Implementation of Methodology for Final Hazard Categorization of a DOE Nuclear Facility (U)

Kevin R. O'Kula

Washington Safety Management Solutions LLC
P. O. Box 5388
Aiken, SC 29804-5388
Email: kevin.okula@wxsms.com

Jerry Hansen

Westinghouse Savannah River Company
730-M Savannah River Site
Aiken, SC 29808
Email: jerry.hansen@srs.gov

INTRODUCTION

U.S. Department of Energy (DOE) nuclear facilities are categorized by the level of hazard they pose to workers, the general public, and the environment. A preliminary hazard category is based on inventory alone and is used to determine the level of analysis, documentation, and associated controls that are needed to prevent or mitigate postulated accident conditions. A final hazard categorization, based on DOE-STD-1027-92 and a limited safety analysis, is typically performed that may result in a different hazard category (1). While a number of nuclear facilities have been reduced in Hazard Category (HC) from HC-2 (potential for significant onsite consequences) to HC-3 (potential for significant but localized consequences), there has been little guidance to reduce a HC-3 facility to radiological, and consequently, few nuclear facilities have been successfully changed from HC-3. This paper applies the methodology outlined in DOE-STD-1027-92 and interpreted in recent DOE guidance to a nuclear material storage facility at the Savannah River Site to reduce the category of the facility to below HC-3.

FINAL HAZARD CATEGORIZATION METHODOLOGY

DOE Technical Position NSTP 2002-2 allows revision of the threshold values for radionuclides that establish the ingestion pathway or direct inhalation exposure as limiting (2). The revision is based on the physical and chemical form and available dispersive energy sources for the facility and its radiological materials, to establish the material-at-risk (MAR) and the fraction impacted by the accident condition (damage ratio - DR), applying DOE-HDBK-3010-94 or other defensible reference data for airborne release fractions (ARFs) and respirable fractions (RFs) (3). This approach can be considered if the alternative airborne release fractions are be shown to be significantly different from the values used in technical background document to DOE-STD-1027-92, for the most conservative material form that may be present.

In summary, NSTP 2002-2 is interpreted to allow threshold quantity values to be adjusted using:

$$\text{Radionuclide } TQ_{ARF} = \Delta_{ARF} * TQ_{EPA} \quad (1)$$

In Equation 1:
Δ_{ARF} is the ratio of EPA airborne respirable fraction to the justified, alternative fraction, and
TQ_{EPA} is threshold quantity from the EPA model.

Nuclear Facility Application

The facility of interest is a nuclear materials storage area used for storage of depleted uranium (0.2 wt.% ^{235}U) in the form of UO_3. The UO_3 is stored in 55-gallon drums lined with plastic bags, in a three-drum stack height. Each drum contains approximately 635 kg.

The radionuclides and quantity conservatively assumed present in each drum in the facility are ^{235}U, (1.27 kg), ^{238}U (528 kg), and ^{238}Pu (1.81E-06 kg).Two bounding unmitigated release conditions are used as a basis for this determination. These are an externally-initiated, seismic event, and an internally-initiated, fire event.

Natural Phenomenon – Seismic Event

In the subject facility, drums are stacked three high, although in some cases the edge of the stacked configuration is only two high, i.e., two tiers. During a seismic event, a number of drums may fall from the third tier, impacting the concrete floor to an extent that the drum containment of the UO_3 is compromised. It would be expected that some of the drums from the second tier would also fall. However, for the unmitigated release condition due to a seismic event, the facility structure is not assumed to collapse.

For this analysis, applicable Damage Ratio data was based on similar storage conditions for another nuclear storage facility (4). In the referenced analysis, a DR of 0.025 is used for drops of waste containers from heights

approximately equivalent to the third layer of the waste stack. The DR is doubled to 0.05 to account for uncertainty in test data and extension to the type containers used for storing UO_3 in the facility of interest. The same analysis concludes that for a drop from the top of a two-tier configuration, the DR is 0.01. In the present case, it is doubled to account for uncertainty in the testing. Thus, the total number of drums involved in a seismic event is (0.05 x 1340) + (0.02 x 1340) = 67 + 27 = 94, or an overall DR of 94/4,016 = 2.3%. For conservatism, this value is rounded up to 2.5%.

DOE-HDBK-3010-94 indicates that the bounding ARF for a powder in a closed container experiencing external impact is 1.0E-03 (4). The bounding respirable fraction for this condition is given as 1.0E-01, yielding an airborne respirable fraction of ARF x RF = 1.0E-04. The ARF x RF scaling factor to adjust the current Threshold Quantities is (1.0E-03)/(1.0E-04) = 10. The sum of fractions, i.e., the ratio of Material at Risk to the renormalized Threshold Quantities, for the seismic event is 0.93.

Process Upset Condition – Fire Event

In examination of the fire event, it is assumed that 180 drums are in proximity of the fire, and that two effects occur. The first effect assumed is pressurization of a number of drums (60) causing them to rupture and release UO_3 during the ensuing depressurization. The second effect assumed is fire-induced fall of the remaining 120 drums that are "influenced" by the fire, and drum breach. In the second effect, it is assumed that all 120 drums are located at the highest (third) tier.

The same sequential logic is used for the fire event as was applied to the seismic event, including evaluation of the MAR, DR, ARF, and RF for each of the two effects. The renormalized category 3 TQs are evaluated with the revised values and compared to the MAR quantities by radionuclide to form the ratio of MAR/(revised TQ) for each radionuclide. The total sum of fractions for the unmitigated fire release condition including the pressurization and fall/breach phases is 0.556 + 0.286 = 0.842.

RESULTS

The bounding unmitigated release conditions have been reevaluated for the nuclear storage facility using revised Final Hazard Categorization methodology compliant with DOE-STD-1027-92 and the guidance contained in NSTP 2002-2. The specific release conditions and the revised airborne respirable fraction (ARF x RF) applied are listed in Table I, along with the sum of fractions (MAR available for unmitigated release/DOE-STD-1027-92 Threshold Quantity for Category 3). For both hypothetical accident conditions, including the seismic and the fire events, the sum of fractions is less than one, indicating that the facility meets the 10 rem at 30 meters criterion, and thus does not present significant localized onsite consequences, given postulated unmitigated release conditions. The re-categorization allows a commensurate change in approach used to meet safety objectives.

Notes on Applying Revised Methodology

Several remarks are offered regarding application of the revised methodology to a specific facility:

- Each facility and activity must be evaluated based on the type of process conducted, chemical and physical form of the MAR, and the inventory
- Accident conditions vary in type and magnitude, but typically there are two to consider, one an external event and another a process upset condition
- Alternate pathways such as ingestion and gamma shine should be investigated, and compared with inhalation.

REFERENCES

1. DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports*, Change Notice No. 1, U. S. Department of Energy, Washington, D. C., (September 1997).
2. U.S. Department of Energy, Office of Nuclear and Facility Safety Policy, Nuclear Safety Technical Position, NSTP 2002-2 (November 13, 2002).
3. DOE Handbook, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*, DOE-HDBK-3010-94, U. S. Department of Energy, Washington, D. C., (December 1994), Change Notice 1 (March 2000).
4. Waste Isolation Pilot Plant CH SAR, DOE-95-2065, Revision 6, (June 2002).

Table I. Summary of Analysis for Unmitigated Release Conditions for the Nuclear Material Storage Facility

Unmitigated Release Condition	Release Mechanism	Default Airborne Respirable Fraction from DOE-STD-1027-92 (EPA Model)	Revised Product, ARF x RF	Sum of Fractions
1. Seismic Event	Drum Failure from third- and second tier fall	1.0E-03	1.00E-04	0.93
2. Fire Event	Pressurization of Drums	1.0E-03	2.00E-03	0.556
	Drum Failure and Subsequent Fall and Breach	1.0E-03	5.00E-04	0.286
	Total Unmitigated Release Condition due to Fire	1.0E-03	Not Applicable.	0.842