safety Project. These criteria are summarized as follows:

(1) The method used to determine k-effective should be specified.

(2) Consistency among experimentally measured parameters is desirable. For example, the fundamental mode multiplication should be determined by more than one method in order to insure consistency.

(3) A rigorous and detailed description of the experimental mockup, its mechanical supports, and its surroundings is necessary. For example, measurements fixing the position of the experiment within the room should be provided. Accompanying photographs and drawings are essential.

(4) A complete specification of the geometry dimensions and material compositions including the methods of determination and the known sources of error and their potential propagation is necessary. Also, for completeness, unknown but suspected sources of error should be listed.

(5) A series of experiments is desirable in order to demonstrate the reproducibility of the results. Positive and negative period measurements provide useful supplementary information for well-defined near-critical systems.

(6) A description of the experiment and results, containing at least the elements of the 1983 ANS Standard 8.1, should appear in a refereed publication.

These criteria were established primarily to provide guidelines for future experiments. Many of the earlier experiments do not satisfy all of these criteria. However, failure to meet these criteria does not automatically disqualify an experiment from being considered as acceptable for use as a benchmark. An attempt is being made here to supplement the originally published data, through the evaluation process, to meet these criteria.

ORGANIZATION

All evaluated criticality safety benchmark data are given in Volumes I through VII of this document. Each volume includes benchmark data representing one of seven different types of fissile material:

VOLUME I:	Plutonium Systems
VOLUME II:	Highly Enriched Uranium Systems (wt.% $^{235}U \geq 60$)
VOLUME III:	Intermediate and Mixed Enrichment Uranium Systems ($10 <$ wt.% $^{235}U < 60$)
VOLUME IV:	Low Enriched Uranium Systems (wt.% $^{235}U \leq 10$)
VOLUME V:	Uranium-233 Systems
VOLUME VI:	Mixed Plutonium - Uranium Systems
VOLUME VII:	Special Isotope Systems

Each of these seven volumes are divided into four major sections, representing the physical form of the fissile material:

Metal Systems
Compound Systems
Solution Systems
Miscellaneous Systems

Each of these four types of systems are subdivided into fast, intermediate, thermal, and mixed spectra systems, depending upon where the majority of the fissions occur. In general, fast, intermediate, and mixed subdivisions are not applicable to solution systems; however, for certain solution systems (e.g.; some heavy-water-moderated systems) the majority of the fissions occur above the thermal range.

In this handbook, fast, intermediate, and thermal systems are defined as systems in which over 50% of the fissions occur at energies over 100 keV, from 0.625 eV to 100 keV, and less than 0.625eV, respectively. Systems for which over 50% of the fissions do not occur in any one of these three energy ranges are classified as "mixed" spectra systems.

Some experiments can be categorized into more than one subsection. In these special cases, the data are assigned where they appear to fit best, with an attempt to include cross-references. Therefore, experimental data are presented only once.

Some experiments have unacceptably large uncertainties or do not provide the level of detail required to develop an acceptable calculational model. Discussion of such experiments is included in the compilation, and the inadequacy is noted, but benchmark specifications are not provided, and calculations are not performed.

Without a high degree of confidence, subcritical measurements or subcritical measurements with large extrapolations to critical are not included in this compilation. However, if neutron multiplication is sufficiently high, and measurement uncertainties are demonstrated to be small, then subcritical data may also be included.

Critical or near critical systems cannot, at the present time, be assembled with many of the "Special Isotopes" designated for inclusion into Volume VII. Data from replacement-type measurements are included for these materials.