Hazard Categorization Reduction via Nature of the Process Argument

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INTRODUCTION

This paper documents the Hazard Categorization (HC) and Criticality Safety Evaluation (CSE) for activities performed using an Inspection Object (IO) in excess of the single parameter subcritical limit of 700 g of U-235. By exceeding the single parameter subcritical limit and the subsequent potential for criticality, the IO is initially categorized as HC2. However, an application of the nature of the process argument was employed to reduce the HC from HC2 to less than HC3 (LTHC3).

With Department of Energy approval, a Hazards Assessment Document with high-level (facility-level) controls on the IO negates the potential for criticality and satisfies the nature of the process argument to reduce the HC from HC2 to LTHC3.

NATURE OF THE PROCESS ARGUMENT

Department Of Energy-Standard-1027[1] requires a facility categorization of HC 2 when greater than 700 grams of U-235 is present. However, Section 4.2.4 of the Supplemental Guidance states in that,

"…the facility may still be shown to be Hazard Category 3 (or less than Hazard Category 3) if it was initially categorized as a Hazard Category 2 facility solely based upon the potential for criticality through an analysis that demonstrates nature of process precludes criticality, provided that no operational criticality safety controls or limits are needed."

"In demonstrating that the nature of process precludes criticality, the analysis should demonstrate that a potential for criticality does not exist for a given material configuration, based on actual quantity, form, shape, and collocation with moderators and reflectors."

Section 4.3 of the Standard continues that a Radiological facility (i.e. LTHC3 facility) may have a Criticality Safety Program and must preclude the potential for criticality through the use of only "high-level controls."

The balance of this presentation demonstrates that:

1. The IO does not present a criticality for a given material configuration, based on actual quantity, form, shape, and collocation with moderators and reflectors, and
2. The IO potential criticality is precluded through the use of *only* "high-level controls."

INSPECTION OBJECT DESCRIPTION

The IO will be manufactured as five clad plates measuring nominally 10 cm in width, 10 cm in length, and 2.0 cm in thickness, having the volume of an approximate 1000-cm^3 uranium cube, as demonstrated in Figure 1 **Error! Reference source not found.**. Note that the IO

may not necessarily be configured in a cube. The five plates will be crafted out of uranium metal (nominally 100%), with enrichment no greater than 20% U-235 by mass. The total mass of the U-235 in the assembled IO (totaling 5 plates) will not be greater than 3.82 kg.

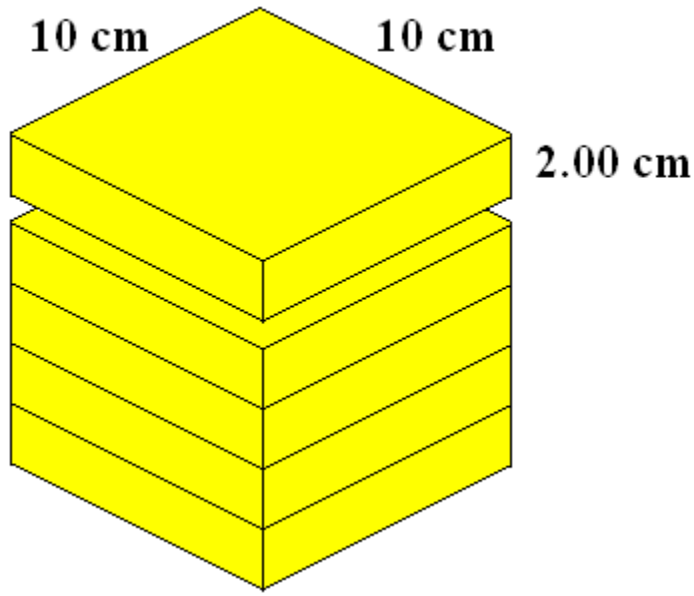

Figure 1. Low-Enriched Uranium Inspection Object composed of five separate plates.

The five IO plates may be arranged in configurations other than a cube and may be in close proximity to reflectors, moderators, or both. In spite of the possibility of various configurations and collocation with a number of moderators and reflectors, the IO fissionable material (five plates and any physically realistic moderator or reflector) cannot achieve criticality[2].

ACTIVITY DESCRIPTION

With Department of Energy approval, a Hazards Assessment Document with high-level (facility-level) controls on the IO negates the potential for criticality and satisfies the nature of the process argument to reduce the HC from HC2 to LTHC3.

Experiments involving the IO may be performed at any INL facility, including Non-Nuclear, or Radiological (LTHC3), facilities but limit the fissile material at these nonnuclear facilities to the IO. The IO may be located in proximity to dense material acting as reflectors, such as lead, concrete, steel, natural uranium, or depleted uranium. Additionally, the IO may be positioned adjacent to reflectors comprised of lighter materials such as polyethylene, light water, heavy water, graphite, or beryllium[2].

The IO may be subjected to photons generated by linear accelerators at various energy levels. Subjecting the IO to this radiation will result in photo-fissioning of U-235 atoms. The nature of the IO ensures that all configurations of the five plates, material quantity, form, shape, and collocation with moderators and reflectors are subcritical, as evidenced by a $k_{eff} < 1$. The k_{eff} of the fissionable material is not affected by an external photon source. Therefore, subjection of the IO to photons generated by linear accelerators at various energy levels cannot create a criticality.

HIGH-LEVEL CONTROLS FOR NON-NUCLEAR FACILITIES

The following Design features pertaining to the Low-Enriched Uranium Inspection Object have been credited:

1. The Inspection Object is enriched to no greater than 20 wt.% ^{235}U,
2. The Inspection Object is comprised of no greater than 3.82 kg of ^{235}U,
3. The Inspection Object is comprised of no more than 5 plates, and
4. Each Inspection Object plate is nominally 10.0 cm square and 2.0 cm in thickness.

Each of the following controls is applicable to the non-nuclear facility:

1. A method of tracking and controlling radioactive material inventory in the facility where the Inspection Object is removed from a fully DOT-compliant shipping container shall be implemented such that the sum of the ratios as described in DOE-STD-1027-92 does not exceed one (1).

2. No other fissionable material may be present within the facility containing the Inspection Object.

CONCLUSION

The five IO plates enriched to no greater than 20 wt. % and weighing no greater than 3.82 kg ^{235}U cannot achieve criticality[2]. Additionally, IO subjection to photons generated by a linear accelerator cannot create a criticality. Only High-Level Controls apply to the IO. Therefore, the potential for the Inspection Object achieving criticality is precluded by the nature of the process. By application of the nature of the process and with concurrence by DOE, the final hazard categorization for the Inspection Object is LTHC3 Radiological.

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1. DOE-STD-1027, "Hazard Categorization and Techniques for Compliance with DOE Order 5480.23," Change Notice No. 1, Mat 2007

2. INL/INT-11-20982, "Criticality Safety Evaluation for the DTRA Low-Enriched Uranium Inspection Object," March 2011