# Present Status of International Criticality Safety Benchmark Evaluation Project (ICSBEP)

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The International Criticality Safety Evaluation Project, ICSBEP was designed to identify and evaluate a comprehensive set of critical experiment benchmark data. Compilation of the data into a standardized format are made by reviewing original and subsequently revised documentation for calculating each experiment with standard criticality safety codes. Five handbooks of evaluated criticality safety benchmark experiments have been published since 1995.

## 1. Introduction

The International Criticality Safety Evaluation Project, ICSBEP is an official activity of the Organization for Economic Cooperation and Development- Nuclear Energy Agency, OECD-NEA. This activity was initiated as the Criticality Safety Evaluation Project ,CSBEP in October of 1992 by the United States Department of Energy, DOE. Main countries contributing to this project are United Kingdom, Japan, Russia, France, Republic of Korea and USA as shown in Figure 1. ICSBEP has evaluated a large number of criticality experiments performed at various nuclear facilities all over the world. The detail specifications of the critical conditions are intended to validate the criticality calculation codes and nuclear data libraries. Criticality safety personnel in 39 different countries are now using the international handbook of evaluated criticality safety benchmark experiments[/1/].

## 2. Classification of Critical Experiments

Criticality safety benchmark experiments are classified into seven different types of fissile materials; (Ⅰ) Plutonium System, (Ⅱ) Highly Enriched Uranium Systems (wt.%$^{235}$U $\geq$ 60), (Ⅲ) Intermediate and Mixed Enrichment Uranium Systems (10 < wt.% $^{235}$U < 60), (Ⅳ) Low Enriched Uranium Systems (wt.%$^{235}$ U $\leq$ 10), (Ⅴ) Uranium-233 Systems, (Ⅵ) Mixed Plutonium - Uranium Systems, and (Ⅶ) Special Isotope Systems. Each of these seven systems are divided into four physical form of the fissile material such as metal, compound, solution and miscellaneous systems. 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. The fruit of this project is a benchmark data handbook consisting of seven volumes representing above different systems for the criticality safety computer codes. The number of evaluations and configurations contained in the five handbooks are listed in Table 1.

### 3. Main Critical Experiment Facilities

In United States, BNWL, LANL, and ORNL are main research organization producing the critical data. BNWL were specially concerning to plutonium and uranium nitrate solution for fast reactor fuel cycle. LANL has accumulated many critical data on high enriched uranium and plutonium metal using critical assemblies such as GODIVA, BIG TEN and FLATTOP. In France, Valduc research center of IPSN has performed various type of experiments for fuel rod lattices with fixed absorber and high enriched uranyl nitrate solution. Experiments on multiple units of tank array containing plutonium solution were also performed. In Russia Federation, IPPE supplied with high enriched uranyl nitrate solution in cylindrical and annular geometry. Reactivity effects of soluble poison such as gadolinium were also measured. In Japan, JAERI has submitted some evaluations of STACY experiments on single unit containing 10 % enriched uranyl nitrate solution and TCA experiments on low enriched uranium oxide fuel rod arrays.

### 4. Sample Evaluation for Uranyl Nitrate Solution[2]

Sample evaluations about uranyl nitrate solution in the benchmark handbook are listed in Table 2.

1) HEU-sol-therm-021

The experiments consisted of cubic arrays of 8, 27, 64, or 125 cylindrical units with height-to-diameter ratios near unity. Each unit of the array contains 5-liter uranyl nitrate solution at concentrations of 415, 279, or 63.3 g/L. The $^{235}U$ enrichment was 92.6 w/o. The array was either bare or reflected by paraffin and/or Plexiglas with thickness between 1.27 and 15.24 cm.

2) HEU-sol-therm-006

The highly enriched uranyl nitrate poisoned with enriched boron in boric acid were contained in a cylindrical tank surrounded by two annular regions, in which various radial reflector existed. The inner annular region contained either air or a thick nickel sleeve. The outer annular region contained air, water, or borated water. Critical configurations had height to diameter ratios in the range from 0.19 to 1.04. Uranium concentration was varied between 293.4 and 297.8 g/L. The boron in the uranyl nitrate solution was enriched to 50.55 w/o $^{10}B$, and concentration was changed within 2.64 gB/L.

3) HEU-sol-therm-014～019

Each experiment involving a single water-reflected tank of highly enriched uranyl nitrate solution (U=70～400g/liter) were performed in IPPE (Russia). These experiments were performed with the concentration of gadolinium within 2.0 g/L. The diameter of the cores was 40 cm or 25 cm. Cores were surrounded by thick water reflectors on the bottom and side.

4) LEU-sol-therm-004, 007～010

Using STACY, critical solution levels were systematically measured for a cylindrical tank of 60 cm in diameter using 9.97 w/o $^{235}U$ enriched uranyl nitrate solution. The core tank was reflected with structural material such as ordinary concrete, borated concrete and polyethylene. The main parameters were the thickness of the reflector and boron concentration. Reactivity effects of these material were also measured. For unreflected and water reflected core, the uranium concentration was changed from 225 to 313 gU/L at free nitric acid of 2 mol/L. Core configurations of experiments on uranium solution system are shown in Figure 2.

## 5. Calculation for Uranyl Nitrate Solution

Critical calculations were made to study the bias of neutron multiplication factor when using Japanese nuclear data library JENDL 3.2. Histogram of calculated neutron multiplication for each experiment is shown in Figure 3. A Continuous energy Monte Carlo code MCNP 4A or 4B was used in order to compare between JENDL 3.2 and ENDF/B-V. For both high enriched and low enreiched uranyl solution system, it should be noted that the calculated keff with JENDL3.2 are about 0.5% $\Delta k$ larger than that with ENDF/B-V for uranyl nitrate solution system. The experimental uncertainties in the neutron multiplication factor due to geometry and composition of fuel and structural region, which were evaluated by sensitivity analyses, are less than 0.2% $\Delta k$.

## 6. Summary

Critical configurations described in the ICSBEP handbook are helpful to verify the reliability of the criticality calculation code system including nuclear data library. As typical input data for reference calculation are also attached in the evaluation, it is easy for users to make calculations with their own code systems. In addition to critical data, ICSBEP has established a subcritical working group which evaluate the subcritical condition including primary data in similar format to make the comprehensive database for criticality safety evaluation.

## References

1) J.B.Briggs et al., ICNC'99 in France (1999)

2)NEA/NSC/DOC(95), NEA NUCLEAR SCIENCE COMMITTEE, International Handbook of Evaluated Criticality Safety Benchmark Experiments, September 1999 Edition