Versa-Pac SAR Amendment

NRC Meeting

February 16, 2021

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Discussion Outline

1. **Content Expansion & Addition in Certificate**
   - Dual Pipe Container Configuration
   - New Criticality Analysis
   - New Thermal Analysis
2. **SAR Changes**
   - Add New Analyses & Clean-up
3. **Proposed Schedule**
4. **Discussion**

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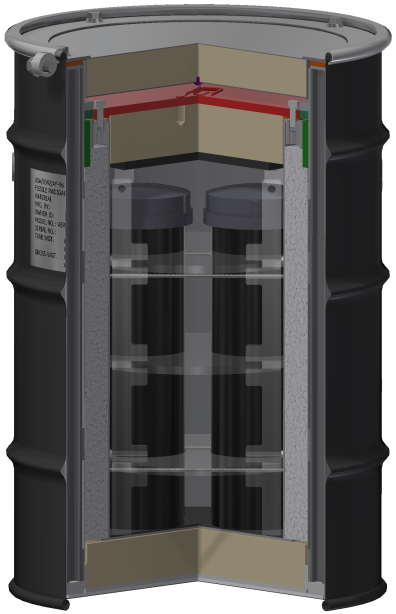
Content Expansion & Addition

Configurations based on operation needs, material size and true content mass

Large TRISO Fuel Compacts (60 mm range)

Three 3-gallon drums for TRISO Fuel Compacts (13 to 25 mm range)

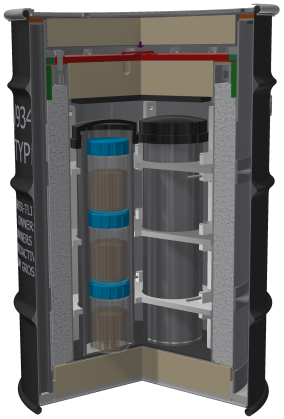


Dual 5” Pipes for TRISO Fuel Particles and LWR Pellets (1 to 12 mm range)

Content Expansion & Addition

Addition of 5-inch Pipe With Limited Hydrogenous Packing Material

- Utilize current licensed 5-inch pipe component and allows up to 2 pipes per Versa-Pac to overcome volume limitations.
- Shoring components will be used for the 5-inch pipe(s) in practice, but not required.
- Current content addition covers 10 wt% (2 pipes per package) and 20 wt% (1 pipe per package) contents.
- No fissile material limit - contents limited to volume of the pipe(s).
- Hydrogenous materials limited to 1.25 lbs (567 g) per pipe. The basis for this limit is to allow for bio-bottles (2 orange lid or 3 blue lid per pipe), but these are not credited or required for the configuration.



Orange bio-bottle
Bottle mass - 240 g
Bottle volume - 2 L

Blue bio-bottle
Bottle mass - 140 g
Bottle volume - 850 mL

Content Expansion & Addition

Addition of 5-inch Pipe With Limited Hydrogenous Packing Material

New CoC Table 6 (or 3A)

Weight Percent U-235	Number of Pipes	CSI
≤ 20%	1	CSI = 1.0 For all compounds
≤ 10%	2	CSI = 1.0 for Uranium Oxides CSI = 1.4 for all others

Notes:

- Contents are limited by the volume of the 5-inch pipe container (6.4 L).
- Single pipe container theoretical mass limit: 122 kg of U-metal, 60 kg UO_2, and 45 kg U_3O_8.
- Dual pipe container theoretical mass limits: 244 kg of U-metal, 120 kg UO_2, and 90 kg U_3O_8.
- Actual content mass will be lower due to material packing efficiency, secondary containers, shoring and package gross weight limit.

Addition to CoC 5.(c)

(6) Contents limited by Table 6 — As listed in Table 6 (or 3A)

Content Expansion & Addition

Expanded Contents – Standard Contents (CoC Table 2)

- Previous base analysis modeled HAC damage in a 5N NCT Array.
- Updated analysis now matches all other contents with a 2N HAC array and 5N NCT array.
- Heterogeneous study added (resulting decrease in 1.25 wt% content).

Current CoC Table:

Weight Percent U-235	U-235 Mass Limit (g)	
	Ground/Vessel	Air
≤ 100%	350	350
≤ 20%	410	410
≤ 10%	470	470
≤ 5%	580	580
≤ 1.25%	2000	--

New CoC Table:

Weight Percent U-235	U-235 Mass Limit (g)	
	Ground/Vessel	Air
≤ 100%	360	360
≤ 20%	445	445
≤ 10%	505	505
≤ 5%	610	610
≤ 1.25%	1,650	--

Content Expansion & Addition

Expanded Contents – 5-inch Pipe (CoC Table 3)

The ^{235}U Limits for ≤ 10 wt% & ≤ 5 wt% currently list the fissile mass at the peak of the H/X curve generated by varying the proportions of U-metal & polyethylene in the pipe.

Note: The 5 wt% 5-inch pipe analysis was removed from the SAR. (Covered by the ≤10 wt% analysis)

** Request removing these mass limits and limiting material by the volume of the pipe. (See following Slide)

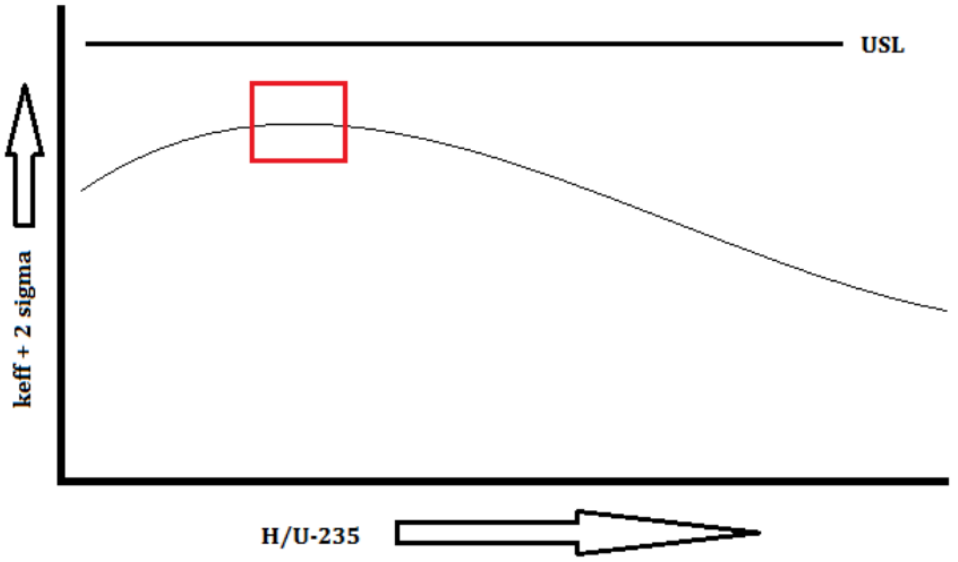


Figure 2-2: Effect of H/U-235 on k_{eff} + 2 sigma for U(10) and U(5) NCT Package Arrays. This trend is plotted for one fill percentage and one array configuration.

Since the value of k_{eff} + 2 sigma never reached or surpassed the USL, the most limiting U-235 mass for U(10) and U(5) was derived from that value of H/U-235 which resulted in the highest value of k_{eff} + 2 sigma, as shown with the red rectangle in Figure 2-2.

Content Expansion & Addition

Expanded Contents – 5-inch Pipe (CoC Table 3)

Current:

Weight Percent U-235	U-235 Mass Limit (g)	
	Ground/Vessel	Air
≤ 100%	695	395
≤ 20%	1,215	495
≤ 10%	1,605	590
≤ 5%	1,065	790

New:

Weight Percent U-235	U-235 Mass Limit (g)	
	Ground/Vessel	Air
≤ 100%	695	395
≤ 20%	1,215	495
≤ 10%	Limited by Pipe Volume [1]	590
≤ 5%	Limited by Pipe Volume [1]	790

Notes: [1]

- Contents ≤10 wt% are limited by the volume of the 5-inch pipe container (6.4 L).
- Theoretical mass limits: 122 kg of U-metal, 60 kg UO_2, and 45 kg U_3O_8.
- Actual content mass will be lower due to material packing efficiency, secondary containers, shoring and package gross weight limit.

Content Expansion & Addition

Expanded Contents

➢ UF6 Contents

Current: 5(b)(1)(iii) Uranium Hexafluoride is authorized for shipment when loaded into 1S or 2S cylinders, utilizing a 9 PCF polyethylene foam liner with a thickness of at least 2 inches.

New: 5(b)(1)(iii) Uranium Hexafluoride is authorized for shipment when loaded into 1S/2S cylinders, or in metal sample tubes when less than 0.1 kg in quantity, utilizing a 9 PCF polyethylene foam liner with a thickness of at least 2 inches.

➢ Allowance for Neutron Poisons

Current: 5(b)(1)(i) …Materials shall be stable and in a non-pyrophoric form. Density is not limited. Materials may include natural thorium in any form.

New: 5(b)(1)(i) …Materials shall be stable and in a non-pyrophoric form. Density is not limited. Materials may include natural thorium in any form. Materials may include neutron poisons (e.g., boron, hafnium, erbia, and gadolinia)

➢ Hydrogen Limited Contents

Expansion of Table 2A, (hydrogenous packaging materials limited to 1 lb.) to include 5%, 10%, and 100% enrichments

Table 2A – Hydrogen Restricted Loading Table for Model Nos. VP-55 and VP-110

Weight Percent U-235	U-235 Mass Limit (g)	
	CSI=0.7	CSI=1.0
≤ 100%	515	-
≤ 20%	605	635
≤ 10%	685	-
≤ 5%	800	-

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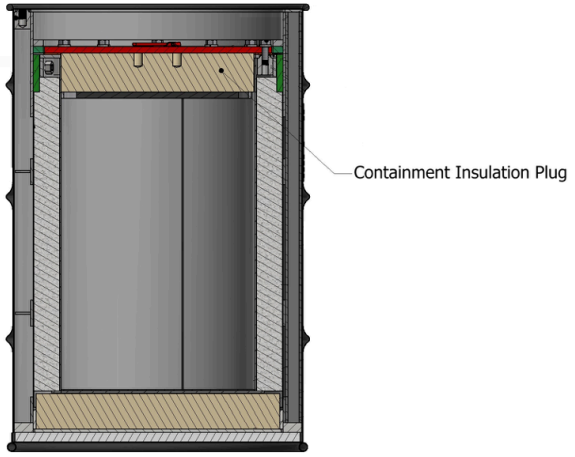
SAR Changes



- **Licensing Drawing Changes**
  - Add note to list Containment Insulation Plug (IG), Containment Plug Retaining Bars (BF), and Bumper Pad (GE) as optional for temperature insensitive contents (e.g., TRISO compacts).
  - Revise note 10 to allow tolerance for drum lid gasket GA thickness.
- **Chapter 2 Consolidation**
  - Reorganization of content to better align with Reg Guide 7.9 format.
  - Removes test reports from appendices and presents relevant data in the chapter body with test matrix (test reports included as references)
- **Chapter 3**
  - One additional analysis to support the change to make the Containment Insulation Plug optional. Shows that the peak cavity wall temperature is higher but not significantly (386°C with vs 397°C without).

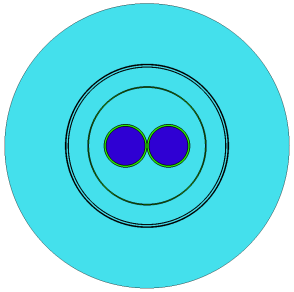
SAR Changes

- **Chapter 6 Changes**
  - Complete re-write. Move most of analyses from appendices to the body of the chapter.
  - Most analyses unchanged, just reorganized. (e.g., air transport, 1S/2S, 5-inch pipe).
  - Rework on "Standard Configuration" (bare Versa-Pac with no internal components or hydrogenous material restrictions).
    - SCALE 4.4 no longer used for 100 wt% enrichment (all in SCALE6.1.3)
    - Package models revised to match other existing analyses, with separate package models for NCT and HAC to reflect test damage.
  - USL calculation replaced.
    - All done in SCALE6.1.3.
    - No longer 1 USL for all enrichments. Individual USL equations developed for each enrichment analyzed.
    - Tsunami c_k parameter used to select applicable cases, but trending analysis based on traditional parameters (H/X).
    - Note: the USL for all enrichments still fall in the 0.939 - 0.941 range.
  - New analysis added for hydrogen limited contents at 5 wt%, 10 wt%, and 100 wt% enrichments. Same method as existing 20 wt% analysis, applied for other enrichments.
  - New analysis added for 5-inch Pipe with limited hydrogenous material

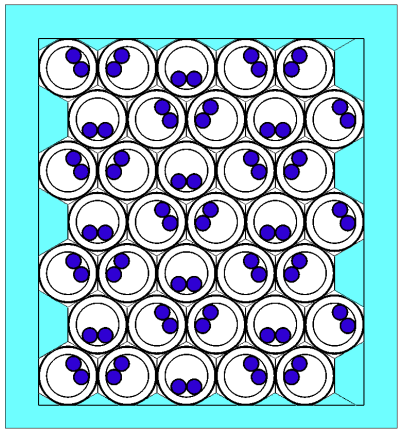
SAR Changes

- **Chapter 6 Changes – 5-inch Pipe with Limited Hydrogenous Packing Material**
  - Covers 10 wt% & 20 wt% enrichments, hydrogenous packing materials limited to 1.25 lbs in each pipe.
  - 10 wt% cases allow unlimited fissile material permitted in two pipes
    - Uranium Oxide material CSI=1.0, other compounds CSI=1.4
  - 20 wt% case allows unlimited fissile material permitted in one pipe
    - All compounds have CSI=1.0

Single Package



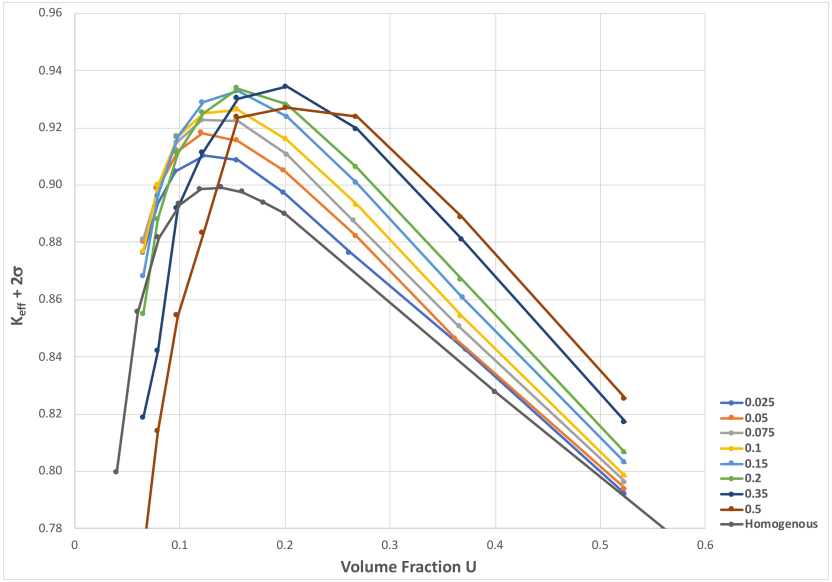
Package Array



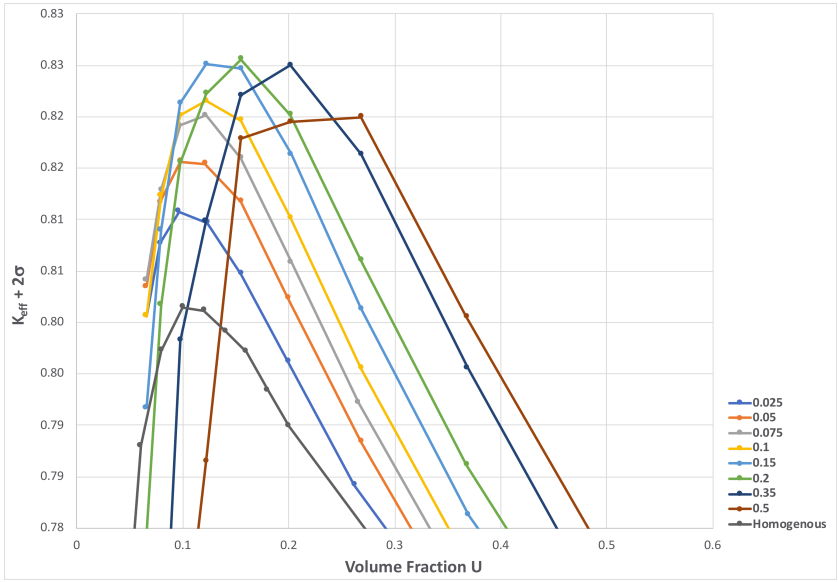
SAR Changes

- **Chapter 6 Changes –5-inch Pipe with Limited Hydrogenous Packing Material**

10 wt% HAC Array (U-Metal / CSI=1.4)



20 wt% HAC Array (U-Metal / CSI=1.0)



Projected Schedule

Updated SAR Submittal	February 2021
CoC Revision 16 requested by	August 2021

Future Submittals

Dual Pipe High-Capacity Basket for U_3O_8	Fall 2021
VP-55XL	First half 2022

Discussion