

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

April 1, 2010

MEMORANDUM FOR: T. J. Dwyer, Technical Director

COPIES: Board Members

FROM: T. Spatz

SUBJECT: Z Machine Hazard Categorization

Introduction. Sandia National Laboratories (SNL) conducts plutonium isentropic compression experiments with the Z machine to provide weapon designers with equation-of-state information. SNL recently refurbished the Z machine, doubling its power capacity; preparations are now underway to perform the first isentropic compression experiment. The Z machine relies on a primary containment feature that includes a set of fast-acting closure valves interlocked with the compression signal, and a secondary containment feature that provides a barrier to any potential release within the vacuum insulator stack. SNL categorized the Z machine as less than Hazard Category 3 (HC-3) based on the quantity of plutonium being less than the threshold quantity for HC-3 facilities (8.4 grams) defined in Department of Energy (DOE) Standard 1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*. As a result, the safety requirements of Subpart B of the Nuclear Safety Management Rule (Title 10 Code of Federal Regulations, Part 830) have not been applied to the facility.

The staff of the Defense Nuclear Facilities Safety Board (Board), T. Spatz, F. Bamdad, and D. Minnema, toured the facility and held a meeting at the site on March 9, 2010, to discuss the contractor's approach to the hazard categorization of this facility.

Background. DOE Standard 1027-92 outlines a two-part methodology for hazard categorization. The first part is the initial hazard categorization, which depends only on the quantity of material in the facility and the appropriate ground rules. The second part is final hazard categorization, which entails analyzing an unmitigated release of hazardous material for the specific activity.

Per the standard, the initial radiological hazard screening "enables facility managers to determine quickly the likely facility categorization...." As noted, this initial screening considers only the quantities of radiological material in the facility; the material form, location, dispersibility, and interaction with available energy sources are not considered. The threshold quantities for radiological materials are given in Attachment 1 of DOE Standard 1027-92. The standard states that DOE used an Environmental Protection Agency model to derive the tabulated threshold quantities for HC-3 facilities. This model and the threshold quantities are

based on airborne release fractions (ARF) for non-volatile metals such as uranium, plutonium, tantalum, thorium, and americium, among others, which have been set at 0.001. Importantly, however, this section of the standard specifies “Whenever questions concerning appropriate facility categorization arise, provide for a margin of error by selecting the higher hazard category.”

DOE Standard 1027-92 next specifies determination of the final categorization based on an “unmitigated release” of available hazardous material. For the purposes of hazard categorization, “unmitigated” is meant to encompass material quantity, form, location, dispersibility, and interaction with available energy sources, but not control features (e.g., ventilation system, fire suppression) that would prevent or mitigate a release. The standard states further that “preventive and mitigative features are not to be considered in hazard categorization.” The lower threshold identified in the standard for designating a facility as HC-3 using the unmitigated analysis is 10 rem total effective dose equivalent at 30 meters, based on a 24 hour exposure.

SNL Hazard Categorization. Before initiating the first series of experiments with the Z machine in 2005, SNL issued *Hazard Categorization Position Paper for the Sandia National Laboratories Z Machine Plutonium Isentropic Compression Experiment* to show that these experiments met the criteria in DOE Standard 1027-92 for designation as less than HC-3. This position paper relied on two “null shot” experiments to demonstrate that the ARF is consistent with that used in deriving the threshold quantities of DOE Standard 1027-92. Therefore, SNL concluded that the Z machine met the initial radiological hazard screening criteria for designation as less than HC-3. However, these experiments were conducted with the vacuum system functional, which mitigated the release of material. The applicability of these tests is not discussed in the present report; however, the staff believes these tests demonstrated only that the secondary containment feature mitigates the hazard. In 2007, after the refurbishment of the Z machine, SNL issued *Post Z Machine Refurbishment Evaluation for the Plutonium Isentropic Compression Experiment, Stand Alone Hazard Analysis Safety Basis*, which relies heavily on the 2005 position paper as the technical basis for concluding that the facility should remain categorized as less than HC-3.

Discussion. The documents provided by SNL to support the hazard categorization decision do not appear to be consistent with DOE Standard 1027-92. The anticipated ARF must be considered when applying the threshold values from Attachment 1 of the standard; any activity that could result in a greater release fraction for a substantial portion of the facility inventory must be fully considered. The vaporization of plutonium during the Z machine operation does not fit within the bounding consequence analysis in the Environmental Protection Agency methodology used to establish the threshold quantities for the initial hazard categorization. In fact, the ARF could be two to three orders of magnitude higher, according to the data given in Appendix A of *Technical Background Document to Support Final Rulemaking Pursuant to Section 102 of the Comprehensive Environmental Response, Compensation, and*

*Liability Act: Radionuclides*¹ for vapors and gases. Therefore, using the threshold quantity of 8.4 grams of plutonium as the basis for hazard categorization is not applicable to the isentropic compression experiments.

The hazard analysis is intended to identify potential initiating events that could affect the hazardous material and lead to a release. However, SNL's analysis for final hazard categorization credited the controls designed to mitigate a release. The secondary containment feature that maintains a vacuum during isentropic compression experiments is a mitigative control and is relied upon to protect workers and the public. Failure of this control would constitute an unmitigated release and is not properly analyzed in the SNL documents. It should be noted that the Z machine can pre-fire (which means that one or more of the 36 modules fires prematurely without receiving a command to fire) or can operate without the secondary containment providing full vacuum (which could result into a release to the outside). Depending on the exact circumstances of the pre-fire, the plutonium target may be damaged. SNL has not presented an analysis showing the radiological consequences of such events.

Conclusion. Instead of performing a hazard analysis to permit proper final hazard categorization, SNL attempted to show that the initial hazard categorization was sufficient by stating that the release fraction for plutonium in the experiment was consistent with that used in deriving the HC-3 threshold quantities. In doing so, SNL credited the use of the secondary containment and its vacuum system for the Z machine, which mitigates the release of hazardous material and reduces the airborne release fraction appropriate during an accident scenario. The Board's staff believes that this approach is not consistent with DOE's recommended methodology for unmitigated analysis.

To comply with DOE Standard 1027-92, a final hazard categorization needs to be performed that is based on the unmitigated consequences with an appropriate ARF value. If the consequences exceed the threshold for HC-3 facilities, the safety requirements of Subpart B of the Nuclear Safety Management Rule (Title 10 Code of Federal Regulations, Part 830) must be followed. These requirements would help ensure that the hazards associated with Z machine operations are comprehensively analyzed, the consequences of postulated accidents are understood, and any controls necessary to mitigate these consequences are identified and rigorously implemented.

¹ A Report to the Emergency Response Division, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, February 1989, Prepared by ICF Incorporated and C-E Environmental, EPA Contract 68-03-3452.