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ANSI/ANS-8.7 Applications for the Storage of Criticality Control Overpacks

Brittany Williamson

Senior Criticality Safety Engineer

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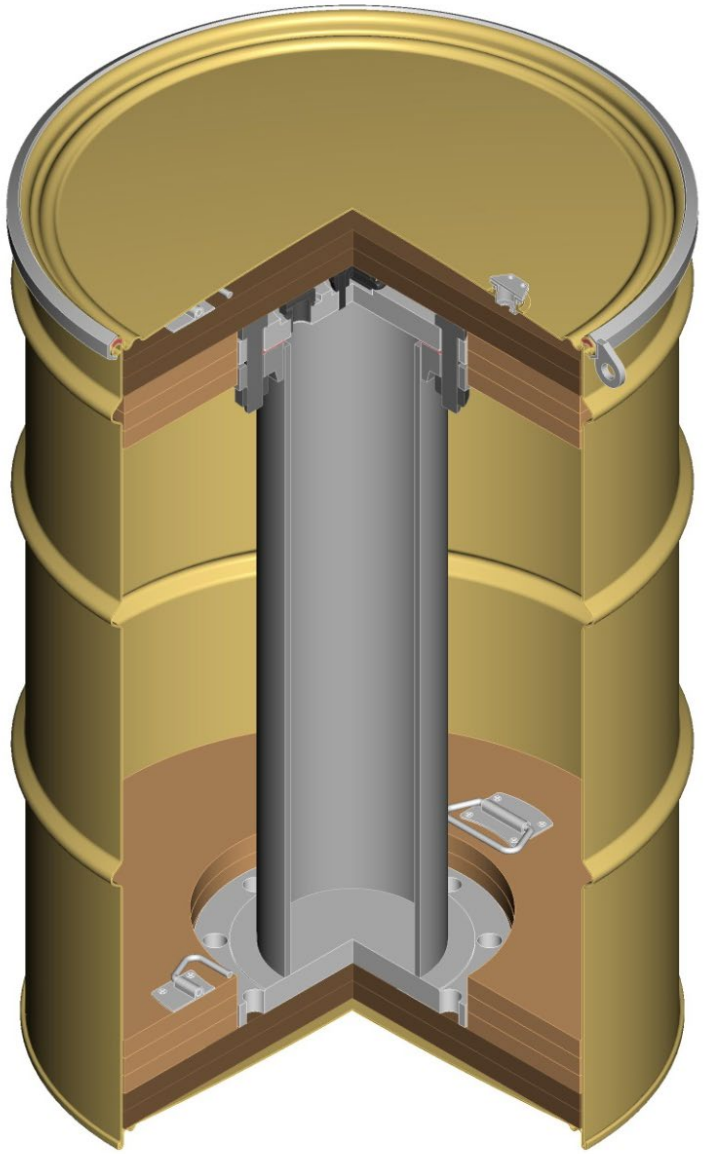
Background – SRS & K-Area

- The Savannah River Site is a 310-square-mile property owned by the Department of Energy and was established in the 1950s to create plutonium and tritium for the Cold War
- K-Area was a plutonium production reactor facility that was converted into a plutonium storage facility in the 1990s
- K-Area stores plutonium primarily in 9975 shipping packages and has both non-destructive assay and destructive examination capabilities

Criticality Control Overpacks (CCOs)

- A CCO is a 55-gallon drum with a 6-inch containment vessel with essentially no dunnage or shielding
- Plutonium oxide is mixed with an adulterant material in a downblend can
- Two downblend cans are placed in a CCO
- CCO mass limit is 380 FGE ^{239}Pu as oxide
- CCOs have an outer diameter of ~22 inches (~57 cm) and a height of ~35 inches (~88 cm)
- The containment vessel has an outer diameter of ~6 inches (16.8 cm)

CCOs



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CCO Storage at SRS

- A dedicated CCO storage pad is being constructed in K-Area
- Thousands of CCOs will be stored, characterized, and loaded into TRUPACT-IIs for transport to WIPP
- CCOs will be stacked 3 tiers high in very large arrays

ANSI/ANS-8.7-1998, *Nuclear Criticality Safety in the Storage of Fissile Materials*

- ANS-8.7 provides subcritical mass values for air-spaced arrays of fissile material
- There are multiple tables that provide series of subcritical mass limits as a function of fissile form, isotopics, spacing, moisture content, and array size
- Spacing is accounted for by using a cubic cell dimension of x mm (x = 254, 305, 381, 457, 508, and 610)
- The lowest mass limit per unit is obtained with the largest array size (1,000 units), highest moisture content (H/X = 20), and smallest cell dimension (254 cm)

Normal Conditions - CCO

- Spacing
  - A CCO is 570 mm in diameter and 880 mm in height
  - The CCO can be conservatively approximated as a cubic storage cell with a unit cell dimension of 570 mm
- Moisture
  - The highest expected H/Pu for downblended Pu oxide is ~15.
- Array size
  - A 10x10x3 array is conservative

Normal Conditions – ANS-8.7

Table 5.8
Unit Mass Limit in Kilograms of Plutonium per Cell in Water-Reflected Storage Arrays: Oxides, 100 wt-% ^{239}Pu

Number of Units in Cubic Storage Arrays	*Minimum Dimension of Cubic Storage Cell (mm)*					
	254	305	381	457	508	610
1000	0.6	0.9	1.3	1.8	2.2	2.9

- The CCO unit cell dimension of 570 mm is not provided, so the next most conservative unit cell dimension is 508 mm
- This indicates that up to 2.2 kg per cell of Pu as oxide, 100 wt.% ^{239}Pu, H/Pu<20, with an array size of 1,000 units and a unit cell dimension of 508 mm is subcritical
- A CCO only has 0.380 kg per cell of Pu – a large margin to 2.2 kg per cell!

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Other Considerations

- Array shape factor
  - The limits in ANS-8.7 were established for cubic arrays (10x10x10)
  - There will be more neutron leakage in our more realistic array shapes
  - ANS-8.7, Section 6.5 states the limits may be applied to arrays of any shape
- Structural materials
  - ANS-8.7 states that the limits allow for thicknesses of steel less than 12.7 mm (0.5 inches) as shelving or as close-fitting containers in contact with the fissile material or spaced to less than 26 mm (~1.0 inch) from the fissile material
  - The only structural material that is close fitting is the downblend can, which has a steel thickness of 6 mm (0.237 inches).
- Plastic bags
  - Section 5.2 of ANS-8.7 states that margins inherent in the mass limits are sufficient to compensate for incidental moderation such as that resulting from enclosing each unit in a thin plastic bag.

Credible Abnormal Conditions – Excess Mass

- The credible abnormal excess mass in a CCO is 500 g Pu as oxide.
- As shown previously, the subcritical mass limit from ANS-8.7 is 2.2 kg Pu as oxide for 100 wt.% ^{239}Pu, H/Pu<20, with an array size of 1,000 units and a unit cell dimension of 508 mm
- Even if the excess mass was four times higher, it would still be subcritical

Credible Abnormal Conditions – Damaged CCO

- The maximum expected damage to CCOs from vehicle impacts or drops is 2 inches radial damage (a decrease of ~102 mm diameter)

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Unit Mass Limit in Kilograms of Plutonium per Cell in Water-Reflected Storage Arrays: Oxides, 100 wt-% ^{239}Pu

Number of Units in Cubic Storage Arrays	*Minimum Dimension of Cubic Storage Cell (mm)*					
	254	305	381	457	508	610
1000	0.6	0.9	1.3	1.8	2.2	2.9

- However, since there is a lack of technical justification, a conservative assumption is made to analyze arrays of damaged CCOs as only the containment vessel.
- The containment vessel has a diameter of 168 mm, which is outside the scope of ANS-8.7

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Credible Abnormal Conditions – Flooding

- CCO storage will be outside and under fire suppression sprinklers.
- The values in ANS-8.7 are applicable for arrays with up to 200 mm water reflection on the outside of the array (no interstitial moderation).
- ANS-8.7, Section 5.2 states that the effects of significant interstitial moderation (more than a plastic bag) should be evaluated through the use of a validated computational technique.

Validation – Normal Conditions

- MCNP models were created to evaluate the normal and credible abnormal conditions for CCO storage
- For an infinite array of triangular pitched CCOs with normal mass and spacing, k_{eff} = 0.141
- Monte Carlo results this low are semi-meaningless, but they do indicate subcriticality as well as the large margin inherent in these systems
- The same conclusions can be drawn from comparing the ANS-8.7 limit of 2.2 kg Pu per unit and the CCO mass of 380 g Pu per unit

Validation – Excess Mass

- For an infinite array of triangular pitched CCOs with excess mass(500 g Pu per CCO) and normal spacing, k_{eff} = 0.146
- These results indicate subcriticality as well as the large margin inherent in these systems
- The same conclusions can be drawn from comparing the ANS-8.7 limit of 2.2 kg Pu per unit and the CCO mass of 500 g Pu per unit

Additional Analysis – Damaged CCO

- An infinite array of containment vessels has a k_{eff} = 0.836
- This is not a realistic representation of any credible abnormal condition, but it is bounding
- If a more realistic damage scenario could be developed and justified, then results from ANS-8.7 could be used and Monte Carlo k_{eff} values would also be lower

Additional Analysis - Flooding

- A large, triangular-pitched array of CCOs with full density interstitial flooding as well as internal flooding inside the containment vessel yielded a k_{eff} = 0.255
- The increase in k_{eff} from the normal condition is due to both the increased reflection on a single unit and the increase in moderation in the fissile material.
- In the fully flooded condition, the units are isolated, and the scenario essentially becomes a single-unit problem
- Partial (low-density) flooding was also considered, but due to the large difference between the spacing between units and the neutron mean free path, full flooding was bounding

Conclusions

- Conservative assumptions were made for the following parameters:
  - Mass, isotopics, moderation, spacing, array size
- These values were used to determine a subcritical mass limit from ANS-8.7, which indicated that the CCO mass limit of 380 g Pu is subcritical with large margins of safety
- These results were validated with MCNP, and additional analysis was performed
- Future improvements: Interstitial moderation guidelines and/or limits would be helpful in ANS-8.7

Questions?

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