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# Model 9975 SAR Submittal


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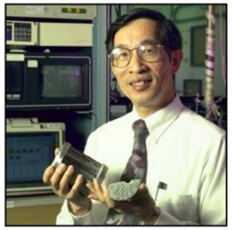





EM Environmental Management
safety ❖ performance ❖ cleanup ❖ closure
DOE Packaging Certification Program

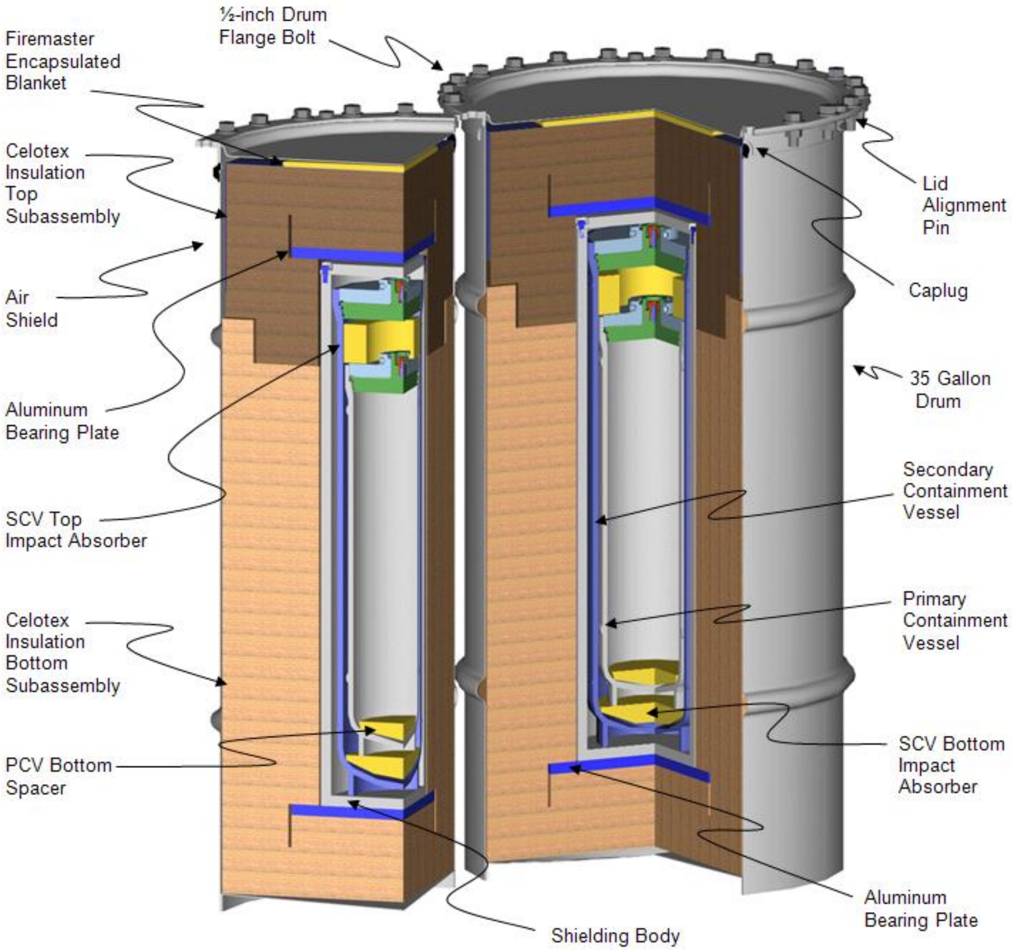
# Agenda

- Introductions, Overview and Submittal Strategy
- Description of 9975
- History of 9975 SARP
- 3013 Description
- Proposed Contents
- Specific Strategies for SAR Chapters

# The Model 9975 Packaging

- The Model 9975 is a drum-style Type B Fissile package with double containment
- Designed for transport of Plutonium metal and Oxide up to 5 kg
- Initial DOE CoC  for *-85* packages on 01/1998 currently on Rev. 29, *-96* packages on 06/2008 currently on Rev. 6
- No changes were made to the 9975 design in the *-96* certification
- The current inventory is ~5000 *-85* and ~1000 *-96* packagings

# Model 9975 Shipping Package



# Model 9975 Shipping Package History

- The Model 9975 was certified by testing and comparison within a family of packages ( 9966, 9967, 9968, 9973, 9974 )
- The current design has been drop tested in an oblique drop and puncture drop
- Analysis of other drop orientations also performed
- All licensed 9975 packages use a bolted closure
- The 9975 is currently certified by DOE for 11 different content envelopes including 3013 containers

# Model 9975 Shipping Package

- **Containment Vessels are designed and fabricated to ASME Section III NB**
- **The PCV and SCV incorporate a single nut closure with double viton O-ring seals**
- **Design Pressures for the PCV and SCV are 900 and 800 psig respectively**
- **Burst Pressure of the PCV is greater than 4000 psig**

# Burst Testing of Early PCV Prototype

# DOE-STD-3013

- **The Standard provides requirements for stabilization and packaging of plutonium bearing materials for safe 50-year storage**
- **Plutonium bearing oxides or metal may be packaged**
- **Must have at least 30 wt% Pu + U**

# DOE-STD-3013 (Continued)

- **Stabilization of plutonium bearing oxides**
  - Maximum content of 5000 grams of oxide (4400 grams Pu)
  - Maximum heat load of 19 watts
  - Oxide must be thermally stabilized for at least two hours
    - 950° C for most oxides
    - 750° C approved for a limited set of material types
  - Oxide must contain less than 0.5 wt% adsorbed moisture
- **Packaging must have a minimum of two nested, individually welded, leak-tested ("leak-tight") stainless steel containers**

# DOE-STD-3013 (Continued)

- **127 mm (5 inch) diameter, 255 mm (10 inch height**
- **Outer container requirements**
  - Must be able to meet “Safety Class” designation
  - ASME Section VIII pressure vessel with minimum Design Pressure of 4920 kPa (699 psig)
  - Must remain leak-tight after 9 meter (30 foot) drop test
  - All outers fabricated from 316L
- **Inner container requirements**
  - Must remain leak-tight after 1.3 meter (4 foot) drop test
  - Lid designed so that if internal pressure reaches 790 kPa (100 psig), lid deflection is measurable with radiography
  - Inners fabricated from either 304L or 316L

# DOE-STD-3013 Container Set

# 3013 Containers Currently in Inventory

- **Over 5000 containers have been packaged, plan ~7000**
  - Packaging began in 2001 and continues
- **Shipped to SRS in 9975 shipping packages**
- **Gamma and neutron radiation rates measured and recorded by packaging/shipping site for bare 3013 containers and 9975s**
- **Chemical impurity analyses NOT performed by packaging site**

# 3013 Containers Currently in Inventory (Continued)

- **Prompt Gamma measurements made for most oxide containers**
- **Prompt Gamma estimates content of Be, F, Cl, Al, Na, K**
  - Be and F impurities can cause elevated radiation dose rates due to $\alpha$-$\eta$ reactions

# Beryllium and Fluorine Content by Prompt Gamma

- **Beryllium**
  - Maximum Be concentration in a container is 2.4% of material mass
  - 40 containers between 1.0% and 2.4%
  - 90 containers between 0.1% and 1.0%
  - Remainder less than 0.1%
- **Fluorine**
  - Maximum F concentration in a container is 7.2% of material mass
  - 160 containers between 1.0% and 7.2%
  - 400 containers between 0.1% and 1.0%
  - Remainder less than 0.1%

# Dose Rates Measured by Shipper ($\gamma$ + n)

- **At surface of bare 3013 Container**
  - Maximum container dose rate was 900 mrem/hr
  - 15 containers between 500 and 900 mrem/hr
  - 185 containers between 200 and 500 mrem/hr
  - Remainder less than 200 mrem/hr
- **30 cm from surface of bare 3013 Container**
  - Maximum  container rate was 230 mrem/hr
  - 5 containers between 200 and 230 mrem/hr
  - Remainder less than 200 mrem/hr

# Dose Rates Measured by Shipper ($\gamma$ + n) (Continued)

- **At surface of loaded 9975 Shipping Package**
  - Maximum shipping package dose rate was 180 mrem/hr
  - 15 shipping package between 100 and 180 mrem/hr
  - Remainder less than 100 mrem/hr

# Proposed Contents

- **Plutonium Oxide in 3013 containers**
- **Light element impurities can lead to high calculated (theoretical) package dose rates**
  - Current 9975 SARP uses dose rate measurement for ensuring regulatory compliance
  - Proposed SAR will include specific dose rate and prompt gamma data on family of 3013 containers to be shipped

# Description of Content Envelope C.11

- **Plutonium Oxide**
  - Oxide must be stabilized to the 3013 Standard (Limited to 0.5 wt% moisture)
- **Isotopic Distribution**
  - Limits on Specific Isotopes in Table
  - 1000ppm limit on isotopes not listed
- **Non-Radioactive Impurities**
  - Impurities such as Al, Be, C, F can make up 70% of content mass
- **Light Elements**
  - Be 500 gram limit , Carbon 1000 gram limit

# Content Envelope C.11 Isotopic Composition

| | Material [a, b] | C.11[e,g,h,i] Pu/U Oxides grams |
|---|---|---|
| **Radioisotope** [m] (Radioactive Material Mass) | $^{236}$Pu[z] | |
| | $^{238}$Pu[n] | 34 |
| | $^{239}$Pu[o] | 4400 |
| | $^{240}$Pu | 2200 |
| | $^{241}$Pu[o, p] | 188.9 |
| | $^{242}$Pu | 2200 |
| | $^{241}$Am + $^{241}$Pu | 188.9 |
| | $^{243}$Am | 1.00 |
| | $^{244}$Cm | 0.0044 |
| | $^{237}$Np | 220 |
| | $^{232}$U | 0.00044 |
| | $^{233}$U[o] | 427 |
| | $^{234}$U[q] | 4400 |
| | $^{235}$U[o] | 4400 |
| | $^{236}$U | 2640 |
| | $^{238}$U | 4400 |
| | $^{232}$Th | 4400 |
| **Impurities** (grams) | Al, B, F, Li, Mg, Na | r |
| | Be | 500 |
| | V | r |
| | Ta | r |
| | C | 1000 |
| **Total Mass** (kilograms) | Radioactive Materials | 4.4 |
| | Impurities | 3.08[t] |
| | All Contents | 5 |

# Content Envelope C.11 Isotopic Composition

| | |
|---|---|
| a | Except as permitted for oxides, all contents shall be dry. |
| b | Pu/U content bulk density shall be no greater than 19.84 g/cc. No minimum bulk density is specified. However, low bulk densities require dilution of the local atmosphere within the content container by a specific gas (helium or nitrogen) and/or reduction in the allowable decay heat as summarized in Table 3.4. |
| c | Up to 1 gram of plutonium contamination is permitted. |
| d | reserved |
| e | Mass limit due to shielding. The heat loading of each mixture needs to be determined. The 188.9 gram limit based on estimate of heat load from WCID-2009-0002 Revision 0. |
| f | reserved |
| g | Plutonium plus uranium mass shall not be less than 30 weight percent of the total content mass. |
| h | Contents shall be stabilized in accordance with DOE-STD-3013, Section 6.1.2. [8] |
| i | The moisture content of the oxide shall be less than 0.5 weight percent of the total content mass. |
| j | reserved |
| k | reserved |
| l | reserved |
| m | Maximum amounts by constituent. |
| n | $^{238}$Pu decays to $^{234}$U, which will result in significant concentrations of $^{234}$U over time. $^{234}$U growth will not adversely impact package performance. |
| o | Nuclide classified as “fissile” per DOE Good Practices Guide, Criticality Safety Good Practices Program, Guide For DOE Nonreactor Nuclear Facilities, DOE G 421.1-1, 3.79 *Fissile Nuclide*, 8-25-99. |
| p | $^{241}$Pu must be less than $^{240}$Pu. |
| q | Applies to $^{234}$U other than $^{234}$U resulting from $^{238}$Pu decay. |
| r | Impurities have a combined mass limit of 3080 grams minus the mass of Be and C present. |
| s | reserved |
| t | Total impurity limit is based on the minimum 30% Pu + U mass within DOE-STD-3013. The limit was calculated from the maximum radioactive material mass (4.4 kg). [4.4 kg 70% = 3.08 kg] |
| u | reserved |
| v | reserved |
| w | reserved |
| x | reserved |
| y | reserved |
| z | $^{236}$Pu is not expected to be present in significant amounts |

# Strategy for SAR Submittal

- Proposed content is plutonium oxide in 3013 containers
  - It is defined in content envelope C.11
  - This is the only content for this submittal
- The 9975 NRC SAR will use the current SARP format
  - The SARP was prepared to an earlier Regulatory Guide
  - This provides needed consistency with existing users
- New calculations will be limited
  - Plutonium oxide specific criticality
  - Thermal sensitivity analysis

# Strategy for SAR Submittal, II

- Drawings, tables, diagrams, figures, etc. not applicable to the NRC Licensed content will be removed from the SAR
  - The removed information will have its identification numbers (e.g., Figure 1-5) "reserved" in the NRC SAR to prevent human factor problems with users
- Retain existing appendix structure to limit the number of reference documents to be submitted
  - Any removed appendices will have its identification numbers (e.g., Appendix ) "reserved" in the NRC SAR to prevent human factor problems with users

# Strategy for SAR Submittal, III

- The submittal will use the current package design drawings
  - All the packagings have been produced and meet the QA requirements of 10 CFR Part 71, Subpart H.
- Specific dose rate and impurity data for the family of 3013 inner containers to be shipped will be provided
- Reintegrate SAR QA references without Chapter 9

# SAR Preparation

- Prepare an NRC application (SAR) based on the SARP for the *-96*
  - Remove content specific operations and references from the SAR that are not applicable to C.11
  - Revise references in SAR Chapters 1-8 to Chapter 9 of the DOE SARP, to the SRS QAP or Subpart H of 10CFR 71 as applicable
  - SARPs formatted per Proposed Rev 2 to RegGuide 7.9 (May 1986). We would prefer to retain this format in the SAR
  - Legacy scanned images are less than that is < 300 dpi to minimize file size. We would prefer not to re-scan legacy images (e.g., approx. 150 dpi)

# Strategy for SAR Chapter 1

- Content envelope to include C.11 only and refer to the specific family of 3013 containers to be shipped
- Sections referring to contents or configurations not included will be listed as “reserved”
- Figures for other content configurations will be listed as “reserved”
- References not pertaining to C.11 content envelope will be removed but the reference number will be “reserved”

# Strategy for SAR Chapter 2

- Structural Chapter to remain unchanged
- Structural Analyses not content specific
- Appendices to remain unchanged
- Analysis of shield body/vessel impacts from 55 feet without fiberboard or drum

# Strategy for SAR Chapter 3

- Thermal chapter has specific references to other content envelopes besides C.11 that will be removed
- Stabilization of the oxide and purging with an inert gas ensure no flammable gas mixture is generated
- For defense in depth, deflagration scenarios are analyzed as well as deflagration to detonation transition (DDT) cell widths
- Specific can dimensions, spacers etc. are specified to prevent DDT
- For consistency, data and analyses addressing flammable gas issues will be retained

# Strategy for SAR Chapter 3 (Continued)

- The Thermal Chapter has 20 appendices that will be retained
- Conservative solar absorptance = 1.0 rather than ~0.5 for as-received stainless steel drum surface
- Fiberboard temperature of worst case NCT configuration is slightly over temperature limit
- Sensitivity analysis will document the significant NCT thermal safety margin of the 9975 package

# Outline

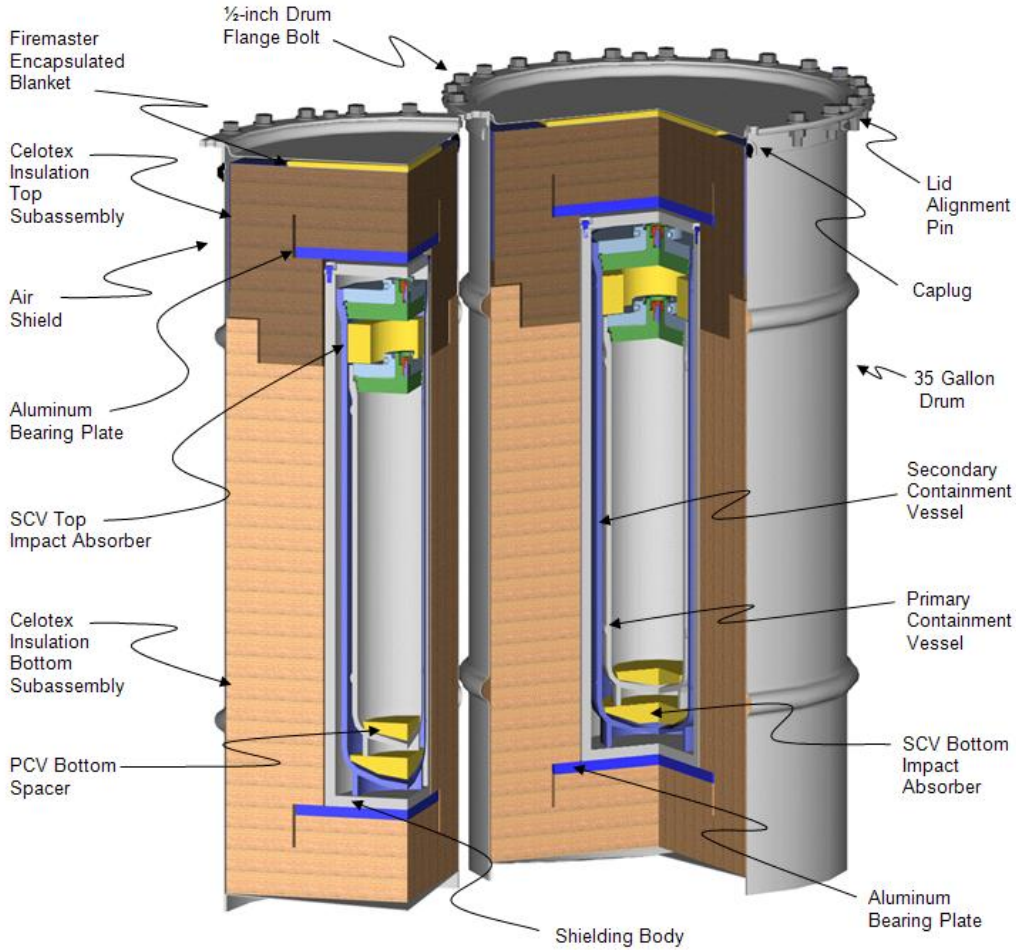
Thermal Design Features

Summary of Thermal Evaluation Results

NCT Thermal Evaluation

HAC Thermal Evaluation

# Model 9975 Shipping Package



# Model 9975 Shipping Package

## Thermal Design Features

- Celotex (Fiberboard) for fire protection
- Air shield for preventing smoldering
- Vent holes to prevent overpack failure during fire
- Thermal blanket in the lid for added fire protection

# Summary of Thermal Evaluation Results

## Maximum Component Temperatures

| | NCT | | HAC | |
|---|---|---|---|---|
| Location | Temperature ( F) | Limit ( F) | Temperature ( F) | Limit ( F) |
| Drum | 255 | N/S | 1475 | 2650 |
| Fiberboard | 257 | 250 | N/A | N/A |
| SCV O-ring | 259 | 400 | 217 | 400 |
| PCV O-ring | 276 | 400 | 212 | 400 |
| SCV | 268 | 300 | 218 | 300 |
| PCV | 285 | 300 | 220 | 300 |
| Lead | 257 | 622 | 428 | 662 |
| Contents | 641 | N/S | 454 | N/S |

**N/A – not applicable; N/S – not specified**

**Significant Observations:**

- Containment vessels design limits are very conservative (low)
- HAC temperatures are lower than NCT temperatures
- Fiberboard temperature is 7 F above the limit – discussed later in the NCT results

# Summary of Thermal Evaluation Results

## Maximum Pressures (psig)

| | SCV | PCV |
|---|---|---|
| **NCT** | 166 | 365 |
| **HAC** | 149 | 331 |
| **Design Limit** | 800 | 900 |

**Notes**:

1. The pressure estimates are based on radiolysis of 0.5% (25 grams) of moisture, helium production from decay of $PuO_2$, plastic off-gassing (if present), and heating of fill gases.
2. For the 3013 container configuration, the PCV pressure is only **258** psig: no plastics in 3013 container.
3. If the 3013 containers do not leak (as expected), the maximum 3013 outer container pressure is 646 psig, below the 3013 limit of 699 psig.

# NCT Thermal Evaluation

**Methodology**

- ❖ Environmental chamber prototype testing
- ❖ Benchmarked computational models

❖ An undamaged 9975 prototype with 21 watts heater in the PCV was tested in a controlled environment. The temperatures at various points were monitored for 120 hours.

❖ Subsequently, a geometrically accurate axisymmetric model was built with proper boundary conditions and analyzed using PATRAN/Thermal software. The calculated temperatures matched well with the measured temperatures. This benchmarked thermal model was used for the NCT analyses.

# NCT Thermal Evaluation

## Model Parameters

- Upright orientation
- Axisymmetric geometry including all the gaps
- Fill gas as air in the 3013 containers rather than helium
- Temperature dependent material properties
- Surface to surface radiation and conduction in gaps
- 19 watts of heat generation
- Insolation all around except at the bottom

## Boundary Conditions

- Bottom adiabatic
- Convection and radiation heat losses from the drum surface
- Solar heat flux all around except at the bottom

# NCT Thermal Evaluation

## Comparison of Benchmark Model with Test Results

| Channel | Position | Test ( F) | Model ( F) | Comments |
|---|---|---|---|---|
| 1 | Drum Bottom | 85 | 107 | At bottom center |
| 2 | Drum Side | 88 | 87 | Mid-height |
| 4 | Drum Lid | 86 | 81 | Top center |
| 6 | Celotex® | 107 | 130 | Approx. maximum |
| 8 | Lead Side | 134 | 134 | Center height |
| 10 | PCV Lid | 168 | 169 | Package centerline |
| 11 | SCV Seal | 149 | 162 | |
| 13 | SCV Side | 149 | 157 | Mid height |
| 15 | Top Bearing Plate | 122 | 120 | At package centerline |

# NCT Thermal Evaluation

## Conservative Model Parameters

- Adiabatic bottom
- Solar flux all around rather than directional
- Solar flux applied assuming solar absorptance = 1.0 rather than about 0.5 for as-received stainless steel drum surface.

## Conclusions

- Derived temperatures during NCT are conservative and still have good safety margins for the components except the Celotex
- 7°F over the limit temperature for the Celotex is highly localized and can be reduced if realistic solar optical properties are used for the drum surface. Sensitivity analyses are planned to address this concern.

# NCT Thermal Evaluation

## Sensitivity Analyses

Sensitivity analyses will be performed to assess the impact of:

- Solar absorptance and thermal emittance of the drum surface.
- Variation in thermal conductivity of the Celotex. NCT analyses used Celotex thermal properties derived from testing of the glued Celotex discs. The resulting radial thermal conductivity was nearly twice the axial thermal conductivity. Sensitivity analysis will be performed to address the uncertainty in the Celotex thermal conductivity values.

# NCT Thermal Evaluation

## Deflagration and Detonation Considerations

3013 containers packaged in accordance with the 3013 standard must have:

- No more than 0.5% adsorbed moisture in the contents
- No more than 5% oxygen in the fill gases. The remaining gases must be inert gases like helium or nitrogen.

The PCV is diluted to minimum of 75% $CO_2$ and the SCV has air. If these conditions are met, a flammable $H_2/O_2$ mixture will not form to cause deflagration or detonation in the PCV or the SCV.

However, as a defense in depth approach to the package safety, the current 9975 SARP does have deflagration and detonation analyses. The SARP assumes:

- Stoichiometric mixture of $H_2/O_2$
- Different percentages of oxygen, helium and $CO_2$ in the containment vessels.

# NCT Thermal Evaluation

## Results of Deflagration and Detonation Analyses

- The deflagration in the PCV is a low-energy event and results in only 1 F increase in PCV gas temperatures. The maximum deflagration pressure is 62 psig.
- If the PCV leaks into SCV, the deflagration pressure is 192 psig.
- Since the deflagration event is not expected, these pressures are not added to the MNOP.
- Deflagration-to-Detonation Transition (DDT) is evaluated using the detonation cell size concepts. The calculated cell sizes are well above the annular spaces in the 3013 configurations and, therefore, no DDT is expected.

# HAC Thermal Evaluation

**Methodology**

- ❖ Prototype furnace tests
- ❖ Benchmarked computational models

- ❖ An undamaged 9975 prototype with 21 watts heater in the PCV was tested in a controlled environment. The specimen was heated for 120 hours to meet the 10 CFR Part 71 <u>initial condition requirement</u>.
- ❖ The package was exposed to 1500°F or higher furnace environment for nearly 40 minutes including the ramp up time of 10 minutes. The component temperatures at critical locations were monitored until cooldown.
- ❖ Subsequently, an accurate axisymmetric models was built and analyzed using PATRAN/Thermal software. This benchmarked thermal model was used for the HAC analyses.

# HAC Thermal Evaluation

## HAC Test and Benchmarked Results

| Location | Test ( F) | HAC Analyzed ( F) | Limit ( F) |
|---|---|---|---|
| Lead shield | 190 | 201 | 622 |
| PCV Lid | 199 | 198 | 400 |
| PCV Side | Not measured | 209 | 300 |
| SCV O-ring | 184 | 190 | 400 |
| SCV Side | 185 | 203 | 300 |

## Important Observations

Analyzed temperatures match well with the test temperatures

# HAC Thermal Evaluation

## HAC Analyses included:

- Proper initial conditions
- Contents thermal loading
- Proper fire temperature (800°C), fire emissivity (1.0), and forced convection thermal loading
- Postfire phase with natural convective cooling, full insolation and proper drum surface emissivity (0.8).

## Conclusions

- The HAC thermal results are based on benchmarked models and represent realistic component temperatures.
- The HAC results have good safety margins and do not require additional evaluation.

# Strategy for SAR Chapter 4

- 9975 Containment Chapter does not include a containment analysis
- No changes anticipated

# Strategy for SAR Chapter 5

- Existing analysis for bounding contents

| Location | Oxides | 10 CFR Limits | Location | Oxides | 10 CFR Limits | Location | Oxides | 10 CFR Limits |
|---|---|---|---|---|---|---|---|---|
| NCT Surface Dose Rates (mrem/hr) | | | NCT 1 m away Dose Rates (mrem/hr) | | | HAC 1 m away Dose Rates (mrem/hr) | | |
| SIDE | | | SIDE | | | SIDE | | |
| Neutrons | 157 | — | Neutrons | 5.26 | — | Neutrons | 6.96 | — |
| Photons | 22 | — | Photons | 0.77 | — | Photons | 3.4 | — |
| Total | 178 | 200 | Total | 6.02 | 10* | Total | 10.36 | 1000 |
| TOP | | | TOP | | | TOP | | |
| Neutrons | 9.57 | — | Neutrons | 0.62 | — | Neutrons | 0.64 | — |
| Photons | 0.89 | — | Photons | 0.09 | — | Photons | 0.18 | — |
| Total | 10.46 | 200 | Total | 0.71 | 10* | Total | 0.82 | 1000 |
| BOTTOM | | | BOTTOM | | | BOTTOM | | |
| Neutrons | 124 | — | Neutrons | 4.09 | — | Neutrons | 5.7 | — |
| Photons | 16 | — | Photons | 0.65 | — | Photons | 2.78 | — |
| Total | 140 | 200 | Total | 4.74 | 10* | Total | 8.49 | 1000 |
| | | | * Transport index may not exceed 10 | | | | | |

# Strategy for SAR Chapter 5

- Include analysis for pure contents in Chapter 5
- Include an Appendix with the dose rate at the surface of each 3013 container and at the surface of the 9975 Shipping Package with each 3013 container
- Only include those 3013 containers for which the dose rate at the surface of the package does not exceed 200 mrem/hr

# Strategy for SAR Chapter 6

- Existing analyses in 9975 SARP
  - Single Unit
    - Dry with metal and oxide contents
    - Flooded with metal contents
    - Solution of metal and oxide contents
  - NCT Array
    - Dry with metal and oxide contents as spheres no 3013
    - Variations (flooding, 3013, etc.) all done for metal only
  - HAC Array
    - Only metal contents analyzed

# Strategy for SAR Chapter 6

- **Repeat studies for oxide case and report results**
  - This is cleaner than including both metal and oxide results and making the case that metals bounds oxides
  - Some of the metal results exceeded $k_{safe}$ and the SARP Chapter 6 included a discussion of why these were acceptable.

    The oxide cases would not need this discussion.

# Strategy for SAR Chapter 7

- Revise references to Chapter 9 (in Chapter 7 of the SARP) to the SRS QAP or  Subpart H of 10CFR 71 as applicable, e.g.,
  - **FROM:** “Package records shall be prepared in accordance with the requirement of 10 CFR 71.91 and maintained in accordance with Section 9.17.”
  - **TO**: “Package records shall be prepared in accordance with the requirement of 10 CFR 71.91 and maintained in accordance with 10 CFR 71.135”

# Strategy for SAR Chapter 8

- Revise references to Chapter 9 (in Chapter 8 of the SARP) to the SRS QAP or Subpart H of 10CFR 71 as applicable, e.g.,
  - **FROM:** "The acceptance tests and the maintenance program shall be conducted in accordance with the Quality Assurance (QA) program described in Chapter 9."
  - **TO**: "The acceptance tests and the maintenance program shall be conducted in accordance with the SRS Quality Assurance (QA) program."

# Quality Assurance – 10 CFR 71 Subpart H Compliance

- The current DOE Certificates of Compliance for the 9975 *(-85* and *-96*) and Safety Evaluation Reports (SER) included approval of the packaging-specific Quality Assurance Program in Chapter 9 of the application (i.e., SARP) for compliance with Subpart H. The SERs state "the DOE PCP staff concludes that the QA program has been adequately described and meets the QA requirements of *10 CFR Part 71, Subpart H*. Packaging-specific requirements are adequate to assure that the packaging is designed, fabricated, assembled, tested, used, maintained, modified, and repaired in a manner consistent with its evaluation."

# Conclusion

- Compliance with 10 CFR Part 71 demonstrated through performance testing supported by analysis
- The applicant will review the SAR, prior to submittal to NRC, for completeness and adequacy with NUREG-1609 *Standard Review Plan for Transportation Packages for Radioactive Material*
- Submission is anticipated in mid-December with the described SAR development strategy