Educating Next Generation Nuclear Criticality Safety Engineers at the Idaho National Laboratory

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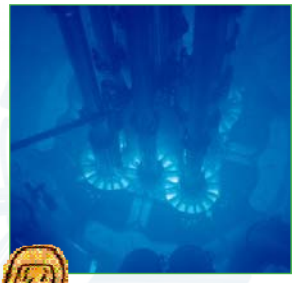
Educating the Next Generation of Nuclear Criticality and Reactor Safety Professionals

- **Challenge of a New Nuclear Safety Workforce:**
  - **Provide assessment of nuclear systems and establish safety guidelines without significant experience or hands-on training prior to graduation**
- **Benchmark Analysis Participation in the ICSBEP/IRPhEP:**
  - **ICSBEP – International Criticality Safety Benchmark Evaluation Project**
  - **IRPhEP – International Reactor Physics Experiment Evaluation Project**
  - **Provide students and young professionals with the opportunity to gain experience and enhance critical engineering skills.**

Why Do We Have Nuclear Benchmarks?

- Criticality Safety
  - Plant Operations
  - Transportation
  - Waste Disposal
  - Experimentation
  - Accident Analysis
  - Standards Development
- Materials
  - Testing
  - Physics Validation
  - Interrogation
- Research and Development
  - New Reactor Designs
  - Design Validation
- Computational Methods
  - Cross-Section Data
  - Code Verification
- Fundamental Physics
  - Model Validation
- Fun

How Does Benchmark Design Apply to You?



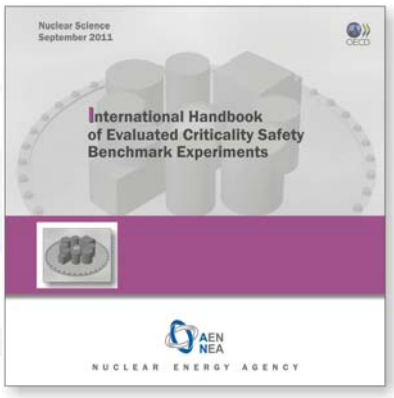
International Criticality Safety Benchmark Evaluation Project (ICSBEP)

- **Purpose:**
  - Identify and verify comprehensive sets of critical benchmark data by reviewing documentation and talking with experimenters
  - Evaluate the data and quantify the overall uncertainty via sensitivity analyses
  - Compile the data into a standardized format
  - Perform calculations of each experiment with standard criticality safety codes
  - Formally document work into a single source
- **http://icsbep.inl.gov**
- **icsbep@inl.gov**

International Handbook of Evaluated Criticality Safety Benchmark Experiments

September 2011 Edition

- **20 Contributing Countries**
- **Spans approximately 58,000 Pages**
- **Evaluation of 533 Experimental Series**
- **4,551 Critical or Subcritical Configurations**
- **24 Criticality-Alarm/Shielding Benchmark Configurations – numerous dose points each**
- **155 fission rate and transmission measurements and reaction rate ratios for 45 different materials**



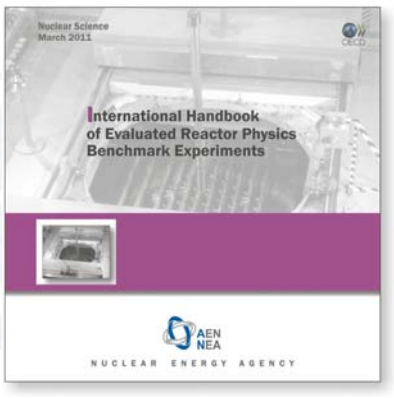
International Reactor Physics Experiment Evaluation Project (IRPhEP)

- Similar to the ICSBEP
- Focus to collect data regarding the numerous experiments in support of nuclear energy and technology performed at research laboratories
- Experiments represent significant investments of time, infrastructure, expertise, and cost that might not have received adequate documentation
- Measurements also include data regarding reactivity measurements, reaction rates, buckling, burnup, etc., that are of significant worth for current and future research and development efforts
- http://irphep.inl.gov/
- irphep@inl.gov

International Handbook of Evaluated Reactor Physics Benchmark Experiments

March 2011 Edition

- 16 Contributing Countries
- Data from 53 Experimental Series performed at 31 Reactor Facilities
- Data from 48 are published as approved benchmarks
- Data from 5 are published in DRAFT form
- Handbook available to OECD member countries, all contributing countries, and to others on a case-by-case basis

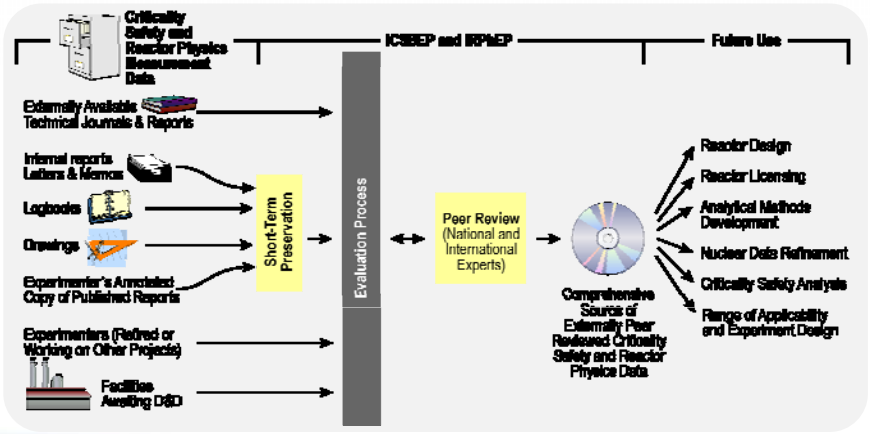


Measurement Types Included as IRPhEP Benchmarks

- The IRPhEP benchmark report follows the same general guidelines as for the ICSBEP Handbook, but includes additional material:
  - Critical/Subcritical
  - Buckling/Extrapolation Length
  - Spectral Characteristics
  - Reactivity Effects
  - Reactivity Coefficient Data
  - Kinetics Measurements Data
  - Reaction-Rate Distributions
  - Power Distribution Data
  - Isotopic Measurements
  - Miscellaneous

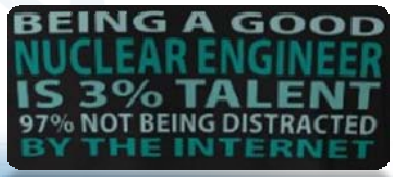
If it is worth measuring, then it is worth evaluating.

The Evaluation Process



Student Investigation Breeds Comprehension

- Benchmark procedures require investigation into
  - History and background
    - Purpose of experiment?
  - Experimental design and methods
  - Analytical capabilities and procedures
  - Experimental results
- Often experiments were performed with the intent to provide data for criticality safety assessments
  - Many are utilized to develop criticality safety standards



Culturing Good Engineering Judgment

- Often experimental information is incomplete or misleading
  - Contact original experimenters (if available)
  - Interact with professionals from the ICSBEP/IRPhEP community
  - Establish a personal network for the young professional engineer

"Do, or do not.
There is no 'try'"
- Jedi Master Yoda

Developing an Analytical Skill and Tool Set

- **Evaluators develop analytical and computational capabilities throughout the evaluation process**
  - **Utility of conventional computational codes and neutron cross section data libraries**
    - **Monte Carlo or Diffusion methods**
    - **MCNP and KENO are the most common in the US**
  - **Application of perturbation theory and statistical analyses**
    - **Uncertainty evaluation**
    - **Bias assessment**
  - **Technical report writing**
  - **Understanding acceptability of results**

Extensive International Review Process

- **ICSBEP and IRPhEP benchmarks are subject to extensive review.**
  - **Evaluator(s) – primary assessment of the benchmark.**
  - **Internal Reviewer(s) – in-house verification of the analysis and adherence to procedure.**
  - **Independent Reviewer(s) – external (often foreign) verification of the analysis.**
  - **Technical Workgroup Meeting – annual international effort to review all benchmarks prior to inclusion in the handbook.**
    - **Sometimes a subgroup is assigned to assess any final workgroup comments and revisions prior to publication.**
  - **Benchmarks are determined to be acceptable or unacceptable for use depending on availability of data, which translates into uncertainty in results.**
    - **All approved benchmarks are retained in the handbook.**
    - **Unacceptable data are published for documentation purposes, but benchmark specifications are not provided**

Opportunities for Involvement – I

- Internships
  - Traditional approach
  - 10-weeks
  - Benchmark review process completed on "free-time" during university studies
  - Encouraged to publish
- Augmented Education
  - Rigorous structure for Master's Thesis
  - Mentor and peer-review network
  - Undergraduate thesis
  - Undergraduate team projects
  - Encouraged to publish

Opportunities for Involvement – II

- Center for Space Nuclear Research (CSNR)
  - Next Degree Program
    - Work as a part- or full-time subcontractor while completing a graduate degree
  - Via local or remote university participation
  - Opportunity for interaction with students participating in space nuclear activities
    - Other Next Degree students
    - Summer fellow students (interns)
  - Collaboration opportunities on other projects

Opportunities for Involvement – III

- Nuclear and Criticality Safety Engineers
  - Pilot program collaboration
    - Battelle Energy Alliance (BEA)
    - U.S. Department of Energy – Idaho (DOE-ID)
  - Idaho State University and University of Idaho
  - Graduate Nuclear Engineering Curriculum
  - Part-time employment (full-time summer)
  - Hands-on training, benchmarking, ANS meetings, thesis/dissertation work, shadow mentors, DOE and ANS standard development, etc.

Past and Present Student Involvement

- Since 1995, ~30 students have participated in the ICSBEP and/or IRPhEP
  - 14 directly at INL
- Students have authored or coauthored over 50 benchmark evaluations
  - 23 + 5 in progress at INL
- They have also submitted technical papers to various conferences and journals

Current Student Benchmark Activities

- ICSBEP
  - Slabs of Enriched Uranium Oxyfluoride
  - Concrete-Reflected Enriched Uranium Metal Cylinders
  - Polyethylene-Reflected Array of HEU Separated by Vermiculite
  - Arrays of Bottles with Plutonium Nitrate Solution
  - Triangular Lattices of 2.49-cm-Diameter LEU (5%) Rods in Water
- IRPhEP
  - Neutron Radiography (NRAD) Reactor
  - Small Compact Critical Assembly (SCCA)
    - UO_2
    - 2 × Graphite-Reflected
    - 1 × Beryllium-Reflected
    - Space Reactor
  - ISU AGN-201 Reactor
  - Spherical Gas Core Reactor Critical Experiment
    - UF_6
    - Space Reactor

Conclusion

- Benchmarks represent an important means for developing and assessing a collection of nuclear experimental data
  - Application to criticality and reactor safety
  - Validation of nuclear activities
- Participation in the benchmark evaluation process can be of significant benefit to young professionals and their ultimate location of employment
- There exist many ongoing benchmarking activities through the ICSBEP and IRPhEP
- ICSBEP/IRPhEP Technical Review Group Chair
  - J. Blair Briggs, J.Briggs@inl.gov

¿Questions?