# Introduction to the NAC Californium Transport System (NAC-CTS)

*September 28, 2006*

***NAC International is a Wholly Owned Subsidiary of USEC Inc., the World's Leading Supplier of Enriched Uranium Fuel for Commercial Nuclear Power Plants.***

# NAC-CTS Cask Application

## NAC-CTS

## Special Forms Transport Cask

## Californium ($^{252}Cf$)

## For ORNL/UT-Battelle

# NAC-CTS Cask Application History

## NAC-CTS Evolution:

- Need for new Californium ($^{252}Cf$) cask identified in mid 90's based on aging of existing casks and more stringent requirements for Type B casks
- No other casks exist capable of shipping Cf without extensive modifications and documentation changes
- Current NRC cask certificates, 71-5740 & 71-6642, will terminate Oct. 1 2008, per DOT directive
- Currently 9 users have Type B DOE owned Cf sources requiring return by contract to DOE by 2018

# NAC-CTS Cask Application History

## NAC-CTS Evolution:

- Original Contract, 23-SV733V, issued in January 1997 by Lockheed Martin Energy Systems to NAC for the development of a Californium Transport System
- Contract Outlined 3 Phases:
  1. Design and License Application Preparation (DOE and NRC)
  2. CTS licensing
  3. Fabrication & delivery
- Meeting with NRC June, 1997 regarding submittal of the package resulted in 2 major issues that required further evaluation
  1. Full scale testing required before licensing
  2. Concern for cracking of the neutron shield

# NAC-CTS Cask Application History

NAC-CTS Evolution (cont):

- NAC addressed the NRC issues in a letter to ORNL and subsequently performed cold drop testing of the neutron shield material
- Original SAR, Revision 0, provided to ORNL February 1999
- Assigned Docket #99-18-9864, reviewed by DOE-ORNL in September, 1999 and provided Q0 Review Questions to NAC

# NAC-CTS Cask Application History

## NAC-CTS Evolution (cont):

- NAC responded to DOE-ORNL Q0 reviews questions in April 2000 regarding:
  1. License Drawing comments
  2. Clarification of ASME applicability, Section III, Subsection NG
  3. Stress evaluation of the NS-4-FR
  4. Tie-down design/performance
  5. Shielding evaluation for post impact results based on the requested NS-4-FR stress evaluations
  6. Acceptance and maintenance programs
  7. Additional information regarding impact foam placement procedures
  8. Test outline/procedure for evaluating shielding integrity
  9. Impact foam aging
  10. Safety classifications for all package components and outline implementing requirements

# NAC-CTS Cask Application History

NAC-CTS Evolution (cont):

- NAC issues SARP Revision CTS-00A April 2000
- NAC/ORNL provides SARP to DOE EM-1 for review
- DOE EM-1 assigns SARP review to Lawrence Livermore National Laboratory
- NAC-CTS SARP review activities delayed due in part to funding
- Docket 9864 cancelled July 2002 due to lack of activity
- ORNL and NAC initiate planning for restart in 2004

# NAC-CTS Cask Application History

NAC-CTS Evolution (cont):

- ORNL/UT-Battelle provides contract in June 2006 to NAC to restart licensing activities based on emerging commercial and international needs for the NAC-CTS Package
- Package is to be licensed in accordance with 10 CFR 71 requirements
- NRC certification required since commercial users are NRC licensees
- Future needs may be in support of the medical community

# NAC-CTS Californium Cask Design

The NAC Californium Transport Cask (CTS) is designed to safely transport $^{252}Cf$ source material (≤ 60mg) in one or more capsules meeting the requirements of 10 CFR 71.75 for special form materials

# NAC-CTS Californium Cask Design

The NAC-CTS provides structural support, thermal protection and biological shielding during all normal conditions of transport and hypothetical accident conditions as required by:

- USNRC 10 CFR 71
- IAEA TS-R-1

# NAC-CTS Californium Cask Design

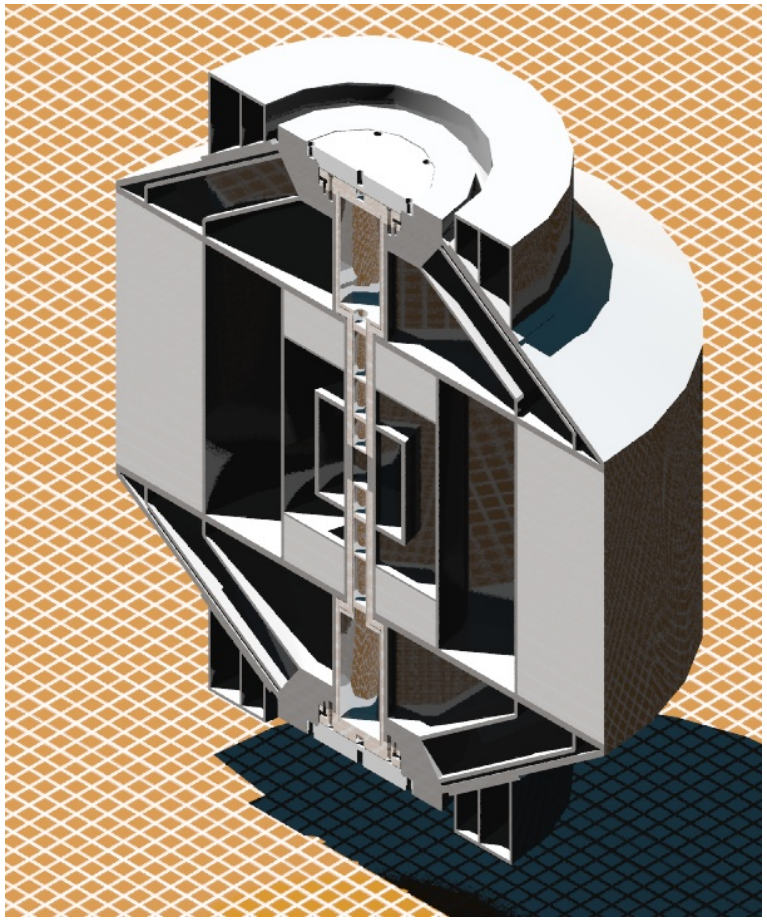
The NAC-CTS design provides more flexibility in loading configurations than previously utilized cask design

- Submersible
- Can be loaded from the top or bottom to meet user facility interface requirements
- Can be pneumatically loaded

# NAC-CTS Californium Cask

## NAC-CTS Design Features:

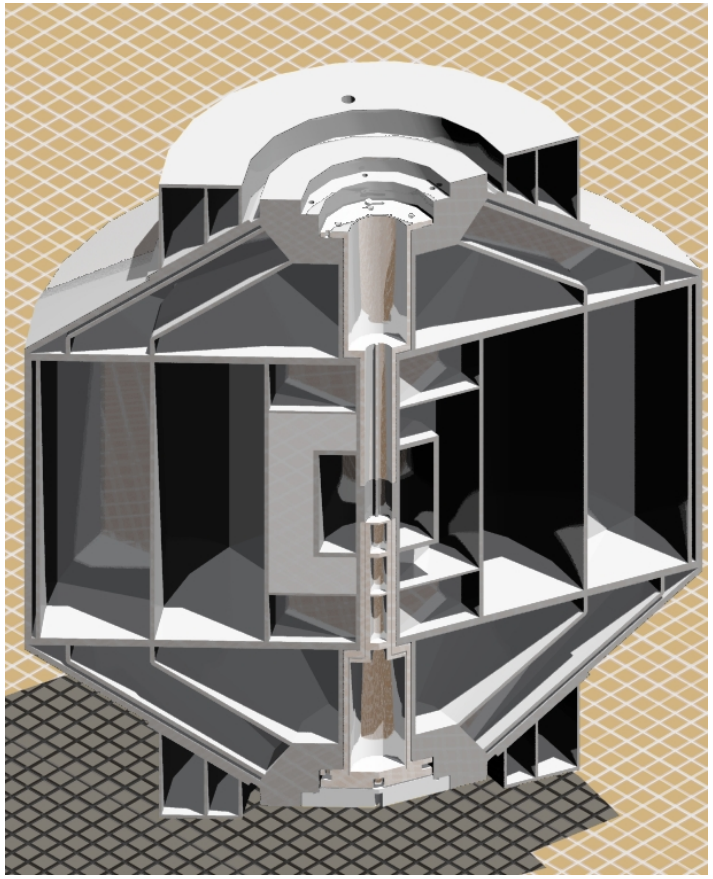
- Total Package weight:  26,400 pounds
- Cask Body is a Right Circular Cylinder with truncated cone top and bottom ends
- 304L Stainless steel, gusseted cylinder construction
- Gussets are staggered to eliminate streaming
- Analysis, fabrication and inspection in accordance with ASME B&PV Section III, Division 1, Subsection NG



# NAC-CTS Californium Cask

## NAC-CTS Design Features:

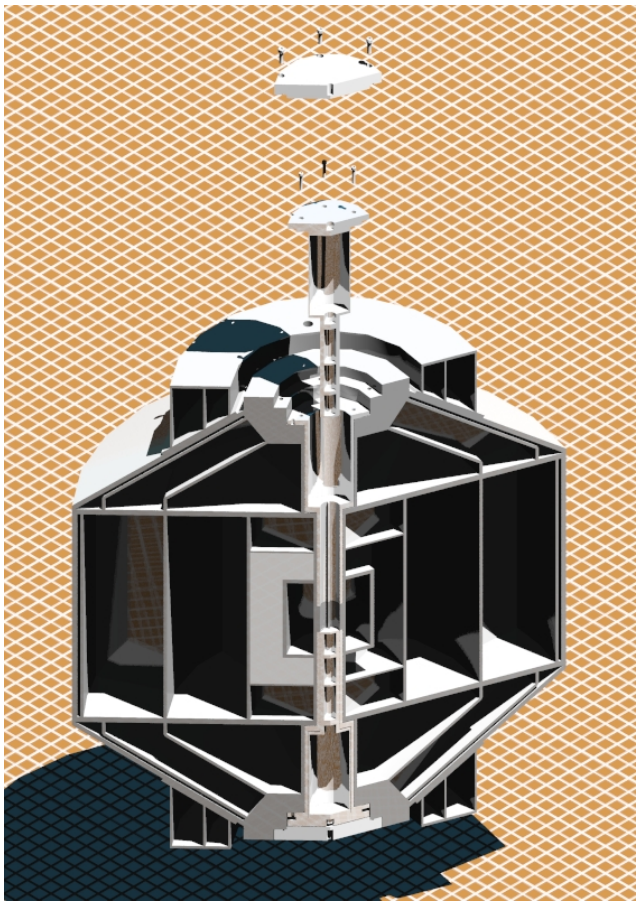
- Multi-compartment, NS-4-FR filled body provides neutron shielding
- External shield compartments are thermally insulated by silicon foam and air gap
- Centrally located basket shielded for gamma radiation by tungsten alloy cylinder enclosed in stainless steel



# NAC-CTS Californium Cask

## NAC-CTS Design Features (cont):

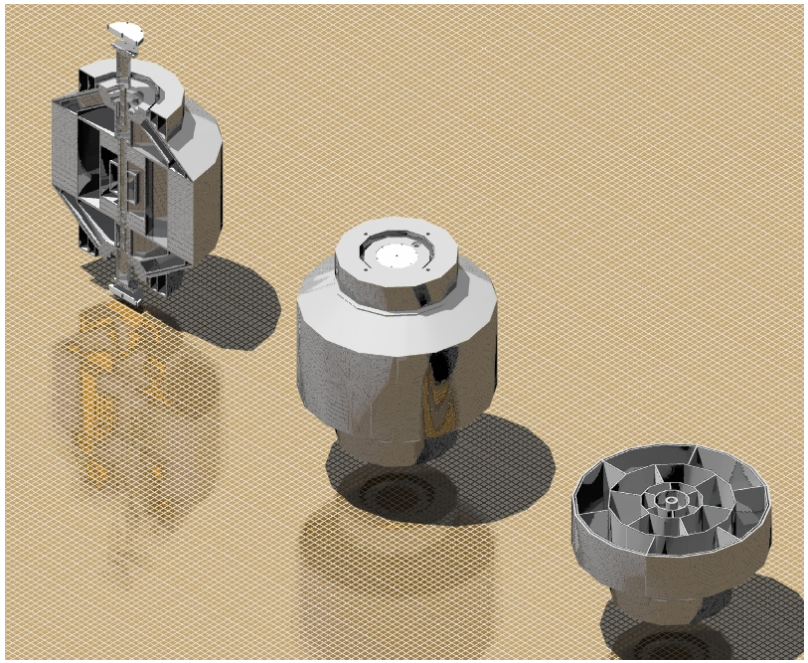
- Source basket loading access provided from either the top or bottom
- Axial cover plates, shield plugs and guide tubes are accessible from each end of the cask
- Sealed internal volume for drying with quick disconnect provided on each end of the cask



# NAC-CTS Californium Cask

## NAC-CTS Design Features (cont):

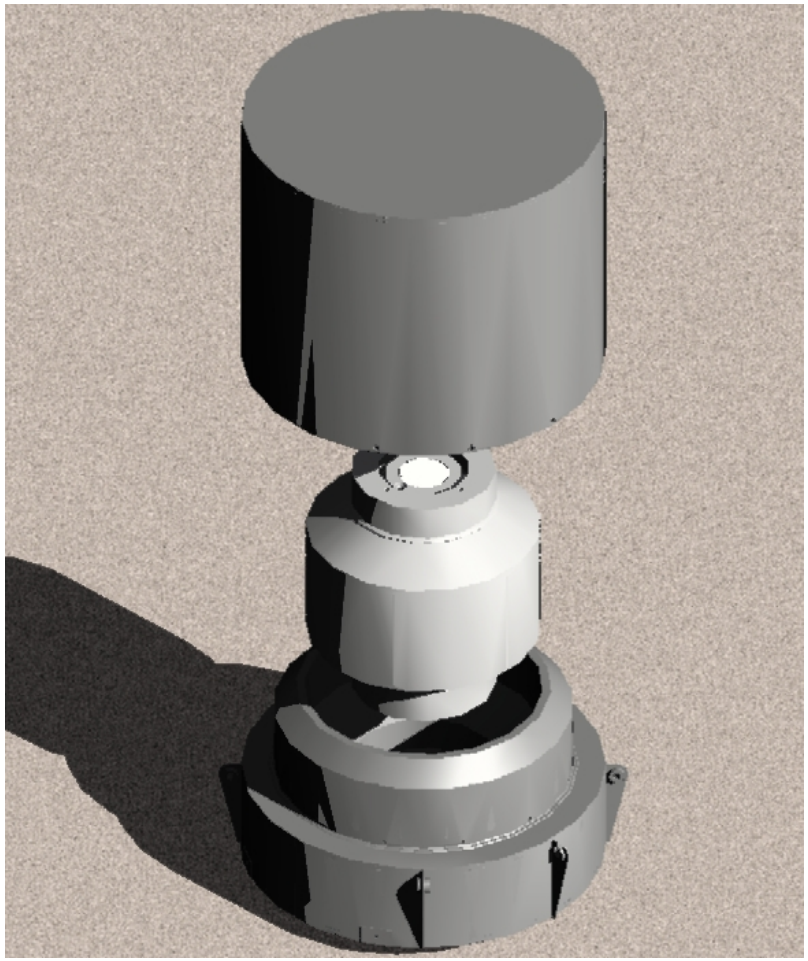
- Integrated single failure lift points and cask supports provided at each end of the cask
- Lifting can be performed on the cask or with the lower impact limiter installed
- Lifting system meets the requirements of 10 CFR 71.45 and ANSI N14.6
- Transport tie-downs are integrated into the impact limiter design



# NAC-CTS Californium Cask

## NAC-CTS Design Features (cont):

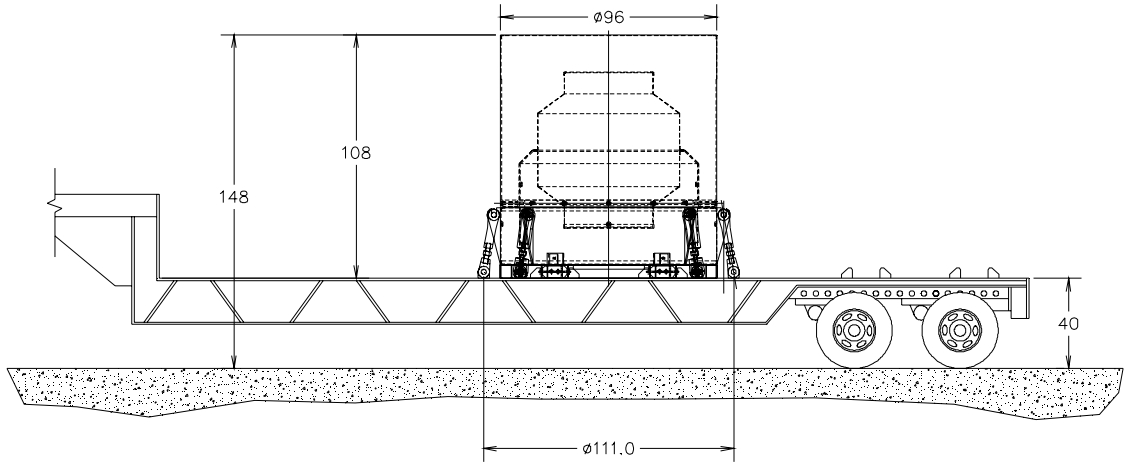
- The NAC-CTS impact limiter design is a 2 piece over-lapping design that fully envelopes the cask body
- The NAC-CTS transport Impact Limiters are fabricated from 304L shells filled with polyurethane foam
- A combination of 3 specific crush strength foams are used to protect the NAC-CTS
- The impact limiters are connected by 12 radially positioned bolts



# NAC-CTS Californium Cask

NAC-CTS Design Features (cont):

- Transportation Skid mounts directly to the lower limiter and incorporates a trailer shear restraint
- Trailer tie-downs are connected to the lower limiter
- Six tie-downs are used for package restraint



SIDE VIEW

# NAC-CTS Contents Description

Aluminum Baskets are designed to accommodate the following $^{252}Cf$ special forms capsules:

1. SR-Cf-100-OR
2. SR-Cf-1000-OR
3. SR-Cf-3000-OR
4. NSD Capsule
5. NSS Capsule

# NAC-CTS Contents Description

- The NAC-CTS cask design addresses the unique properties of the $^{252}Cf$ capsules
- The NAC-CTS is not limited to the capsules identified, but will be certified to transport any capsule which meets 10 CFR 71.75 requirements and the analytical constraints of the cask design
- Multiple basket designs will be developed for these capsules and will address special handling methods for loading and unloading

# NAC-CTS Participating Organizations

- NAC International
- Oak Ridge National Laboratory
- USNRC

# Summary of Structural and Thermal Evaluations for the NAC-CTS

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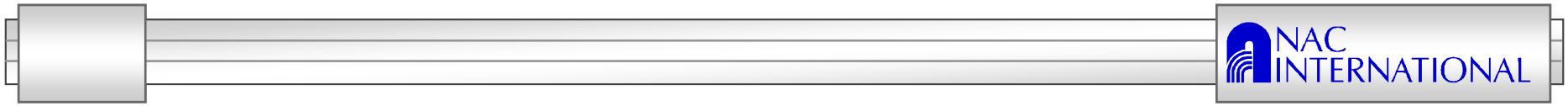
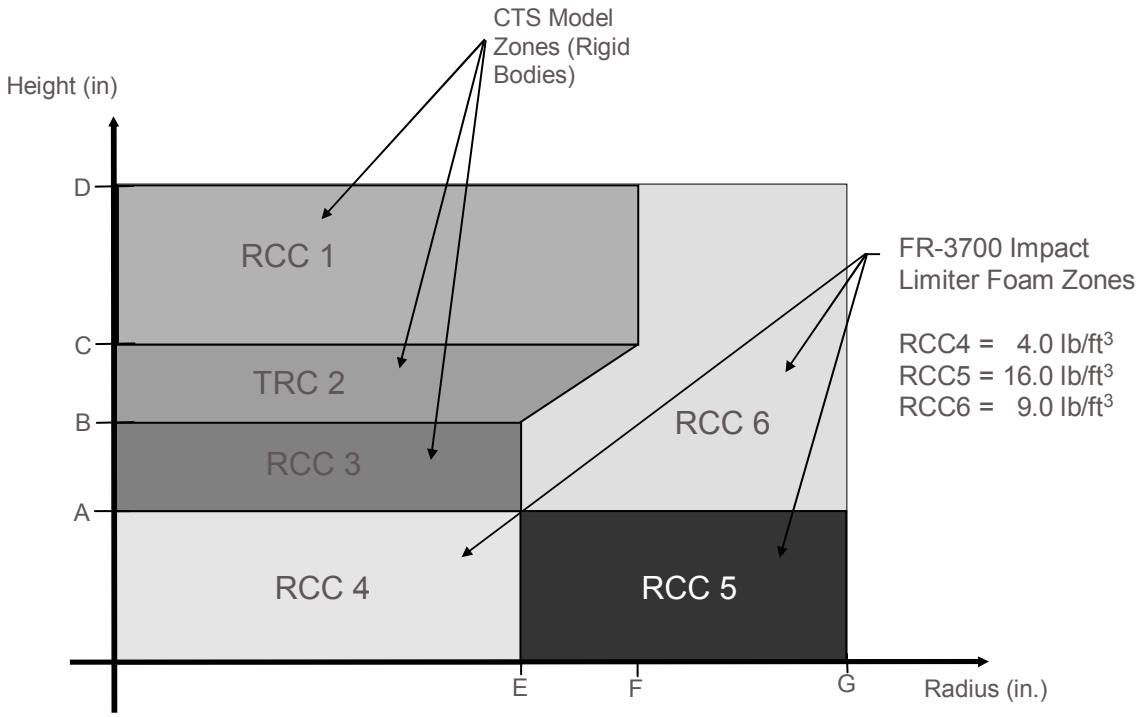


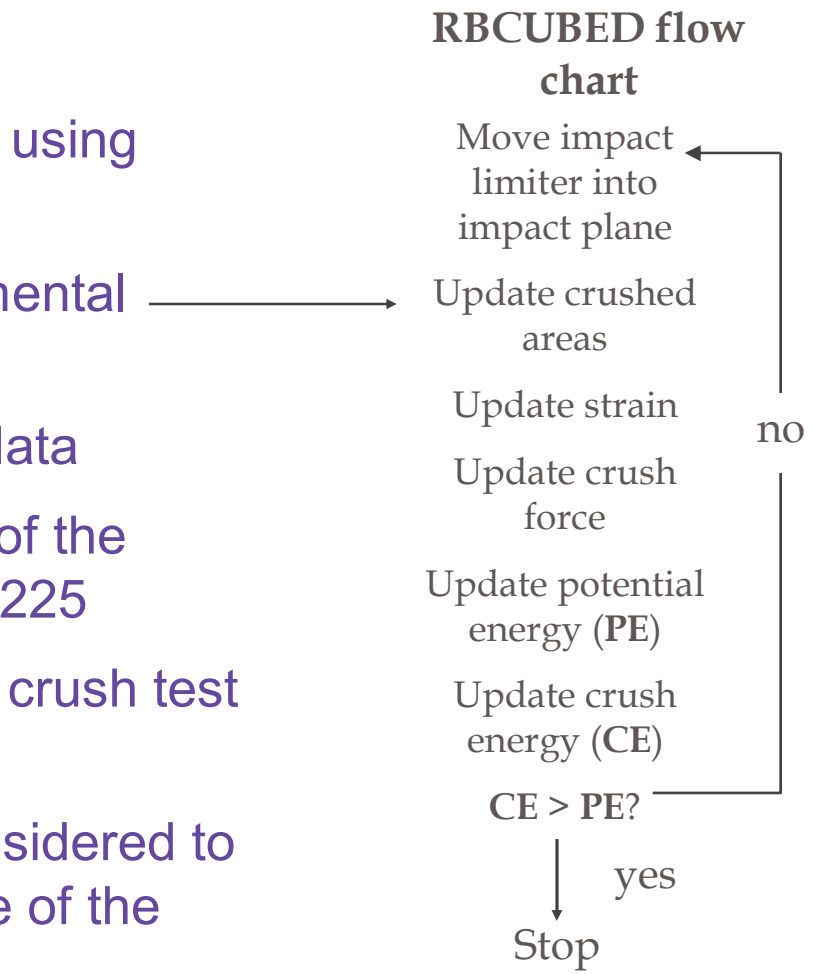
# Impact limiter design

- General Plastics Foam FR-3700 comprises the impact limiter
- Crush strength properties are well documented
  - Temperature effect, tolerance band during pouring
- Multiple densities are used to minimize accelerations for the end, corner and side drop
- Stainless steel shell has been used and tested in numerous NAC impact limiter designs
- Aspect ratio of cask reduces slap down to an insignificant level



# Impact limiter evaluation

- Impact limiter evaluation is performed using RBCUBED
- Solution methodology employs incremental energy absorption
- Input into RBCUBED is stress strain data
- RBCUBED was used in the licensing of the NAC-LWT cask, Docket Number 71-9225
- Validation was performed using static crush test for honeycomb aluminum
- Static testing using honeycomb is considered to bound the more homogeneous texture of the FR-3700 foam material
- Test data from the NAC-LWT cask will be included in the CTS SAR



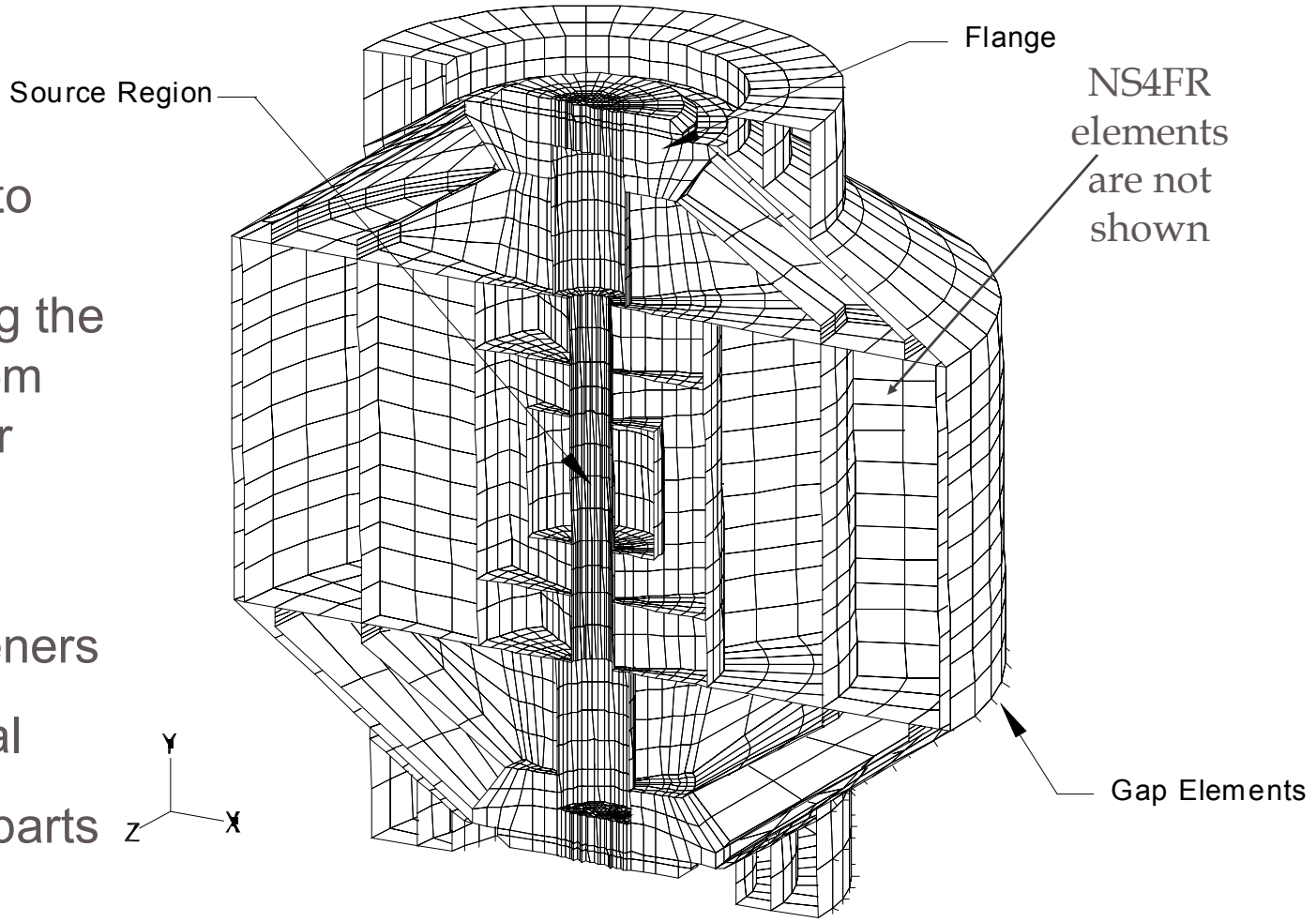
# Impact limiter analysis results

| Drop Height (ft) | Temperature Condition | Drop Angle | Impact Deceleration (g) | Maximum Displacement (in) | Max. Potential Crush Depth (in) | Maximum Strain (%) |
|---|---|---|---|---|---|---|
| 2 | Cold | 0° | 42.0 | 1.1 | 15.9 | 6.9 |
| 2 | Cold | 43.3° | 10.1 | 6.0 | 30.4 | 19.7 |
| 2 | Cold | 90° | 33.7 | 1.7 | 15.7 | 10.8 |
| 2 | Hot | 0° | 21.0 | 2.1 | 15.9 | 13.2 |
| 2 | Hot | 43.3° | 7.1 | 9.1 | 30.4 | 29.9 |
| 2 | Hot | 90° | 17.8 | 2.8 | 15.7 | 17.8 |
| 30 | Cold | 0° | 72.2 | 6.3 | 15.9 | 39.6 |
| 30 | Cold | 43.3° | 62.1 | 14.5 | 30.4 | 47.7 |
| 30 | Cold | 90° | 91.7 | 6.6 | 15.7 | 42.0 |
| 30 | Hot | 0° | 75.3 | 12.2 | 15.9 | 76.7 |
| 30 | Hot | 43.3° | 41.0 | 20.9 | 30.4 | 68.8 |
| 30 | Hot | 90° | 72.3 | 11.6 | 15.7 | 73.9 |

# CTS finite element evaluation for normal and accident conditions

ANSYS is used to perform static evaluations using the accelerations from the impact limiter evaluations

- Detailed model includes all stiffeners
- NS4 FR material
- Gaps between parts are modeled



# Stress results for the 30-foot drop evaluations

- Stress evaluations consider the plates and the welds separately
- Welds require weld quality factors under Subsection NG
- Nodal forces are used to compute the force/length quantity

| Drop Orientation | Stress State | Real Constant | Quality Factor | Weld Size | Allowable Force/Length | Tens/Comp Force/Length | Margin of Safety |
|---|---|---|---|---|---|---|---|
| End | Tension/Comp. | 62 | 0.50 | 0.38 | 7.52 | 5.52 | 0.36 |
| End | Shear | 65 | 0.30 | 0.38 | 2.25 | 2.12 | 0.07 |
| Side 'A' | Tension/Comp. | 6 | 0.90 | 0.63 | 22.55 | 20.59 | 0.09 |
| Side 'B' | Shear | 6 | 0.90 | 0.63 | 11.27 | 11.21 | 0.01 |
| Corner 'A' | Tension/Comp. | 63 | 0.90 | 0.38 | 13.53 | 9.33 | 0.45 |
| Corner 'B' | Shear | 65 | 0.30 | 0.38 | 2.25 | 2.08 | 0.09 |

## Stress results for the 30-foot drop evaluations-continued

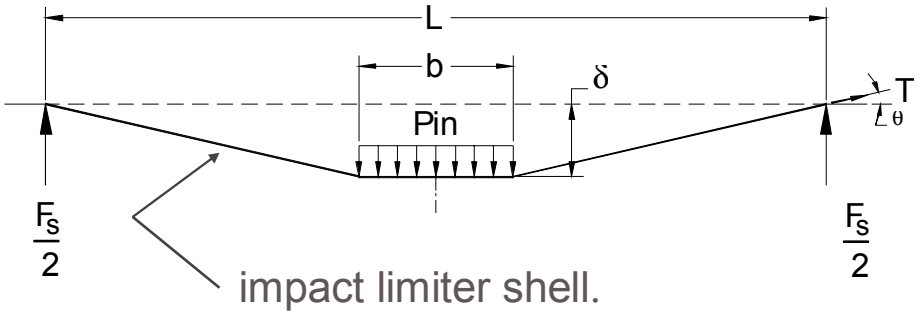
•Shell element output from the analysis provide the membrane (Pm) and the bending plus membrane (Pm+Pb) stresses directly

| Drop Orientation | Stress State | Real Constant(s) | Allowable Stress (ksi) | Stress Intensity (ksi) | Margin of Safety |
|---|---|---|---|---|---|
| End | $P_m$ | 63, 68, 67 | 40.08 | 30.52 | 0.31 |
| End | $P_m+P_b$ | 63, 68, 67 | 60.12 | 48.43 | 0.24 |
| Side 'B' | $P_m$ | 11, 6, 60 | 40.08 | 37.08 | 0.08 |
| Side 'A' | $P_m+P_b$ | 11, 6, 60 | 60.12 | 58.77 | 0.02 |
| Corner 'A' | $P_m$ | 63, 68, 67 | 40.08 | 27.07 | 0.48 |
| Corner 'A' | $P_m+P_b$ | 63, 68, 67 | 60.12 | 46.29 | 0.30 |

The analysis results demonstrate the cask meets the specified design criteria for hypothetical 30-foot drop conditions.

# Pin puncture evaluation

•Pin puncture must penetrate the stainless steel shell and crush the foam.




•As the pin moves into the limiter, the shell will develop membrane stresses

•The solution is obtained by equating the potential energy to the absorbed energy of the foam the strain energy in the stainless steel shell

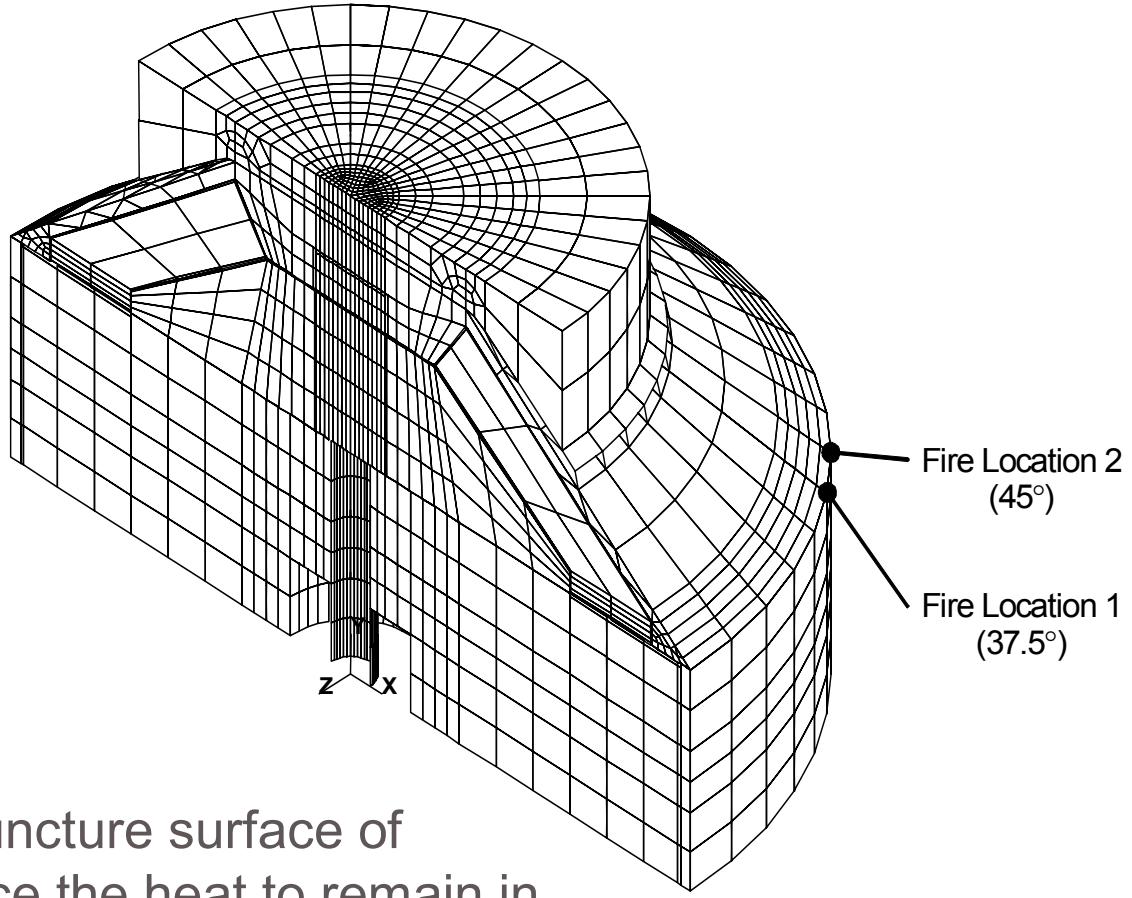
•Due to the stiffer foam, the side pin puncture does not penetrate the impact limiter shell. Accelerations of the side pin puncture is bounded by the side drop

•Due to the softer foam for the end drop, the shell is penetrated. The model for the 30-foot drop is used to determine the stresses due to pin loading on the cask body. Minimum M.S is +0.17

# Thermal Evaluation Summary

- Heat load of the $^{252}Cf$ is 3 Watts
- Normal conditions need only consider the solar insolance to determine component temperatures (NS4FR, stainless steel, FR3700 foam)
- Fire accident condition
  - Initial conditions correspond to normal conditions
  - The convective heat transfer coefficient during the fire is a constant, 0.01223Btu/hr-in$^2$-°F. A value of 0.02446 Btu/hr-in$^2$-°F is applied
  - Accounts for the impact limiter crush
    - Reduction of thickness
    - Increased density by conservation of mass
  - Accounts for pin puncture by removing the foam from the surface of the cask body

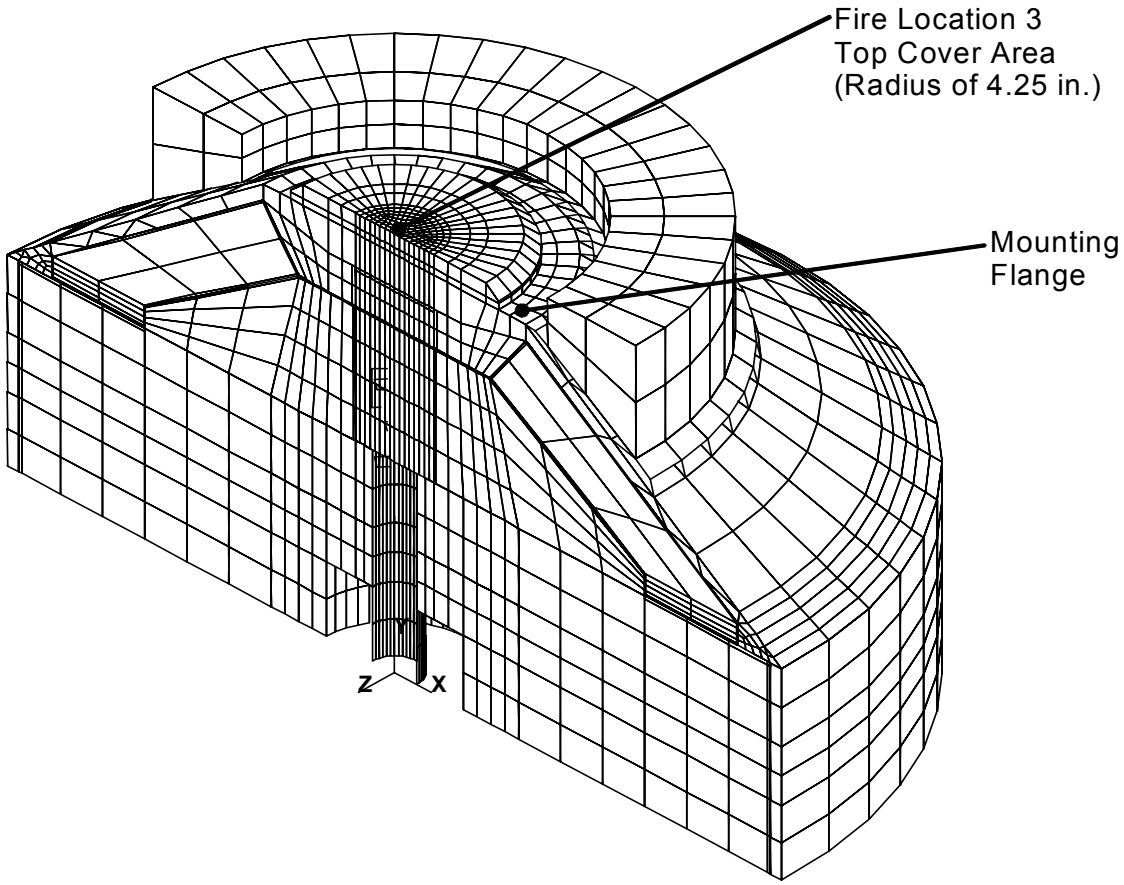
# Fire accident condition




- Three conditions are considered
  - Pin puncture is based on the location of the stiffener
  - Outside region of pin puncture surface of model is adiabatic to force the heat to remain in the model

# Fire accident condition-continued

- A pin puncture is considered on the end to maximize the heat into the special form capsule



# Maximum component temperatures for the fire accident

| Component | Accident Condition (°F) |
|---|---|
| Basket | 190 |
| NS-4-FR | 289 |
| Cask Outer Surface | 986 |

- Maximum temperatures are below the allowable temperatures

# Summary of Nuclear Evaluations for the NAC-CTS

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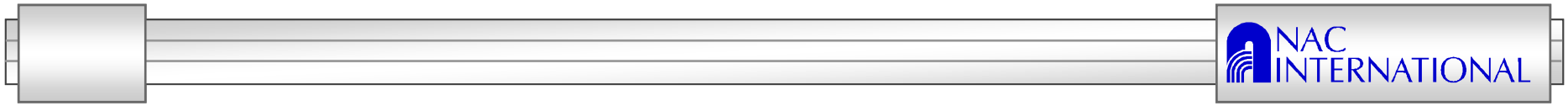


# Containment Evaluation Summary

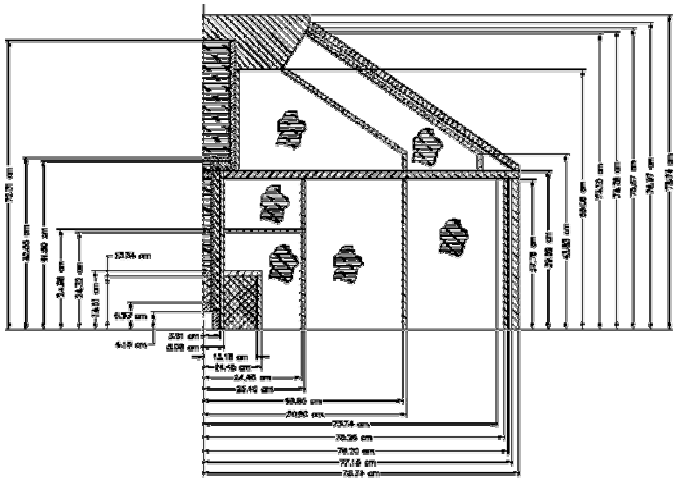
- Californium capsule is special form per 10 CFR 71.75
- Capsule is the containment boundary for Cf and is helium leak tested to $1.4 \times 10^{-8}$ $cm^3$/sec (detail provided in Chapter 4 of SAR)
- Tested for normal and accident conditions required of special form capsules
  - Includes pressure considerations for maximum helium build-up due to radioactive decay of source

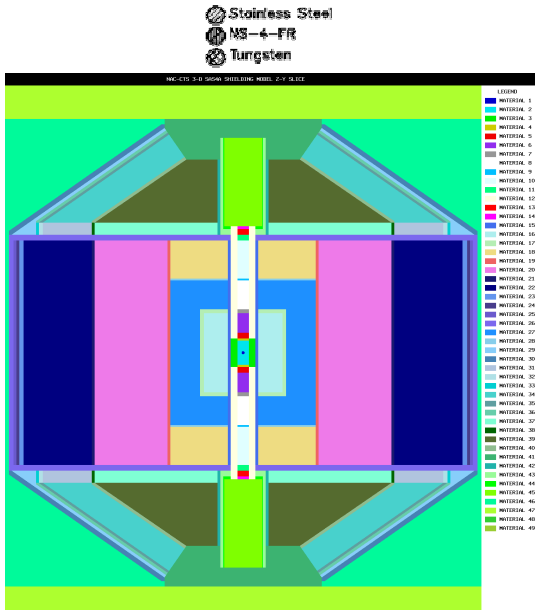
# Shielding Evaluation Summary

- Source (60 mg $^{252}Cf$)
  - Neutron source comparisons performed for
    - SCALE 4.3 ORIGEN-S ENDF/B-IV
    - ORNL ENDF/B-VI
    - Source as pure $^{252}Cf$, addition of associated isotopics, and oxide form
    - Bounding source ENDF/B-VI source spectrum / ORIGEN-S source magnitude
  - ORIGEN-S generated gamma source
- SCALE 4.3 (MORSE) 3-D shielding evaluation
- SCALE (SAS1/ORIGEN) activation evaluation

# 3-D Shielding Evaluation

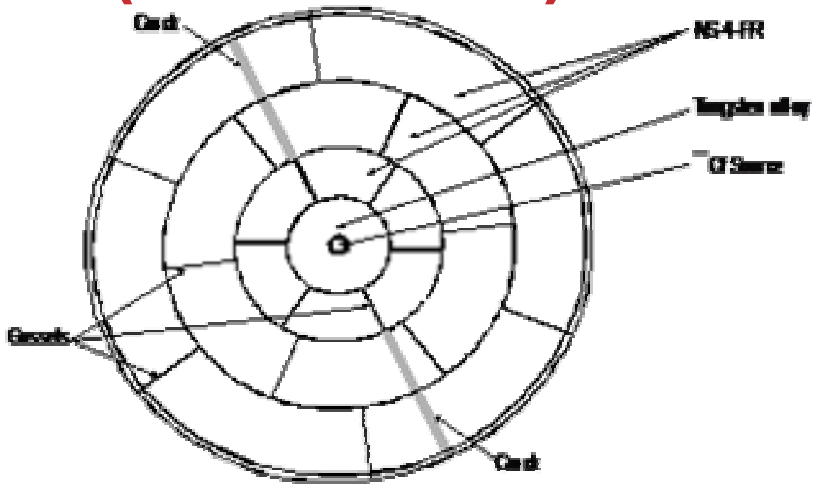
- Axisymetric model
- Primary gamma shield – tungsten cylinder
- Primary neutron shield – NS-4-FR with 6.5 wt% $B_4C$
  - Negligible depletion (< $2x10^{-5}$ % over 40 year system life)
  - Neutron shield steel enclosed
- Normal conditions conservatively neglect impact limiters
  - Includes NS-4-FR gap in outer neutron shield section (potential gap due to material pour)

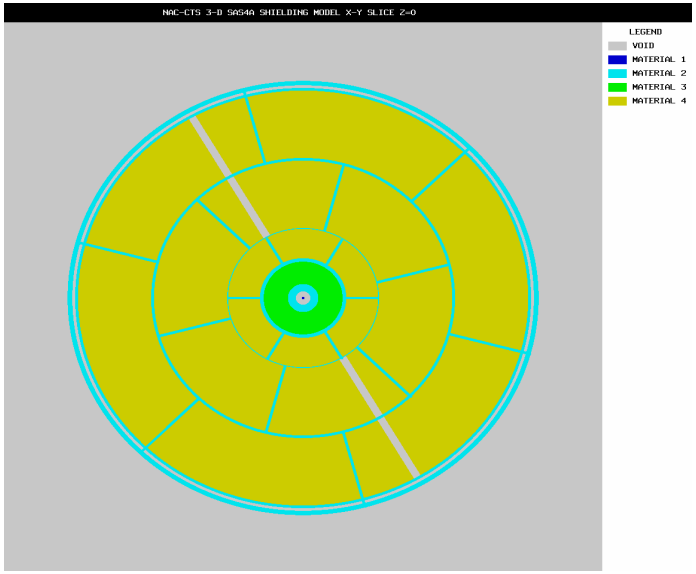




# 3-D Shielding Evaluation (continued)

- Accident conditions consider
  - loss of impact limiter
  - fire depletion of NS-4-FR, and
  - neutron shield fracture
- Drop accident model
  - 1” square gap through shield
  - Several combinations evaluated
  - Bounding configuration is gap through outer two layers in line with inner gusset



# Shielding Evaluation Result Summary

- Normal Condition
  - Cask (Impact limiter) surface < 7 mrem/hr
  - 2 meter from impact limiter < 1 mrem/hr
- Accident Conditions
  - Maximum dose < 40 mrem/hr on cask surface (to obtain better statistics surface dose was calculated)
- Activation after 40 year life (continuous use) calculated dose of ~0.1 mrem/hr on cask surface

# Criticality Evaluation Summary

- No computer code evaluations
- Criticality control based on critical mass limits per ANSI/ANS 8.15
- Smallest mass limit is for $^{251}Cf$ – 5 grams
  - Only odd number isotopes support thermal fission
  - Even numbered isotopes may fast fission but kg quantities required
- Payload limited to
  - The maximum quantity of Cf and Cm shall not exceed 5 grams
  - The maximum quantity of $^{252}Cf$ shall not exceed 60 mg
  - The maximum quantity of $^{249}Cf$ shall not exceed 1.5 grams
  - The maximum quantity of $^{251}Cf$ shall not exceed 1.0 grams

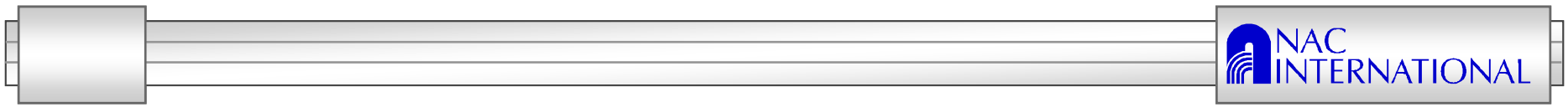
# Criticality Evaluation Summary (continued)

- Criticality Safety Index (CSI) = 0
  - Each package contains subcritical mass
  - Cask maximum neutron surface dose < 20 mrem/hr (i.e., no significant neutron interaction between casks)

# NAC-CTS Submittal Schedule

- February 28, 2007 - NAC to submit NAC-CTS SAR NRC
- October 31, 2007 - NRC Review Complete
- February 28, 2008 – NRC Issue Certificate of Compliance

# Questions?



# Upcoming Amendment Request for NAC-LWT Package – Docket No. 71-9225

Changes under consideration are:

- Increase TRIGA fuel length (from 45” to 48”)
- Increase hydrogen/zirconium ratio and zirconium mass
- Include unirradiated fuel as approved contents for all fuel types
- Include irradiated hardware as approved contents (GTCC)
- Make weather seal into an optional design feature
- Eliminate redundant check of shield fluid level before every shipment (perform visual inspection for leaks)
- Remove outdated material specifications and non-essential information from license drawings
- Miscellaneous editorial changes

# NAC-LWT Amendment Request
# Estimated Schedule

- Submittal to the NRC – End of October 2006
- Need for revised CoC – April 2007 to support RERTR Shipment

# Licensing Overview of NAC-UMS® Amendment Application - Docket No. 72-1015

*September 28, 2006*

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# Licensing Summary
# NAC Universal Storage System (NAC-UMS®)

- Licensing Basis:  CoC No. 1015, Amendment 4, October 11, 2005
- Final Safety Analysis Report (FSAR) Revision 5C
- Amendment Request (FSAR Rev. UMSS-06A) submitted September 22, 2006
- 24-month 72.48 update scheduled for November 2006
- Desired final effective date for Amendment 5 is October 1, 2007

# Amendment Request Submitted September 22, 2006

- Incorporated high burnup PWR fuel as approved contents
- Made the requirement for tamper-indicating seal on the concrete cask bolts optional (CoC change)
- Eliminated the Technical Specification requirement for helium leak testing of canister shield lid to canister weld (per ISG-15 and ISG-18 guidance)
- Revised written reporting requirement to 60 days from 30 days [per 10 CFR 72.75(g)]
- Eliminated the requirement for Charpy impact test of BWR support disk material (0.625 in. nominal thickness)
- Made the use of threaded plugs and dowel pins on the structural lid and shield lid optional (ALARA considerations)

# Structural and Thermal Considerations for High Burnup Fuel Content for NAC-UMS®

- Methodology used for the fuel rod buckling evaluation and the side drop evaluation has not been altered from previous submittals. Fuel rod does not buckle for the 24 inch drop.
- Properties for the cladding are established by ISG-12 and PNNL (Geelhood)
- Heat load does not change for the thermal evaluation
- Thermal properties are considered to remain the same in terms of emissivity and conductivity
- Maximum fuel clad temperature is limited to ISG-11guidance

# Summary of Nuclear Evaluations for the PWR High Burnup Fuel Amendment

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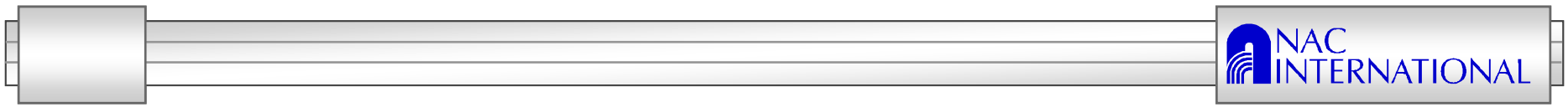


# Confinement

- No changes
  - Leaktight canister configuration
  - Pressure previously evaluated for 60,000 MWd/MTU fuel at 1.9 wt% $^{235}U$ (bounding for any burnup/enrichment combination)

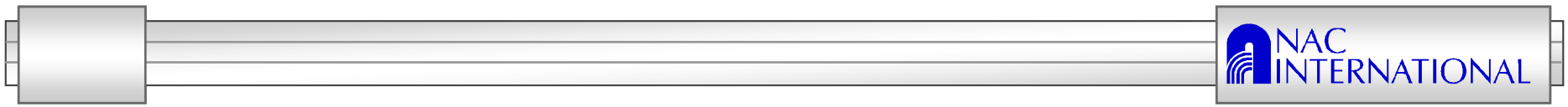
# Criticality

- No changes
  - Fuel remains intact through storage normal and accident conditions
  - Added peak rod average burnup limit of 62,500 MWd/MTU to FSAR

# Shielding / Source Term

- Source Term
  - Updated to include references to high burnup SAS2H (ORIGEN) validation
  - Extended burnup matrix to 60 GWd/MTU in 5 GWd/MTU increments
- Generated cool time matrix for 50, 55, and 60 GWd/MTU (assembly average)
  - Retained heat load / dose rate limits and SAR evaluation method
    - Initial UMS evaluations based on 40 GWd/MTU, 5 year cool design basis assembly at 3.7 wt% $^{235}U$
    - Licensing process expanded the initial design values to 45 GWd/MTU and a range of enrichments by assuring initial design basis dose rates and heat load limits are not exceeded
    - Dose rates evaluated by folding source (spectrum lines) for any burnup/enrichment against dose response function (unit source dose effect for each spectrum line)
    - Identical method employed in extending burnup out to 60,000 MWd/MTU

# Questions?



# Licensing Overview of NAC-MPC Amendment Application - Docket No. 72-1025

*September 28, 2006*

***NAC International is a Wholly Owned Subsidiary of USEC Inc., the World's Leading Supplier of Enriched Uranium Fuel for Commercial Nuclear Power Plants.***

# Licensing Summary
# NAC Multi-Purpose Canister (NAC-MPC)

- Licensing Basis: CoC No. 1025, Amendment 4, October 27, 2004 and NAC-UMS® CoC No. 1015, Amendment 4
- NAC-MPC Final Safety Analysis Report (FSAR) Revision 6A
- Amendment Request (FSAR Rev. MPC-06A) submitted July 17, 2006, supplemented September 13, 2006 (MPC-06B)
- Desired final effective date for CoC 1025, Amendment 5 is March 2007

# Amendment Request Submitted July 17, 2006 and Supplement Dated September 13, 2006

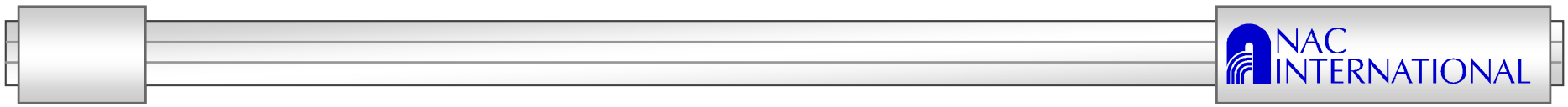
July 17, 2006 Submittal:

- Included alternative for daily visual inspection of air inlet and outlet screens for blockage, as well as inspection after any natural phenomena event (temperature monitoring)
- Removed reference to air from component operating environment (per ISG-22)
- Revised reporting requirement from 30 to 60 days [per 10 CFR 72.75(g)]

September 13, 2006 Supplement:

- Made the requirement for tamper-indicating seal on the concrete cask bolts optional (CoC change)

# Questions?



# Applicability of Storage System CoC/Tech. Spec. Amendments to Existing Installations

- Industry issue
- Available regulatory guidance
- Options for general licensees to implement CoC amendments
- Complete or partial implementation of an amended CoC
- Action required from general licensee
- Action required from CoC holder
- Backward and forward compatibility of hardware
- 72.212 report update