DEFENSE NUCLEAR FACILITIES SAFETY BOARD

625 Indiana Avenue, NW, Suite 700, Washington, D.C. 20004
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May 19, 1997

The Honorable Federico F. Peña
Secretary of Energy
1000 Independence Avenue SW
Washington, D.C. 20585

Dear Secretary Peña:

On May 19, 1997, the Defense Nuclear Facilities Safety Board (Board), in accordance with 42 U.S.C. § 2286a(a)(5), unanimously approved Recommendation 97-2, which is enclosed for your consideration. This recommendation addresses the continuation of criticality safety at defense nuclear facilities in the Department of Energy (DOE) complex.

42 U.S.C. § 2286d(a) requires that after your receipt of this recommendation, the Board promptly make it available to the public in DOE's regional public reading rooms. The Board believes the recommendation contains no information that is classified or otherwise restricted. To the extent this recommendation does not include information restricted by DOE under the Atomic Energy Act of 1954, 42 U.S.C. §§ 2161-68, as amended, please arrange to have it promptly placed on file in your regional public reading rooms.

The Board will also publish this recommendation in the *Federal Register*.

Sincerely,

John T. Conway
Chairman

Enclosure

c: Mr. Mark B. Whitaker, Jr.

RECOMMENDATION 97-2 TO THE SECRETARY OF ENERGY

Pursuant to 42 U.S.C. § 2286a(a)(5),
Atomic Energy Act of 1954, As Amended

Dated: May 19, 1997

In the first two or three decades following the Manhattan Project, nearly every laboratory of the Atomic Energy Commission (AEC) had an active program addressing some phase of the physics of neutron chain-reacting systems. Each such study included a balance of experiment and theoretical analysis, as is common in engineering research. Some of the programs supported the design of nuclear weapons, some were directed at the design of nuclear reactors, and some were conducted simply as basic engineering research.

As a result of these programs, expertise in neutron chain–reacting systems was widespread; there was an abundance of individuals skilled in achieving and controlling neutron chain reactions. These individuals usually became expert as well in methods for avoiding a chain reaction when this is not desired. The state of a self-sustaining chain reaction is commonly called "criticality." Guidance by these knowledgeable individuals helped establish an admirable record of criticality safety in the many programs the AEC conducted with fissionable material. While occasional accidental criticality did occur at the peak of AEC activity, it seldom caused injury to workers, and never led to radiation affecting individuals off site. Furthermore, the last such instance of inadvertent criticality in the United States occurred about 20 years ago.

Some criticality research continued to replenish the supply of these experts through the era of the Energy Research and Development Administration (ERDA) and into the period of the Department of Energy (DOE), though at a steadily reduced rate. Today there is almost no theoretical research in criticality being conducted, although university courses continue to instruct students in the theoretical expertise that has already been developed. However, most of the early experts in criticality safety control were drawn from experimental research programs. For a number of years, the DOE complex placed its reliance for criticality safety on the diminishing number of such criticality control experts developed in earlier years. Recently, however, DOE has been forced to supplement that group with engineers trained on the job in the conduct of criticality calculations. The latter group contains few individuals who have conducted critical mass experiments. Thus collectively they have little practical experience pertinent to avoiding chain reactions in nonreactor environments.

In 1993, the Defense Nuclear Facilities Safety Board (Board) sensed that the source of experimental competence in prevention of inadvertent criticality was in danger of being lost entirely as a result of DOE's impending closure of the last critical mass facility in the country. That closure would have ended the hands-on education of new generations of scientists and engineers in the properties and behavior of critical systems. However, expertise in criticality safety will continue to be needed as long as fissionable material is used and stored. The Board viewed the end of experimental criticality studies as a threat to criticality safety in future DOE activities, and issued Recommendation 93-2, which advised against such action. As stated in that Recommendation,

> The Board believes it is important to maintain a good base of information for criticality control, covering the physical situations that will be encountered in handling and storing fissionable material in the future, and to ensure retaining a community of individuals competent in practicing the control.

The Secretary accepted Recommendation 93-2 on May 12, 1993, noting the importance of (1) improving and maintaining a criticality control information base, especially to support future operations in handling, processing, and storage or disposal of fissionable material; (2) retaining a cadre of individuals competent in practicing criticality control and safety; (3) continuing an experimental program; (4) continuing an education program for criticality safety professionals; (5) coordinating the criticality program among various users; (6) performing a criticality assessment with respect to defense nuclear facilities to determine the scope of current and future requirements for criticality experiments, predictability, and training; and (7) investigating the mission requirements, program funding, and landlord issues.

Since Recommendation 93-2 was issued, DOE has made substantial progress in coordination and implementation of the criticality experiments program. Funding for the program has stabilized, albeit at a low level, and work has been initiated on a prioritized list of experiments. However, a basic set of problems continues to exist throughout the DOE complex with regard to criticality control. Among the problems are the following:

1. In the past, it was found that only a few experienced criticality engineers were needed to guide criticality safety at even the most complex facilities. However, at the majority of DOE facilities where accidental criticality is currently a potential issue, the number of engineers assigned to criticality control is surprisingly large. The typical criticality safety staff consists mainly of individuals who have no prior first-hand experience in criticality, and who have been trained on the job in analytical aspects of criticality control after being hired. They lack background in neutron physics on a fundamental level, and are not familiar with work on assemblies near the critical state, activities that would foster intuitive approaches to criticality control. Therefore, when faced with the need to determine what must be done to avoid a chain reaction, they most frequently fall back on complex multidimensional Monte Carlo calculations. Their use of simplified methods and their reliance on published data are minimal. The Board points out that complex analysis may be needed for some cases, such as those with difficult geometry, but such analysis is time-consuming and may dramatically slow preparation for the activities being evaluated.

2. Operational practices at some DOE facilities place criticality control in a central position in operations, with the criticality engineer establishing certain aspects of

operation for safety reasons. Effectively, the criticality engineer, with all the shortcomings described in 1 above, becomes the critical path for line management. This causes delays in the ability of the line management to develop overall safety requirements.

3. In the past, most of the criticality safety data in guidance documents has been directed to activities involving production of nuclear weapons. The guidance has incorporated data from several experimental programs established to ensure avoidance of unintentional criticality in weapons programs. The experimental data has often been generalized by analysis of the experimental results and by theory benchmarked against experiments. The missions of DOE have changed substantially, however, and guidance for other types of activities is now needed. It is particularly important that guidance be developed to help in analyzing the safety of cleanup operations and the handling, storage, and shipping of miscellaneous containers that include fissionable material mixed with other material.

The above problems have had a significant effect on the productivity of several DOE operations. They have adversely affected safety by extending the period of time required for meeting safety commitments, such as those responding to Board Recommendation 94-1. In so doing, they have absorbed resources potentially needed for other safety-related activities at DOE's defense nuclear facilities. In this light, the Board believes action should be taken to eliminate these problems and to ensure that criticality safety can continue to be achieved efficiently in DOE's future operations.

Therefore the Board recommends that DOE:

1. Restructure the program of experimental research in criticality established under the Implementation Plan for Recommendation 93-2 to emphasize determination of bounding values for criticality of systems most important in the current programs at DOE facilities.

2. Organize the records of calculations and experiments conducted to ensure the criticality safety of DOE's past operations so as to provide guidance for criticality safety in similar situations in the future and avoid repetition of past problems.

3. Establish a program to interpolate and extrapolate such existing calculations and data as a function of physical circumstances that may be encountered in the future, so that useful guidance and bounding curves will result.

4. Collect and issue the experimental and theoretical data from the above in a publication as guidance for future activities.

5. Clarify in guidance that simple, bounding methods of analysis can be used in place of specific theoretical analysis in setting criticality limits for processes, and that limits derived in this

manner are even preferable where they serve the purpose. The decreasing order of preference should be experimental data, theory benchmarked against experimental data, and nonbenchmarked criticality analysis with an adequate safety margin.

6. Develop and institute a short but intensive course of instruction in criticality and criticality safety at DOE's criticality experiments facility to serve as the foundation for a program of formal qualification of criticality engineers. This course should instill in students a familiarity with the factors contributing to criticality, the physical behavior of systems at and near criticality, and a theoretical understanding of neutron multiplication processes in critical and subcritical systems. A goal would be for reliance for criticality safety at any DOE facilities to rest in a group of individuals endowed with such experience.

7. Where not already done, assign criticality safety as a staff function assisting line management, with safety responsibility residing in line management.

8. Identify a core group of criticality experts experienced in the theoretical and experimental aspects of neutron chain reactions to advise on the above steps and assist in resolving future technical issues.

9. Organize funding of the criticality research and instruction program to improve its stability and to recognize the cross-cutting importance of this activity.

John T. Conway, Chairman