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Title: Quantifying the Severity of Criticality Limit Violations

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Introduction

Since August of 1994, the Los Alamos National Laboratory has been using the LANL Categorization Criteria Matrix for determining the need for and level of reporting criticality safety limit violations. The LANL Categorization Criteria Matrix is DOE approved, and is cited in a DOE approved SAR for the LANL Plutonium Facility as the method used to determine whether a criticality limit violation is reportable to DOE via 5000.3B "Occurrence Categorization, Notification and Reporting Requirements" (replaced by DOE O 232.1). The use of the LANL Categorization Criteria Matrix provides a framework that allows criticality limit violations to be objectively reviewed in terms of what were the consequences of the criticality safety limit violation. Using the LANL Categorization Criteria Matrix helps the criticality safety engineer and line supervision explain to others, in a

quantifiable manner, the significance of the criticality limit violation, the levels of margin of safety built into operations, and demonstrate the difference between evaluated conditions and working conditions.

Description

The criticality safety portion of the LANL Categorization Criteria Matrix is divided into six sections. The sections that are of particular importance for criticality safety limit violations are Sections III and IV. The other four sections pertain to criticality accidents, emergency evacuation alarm perturbations (procedural and mechanical), counting/assaying instrumentation malfunctions/perturbations, and holdup.

Section III. "*Compromised criticality controls and barriers*". In this section a determination is made as to the number of barriers (neutronic coupling, poisons, density, reflection, shape, volume, concentration, enrichment, moderation, and mass) that are left in place. If there are at least two barriers left in place, then proceed to Section IV. If only one barrier is left in place, then the criticality limit violation is at least an off normal, and proceed to Section IV. If there are no barriers left in place, then the criticality limit violation is an unusual occurrence.

Section IV. "*Events or conditions resulting in abnormal system k_{eff}.*" The evaluation of this section is based on the normal maximum system k_{eff}(max, normal), and the k_{eff} for the abnormal condition k_{eff}(abnormal). After determining k_{eff}(max, normal), we determine $\alpha \equiv 1 - k_{eff}$(max, normal). Next we determine k_{eff}(abnormal) and Δk_{eff}, which is

equal to k_{eff}(abnormal) minus k_{eff}(max, normal). If Δk_{eff} is less than $\alpha/5$, then the event is not necessarily reportable unless from Section III. it has been determined that it is an off normal event. If $\alpha/5 \leq \Delta k_{eff} \leq \alpha/2$, then the event is off normal. If $\Delta k_{eff} > \alpha/2$, then the event is unusual.

Results

A hypothetical example will highlight the LANL Categorization Criteria Matrix.

Assume the following criticality safety limits for a work station exist:

4,500 grams Pu as metal or oxide.

Assume that the metal limit is violated by 4,500 grams, i.e., an operator inadvertently introduces into the same workstation an additional 4,500 grams of Pu metal and then realizes that the criticality limits have been violated. Also assume that after working through Section III there are at least two barriers left in place. Based on Section IV, is this a reportable limit violation? Assume the original evaluation for this operation included: 4,500 grams Pu as a metal sphere, at theoretical density, and with 5% ^{240}Pu.

Assume that the operation is the conversion of oxide to annular, metal rings that have an outer diameter of three inches and a height to diameter of one. From the above we can use the DANTSYS codes (a set of discrete ordinate codes) to evaluate k_{eff}(max, normal) and k_{eff}(abnormal).

The k_{eff}(max, normal) is based on 4500 grams plutonium as a sphere at theoretical density

and 5% ^{240}Pu. This was done to provide operating personnel flexibility in designing crucibles. This results in a k_{eff}(max, normal) of 0.779. If Monte Carlo codes are used, then care must be taken to assure that the Δk_{eff} is greater than its standard deviation[1, 2]. Therefore, $\alpha \equiv 1 - 0.779 = 0.221$.

Even though spacing of fissile material is desired, the overbatch was modeled as one annular ring stacked on top of the other annular ring, which is conservative. Using the above model, which is for a total of 9,000 grams of Pu metal, k_{eff}(abnormal) = 0.649. This results in a $\Delta k_{eff} = 0.649 - 0.779 = -0.13$.

What does a negative Δk_{eff} imply? Simply that the level of conservatism built into the original analysis swamps the actual k_{eff} associated with the designed operations.

Using this method to evaluate whether this incident is reportable, based solely on criticality safety, one would have to conclude that it is not. This does not mean it would not be reportable for other reasons, but it gives the evaluators the means to now redirect their attention to other areas, such as, conduct of ops, procedures, etc.

If Δk_{eff} would have been greater than zero, then the determination on the level of reporting would be based on the evaluation of Δk_{eff} to the following:

If $\Delta k_{eff} \leq \alpha/5$,	then it is not reportable
If $\alpha/5 \leq \Delta k_{eff} \leq \alpha/2$,	then report as off normal
If $\Delta k_{eff} > \alpha/2$,	then report as an unusual occurrence.

Conclusions

Use of the LANL Categorization Criteria Matrix has provided a quantifiable method for determining the need for and level of reporting of criticality limit violations. Its use has resulted in savings of both time and money (approximately $7,000 per report at LANL), and demonstrates, to non-criticality safety professionals, the level of criticality safety margins in place. Finally, its use has minimized the reporting of inconsequential process upsets in occurrence summaries compiled by regulatory bodies.

References

1. Stuart G. Vessard, "A Review of the Statistics Used in Monte Carlo Codes," LA-UR-95-1692, NCTSP (Nuclear Criticality Technology and Safety Project), San Diego, Ca., May 1995.

2 R. Douglas O'Dell, "The Use of Deterministic Codes for 'Separating the Wheat from the Chaff' in Benchmarking Models and Calculations," LA-UR-95-951, NCTSP (Nuclear Criticality Technology and Safety Project), San Diego, Ca., May 1995.