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The International Criticality Safety Benchmark Evaluation Project

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Introduction: Need for Criticality Safety Benchmarks

Most safety concerns associated with operations at nuclear facilities are very similar to the safety concerns associated with operations at non-nuclear facilities. The potential for a nuclear criticality accident is one concern that is unique to the nuclear industry. However, if managed properly, the risk of a criticality accident can be reduced to an acceptable level. In fact, the risk of a criticality accident can generally be reduced to a level that is much lower than the risk associated with non-nuclear activities that have similar consequences.

As the world searches for ways to address the issues associated with decontamination and decommissioning efforts and waste remediation efforts (including waste storage, retrieval, characterization, volume reduction, and stabilization) as well as ways to address issues associated with the next generation of nuclear power production plants, many new criticality safety problems are being encountered. In order to properly manage the risk of a nuclear criticality accident, it is important to establish the conditions for which such an accident becomes possible for any activity involving fissile material. Only when this information is known is it possible to establish the likelihood of actually achieving such conditions. It is therefore important that criticality safety analysts have confidence in the accuracy of their calculations. Confidence in analytical results can only be gained through comparison of those results with experimental data.

Criticality safety organizations, worldwide, are frequently required[1] to compare results obtained from their calculational techniques with available experimental data. Common practice includes the tedious process of researching experimental data reported in journals, transactions, or reports. This process is followed repeatedly at non-reactor nuclear facilities throughout the world in order to ensure that calculated criticality safety margins are accurate. This is an increasingly costly process as well as an inefficient use of resources. However, even in the absence of regulations, those responsible for operations involving fissile material have an obligation to their workers and to the public to provide thorough safety analyses with adequate validation.

[1] Regulatory drivers are in place in most countries that require that a bias be established by correlating results of experiments with results obtained for similar systems by the calculational method being validated.

History of the International Criticality Safety Benchmark Evaluation Project

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

The Criticality Safety Benchmark Evaluation Project (CSBEP) was initiated in October of 1992 by the US Department of Energy. The project was managed through the Idaho National Engineering and Environmental Laboratory (INEEL), but involved nationally known criticality safety experts from Los Alamos National Laboratory, Lawrence Livermore National Laboratory, Savannah River Technology Center, Oak Ridge National Laboratory and the Y-12 Plant, Hanford, Argonne National Laboratory, and the Rocky Flats Plant. (See Figure 1)

An International Criticality Safety Data Exchange component was added to the project during 1994 and the project became what is currently known as the International Criticality Safety Benchmark Evaluation Project (ICSBEP). Representatives from the United Kingdom, France, Japan, the Russian Federation, Hungary, Korea, Slovenia, Yugoslavia, Spain, and Israel are now participating on the project (See Figure 2). In December of 1994, the ICSBEP became an official activity of the Organization for Economic Cooperation and Development - Nuclear Energy Agency's (OECD-NEA) Nuclear Science Committee. The United States currently remains the lead country, providing most of the administrative support.

Purpose of the ICSBEP

The purpose of the ICSBEP is to:

(1) Identify and evaluate a comprehensive set of critical benchmark data;

(2) Verify the data, to the extent possible, by reviewing original and subsequently revised documentation, and by talking with the experimenters or individuals who are familiar with the experimenters or the experimental facility;

(3) Compile the data into a standardized format;

(4) Perform calculations of each experiment with standard criticality safety codes;

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

Accomplishments of the ICSBEP

The work of the ICSBEP is documented as an OECD handbook entitled, "International Handbook of Evaluated Criticality Safety Benchmark Experiments" (See Figure 3). This handbook is available on CD-ROM or on the Internet (http://icsbep.inel.gov/icsbep).

Over 150 scientists from around the world have combined their efforts to produce this Handbook. The 2000 publication of the handbook will span over 19,000 pages and contain benchmark specifications for approximately 284 evaluations containing 2352 critical configurations. The contribution, in terms of the number of evaluations, that have been contributed by the various participating countries is shown in Figure 4. The contributions from the United States and the Russian Federation, in terms of number of evaluations are roughly equal. However, in terms of number of configurations, the contribution from the United States is still significantly higher than other participating countries since many evaluations from the Russian Federation are "single-configuration" evaluations while most evaluations contributed by U.S. participants present multiple configurations.

The Handbook is divided into seven volumes. 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

The distribution of the 2352 configurations, in terms of fissile material type and physical form, is given in Figure 5.

The handbook is currently in use in 45 different countries (See Figure 6).

Benefits Derived from the ICSBEP

Thorough validation efforts are extremely labor intensive. However, the "International Handbook of Evaluated Criticality Safety Benchmark Experiments" contains concise descriptions of benchmark models that are ready to be used in the preparations of computer models for any code system with little or no additional manipulation. These models have undergone a rigorous peer review and approval process by an international working group. As a result, ***a large portion of the tedious, redundant, and very costly research and processing of criticality safety experimental data has been eliminated***. The necessary step in criticality safety analyses of ***validating computer codes with benchmark data is greatly streamlined***. The economic benefits are substantial savings in man-time spent in validation efforts. These savings enable criticality safety professionals to spend more time focusing on criticality safety issues associated with the day-to-day activities at their facility.

The "International Handbook of Evaluated Criticality Safety Benchmark Experiments" is currently being used as the basis for an international project that is seeking to develop quantitative methods to establish the range of applicability for experiments. The results from this work will enable criticality safety practitioners to estimate an appropriate bias and uncertainty to use in criticality safety analyses. Such methods can also be ***used to identify experimental regimes where new experiments are needed***, ***assist with the design of new experiments, and help justify and demonstrate benefits*** (e.g., reduced uncertainty, economic advantage, etc.) obtained from new experiments. These methods can also show when a proposed experiment is ***not*** needed, thereby saving the expense of performing an experiment from which little or no new information is gained.

Through the evaluation process, ICSBEP participants are required, when possible, to talk with the experimenters and examine logbooks. By talking with experimenters and/or others who are familiar with the experiments and the experimental facilities and by examining logbooks, ***many data have been retrieved that were omitted from published documentation and were considered lost***. Many data have been destroyed, but some are stored at archive facilities or, in some cases, at the homes of the experimenters, many of whom have retired.

The purpose of the ICSBEP is not to validate specific calculational techniques, but to provide tools that will enable criticality safety specialists to more easily validate their own work. However, calculations are performed with multiple codes and cross section data sets and the results of these calculations are included in the Handbook. Occasionally, significant disagreement between these codes and cross sections are obtained. Code and cross section developers are made aware of large discrepancies. In such circumstances, ***deficiencies and errors in cross section processing codes and neutronic codes are often identified.***

Summary and Conclusions

As a result of the efforts of the ICSBEP:

(1) A large portion of the tedious, redundant, and very costly research and processing of criticality safety experimental data has been eliminated;

(2) The necessary step in criticality safety analyses of validating computer codes with benchmark data is greatly streamlined;

(3) Gaps in data are being highlighted;

(4) Lost data are being retrieved;

(5) Deficiencies and errors in cross section processing codes and neutronic codes are being identified; and

(6) Over a half-century of valuable criticality safety data are being preserved.

The accomplishments of the ICSBEP represent a tremendous economic benefit to safety analysis efforts, worldwide. Data that were generated over the last 50 years for both military and power production applications are now, not only available to address criticality safety issues associated with the next generation of nuclear power production, but also to address issues associated with waste management activities.

Furthermore, the preservation of data that may not be of obvious use today will likely be of use again in the future. As the cost of performing new criticality safety benchmark experiments increases and the availability of facilities to perform such experiments decreases, the economic benefit of preserving existing data becomes immeasurable. These data will be of great value to criticality safety personnel, worldwide, for decades to come.

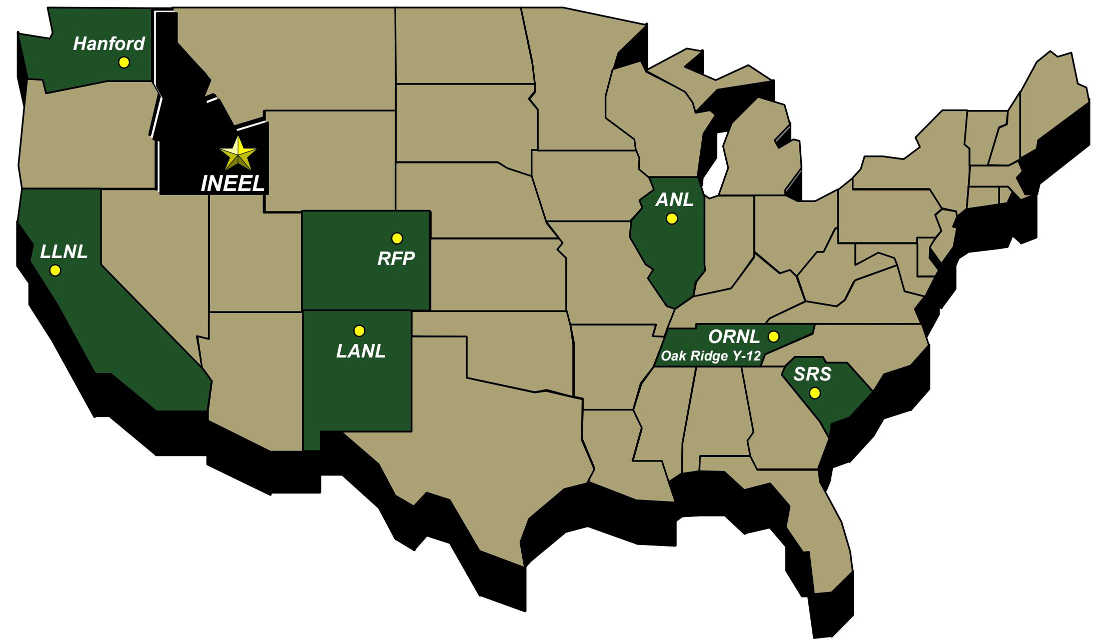

Figure 1. U.S. Participants, ICSBEP.

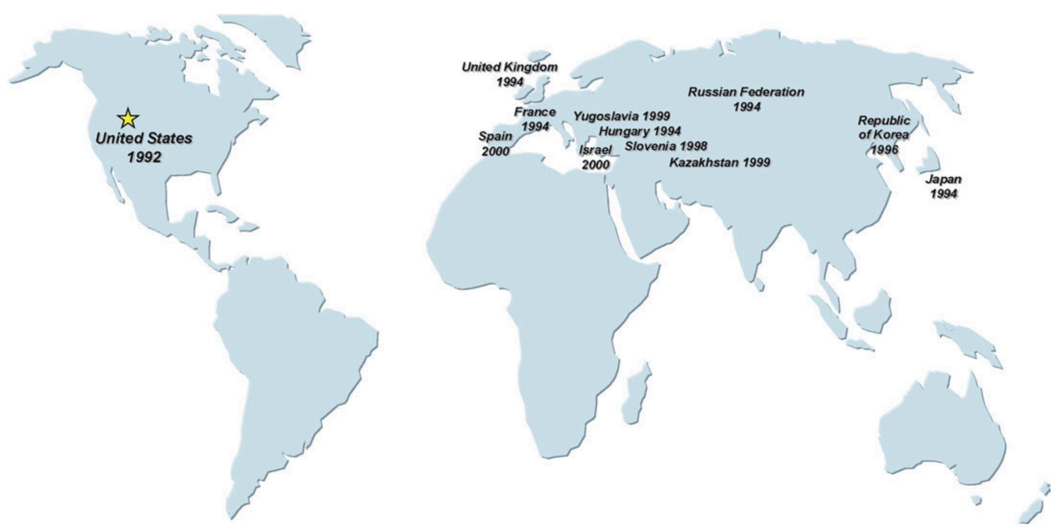

Figure 2. International Participants, ICSBEP.

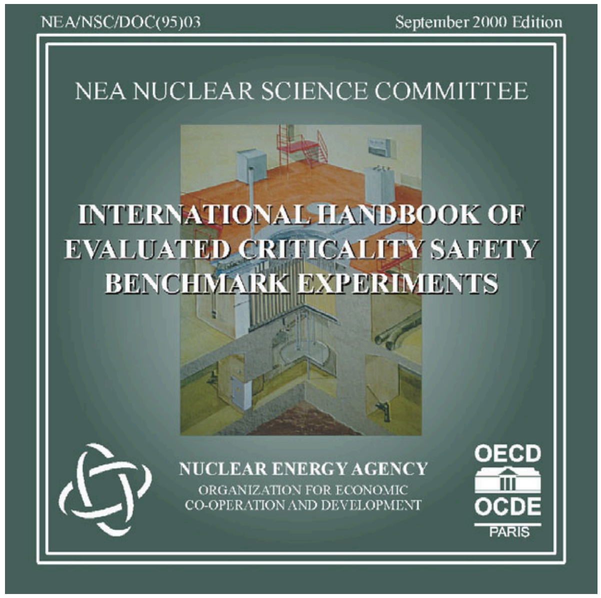

Figure 3. The 2000 edition will contain evaluation of 284 experimental series and nearly 2352 critical configurations.

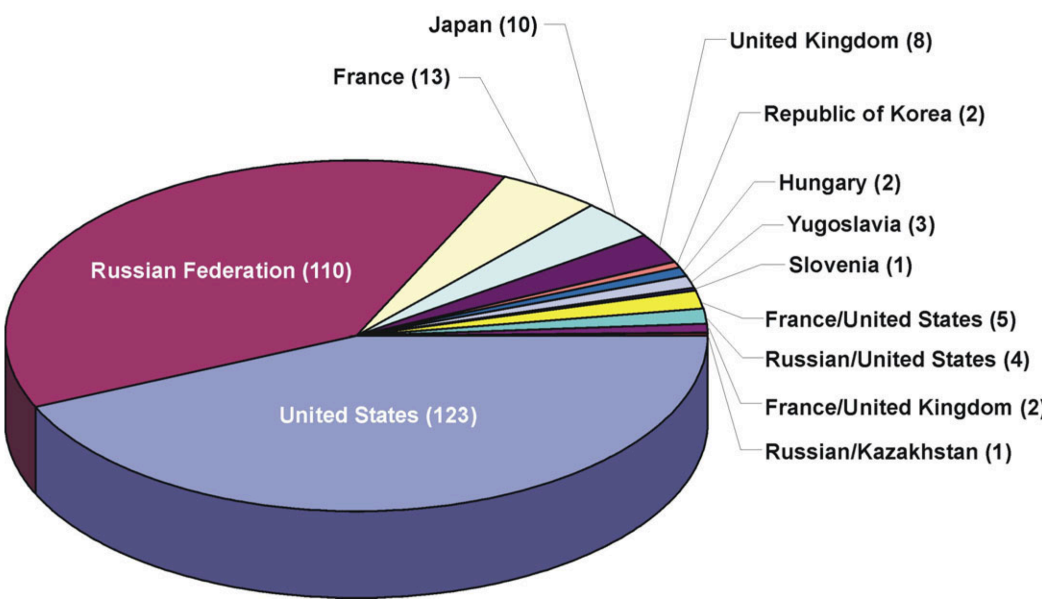

Figure 4. Distribution by Country.

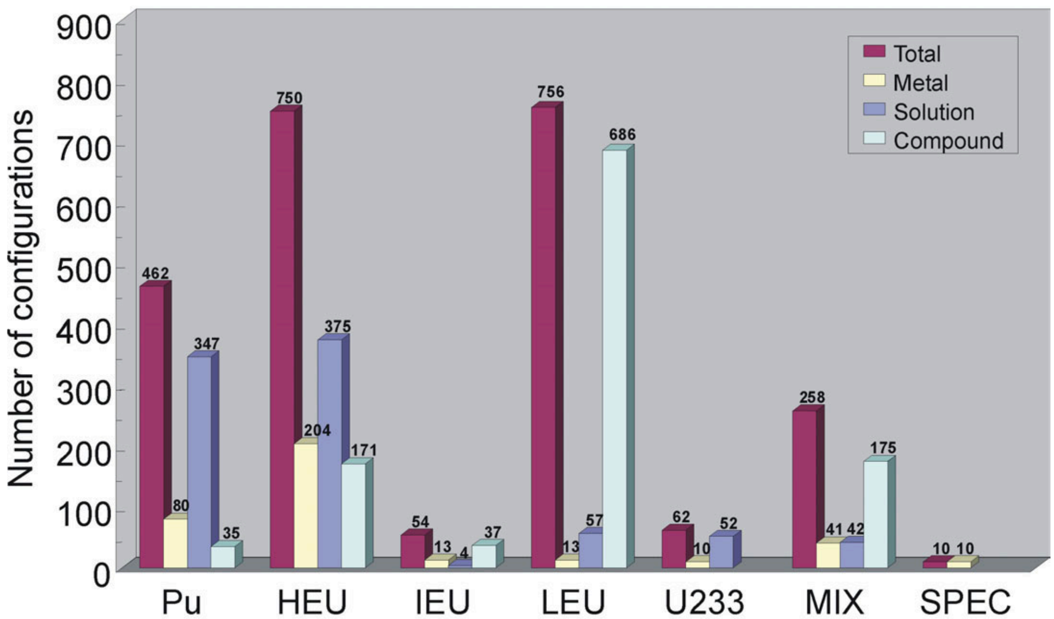

Figure 5. Distribution of Critical Configurations.

Figure 6. The handbook is in use in 45 different countries.