

Versa-Pac SAR Amendment

NRC Meeting
February 16, 2021

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

Content Expansion & Addition

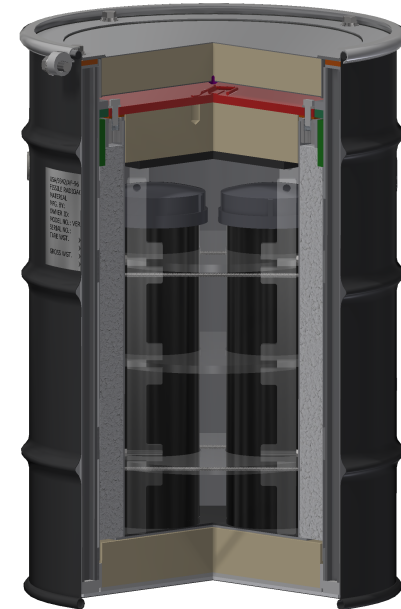
Configurations based on operation needs, material size and true content mass



Large TRISO Fuel
Compacts
(60 mm range)



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

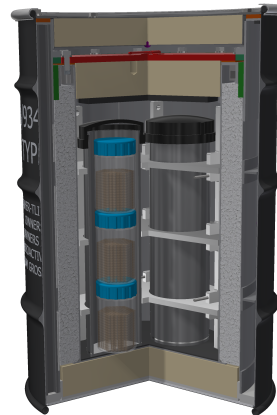
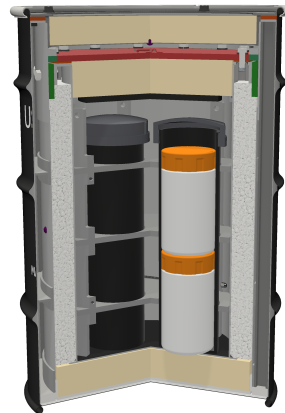
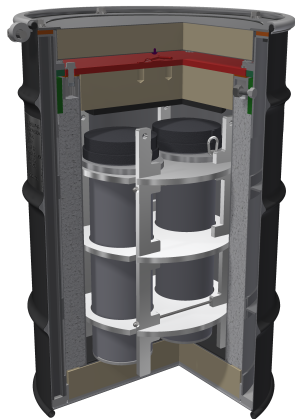


Dual 5" Pipes for
TRISO Fuel Particles
and LWR Pellets
(1 to 12 mm range)

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 |
|----------------------|-----------------|--|
| $\leq 20\%$ | 1 | CSI = 1.0 For all compounds |
| $\leq 10\%$ | 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 | -- |

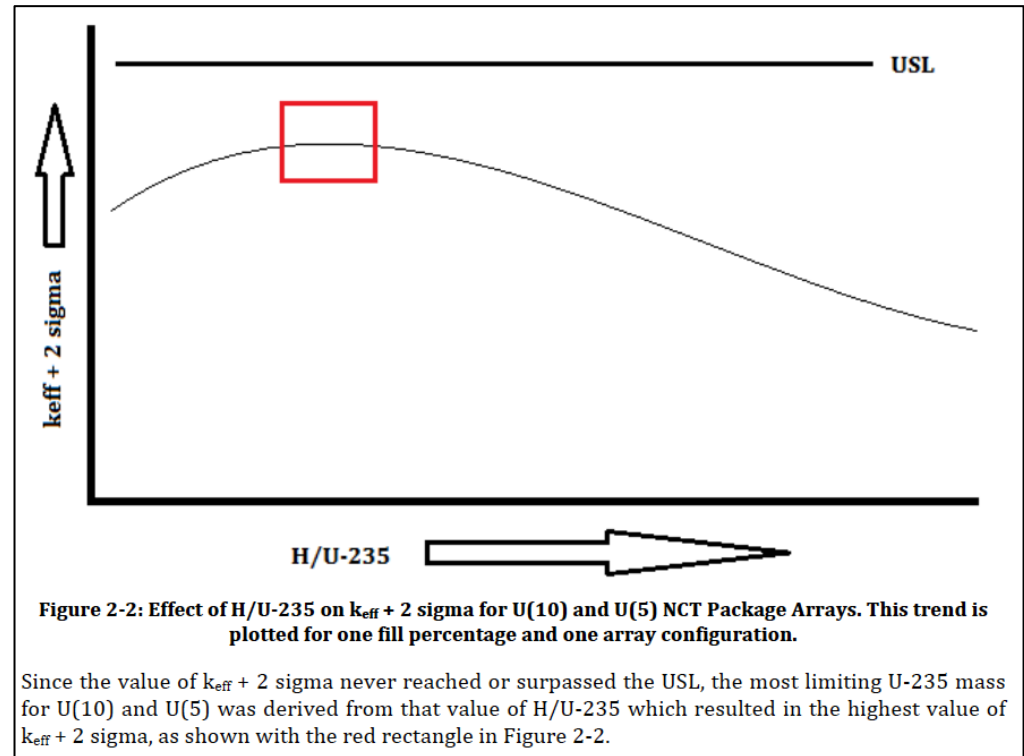
Content Expansion & Addition

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

The ^{235}U Limits for $\leq 10 \text{ wt\%}$ & $\leq 5 \text{ wt\%}$ 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 $\leq 10 \text{ wt\%}$ analysis)

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



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 UO₂, and 45 kg U₃O₈.
- 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 | - |

SAR Changes

➤ Licensing Drawing Changes

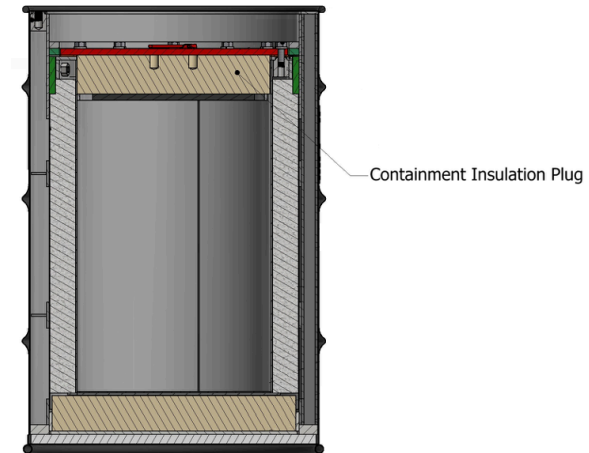
- Add note to list Containment Insulation Plug (IG), Containment Plug Retaining Bars (BF), and Bumper Pad (GE) as optional for temperature insensitive contents (e.g., TRISO compacts).
- Revise note 10 to allow tolerance for drum lid gasket GA thickness.

➤ 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

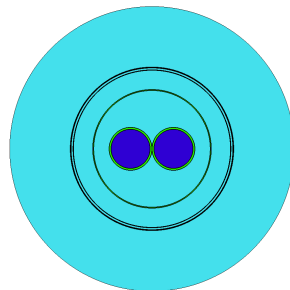
➤ Chapter 6 Changes

- 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

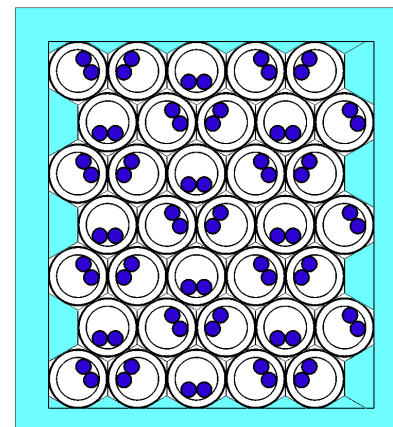
SAR Changes

- **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



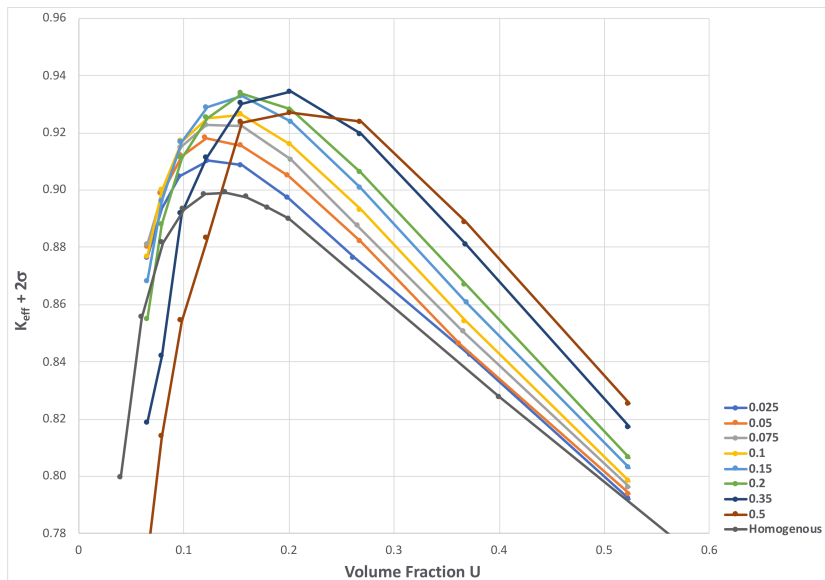
Package Array



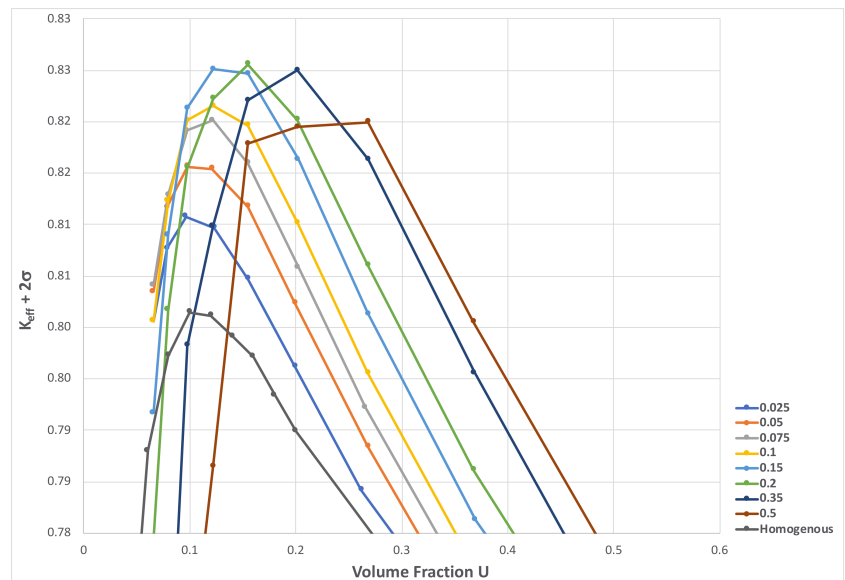
SAR Changes

➤ 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
CoC Revision 16 requested by

February 2021
August 2021

Future Submittals

Dual Pipe High-Capacity Basket for U_3O_8
VP-55XL

Fall 2021
First half 2022

Discussion