Nuclear Data Activities in Support of the DOE Nuclear Criticality Safety Program

R. M. Westfall* and R. D. McKnight**

*Oak Ridge National Laboratory, Oak Ridge, TN 37831-2008, USA
**Argonne National Laboratory, Argonne, IL 60439-4841 USA

Abstract. The DOE Nuclear Criticality Safety Program (NCSP) provides the technical infrastructure maintenance for those technologies applied in the evaluation and performance of safe fissionable-material operations in the DOE complex. These technologies include an Analytical Methods element for neutron transport as well as the development of sensitivity/uncertainty methods, the performance of Critical Experiments, evaluation and qualification of experiments as Benchmarks, and a comprehensive Nuclear Data program coordinated by the NCSP Nuclear Data Advisory Group (NDAG).

The NDAG gathers and evaluates differential and integral nuclear data, identifies deficiencies, and recommends priorities on meeting DOE criticality safety needs to the NCSP Criticality Safety Support Group (CSSG). Then the NDAG identifies the required resources and unique capabilities for meeting these needs, not only for performing measurements but also for data evaluation with nuclear model codes as well as for data processing for criticality safety applications. The NDAG coordinates effort with the leadership of the National Nuclear Data Center, the Cross Section Evaluation Working Group (CSEWG), and the Working Party on International Evaluation Cooperation (WPEC) of the OECD/NEA Nuclear Science Committee. The overall objective is to expedite the issuance of new data and methods to the DOE criticality safety user. This paper describes these activities in detail, with examples based upon special studies being performed in support of criticality safety for a variety of DOE operations.

INTRODUCTION

In the last decade, the Department of Energy Nuclear Criticality Safety Program (NCSP) has been developed in recognition of the general need to maintain the technologies required to perform validated nuclear criticality safety evaluations. In recommendation 93-2, the Defense Nuclear Facilities Safety Board (DNFSB) called for the retention of the DOE program to perform critical experiments and improvement in the prediction of criticality. In its recommendation 97-2, the DNFSB recognized progress in meeting the Rec. 93-2 objectives, but called for further integration of these resources into the training and qualification of criticality safety practitioners. The development of the Nuclear Criticality Safety Program over the past decade is described in a companion paper [1]. Also addressed in Rec. 97-2 was the need to provide criticality safety data to support the evolving DOE missions. In a presentation [2] at the 1994 international nuclear data conference, these missions in terms of new fissionable-material operations requiring new and more precise nuclear data were addressed. The present paper describes the nuclear data work element of the NCSP. After a background discussion of the type of operations requiring more precise data, the paper describes the functioning of the NCSP Nuclear Data Advisory Group (NDAG).

DEPARTMENT OF ENERGY FISSIONABLE-MATERIAL OPERATIONS OUTSIDE REACTORS

The purpose of nuclear criticality safety is to prevent accidental criticality events from occurring in fissionable materials outside of reactors. Since nuclear reactors are designed to operate at delayed critical, the nuclear data for the select reactor materials (fuels, control and structural materials, coolants, reflectors, and shields) have been, of necessity, measured and evaluated to a reasonable degree of precision. Emphasis has been on nuclear data supporting criticality in the fast and thermal...
neutron energy ranges. However, in addition to these materials, many of the fissionable-material operations requiring criticality safety evaluation involve materials required in the conditioning, transportation, and storage of nuclear fuel formerly utilized as reactor and weapons production components. Defense nuclear waste includes hundreds of tons of fissile metal weapons components being reconfigured into thermal-reactor fuel feedstock, as well as thousands of tons of spent fuel assemblies from production, test, research and propulsion reactors requiring conditioning, packaging, transportation, and storage. Civilian nuclear waste includes approximately one hundred thousand commercial reactor spent fuel assemblies requiring similar operations.

In addition, there are hundreds of millions of gallons and hundreds of thousands of drums of nuclear waste (defense and commercial) that must be characterized as acceptably subcritical. In general, the non-reactor materials appearing in these operations are the intermediate mass structural, packaging and storage materials (concrete, metals, glass, and soil forms). The nuclides contained in these materials act as poor neutron moderators and weak neutron absorbers. However, although not ideal, partially moderated systems will support criticality, and therefore the intermediate neutron energy range between 100 eV and 100 keV must be addressed. Thus the early focus of the NCSP nuclear data element has been on the improvement of the intermediate-energy range data for the intermediate-mass nuclides that appear in these operations. In keeping with the DNFSB recommendations, the motivation has been to provide improved precision in the determination of safe margins of subcriticality, which, in turn, provide for safer and more efficient operations.

**INITIAL NCSP NUCLEAR DATA WORK**

Out of several user surveys performed in the early 1990s, approximately 60 isotopes were identified as being in need of improved nuclear data for criticality safety evaluations. Initial nuclear data effort under the NCSP focused on improved evaluation of U-235 and additional measurement and evaluation of U-233.

Resonance measurements are performed with the Oak Ridge Linear Electron Accelerator (ORELA) at ORNL. Resonance evaluations are performed with the SAMMY code at ORNL and high-energy evaluations are performed with the GNASH code at LANL. Resonance measurement and evaluation has been performed on the intermediate mass nuclides: oxygen, aluminum, silicon, fluorine, chlorine, and potassium.

Early in the program, it was recognized that the major tasks of measurement, evaluation, processing, and data testing are complementary with the work program of the Cross Section Evaluation Working Group [3]. Nuclear data element planning sessions were held in conjunction with the annual CSEWG meetings beginning in 1996. The NCSP also sponsors collaborative work on an international basis with the OECD Nuclear Science Committee Working Party on Evaluation Cooperation and IAEA functions such as tutorial workshops on the SAMMY code system.

**NUCLEAR DATA ADVISORY GROUP**

The Nuclear Data Advisory Group was formed in 2002 to better coordinate the work program of the NCSP Nuclear Data element. Each of the functional elements of the NCSP—Analytical Methods, Critical Experiments, Benchmarking, Nuclear Data, etc.—have input into the deliberations of the NDAG. Figure 1 demonstrates the various roles of these functional elements in developing the safety basis for applications. The NDAG has a central role in establishing the needs for nuclear data activities. Portions of the NDAG Charter on the NDAG Mission, Membership and Leadership are excerpted and presented here.

**NDAG Mission:** The Nuclear Data Advisory Group, through making recommendations to the NCSP Criticality Safety Support Group (CSSG), enhances the coordination of the NCSP Nuclear Data Element work program with current and future DOE needs and promotes the integration of this work program with the other elements of the NCSP. Towards these objectives, the NDAG performs the following functions:

1. The NDAG gathers and evaluates differential and integral nuclear data, identifies deficiencies, and recommends priorities on meeting DOE criticality safety needs to the CSSG.
2. The NDAG identifies the required resources and unique capabilities for meeting these needs, not only for performing measurements but also for data evaluation with nuclear model codes as well as for data processing for criticality safety applications.
3. In performing functions 1 and 2, the NDAG communicates and works with the DOE programs involving fissionable material, with the Critical Experiments, Benchmarking, AROBCAD...
sensitivity/uncertainty methods, and Analytical Methods Elements of the NCSP and the leadership of the National Nuclear Data Center, the Cross Section Evaluation Working Group, and the Working Party on International Evaluation Cooperation of the OECD/NEA Nuclear Science Committee to expedite issuance of new data and methods to the DOE criticality safety user community.

4. The NDAG evaluates and determines high-level concerns (i.e., any data deficiencies/concerns/issues with potential to significantly impact safety or efficiency of current fissile material operations) for immediate or short-term attention and/or correction and communicates these concerns through the CSSG and the NCSP Manager to the NCSP web site for dissemination to and use by the criticality safety community.

5. The NDAG assists in NCSP work program planning such that the Nuclear Data work program is successfully integrated into the federal budget cycle.

6. The NDAG shares observations and makes recommendations to the CSSG on additional useful functions that the NDAG could perform for the NCSP.

7. The NDAG will perform an annual self-assessment of the Nuclear Data Element to identify opportunities for improvement in the Nuclear Data Arena, assign responsibility for those improvements, and track them to closure. These improvements will be focused on better responsiveness to the DOE User Community, identifying improvements in coordination, and streamlining the process leading to issuing new/improved data to the end-users.

**NDAG Membership:** The NDAG membership benefits from the representation of several important areas of expertise, experience and responsibility:

1. Nuclear data specialists (Experimentalists, Evaluators, Processors).
2. Criticality safety analysts from the major DOE sites.
3. Program management and technical leadership from the NCSP work elements (Nuclear Data, Critical Experiments, Benchmarking, AROBCAD, and Analytical Methods).
4. To the extent feasible, individuals with more than one of these areas serve on the NDAG. Alternates back-up key areas of expertise and/or activity.

**NDAG Leadership:** The NDAG is chaired by R. D. (Dick) McKnight of Argonne National Laboratory. McKnight has responsibility for the technical leadership of NDAG. The NDAG administrative/logistical responsibilities are performed by R. M. (Mike) Westfall of Oak Ridge National Laboratory, as
part of his overall responsibility as manager of the NCSP Nuclear Data Element. C. L. (Charlie) Dunford, former head of the National Nuclear Data Center of Brookhaven National Laboratory, serves in a special consultancy to the NCSP on nuclear data matters and exercises an NDAG leadership role in overall program evaluation and interfacing with the nuclear data community (CSEWG, WPEC, etc.). J. N. (Jerry) McKamy, chair of the Criticality Safety Coordinating Team of criticality specialists in federal service, as well as a DOE/HQ member of the CSSG, has an NDAG leadership role in communicating DOE programmatic needs for enhanced nuclear data in criticality safety applications.

The NDAG conducted its fifth meeting in May 2004. The NDAG operation in terms of the seven functions in the Mission Statement is not fully mature. However, it is well supported by the criticality safety community, it is meeting regularly, and it is beginning to make recommendations to the NCSP Criticality Safety Support Group.

As noted above in Item 1 in the NDAG mission statement, the NDAG is trying to prioritize the data needs of the criticality safety community. By interfacing with the CS applications and practitioners, their data needs are identified and evaluated (e.g., is the need for a differential or integral data measurement or evaluation?). These needs are assigned highest priority for NCSP resources. Data requests not derived directly from a CS field application are addressed as lower priority and support the valuable mission to maintain CS nuclear data and methods infrastructure and capabilities. It may be noted that this NDAG “top-down” approach to establish NCSP data need priorities is consistent with the recent restructuring of the NEA WPEC High Priority Request List for nuclear data, as reported in this conference [4].

CURRENT NUCLEAR DATA ACTIVITIES FOR CRITICALITY SAFETY APPLICATIONS

A number of nuclear data efforts sponsored directly and/or coordinated with the NCSP have provided significant results. Reported in this conference are results in actinide evaluation and data testing at LANL [5], ORELA measurements and resonance evaluations at ORNL [6], and an international effort to extend the resolved resonance range of U-238 to 20 keV [7].

Additional nuclear data activities involve the development of improved data for the DOE Office of Environmental Management. An application at the Savannah River Site involves the qualification of the gadolinium isotopes for service as admixed absorbers in the processing of plutonium dioxide waste forms into permanent disposition in glass logs. Higher loadings could potentially reduce the number of glass logs at a savings of ~$100k per log. Activities include the preparation of gadolinium covariance files that have been prepared to test new covariance formats being prepared for ENDF/B-VII submittals. Data improvements for the EM operations at Idaho Falls include ORELA measurements on Mn-55. It has been determined that manganese is the constituent of stainless steel with the highest uncertainty in its nuclear data. Stainless steel appears frequently in operations involving storage racks and shipping containers. Elements of priority interest in the tank farm work at Hanford include Fe, Cr, Ni, Mn, and depleted uranium. The Hanford conservative waste model includes Fe, Si, Na, N, Al, P, and O. Subcritical mass ratios involve the following elements: Al, C, Ca, Ci, Cu, N, Na, Ni, Si, Zr, Bi, Fe, Mn, La, Th, and depleted uranium. The nuclear data work for DOE/EM includes the performance of cooperative sensitivity/uncertainty studies with the staff members of the EM site criticality safety groups.

Additional application areas are utilizing the NCSP nuclear data development capabilities. An example is the space nuclear program, which has a need for improved data for the refractory metals. Currently the NCSP is developing covariance files for rhenium, which is a potential candidate for service as a passive shutdown absorber in accident scenarios involving water immersion of the small fast space reactors.

FUTURE PROGRAM OBJECTIVES

Several new program objectives are being adopted for the NCSP Nuclear Data work element. In order to expedite the utilization of the new AROBCAD sensitivity/uncertainty methodology, increased emphasis will be placed on the development of covariance files. Additional application areas will be developed for nuclear data measurements. The intention is to broaden the customer base and institutional support for continued operation of ORELA. Also an effort is underway to provide career opportunities for nuclear data specialists through post doctoral assignments and recruitment for new nuclear data staff positions.
CONCLUSION

The Nuclear Data work element of the DOE Nuclear Criticality Safety Program is functioning well in the areas of measurement, evaluation, testing, and processing. The identification of nuclear data needs and the coordination of resources for meeting these needs are being performed on a collaborative basis through the Nuclear Data Advisory Group.

REFERENCES