DEPARTMENT OF ENERGY
ANNUAL REPORT
FOR
DEFENSE NUCLEAR FACILITIES SAFETY BOARD
RECOMMENDATION 93-2

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Defense Nuclear Facilities Safety Board
Recommendation 93-2 Annual Report

Introduction

On March 23, 1993, the Defense Nuclear Facilities Safety Board (DNFSB) issued Recommendation 93-2, Critical Facilities Infrastructure, to the Secretary of Energy. The DNFSB recommended the following:

1. The Department of Energy should retain its program of general purpose critical experiments.

2. This program should normally be directed along lines satisfying the objectives of improving the information base underlying prediction of criticality, and serving in education of the community of criticality engineers.

3. The results and resources of the criticality program should be used in ongoing departmental programs where nuclear criticality would be an important concern.

On May 12, 1993, the Department fully accepted Recommendation 93-2 and submitted an Implementation Plan to the DNFSB on August 10, 1993. The DNFSB accepted this Plan on September 30, 1993. Referring to the Implementation Plan, the acceptance letter stated the following:

> "The DNFSB applauds the Department's setting of department-wide, long-term goals that include well documented critical experiments to confirm the adequacy of criticality computer codes and nuclear data, general critical experiments and training capability, and the improvement of criticality predictability."

The Department is pleased to report that, indeed, an ongoing process has been established to manage the criticality experiments program effectively with a long-term view toward continuing improvement in criticality predictability and training of criticality engineers. The Department recognizes that application of improved criticality predictability not only enhances criticality safety, but could also lead to significant cost savings in the handling and storage of fissile material.

The DNFSB also provided a comment concerning its sense of what would be required to successfully carry out the Implementation Plan:

> "The success of the Implementation Plan for Recommendation 93-2 seems highly dependent on the participation of all concerned parties. Vigilance will be needed at high levels to ensure that both the users and suppliers of experiments, computer codes, nuclear data, and training will participate. In the past, because of budget constraints, many concerned parties were unwilling to share responsibility."

The Department agrees with the DNFSB on the issue of shared responsibility, and the Secretary of Energy addressed this issue by tasking the Assistant Secretary for Defense Programs (DP-1) with the responsibility for developing the Implementation Plan in consultation with all the Departmental

Stakeholders. The Assistant Secretary for Defense Programs is the senior level authority within the Department, responsible for implementation of the critical experiments program.

The Implementation Plan established the Nuclear Criticality Steering Committee (NCESC) whose charter is to provide DP-1 with advice on matters affecting the Department's criticality functional capability and corresponding experiments program. The NCESC consists of representatives of the various stakeholders within the Department who share the responsibility for the criticality experiments program. The NCESC and its subcommittees provide the Department with an established forum for the exchange of ideas among the stakeholders with a clear focus on criticality experimental and hands-on training needs. The NCESC is consolidating and prioritizing experimental and training needs and making recommendations to DP-1 on how to meet those needs. Recommendations from the NCESC to improve the program are being actively supported by senior management.

The NCESC has reviewed and will continue to review the nuclear criticality experiments program from a systems engineering perspective. One of the Department's missions is to maintain its competency in conducting criticality experiments. Because maintenance of competency in conducting criticality experiments requires a long-term commitment from the Department, life-cycle considerations for the facilities that support this program must be included in the process. Along with planning for the operation of existing facilities and potential construction of new facilities, the Department recognizes the need to plan for the eventual decommissioning and decontaminating of these facilities and environmental remediation of the sites where the facilities were located.

The first annual report, contained herein, informs the DNFSB of the overall status of the Department's critical experiments program, including projected funding through Fiscal Year 1995. The report is divided into the following three sections:

Section 1.0 contains a current status of the Department's critical experiments program. This section is divided into the four major subprogram areas. Each of these subprogram areas is vital to the success of the Department's critical experiments program. The status of each subprogram area is provided with regard to current capability, requirements, funding, and anticipated future needs.

Section 2.0 discusses program coordination between the Department and its criticality experiments customers. Because the Department of Energy maintains the vast majority of capability to conduct critical experiments and hands-on criticality training, the Nation relies heavily on the Department to meet its needs in these areas.

Section 3.0 outlines key issues facing the Department that must be resolved in order to maintain capability and establish a culture that encourages continuous improvement in the critical experiments program. To maintain capability and satisfy anticipated future requirements, the Department is canvassing the criticality community to identify requirements as soon as possible so they can be factored into program planning. In addition, budgets are being developed that permit programmatic agility to meet unanticipated requirements as they arise.

1.0 Nuclear Criticality Experiments Program Status

The following sections present a current status of the Department's critical experiments program. Each of the four sections is focused on one of the subprogram areas: Facilities and Personnel, the Experimental Program, Predictability, and Training. Each of these subprogram areas is organized into four subsections. These subsections (current status, current requirements, funding, and anticipated future needs) provide a structured picture of the current program status as well as a projected direction that each of the subprogram areas must take in order to maximize the Department's return on its investment in its critical experiments program.

1.1 Facilities and Personnel

Maintenance of capability in nuclear criticality experiments cannot be accomplished without adequate facilities and qualified personnel. Maintaining the required facilities to conduct experiments in a safe and reliable manner is very important. However, maintaining a highly trained and qualified staff is equally important. One cannot maintain capability in this technical field without conducting operations. Likewise, one cannot retain quality individuals without challenging them. The Department recognizes this and has factored these considerations into the development of its enduring critical experiments program.

1.1.1 Current Status of Critical Experimental Facilities and Personnel

A survey of Departmental nuclear research facilities that are fully capable of conducting critical experiments yielded two facilities: The Los Alamos Critical Experiments Facility (LACEF) and Area V at Sandia National Laboratories. All other Departmental facilities where critical experiments had previously been conducted are either in operational standby or shut down and awaiting decommissioning. Both the LACEF and Area V are active nuclear research centers. Historically, the nuclear testing done at Area V has not been focused on criticality issues. Rather, it has involved radiation hardness of systems components, nuclear fuel assessments, and a host of other advanced concept experiments. Aside from one critical experiment, scheduled to be conducted at Area V during the next two years, all other scheduled or proposed critical experiments are being conducted at the LACEF. With its ten critical assemblies, the LACEF currently offers the flexibility required to meet most of the Department's critical experimental needs, all at one location.

Both the LACEF and Area V have trained and certified staff for conducting nuclear operations. Because of the decrease in nuclear testing requirements as a result of the end of the Cold War, both facilities have undergone a decrease in staff. The NCESC is aware of this situation and is monitoring it to ensure that staffing levels are maintained commensurate with operational requirements and identified experimental needs.

1.1.2 Current Requirements

The Department has determined that the facilities contained within the LACEF are adequate to meet most of the current requirements for conducting critical experiments and training criticality experts. Some of the high priority experiments identified by the NCESC, such as criticality issues associated with plutonium in solution and mixed plutonium and uranium oxides, will require the development of new experimental facilities. The Department recognizes these needs and is including them in future planning according to their priority.

1.1.3 Funding

The following table outlines the current funding for Fiscal Year 1994 and projected funding for critical experimental facilities for Fiscal Year 1995. Projected funding for critical experiments facilities is adequate to meet the Department's needs for the foreseeable future.

FISCAL YEAR:	1994	1995
LOS ALAMOS NATIONAL LABORATORY (LACEF)	2,900	4,300
SANDIA NATIONAL LABORATORIES AREA V[1]	20	20

NOTES: $ in thousands
[1] funding for maintenance of facilities required to support the Spent Fuel Safety Experiments

1.1.4 Anticipated Future Needs

Experimental needs dictate facility requirements. Consequently, the high priority criticality experiments identified by the NCESC help to determine experimental facility requirements for the future. In addition, the Department's critical experiments program is flexible enough to allow unanticipated needs to be met. The NCESC is chartered to coordinate such occurrences.

Future experimental facility development will be required to support some of the priority experiments identified by the NCESC. For example, the criticality issues associated with plutonium in solution and mixed uranium and plutonium oxides will require that new experimental facilities be developed. The most likely location for these new experimental facilities is the LACEF; however, appropriate environmental analysis will have to be conducted in support of a siting decision. The NCESC will oversee required facility development in support of these anticipated experimental requirements.

As for the existing experimental facilities at the LACEF, many of them are now over 40 years old and require an increasing amount of maintenance to assure safe operations. As part of the Department's commitment to maintaining capability in this area, the NCESC will evaluate and recommend facility upgrades at the LACEF as appropriate.

1.2 Criticality Experimental Program

As the demand for new nuclear systems declined, the need for critical experiments associated with the development of these systems declined as well. Nevertheless, critical experiments are still required to support a number of important Departmental missions. These missions include environmental restoration and waste management, storage of special nuclear material from dismantled weapons, reconfiguration of the weapons complex, improving predictability of nuclear criticality, and maintenance of capability in nuclear weapons development and testing technology. During Fiscal Year 1994 the Methodology and Experiments Subcommittee of the NCESC conducted a survey of the criticality community to determine the experimental needs associated with these missions. The 58 criticality experiments contained in the resulting needs assessment were prioritized, and the top 16 were presented to the NCESC for consideration. These 16 experiments, contained in Attachment 1 to this report, are being used as the basis for a structured critical experiments program.

1.2.1 Survey of Current Critical Experiments

Three of the 16 priority experiments are currently being conducted at the LACEF: experiment No. 206, Sheba Reactivity Parameterization; experiment No. 207, Sheba Reactivity Void Coefficient; and experiment No. 503, Validation of Criticality Alarms and Accident Dosimetry. These three experiments are coupled in one respect. Characterization of the Sheba critical assembly at the LACEF must be accomplished prior to using Sheba in the validation of criticality alarms and accident dosimetry. Not only is this work important to the Department, but it is also a high priority for the United States Nuclear Regulatory Commission (USNRC). In addition, the LACEF staff has established an international collaborative effort with the French in this area. An intercomparison study of French data and Sheba data is planned as part of the work in assessing criticality alarms and accident dosimetry.

One other critical experiment, No. 702, the Spent Fuel Safety Experiments, is funded and will be conducted at Area V, Sandia National Laboratories in early Fiscal Year 1995. This is the only critical experiment that will be conducted at Sandia for the foreseeable future.

1.2.2 Current Experimental Requirements

The LACEF is adequate to support most of the current high priority experiments. Because funding for critical experiments is limited, only those with a high priority will be funded. Experiments will either be funded by programs that require the experiment or funded by the Department as part of its commitment to maintain the capability to conduct critical experiments. Also, the critical experiments program is flexible enough to accommodate an emergency requirement, should it arise.

1.2.3 Critical Experiments Funding

Funding for criticality experiments is contained in the following table, by program and facility, for Fiscal Year 1994. Projected funding for Fiscal Year 1995 is also included. Projected funding for critical experiments is adequate to meet the Department's needs for the foreseeable future.

PROGRAM OR EXPERIMENT	FACILITY	1994	1995
CURRENTLY FUNDED EXPERIMENTS	LACEF	296	451
#702	AREA V (SANDIA)	250	350

NOTES: $ in thousands

1.2.4 Anticipated Future Experimental Needs

No critical experiments facility in the U.S. can support all of the proposed experiments on the priority list. The experiments involving mixed oxides of plutonium and uranium and plutonium in solution require new experimental facilities. These facilities could be accommodated at the LACEF, and the LACEF staff has proposed establishing them in the future.

The Department will provide funding for one or two critical experiments per year from the priority list beginning in Fiscal Year 1996. This list will be reviewed annually within the criticality community to assure that experiments receive an appropriate priority based on the Department's missions and priorities.

1.3 Predictability

Predictability of the critical state of a system, based on theoretical understanding of the nuclear reaction processes involved, and using methods that employ theory properly benchmarked against experiment is a principal ingredient of nuclear criticality control. Although the calculational methods that are inherent in computer codes used to predict the criticality state of a system and the nuclear data libraries that they incorporate by combining measured cross sections with their theoretical representation in terms of resonance parameters have all dramatically improved over the years, many limitations still remain. This section describes the efforts being made by the Department to continually improve the state of the art of criticality predictive capability.

1.3.1 Survey of Current Programs

The Methodology and Experiments Subcommittee of the NCESC conducted a survey of ongoing efforts in the areas of benchmarking, code development, and nuclear data refinement. The following three sections provide a current status of programs in these areas.

1.3.1.1 Benchmarking

The Department's program of critical experiments is accompanied by a broad assessment of available criticality benchmark data and the state of the art in verifying and validating criticality computational methodology. The recent study documented in LA-12683 outlines U.S. Needs for Criticality Experiments and Experimental programs. The needs of other countries have been documented in reports to the last two International Conferences on Nuclear Criticality Safety. Various requirements for Standard Reference Data have been addressed by the American Nuclear Society (ANS) 19.5 Working Group. It is expected that this ANS 19.5 standard can be usefully applied to criticality benchmark data which is applicable to the validation of criticality calculations.

The Criticality Safety Benchmark Evaluation Project (CSBEP) was initiated by the Department in 1992. The project is managed through the Idaho National Engineering Laboratory, but involves nationally known criticality safety experts from a number of Department of Energy Laboratories. In addition, an international data exchange is planned with representatives of the United Kingdom, Russia, Japan, France, and Hungary. The purpose of the project is to identify and evaluate a comprehensive set of critical benchmark data, verify the data to the extent possible, compile it into standardized form, perform calculations of each experiment, and formally document the work. Approximately 50 evaluations will be completed by the end of Fiscal Year 1994 with formal publication of the work in Fiscal Year 1995.

1.3.1.2 Codes

Codes employed to predict the critical state of a system, particularly those that are used in connection with criticality safety calculations, are central to an efficient criticality safety program. An important use of such codes is to perform calculations to support mandatory safety analyses reports involving criticality. These codes are indispensable for analyzing accident scenarios required for those reports.

Current projects involving codes supported by the Department are as follows: Work is being done at the Oak Ridge National Laboratory (ORNL) to modify the MCNP code for criticality safety applications. Also at ORNL, improvements to the KENO code are being made, and a 3-D version of KENO is being developed. At present, the MCNP code does not incorporate a treatment of unresolved resonances that is comparable to the probability table method used in the VIM code. The MCNP code uses the less rigorous Bondarenko method. Although the VIM code uses the more rigorous probability table method for treating unresolved resonances, it does not treat the resolved resonances in a manner that is most appropriate for accommodating the ENDF/B-VI files such as is done in the MCNP code. The NCESC will be considering the utility of a proposed modification of the VIM code to improve its handling of the resolved resonance regions for use with ENDF/B-VI and changes to the MCNP code to treat unresolved resonances using the probability table method.

In the early 1960s, the development of S_n computer programs at Los Alamos and Oak Ridge, the development of The GEM code in the United Kingdom, and the development of the KENO program at Oak Ridge gave stimulus for critical experiments to validate complex three-dimensional criticality calculations. Recent code developments include the MCNP and VIM Monte Carlo Codes at Los Alamos and Argonne National Laboratory, respectively. With accurate nuclear data and careful validation procedures, the latter codes are likely to meet most U.S. criticality analysis needs. The problem remains to obtain accurate nuclear data and to complete the validation process using appropriate critical experiment data.

1.3.1.3 Nuclear Data

Accurate nuclear data is the foundation of nuclear criticality predictability. Without it, the codes have very limited worth. Accordingly, the NCESC has established preliminary contacts with the chairman of Cross Section Evaluation Working Group (CSEWG), as well as other cognizant experts, involved in the development of nuclear data files. The CSEWG is an established interlaboratory working group that produces the Department of Energy sponsored Evaluated Nuclear Data File (ENDF). The Methodology and Experiments Subcommittee of the NCESC will continue to work with this group with a view toward continuous improvement of the nuclear data that support the modeling codes.

There are two major issues that require resolution. Shortcomings or gaps in the nuclear data require identification and attention. Also, the availability of new and improved nuclear data files, such as ENDF/B-VI, has not been fully exploited by the Department to meet criticality safety needs. This is due in part to the need for further processing of ENDF/B-VI to produce multigroup or point data libraries. It is also due to the need for further validation of advanced computational codes such as VIM and MCNP for use in various criticality computational applications. The NCESC is very interested in resolution of these two issues.

Current projects supported by the Department involving nuclear data are as follows: The CSEWG is continuing the development of the latest version of the Evaluated Nuclear Data File, ENDF/B-VI. Work is being done at ORNL to update the Hansen-Roach cross section library for the KENO code. At Westinghouse Hanford Corporation, a nuclear criticality parameter study data base is being prepared.

The NCESC plans to cooperate with the ongoing CSEWG efforts to ensure that nuclear data are adequate for nuclear criticality applications. It is noted that the CSEWG efforts are further coordinated with the Organization for Economic Cooperation and Development/Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency nuclear data evaluation and measurement efforts. Recent reviews by the Department of Energy/National Science

Foundation Nuclear Science Advisory Committee and by the OECD/NEA Nuclear Science Committee have identified the major nuclear data application needs. The NCESC will coordinate its activities to improve nuclear data for criticality applications with the aforementioned activities.

1.3.2 Current Requirements

The NCESC has just recently begun its review of the Department's needs in the area of criticality predictability. Requirements far exceed current funding levels, and budgets for nuclear activities continue to decline. The NCESC will assess the requirements and make programmatic recommendations on funding of key elements of criticality predictability programs as appropriate.

1.3.3 Funding

The following table depicts the funding for Fiscal Year 1994 and projected funding for Fiscal Year 1995 in the areas of benchmarking, codes, and nuclear data.

	1994	1995
BENCHMARKING	2,000	2,000
CODES	900	900
NUCLEAR DATA	2,000	1,500

NOTES: $ in thousands

1.3.4 Anticipated Future Needs

Most of the current efforts in this area appear to be underfunded and will require more attention from the NCESC in the future. Prioritization of needs and subsequent advocacy for appropriate funding is a top priority for the NCESC in the coming year.

1.4 Training

The Department recognizes that hands-on criticality training is absolutely essential in maintaining an effective criticality safety program. The NCESC began reviewing the Department's hands-on criticality safety training program early in Fiscal Year 1994 and immediately faced a difficult situation. A funding shortfall had forced the suspension of all hands-on criticality safety training. With the support of DP-1, the NCESC was able to secure $150 thousand in funding for training in Fiscal Year 1994 from among the stakeholders and subsequently directed the restart of classes. There will be four classes offered in Fiscal Year 1994. The NCESC will continue to oversee training to maximize the return on the Department's investment by ensuring that this important training function meets the Department's needs and is provided first to those who need it most.

In addition to overseeing hands-on criticality safety training, the Training Subcommittee of the NCESC has focused its efforts on identifying all criticality safety training needs for both Federal and contractor staff, determining which facilities and other resources are required to meet identified needs, and determining an equitable funding scheme to support the training. This section provides a status of the Department's hands-on criticality training program.

1.4.1 Survey of Current Training Needs

The Training Subcommittee of the NCESC conducted a hands-on criticality safety training needs survey within the Department's training community and determined that there is a continuing need for this training. In fact, the Los Alamos staff, who conduct the hands-on criticality safety training at the LACEF, has a backlog of over 100 requests for admission to the hands-on criticality training courses that are offered at the LACEF. Based on the identified needs, the NCESC is supporting a schedule of six hands-on criticality safety courses per year. A training needs survey will be conducted annually, and the number of required courses will be adjusted accordingly.

1.4.2 Current Facility Requirements to Support Training

The Training Needs Survey also requested information related to training resources available that are being used within the Department. The responses revealed that there are a number of well regarded classroom training courses being used at the various sites. However, the LACEF is the only Departmental facility that currently conducts hands-on criticality safety training. The LACEF is adequate for this purpose, and developing another facility for hands-on criticality safety training at this time would not be cost effective.

1.4.3 Funding

The following table depicts the hands-on criticality safety training funding for fiscal year 1994 and projected funding for Fiscal Year 1995. Projected funding for hands-on criticality safety training is adequate to meet the Department's needs for the foreseeable future.

	1994	1995
LACEF	150	200

NOTES: $ in thousands

1.4.4 Anticipated Future Training Needs

Hands-on criticality safety training will continue to be required at the Department for the foreseeable future. Training requirements are likely to increase slightly as the training requirements for the technical staff are identified, particularly if qualification standards are imposed on criticality specialists and engineers. The Department is committed to technical excellence and the continuing need to develop criticality safety expertise both within the Department and its contractor organizations.

2.0 Coordination

Representatives from the NCESC have met with members of the USNRC staff and solicited comments on the Department's critical experiments program. The USNRC depends on the Department for support in criticality experiments and hands-on training. This coordination has reinforced the current focus of the NCESC because the USNRC echoed many of the concerns that the Department considers to be important and plans to address.

The Methodology and Experiments Subcommittee of the NCESC has made contact with the various organizations that develop cross section data such as the CSEWG and the Hansen-Roach development group at ORNL. This will allow the NCESC to remain abreast of new developments and address issues that could jeopardize the Department's commitment to continuous improvement of criticality predictability.

The principal coordinating organization for the U.S. criticality community is the Nuclear Criticality Technology and Safety Project (NCTSP). A work group associated with the NCTSP prepared the "Forecast of Criticality Experiments Needed to Support Nuclear Operations in the United States of America: 1993-1998." The NCESC used this document as the basis for its assessment of needs which resulted in the priority experiments list (Attachment 1). The NCESC will continue to rely on the NCTSP for the annual review of criticality experiment needs.

Another organization, active in the U.S. criticality community, is the American National Standards Institute/ANS Standards Committee N16. Members of the Methodology and Experiments Subcommittee of the NCESC participate in the standards development process sponsored by this group.

Many members of the NCESC and its subcommittees are active participants in the Nuclear Criticality Safety Division of the ANS. Letters of mutual support have been exchanged between this organization and the NCESC. Continued interaction with the ANS is absolutely necessary if the Department is to maintain its commitment to support the needs of the entire criticality community.

3.0 Future Direction and Key Issues

Although the NCESC made considerable progress during this past year, much work remains to be done. The following list of issues that the Department considers important will continue to be addressed in the coming year.

* Maintenance of funding for predictability.
* Maintenance of capability and competency.
* Improving the quality of hands-on criticality safety training.
* Annual review and prioritization of criticality experiments.
* Life cycle planning for facilities required for the Department's critical experiments program.

Conclusion

The Department recognizes the importance of maintaining an effective criticality safety program to protect the public, workers, Government property, and essential operations from the effects of a criticality accident. An indispensable part of this criticality safety program is the critical experiments program. This critical experiments program is divided into the four major subprogram areas. Each of these subprogram areas is vital to the success of the Department's critical experiments program. This report presented the status of each subprogram area with regard to current capability, requirements, funding, and anticipated future needs.

Since accepting DNFSB Recommendation 93-2, the Department has endeavored to lay a foundation from which capability in the four subprogram areas can be assessed and maintained in accordance with Departmental priorities and needs. Though Defense Programs is responsible for coordinating these efforts, all stakeholders must share the responsibility for maintenance of this important capability. Much has been accomplished during the past year, and the Department's critical experiments program has been granted an appropriate priority. With the support of senior management, the NCESC will continue to build on the foundation and develop a quality program that meets the Nation's current and future criticality experimental needs.

Attachment 1

NUCLEAR CRITICALITY EXPERIMENTS STEERING COMMITTEE

METHODOLOGY AND EXPERIMENTS SUBCOMMITTEE

CONSENSUS OF

HIGH PRIORITY EXPERIMENTS

Table of Contents

Introduction

The Nuclear Criticality Experiments Steering Committee (NCESC) tasked its Methodology and Experiments Subcommittee with developing a list of the highest priority critical experiments, given the Department's current priorities. The initial list of experiments that the Methodology and Experiments Subcommittee considered was that included in the "Forecast of Criticality Experiments and Experimental Programs Needed to Support Nuclear Operations in the United States of America: 1994-1999." This document was emended to redirect its focus to be relevant to Recommendation 93-2. The 58 experiments in the emended document were evaluated and prioritized as described below. Sixteen experiments have been assigned high priority. Consensus has been achieved on the high priority of these 16 experiments relative to the original group of 58 experiments. However, a final consensus has not yet been achieved on the relative ranking among the 16 experiments. This will be accomplished in the near future.

Operations at LACEF are currently required to accommodate most of these experiments over the coming years. This prioritization of experiments allows specific budget guidance to be given to LACEF to align the Department's critical experiments program with its priorities.

Two classes of experiments were identified: Project-dependent-only and its complement, Project-independent. These two classes form a complete set of the experiments. Project-dependent-only experiments have priorities that are driven strictly by a project schedule.

Prioritization criteria were defined to represent potential safety concerns as follows:

S1 = ill-defined subcriticality margin: rating = 8;

S2 = uncertain protection by well-defined subcriticality margin: rating = 5;

S3 = discrepant validation of subcriticality margin: rating = 3;

S4 = criticality safety enhancement through economic gain: rating = 2;

S5 = enhancement of criticality safety knowledge base: rating = 1;

S6 = economic gain, independently: rating = 0;

Undecided (U) or Independent of the rating system (I).

Prioritization criteria were also defined to include ancillary factors.

A1 = No machine or funding problems, and multiple stakeholders: rating = 5;

A2 = No machine or funding problems, and a single stakeholder: rating = 3;

A3 = either machine or funding problems, and multiple stakeholders: rating = 2;

A4 = either machine or funding problems, and a single stakeholder: rating = 1.

The S ratings may be multiple, except for those of the S1 and S2 categories since these categories are mutually exclusive. Since multiple ratings can allow an experiment with a set of lower category ratings (e.g., S3+S4+S5) to outscore an experiment with a single S5 rating if a 1,2,3,4,5 rating system were used, a Fibonacci series was used to set the ratings (i.e., 1, 2, 1+2=3, 2+3=5, 3+5=8). This was also used for the A ratings to give extra weight to the A1 category. S prioritization was performed first. Discussion of the ratings among subcommittee members were held to avoid rigid adherence to a not-perfect rating/scoring system.

List of Experiments

Number	Title	Priority	Page
102	Large Array of Small Units	3	
104*	Advanced Neutron Source	Pdo	
105	High-Energy Burst Reactor Experiments	9	
206**	Sheba Reactivity Parameterization	IP	
207**	Sheba Reactivity Void Coefficient	IP	
301	Plutonium Solution in Concentration Range from 8 to 17 g/l	10	
402*	Mixed Oxides of Pu and U at Low Moderation	Pdo	
501	Assessment Program for Materials Used to Transport and Store Discrete Items and Weapons Components	11	
502a	Absorption Properties of Waste Matrices	1	
502g	Determination of Fissionable Material Concentrations in Waste Materials	7	
503**	Validation of Criticality Alarms and Accident Dosimetry Program	IP	
504	Accident Simulation and Validation of Accident Calculations Program	8	
505	A Program to Evaluate Measurements of Sub-Critical Systems	4	
601[a]	Critical Mass Experiments Program for Actinides	6	
609[b]	Validation of Calculational Methodology in the Intermediate Energy Range	5	
702	Spent Fuel Safety Experiments (SFSX)	2	

* Project-dependent only (Pdo)

** In Progress (IP)

[a]Includes 605a

[b]Includes 502i

Experiment Description Format

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DOE Contractor Who Needs Experimental Data

Name of Contractor

Experiment Category (choice of one)

Highly Enriched Uranium
Plutonium
Plutonium/Uranium
Applications
Baseline Theoretical
Criticality Physics
Applicable Experiment Categories

Safety Application (choice of one or more)

Resolution of Outstanding Subcriticality Margin Issue
Resolution of Subcriticality Margin Issue for New DOE Program
Resolution of Experiment/Calculation Discrepancy
Improvement in Economics that Promotes Criticality Safety
Enhancement of Knowledge Base

Status (choice of one)

Proposed
In Progress
Completed But Not Documented
Subsumed

Priority (choice of one)

n: Priority Number
NA: Non-Applicable Priority Number
Pdo: Project-dependent-only

***

Description of Operation and Experimental Data Needed

Succinct Description and Discussion of Experiment; Related Information

***

Suggested Experimental Facility

Name of Facility and, where appropriate, Name of Machine

Contacts

Name(s), Address(es), Telephone(s)/FAX(s)

Description of Experiments

Experiment 102

Large Array of Small Units

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DOE Contractor Who Needs Experimental Data

Y-12 Plant (Martin Marietta Energy Systems).

Experiment Category

Highly Enriched Uranium.

Application

Resolution of Outstanding Subcriticality Issue;
Resolution of Experiment/Calculation Discrepancy.

Status

Proposed.

Priority

n.

***

Description of Operation and Experimental Data Needed

Available experimental data for arrays of highly enriched uranium (and plutonium) have: (1) individual units that are relatively massive compared to the actual units that are typically stored; (2) much closer spacings between individual units than the spacings ordinarily encountered in storage; and (3) considerably fewer units in the experimental array compared to the number in typical storage arrays. Monte Carlo nuclear criticality safety codes are validated by comparison with the experimental data and then are used to calculate storage arrays that are characteristically different from the experimental arrays, as described above. The neutron coupling in actual large arrays of relatively small units may be different, hence less conservative, than that in the experimental small arrays of relatively large units. This possibility is applicable to both uranium and plutonium, both of which will likely require more storage in the future.

These experiments could also be combined with other proposed array experiments such as studies of inter-unit moderation.

If extrapolation of the range of validated applicability can reasonably lead to non-conservative results, safety can be compromised by the acceptance of conditions that result in insufficient subcriticality.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that further neutron chain-reacting critical experiments be conducted that are targeted at the major sources of discrepancy between the theory and the experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF), or
Rocky Flats (arrays of uranium solutions).

Contacts

John Tanner
Westinghouse Idaho Nuclear Company
P.O. Box 400; MS5222
Idaho Falls, ID 83404
(208) 526-9643 FAX (208) 526-9805

Calvin Hopper
Martin Marietta Energy Systems
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6370
(615) 576-8617 FAX (615) 576-3513

Ernest Elliott
Martin Marietta Energy Systems
Oak Ridge Y-12 Plant
P.O. Box 2007
Oak Ridge, TN 37831-8238
(615) 241-2771 FAX (615) 241-2772

Experiment 104 --- **Project-dependent-only**

Advanced Neutron Source

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DOE Contractor Who Needs Experimental Data

Oak Ridge National Laboratory.

Experiment Category

Highly Enriched Uranium.

Application

Resolution of Subcriticality Issue for New DOE Program.

Status

Proposed.

Priority

Pdo.

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Description of Operation and Experimental Data Needed

The Advanced Neutron Source reactor program has been authorized by DOE. This will become the largest such facility in the world. The program will develop an ultra-high-flux compact reactor concept to provide a high-intensity, steady-state source of neutrons for research on condensed matter. It uses a D_2O moderated, high-density fuel with large core pieces. Several reactor designs are currently under consideration. One possible fuel for the Advanced Neutron Source reactor is highly enriched uranium/silicon/aluminum plates.

A criticality experiment will be needed to support reactor design, and fabrication and subsequent handling and storage of the fuel.

There is insufficient U.S. experience, and there are insufficient U.S. validated data, relevant to the criticality safety limits of the fuel being proposed for this reactor.

There has been recent experimental validation relevant to the ANS Reactor.

FOEHN was a critical experiment performed by a French-German team in the course of the design of their High Flux Reactor. The similarities of this reactor with the ANS reactor suggest that a validation of the neutronic design methods for the ANS can be achieved by modeling FOEHN. An MCNP model of the Franco-German FOEHN Critical Experiment has been developed. The model improves the fidelity over that of a previously reported simpler version. The new results show a significant increase in accuracy, and, when errors persist, they are now consistent with those expected of Monte Carlo procedures.[1]

1. Abderrafi M. Ougouag, Charles A. Wemple, Guillermo A. Rubio, John M. Ryskamp, and Shawn C. Mason, "MCNP Neutronic Analysis of the FOEHN Franco-German Critical Experiment," Proc. of the 1994 Topical Meeting on Advances in Reactor Physics, III, 263, Knoxville (April 11-15, 1994).

The FOEHN critical experiments were analyzed to validate the use of multigroup cross sections in the design of the ANS reactor. Eleven critical configurations were evaluated using the KENO, DORT, and VENTURE neutronics codes. Eigenvalue and power density profiles were computed and show very good agreement with measured values.[2]

2. L.A Smith, J.C. Gehin, B.A. Worley, and J.P. Renier, "Validation of Multigroup Neutron Cross Sections for the Advanced Neutron Source Against the FOEHN Critical Experimental Measurements," Proc. of the 1994 Topical Meeting on Advances in Reactor Physics, III, 262 and 444, Knoxville (April 11-15, 1994).

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that a good base of information for criticality control in handling and storing fissionable material must be maintained.

***

<u>Suggested Experimental Facility</u>

Los Alamos Critical Experiments Facility (LACEF)/Sandia National Laboratory.

<u>Contact</u>

D. Selby
Oak Ridge National Laboratory
104 Union Valley Road
P.O. Box 209, MS 8218
Oak Ridge, TN 37830
(615) 574-6161

Experiment 105

High-Energy Burst Reactor Experiments

***

DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory.

Experiment Category

Highly Enriched Uranium.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

n.

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Description of Operation and Experimental Data Needed

The state-of-the-art of neutron fast burst reactors allows the production of few-tens of microsecond pulses with energy yields approaching 10^{17} to 10^{18} fissions. Much beyond this, uranium metal and currently used alloys melt or fracture. Current weapon technology allows reliable production of low yields in the range of a few tons of yield. At present, there are little or no experimental measurements of burst reactor behavior in the range up to 50 lbs of HE equivalent yield. The only available data on these systems at such yields come from accident situations, which were not precisely instrumented. Furthermore, there are no validated computer codes which can calculate the behavior of burst assemblies in this range.

This information is important because design basis accidents for burst reactor facilities (Godiva-IV, Skua, HPRR, SPR-II, SPR-III, WSMR-Molly-G, and APRFR) are calculated without adequate validation data in the accident range of interest (10^{18}-10^{19} fissions). Such information would serve as a basis for defining the safety envelopes of the high-energy burst reactor SARs more accurately.

Furthermore, the state of the art in burst reactors has reached the limit of current fuel technology. Production of bursts beyond 2×10^{17} will require new fuel materials and technology currently not in use.

Specifically, we propose a program of high-energy burst reactor experiments (up to 50 lbs equivalent HE yield) to be performed within a containment sphere. Here, we define high-explosive (HE) equivalent yield as:

Fission yield x (Kinetic Energy/Total Energy) = HE equivalent yield

10^{17} fissions:	1.4 lb HE x 1% = 0.014 lb HE equivalent
10^{18} fissions:	14 lb HE x 5% = 0.7 lb HE equivalent
10^{19} fissions:	140 lb HE x 10% = 14 lb HE equivalent

The experiments would be performed using a Godiva-class burst assembly which would be incrementally driven to hydrodynamic disassembly with suitable diagnostics to measure yield, initial period, FWHM, fuel state (dynamic pressure and temperature). Extra cores from several current or retired burst machines might be available for such experiments. The site for such a test bed could be LACEF (Kiva III) or the Nevada Test Site.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Rick Paternoster
Los Alamos National Laboratory
P.O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 667-4728 FAX (505) 665-3657

Experiment 206

Sheba Reactivity Parameterization

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DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory.

Experiment Category

Applicable Experiment Categories.

Application

Resolution of Subcriticality Issue for New DOE Program.

Status

In Progress.

Priority

NA.

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Description of Operation and Experimental Data Needed

This experiment includes the measurements for the first operations of Sheba, such as the initial approach to critical, initial delayed-critical operations, and measurements of temperature coefficients, absolute power calibrations, etc.

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that a theoretical understanding of neutron multiplication processes in critical and subcritical systems must underlie criticality safety analyses.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Ken Butterfield
Los Alamos National Laboratory
P.O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 667-8944 FAX (505) 665-3657

Experiment 207

Sheba Reactivity Void Coefficient

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DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory.

Experiment Category

Applicable Experiment Categories.

Application

Resolution of Subcriticality Issue for New DOE Program;
Enhancement of Knowledge Base.

Status

In Progress.

Priority

NA.

***

Description of Operation and Experimental Data Needed

This experiment will measure the reactivity void coefficient for several regions in Sheba. The first phase is already underway, and consists of calculations using MCNP. This experiment will also provide a validation of MCNP.

The primary shutdown mechanism in an excursion in a solution system is the introduction of voids due to radiolytic gas formation. The net reactivity effect depends upon the location of the void and the displacement of the free surface. Although it is very difficult to calculate the effects in three dimensions, a better understanding of the reactivity provided by experiment is necessary to model kinetic behavior.

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Ken Butterfield
Los Alamos National Laboratory
P.O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 667-8944 FAX (505) 665-3657

Experiment 301

Plutonium Solution in Concentration Range from 8 to 17 g/l

***

DOE Contractor Who Needs Experimental Data

Westinghouse Hanford Company; Los Alamos National Laboratory; Rocky Flats Plant.

Experiment Category

Plutonium.

Application

Resolution of Outstanding Subcriticality Issue; Enhancement of Knowledge Base.

Status

Proposed.

Priority

n.

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Description of Operation and Experimental Data Needed

This plutonium concentration range is of interest in the current head-end operation of plutonium processing. These concentration levels are used routinely at TA-55 at LANL and at RFP.

Experimental critical data are insufficient to cover the concentration range from 8 to 17 g/l (H/Pu from 2700 to 1200). Results of calculations at 8 g/l and above 17 g/l appear to be contradictory, with computational bias appearing to become strongly negative below 20 g/l.

Criticality experiments to verify calculations in the 1200 to 2700 H/Pu range will have long-range benefits in applications to head-end plutonium processing and waste storage.

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that further neutron chain-reacting critical experiments be conducted that are targeted at the major sources of discrepancy between the theory and the experiments.

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Suggested Experimental Facility

None available at the present time.

Contact

Robert Rothe
EG&G Rocky Flats
P.O. Box 464
Golden. CO 80402-0464
(303) 966-2989 FAX (303) 966-7326

Experiment 402 --- **Project-dependent-only**

Mixed Oxides of Pu and U at Low Moderation

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DOE Contractor Who Needs Experimental Data

To be determined.

Experiment Category

Plutonium/Uranium.

Application

Resolution of Subcriticality Issue for New DOE Program.

Status

Proposed.

Priority

Pdc.

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Description of Operation and Experimental Data Needed

For the proposed weapons-grade plutonium burner (LWR version), the following critical experiments will be required:

1. Homogeneous Systems

   These experiments will provide data on dry and damp powders to determine critical mass and volume as a function of Pu or U concentration. This information is needed to reduce uncertainties in critical volumes and masses, and to serve as benchmarks for validation of calculational methods; this information will be required if mixed oxide fuel is used in LWRs. Variables: Pu content in mixed oxides (3-6 wt% of PuO_2); ^{240}Pu content of Pu (5 wt%); H/Pu ratio (moderation) in the range from 0-3.

2. Heterogeneous Systems

Data on lattices of fuel rods in water are needed to determine minimum critical volumes and the effect of heavier isotopes of Pu on criticality. Variables: Fuel-pin diameter, Pu content in mixed oxides (3-6 wt% of PuO_2); ^{240}Pu content of Pu (5 wt%); H/Pu ratio (moderation) in the range from 0-3.

Although this fuel is typical of that used to recycle plutonium in LWRs, two criticality safety considerations must be addressed. First, the conversion of plutonium from weapons grade to reactor grade is a new process, thus requiring new criticality safety analyses. Second, U.S. experience with LWR plutonium fuel is not current, plutonium recycle studies having been discontinued 15 years ago, thus criticality safety for recycle plutonium must be reconsidered.

There has been recent experimental validation relevant to the use of mixed oxides in PWRs.

A program called EPICURE has been developed by the French to validate the calculational schemes for PWRs partially loaded with MOX assemblies. This program has as its objective reduction of the uncertainties associated with MOX fueling to a level comparable to that of uranium fueling. Clean-core experiments will be performed to examine the influence of nuclear data uncertainties on k-infinity (by buckling measurements), ß-effective (by source multiplication and by noise analysis), temperature coefficient (water density effects and spectrum effects), worths of absorbers, and effects of local voiding and bowing on fine [pin] power distribution. A series of experimental cores is planned to validate predictions of pin power distribution and predictions of the efficiency of various absorbers, and also to study the problem of the uncertainty in pin power from incore instrumentation.

The first EPICURE program experimental results have been analyzed with the APOLLO multigroup transport cell code (using the CEA-89 cross section library [different from the ENDF (U.S.) and JEF (European, but not French) libraries]) that feeds a 99-fine-group cross section set to the BISTRO S_n XY-geometry transport code. Group collapsing as a source of error is avoided by BISTRO's use of the full 99 groups. Power distribution differences between calculation and experiment for both MOX assemblies and uranium assemblies are less than 2%. The EPICURE program is planned to last for about 3 years.[1]

1. J. Mondot, et al., "EPICURE: An Experimental Programme Devoted to the Validation of the Calculational Schemes for Plutonium Recycling in PWRs," Proc. of the International Conference on the Physics of Reactors: Operation, Design and Computation, 1, VI.53, Marseille (April 23-27, 1990).

Further work has been done to determine the origin of discrepancies in MOX cores between calculation and measurement when using the APOLLO2 code with the CEA93 cross section library.[2]

2. Philippe Fougeras, Stephane Cathalau, Jacques Mondot, and Pavel Klenov, "Analysis of the Neutronic Balances and Pin Power Distribution in a MOX-UO_2 Lattice Using the APOLLO2 Code and the CEA93 Library," Proc. of the ANS 1994 Topical Meeting on Advances in Reactor Physics, III, 113, Knoxville (April 11-15, 1994).

A program called VIP has been developed by the Belgians to provide an extensive nuclear data base for the development and validation of nuclear calculational methods for MOX fuels used in light water reactors (LWRs).[3]

3. A. Charlier, J. Basselier, and L. Leenders, "VENUS International Programme (VIP): A Nuclear Data Package for LWR Pu Recycle," Proc. of the International Conference on the Physics of Reactors: Operation, Design and Computation, 1, VI.65, Marseille (April 23-27, 1990).

The Japanese have used VIP criticals to benchmark the CASMO-4/SIMULATE-3 code system for application to their planned Pu recycle designs.[4]

4. Masaaki Mori, Mitsuru Kawamura, and Shin Inoue, "CASMO-4/SIMULATE-3 Benchmarking Against VIP-PWR MOX Fuel Critical Experiment," Proc. of the 1994 Topical Meeting on Advances in Reactor Physics, III, 93, Knoxville (April 11-15, 1994).

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that a good base of information for criticality control in handling and storing fissionable material must be maintained.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Burton Rothleder
U. S. Dept. of Energy, EH-64
19901 Germantown Road
Germantown, MD 20874
(301) 903-3726 FAX (301) 903-9523

Experiment Program 501

Assessment Program for Materials Used to Transport and Store Discrete Items and Weapons Components

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DOE Contractor Who Needs Experimental Data

All DOE facilities, including Pantex, Rocky Flats Plant, Y-12 (Martin Marietta Energy Systems), Savannah River Plant.

Experiment Category

Applications.

Application

Improvement in Economics;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

n.

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Description of Operation and Experimental Data Needed

Program Applicability:

This program is needed for the current and long-term weapons component storage mission of the DOE and also includes transport and storage of discrete items in well-characterized shipping containers.

Current Calculational Pitfalls and Deficiencies:

Criticality safety assessments in this area have an inadequate or non-existent experimental basis. This has caused over-conservatism in the transport and storage requirements (e.g., the transport index), and the calculations are not validated as specified in ANSI/ANS-8.1.

Potential Benefit (Risk Management):

This program will enable the DOE to take credit for the neutronics properties of the defined shipping container configurations which will reduce conservatisms in calculations. This can permit larger numbers of containers to be transported and stored in existing facilities. This program will provide relevant basic criticality safety data, quantify safety margins more accurately, reduce calculational conservatisms, and establish compliance with ANSI/ANS-8.1.

Description of Program:

This program will use currently available U and Pu components and materials commonly used in shipping containers (i.e., iron, stainless-steel, wood, Celotex, lead, firedike, foamglas, expanded borated polyfoam, polyethylene, plexiglas, depleted uranium, etc.). These will be used in various reflector and moderator configurations such that a wide range of neutron spectra will be obtained at critical. All selected actual reflector and moderator conditions will be characterized in this program. Neutron fluxes, spectra, and lifetimes within, between, and exterior to the components will be measured. This program is specifically applicable to pits, weapons components, fuel assemblies, and parts. These experiments could utilize the existing enriched uranium hemishells being delivered to LACEF from RFP in a water-moderated array containing the interstitial material of choice.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

J. N. McKamy
EG & G Rocky Flats
P. O. Box 464, Bldg. 886
Golden, CO 80402-0464
(303) 966-4017 FAX (303) 966-7326

Experiment 502a

Absorption Properties of Waste Matrices

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DOE Contractor Who Needs Experimental Data

Idaho Nuclear Energy Laboratory; Westinghouse Hanford Company; Savannah River Plant; Rocky Flats Plant.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Resolution of Experiment/Calculation Discrepancy;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

1.

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Description of Operation and Experimental Data Needed

Some of the predominant waste matrix materials of interest are SiO_2, MgO, graphite, cellulose, CaO_2, and NaCl. With the exception of NaCl, these materials are among the more reactive materials that are present in waste. The limiting critical concentration of plutonium or uranium in most of these materials is less than the limiting critical concentration in some of the more traditional and well-known materials, water and polyethylene. However, large differences (greater than 10%) in calculated k_{eff} values are obtained for systems that contain significant quantities of these materials by simply changing cross section data sets. In order to demonstrate the safety of waste streams containing large quantities of these materials, experimental results to compare with calculational results are needed to resolve these differences and to establish realistic biases.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

J. Blair Briggs
Idaho National Engineering Lab.
P.O. Box 1625
Idaho Falls, ID 83415-3890
(208) 526-7628 FAX (208) 526-0528

Experiment 502g

Determination of Fissionable Material Concentrations in Waste Materials

***

DOE Contractor Who Needs Experimental Data

Westinghouse Hanford Company.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

n.

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Description of Operation and Experimental Data Needed

It is important for criticality and accountability purposes to know concentrations of fissionable elements in waste streams or in waste containers. These concentrations may be too low for subcritical measurements. However, total quantities in containers may be substantial, and under some upset conditions, concentrations could increase to become a criticality concern. Knowledge of total fissionable material content of tanks or drums is important also for material accountability. Waste assay methods can be used to evaluate fissile concentrations, and therefore total tank inventories. Neutron detection methods employed have to be calibrated in a facility where calibration standards can be prepared and handled.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that a good base of information for criticality control in handling and storing fissionable material must be maintained.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Hans Toffer
Westinghouse Hanford Company
P. O. Box 1970; MS H0-38
Richland, WA 99352
(509) 376-2894 FAX (509) 376-1293

Experiment Program 503

Validation of Criticality Alarms and Accident Dosimetry Program

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DOE Contractor Who Needs Experimental Data

DOE Complex.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Resolution of Subcriticality Issue for New DOE Program;
Enhancement of Knowledge Base.

Status

In Progress.

Priority

NA.

***

Description of Operation and Experimental Data Needed

Criticality accident alarm systems are utilized to alert personnel in need of evacuation. Risk reduction requires that the potential for false alarms be minimized. Proper testing and validation requires the ability to provide exposures which simulate accidents for the complete range of potential accident scenarios. Sheba and Godiva can provide this service, particularly when augmented by the Health Physics Research Reactor (HPRR).

Sheba provides a low-energy spectrum characteristic of solution accidents, and Godiva provides the capability for simulating super-prompt critical excursions. In addition, it is proposed to reactivate the HPRR at LACEF. This well-characterized reactor was specifically developed to evaluate radiation exposures in a mixed (neutron/gamma-ray) environment. It was employed for international intercomparisons of accident dosimetry for over 20 years before its shutdown in 1986.

A program is proposed that will provide, on a periodic basis, calibration and intercomparison of radiation detection instrumentation, dose measurement devices, accident dosimeters, and accidental criticality alarm systems from the entire the DOE complex and from other national and international organizations.

The data will be used to assure that ANSI and ISO Standards are correct, and that a proper level of protection is provided to workers and the public.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Richard E. Malenfant/Ken Butterfield
Los Alamos National Laboratory
P. O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 665-5645 FAX (505) 665-3657

Experiment Program 504

Accident Simulation and Validation of Accident Calculations Program

***

DOE Contractor Who Needs Experimental Data

DOE Complex.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Improvement in Economics.

Status

Proposed.

Priority

n.

***

Description of Operation and Experimental Data Needed

Present safety protection standards and Safety Analysis Reports (SARs) are based on data from accidents, which by their very nature, are not well characterized due to lack of monitoring equipment or, in many instances, accident dosimetry. This program will apply machines such as Godiva, Sheba, and Silene (French), to the validation of accident calculations through simulation, development, and validation of accident models.

ANSI/ANS Standard 8.13 specifies the minimum accident of concern in terms of detectability. However, in the absence of well-characterized experiments to simulate accidents, a highly conservative fission yield must be assumed for the SAR. The results of this assumption are then reflected in overly conservative system design or in reduced inventories of material.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that a theoretical understanding of neutron multiplication processes in critical and subcritical systems must underlie criticality safety analyses.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Richard E. Malenfant/Ken Butterfield
Los Alamos National Laboratory
P. O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 665-5645 FAX (505) 665-3657

Experiment Program 505

A Program to Evaluate Measurements of Sub-Critical Systems

***

DOE Contractor Who Needs Experimental Data

Westinghouse Hanford Company; Savannah River Plant; and other DOE sites.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

[illegible].

***

Description of Operation and Experimental Data Needed

This program is aimed at the development of a meter, or meters, to evaluate the degree of sub-criticality in a system or array of fissile material. The need for such a meter has been long recognized, but the difficulties involved are apparent in that no such instrument has been developed in the fifty years of work with fissile systems. Techniques that would be employed include (1) source jerk, (2) cross-correlation techniques, e.g. ^{252}Cf noise analysis, (3) Rossi-alpha, (4) pulsed neutron, and (5) reciprocal multiplication. Successful development and validation of a technique will contribute substantially to worker and public safety and reduce the degree of conservatism.

Liquid waste tanks at Hanford, Rocky Flats, Savannah River, and other DOE sites contain fissile nuclides that have not been fully characterized in terms of their content, form, or behavior with time. Therefore, their margins of subcriticality have not been ascertained with sufficient certainty to meet current criticality safety standards. The proposed subcriticality meter would provide measurements to meet these standards.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

J. Richter
Los Alamos National Laboratory
P. O. Box 1663, MS F699
Los Alamos, NM 87545
(505) 667-1390 FAX (505) 665-7725

Richard E. Malenfant
Los Alamos National Laboratory
P. O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 665-5645 FAX (505) 665-3657

Experiment Program 601

Critical Mass Experiments Program for Actinides

***

DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory; Oak Ridge National Laboratory;
Idaho Chemical Processing Plant; Savannah River Plant; and Others.

Experiment Category

Baseline Theoretical.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

[illegible].

***

Description of Operation and Experimental Data Needed

Critical mass estimates have been developed for some of the actinide elements using reactivity coefficient measurements in fast-metal assemblies. This technique results in large uncertainties in the minimum critical masses. The nuclides ^{236}U, ^{237}Np, ^{241}Pu, ^{242}Pu, and ^{241}Am exist in the DOE complex in quantities exceeding critical masses. However, there have been no direct measurements of the critical masses for any of these special actinides. Therefore, new measurements are necessary for validating mass limits to be used in processing, transport, and storage of these materials. We can perform some of these measurements to determine the critical mass for these actinides and additional, refined worth measurements for the higher atomic number actinides.

The results of this program would address known inadequacies in the standard ANSI/ANS 8.15 "Nuclear Criticality Control of Special Actinide Elements."

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contacts

Rene Sanchez
Los Alamos National Laboratory
P. O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 665-5343 FAX (505) 665-3657

Experiment 605a --- Included in Experiment 601

Delayed Neutron Fraction Measurement from ^{237}Np

***

DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory.

Experiment Category

Baseline Theoretical.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Data Base.

Status

Subsumed.

Priority

NA

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Description of Operation and Experimental Data Needed

The delayed neutron spectra from ^{237}Np needs to be measured. A ^{235}U target will be used as the reference. A time domain of 0.5 to 5 sec after the fission will be used. We need very small self-multiplication; a 1 gm sample will suffice. NE213 and Cutler-Shalev detectors will be used to measure the neutron spectrum over the energy range 5 kev - 5 MeV.

The fissions will be produced using Godiva-IV, and the target samples will be transferred using the existing pneumatic system to the existing counting system in Kiva III.

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that a theoretical understanding of neutron multiplication processes in critical and subcritical systems must underlie criticality safety analyses.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

Charles Goulding
Los Alamos National Laboratory
P.O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 667-0769 FAX (505) 665-3657

Experiment 609

Validation of Calculational Methodology in the Intermediate Energy Range

***

DOE Contractor Who Needs Experimental Data

Los Alamos National Laboratory; Oak Ridge National Laboratory; Rocky Flats Plant; Savannah River Plant; Lawrence Livermore National Laboratory; Enrichment Facilities; and Others.

Experiment Category

Baseline Theoretical.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

1.

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Description of Operation and Experimental Data Needed

Fissile material in facilities under remediation and decommissioning are subject to low-moderation and generate intermediate energy spectra. Criticality calculations for systems typically found in such facilities (i.e., systems involving relatively thin fissile regions (1 to 3 mm thick) separated by 1-3 cm of hydrogenous material) would depend on the representation of the cross sections pertinent to those systems. A search of the literature fails to find any critical experiments for which a large fraction of the fissions occur between neutron energies of 1 Ev and 100 KeV. Many experiments have been done for thermal systems (fissile solutions) for which nearly all fissions occur at energies below 1 Ev.

At the other extreme, many experiments have been done for "fast" systems (fissile solids) for which nearly all fissions occur at energies above 100 KeV and up to 2 MeV.

This situation leaves a very large range of systems which have never been tested experimentally. For any thermal systems, neutrons must slow down from fast to thermal. They exist and interact at many energies between fast and thermal.

Furthermore, this region is often characterized by the "resonance region" which exhibits wide fluctuations in cross section. One does not know if good agreement between theory and experiment for a thermal system is the result of:

(1) canceling errors in the code's handling of neutron slowing down through these energies; or

(2) a real bias in the code which is added to, subtracted from, or unaffected by the code's handling of the slowing down of neutrons.

These cross sections are defined in the existing cross section sets, but little data exist to verify that these cross sections are correctly represented.

An experiment has been designed to provide such a test.

If interpolation in the wide range (neutron energies from 1 Ev to 100 KeV) that exists between the points of validated applicability can reasonably lead to non-conservative results, safety can be compromised by the acceptance of conditions that result in insufficient subcriticality.

This experiment will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

***

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

R. E. Anderson
Los Alamos National Laboratory
P. O. Box 1663, MS J562
Los Alamos, NM 87545
(505) 667-2821 FAX (505) 665-3657

Experiment 502i --- Included in Experiment 609

Criticality Studies Which Emphasize Intermediate Energies

***

DOE Contractor Who Needs Experimental Data

Rocky Flats Plant; Pacific Northwest Laboratory.

Experiment Category

Applications.

Application

Resolution of Outstanding Subcriticality Issue;
Enhancement of Knowledge Base.

Status

Subsumed.

Priority

N

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Description of Operation and Experimental Data Needed

Many experiments have been done in the past that could be used for some degree of validation for large, chunky metal systems and for pure and nearly pure solution systems. These were the easiest to do, and they were the most needed when nuclear weapons were being manufactured. A plant had pieces of metal, and the recovery of the fissile component during subsequent processing lead to many kinds of fissile solutions. The recent decision to stop manufacturing nuclear weapons changes the nature of the processes involved in recovery to a large extent. This decision does not make the potentially dangerous fissile material go away. Instead, the material will be in a much less common form: relatively large quantities of fissile metal will start showing up in recovery plants in processes not encountered years ago.

This waste will be characterized by a high hydrogen content due to the paper, plastics, rubber, and other organic materials used, but it will also have fissile metal content in potentially critical concentrations.

Devise a set of critical experiments which purposefully approximate the [H/X] ratio of typical waste streams. Extend this study to include cases where the fissile contaminants are not distributed uniformly.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Contact

R. E. Rothe
EG&G Rocky Flats
P.O. Box 464
Golden, CO 80402-0464
(303) 966-2989 FAX (303) 966-7326

Experiment 702

Spent Fuel Safety Experiments (SFSX)

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DOE Contractor Who Needs Experimental Data

Sandia National Laboratory.

Experiment Category

Criticality Physics.

Application

Resolution of Outstanding Subcriticality Issue;
Improvement in Economics;
Enhancement of Knowledge Base.

Status

Proposed.

Priority

[illegible]

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Description of Operation and Experimental Data Needed

Applications exist throughout the DOE complex for the storage, transportation, disposal of spent nuclear fuel from DOE reactors as well as from commercial reactors in support of the Civilian Radioactive Waste Management Program. Data from these experiments could also be utilized by commercial reactor vendors and by the NRC to evaluate on-site storage of spent fuel. In addition, the data could be applied to U.S. programs that assist Russian and Ukraine authorities in the management of their spent fuel.

This experiment is required to validate burn-up credit.

1. Fuel Rod Consolidation:

   Monitored Retrievable Storage will provide capability to disassemble fuel assemblies and consolidate the fuel rods in storage canisters. Experimental data will benefit the safety and economics of this operation.

2. Spent Fuel Burnup Versus Reactivity:

DOE contractors and NRC licensees need to obtain criticality data for spent LWR fuel to confirm calculations. Operational and storage restrictions can be significantly reduced if credit is taken for burnup. The calculations must account for: (1) ^{235}U depletion and fission product formation, which decrease reactivity; and (2) the formation of plutonium, which increases reactivity.

3. Reactivity Worth of Spent Fuel:

Reactivity worth of spent fuel samples will be experimentally verified. These samples will be taken from a fully characterized spent fuel assembly that will include chemical assay data as part of the characterization.

4. Experimental Method:

This experiment will be performed as an approach to critical in three steps: (1) as an array of fresh fuel rods, where the lattice array will be composed of (a) fuel rods having differing enrichments, (b) water rods, and (c) Gd-bearing rods to simulate BWR design; (2) as an array modified by replacement of central rods with spent fuel representing assembly average conditions; and (3) as an array modified by replacement of central rods with spent fuel rods representing the burnup typical of the tips of fuel rods (a consequence of axial burnup distribution in PWRs).

This experiment is related to Experiment 204.

Spent-fuel storage requirements at many of the nation's nuclear power plants will soon exceed the available storage space. To increase storage in this limited space, criticality safety limits will have to be extrapolated beyond their range of validation. Such extrapolation can be inimical to safety. On the other hand, such extrapolation will avoid the unacceptable alternative of implementing reactor shutdowns as the means to alleviate the spent-fuel storage problem. Such shutdowns would necessitate replacement of the nation's nuclear electric power production (potentially 20%) by fossil sources, which could result in an unacceptable addition to environmental pollution and, during the transition, in an undesirable economic dislocation. The proposed experiment will avoid this dilemma by validating consolidation of stored spent-fuel through accounting for burnup credit, thus averting criticality safety limit extrapolations and obviating consideration of reactor shutdowns. The long-term solution to spent-fuel storage -- establishment of a permanent repository -- will still be necessary.

In a recent paper, Holman and Wittkopf[1] report that in determining fuel assembly burnup credit for safe storage of spent fuel, the non-uniform burnup effect is quite sensitive to the burnup profile used and to the burnup range over which it is applied. In particular, these investigators report that use of a "worst case" profile over the entire burnup range could result in a non-uniform burnup penalty that is conservative in terms of enrichment by as much as 1.6 w/o ^{235}U. Conversely, use of a burnup profile near end-of-life could over-predict the enrichment limit by as much as 0.3 w/o ^{235}U. These investigators conclude that a standard method should be developed for the selection of non-uniform axial burnup profiles, and that all burned fuel storage rack designs should comply with this standard. The proposed experiment can also be used to validate such a standard method by incorporating axial burnup profiles in the fuel loadings used in the critical experiments.

1. P.L. Holman and W.A. Wittkopf, "Axial Burnup Profiles and Spent Fuel Rack Burnup Credit," Proc. of the 1994 ANS Topical Meeting on Advances in Reactor Physics, III, 378, Knoxville, April 11-15, 1994.

These experiments will foster the objective set forth in DNFSB Recommendation 93-2 that prediction of the critical state of a system by methods that use theory must be benchmarked against good and well characterized critical experiments.

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Suggested Experimental Facility

Sandia National Laboratory.

Contact

Michaele C. Brady
Sandia National Laboratories
Dept. 6643, P.O. Box 5800
Albuquerque, NM 87185-5800
(505) 845-9099 FAX (505) 844-0244

Prioritization of Experiments

Application	Rating
Resolution of Outstanding Subcriticality Issue	8
Resolution of Subcriticality Issue for New DOE Program	5
Resolution of Experiment/Calculation Discrepancy	3
Improvement in Economics	2
Enhancement of Knowledge Base	1

Experiment 102: Large Array of Small Units

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Resolution of Experiment/Calculation Discrepancy.	3	11	2/2: 3

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF), or Rocky Flats (arrays of uranium solutions).

Experiment 105: High-Energy Burst Reactor Experiments

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 9

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment 301: Plutonium Solution in Concentration Range from 8 to 17 g/l

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 10

Suggested Experimental Facility

None available at the present time.

Experiment Program 501: Assessment Program for Materials Used to Transport and Store Discrete Items and Weapons Components

Application	Rating	Score	Place
Improvement in Economics;	2		
Enhancement of Knowledge Base.	1	3	4: 11

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment 502a: Absorption Properties of Waste Matrices

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Resolution of Experiment/Calculation Discrepancy;	3		
Enhancement of Knowledge Base.	1	12	1: 1

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment 502g: Determination of Fissionable Material Concentrations in Waste Materials

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 7

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment Program 504: Accident Simulation and Validation of Accident Calculations Program

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Improvement in Economics.	2	10	3: 8

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment Program 505: A Program to Evaluate Measurements of Sub-Critical Systems

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 4

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment Program 601: Critical Mass Experiments Program for Actinides

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 6

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment 609: Validation of Calculational Methodology in the Intermediate Energy Range

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Enhancement of Knowledge Base.	1	9	3/6: 5

Suggested Experimental Facility

Los Alamos Critical Experiments Facility (LACEF).

Experiment 702: Spent Fuel Safety Experiments (SFSX)

Application	Rating	Score	Place
Resolution of Outstanding Subcriticality Issue;	8		
Improvement in Economics;	2		
Enhancement of Knowledge Base.	1	11	2/2: 2

Suggested Experimental Facility

Sandia National Laboratory.

NUCLEAR CRITICALITY STEERING COMMITTEE

LTC Jim Felty (Co-Chairman), DP-241, 3-5494, FAX 3-9743
William Miller (Co-Chairman), DP-652, 3-9841, FAX 3-6628
Dennis Cabrilla, EM-431, 427-1693, FAX 427-1881
Max Clausen, FM, 6-8217, FAX 6-3161
Al Evans, ER-13, 3-3427, FAX 3-9513
Tom Evans, HR, 6-3887, FAX 6-3472
Ivon Fergus, EH-11, 3-6364, FAX 3-4672
Philip Hemmig, NE-42, 3-3579, FAX 3-3808
Burton Rothleder, EH-64, 3-3726, FAX 3-9523
Barry Sullivan, LM, 6-5623, FAX 6-3119

METHODOLOGY AND EXPERIMENTS SUBCOMMITTEE

Dennis Cabrilla (Co-Chairman)
Burton Rothleder (Co-Chairman)

R. Michael Westfall	615-574-5267	615-574-3527	ORNL
Ivon Fergus	3-6364	3-3672	EH-11
J. Blair Briggs	208-526-7628	208-526-0528	INEL
Richard Malenfant	505-665-5645	505-665-3657	LANL
Ed Fujita	708-252-4866	708-252-4500	ANL
Dennis Galvin	3-2972	3-8754	DP-68

TRAINING SUBCOMMITTEE

Max Clausen (Chairman)

Dick Trevillian	3-3074	3-4672	EH-11
Tom Mclaughlin	505-667-7628	505-665-4970	LANL
Henry Harper	208-533-7775	208-533-7623	ANL
Richard G. Vornehm	615-576-2289	615-241-2772	Y-12
Nick Delaplane	6-9403	6-7734	EM-121
George Kachadorian	202-275-6445	201-275-7710	HR-33

Attachment 3

LIST OF ACRONYMS

ANS	American Nuclear Society
CSBEP	Criticality Safety Benchmark Evaluation Project
CSEWG	Cross Section Evaluation Working Group
DNFSB	Defense Nuclear Facilities Safety Board
DP-1	Assistant Secretary for Defense Programs
ENDF	Evaluated Nuclear Data File
LACEF	Los Alamos Critical Experiments Facility
NCESC	Nuclear Criticality Experiments Steering Committee
NCTSP	Nuclear Criticality Technology and Safety Project
OECD/NEA	Organization for Economic Cooperation and Development/ Nuclear Energy Agency
ORNL	Oak Ridge National Laboratory
USNRC	United States Nuclear Regulatory Commission