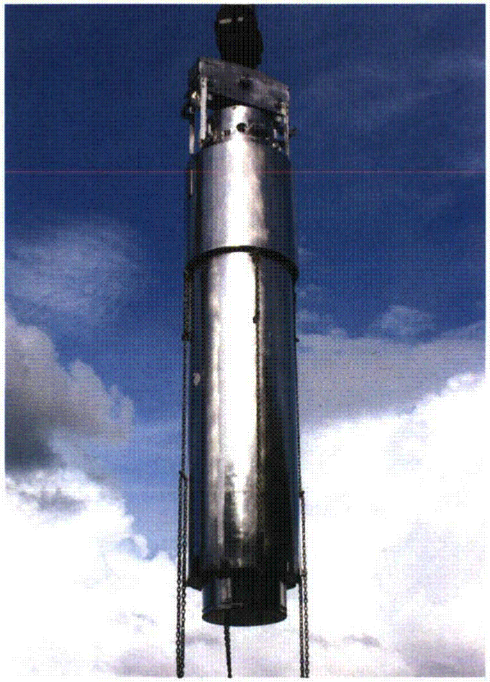
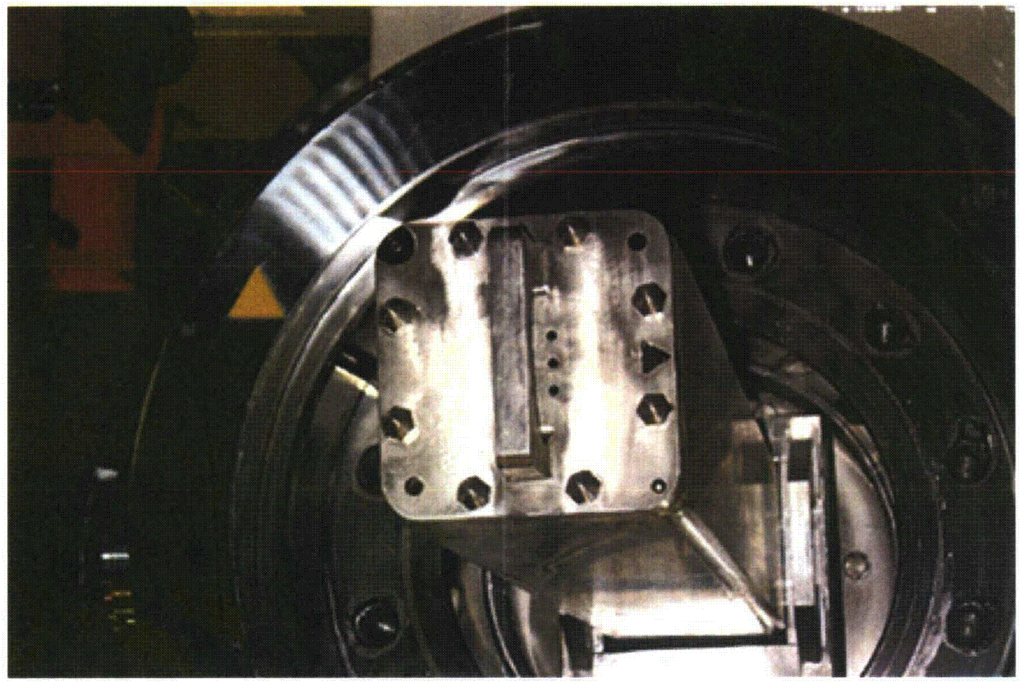
NAC-LWT MOX SAR Amendment





February 25, 2008

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MOX Applications

NAC-LWT Legal Weight Truck

Spent Fuel Transport Cask

Docket #71-9225

MOX Transport Supporting Pu Disposition Program

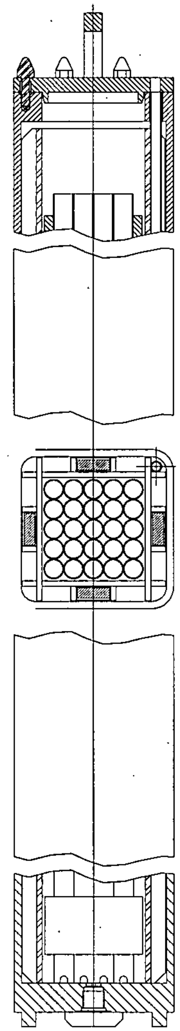
MOX Amendment Summary

NAC prepared and submitted an amendment request for the NAC-LWT CoC by revising the SAR to incorporate the following new content conditions:

- Mixed Oxide (MOX) Fuel Rods irradiated in a pressurized light water reactor (PWR)
  - The new content requested for inclusion in the CoC is a mixed load of up to 16 MOX and PWR fuel rods (plus the ability to load nonfuel hardware into open tubes within the 5x5 array)
  - Current PWR/BWR rod transport canister and 5x5 insert will be used
  - Current CoC authorizes the transport of up to 25 PWR UO_2 rods in 5x5 insert contained in a PWR/BWR rod transport canister

MOX Fuel Rod Shipping Configuration

- Up to 16 MOX/PWR rods loaded into a licensed 5x5 insert
- Insert located in a free flow rod or screened rod transport canister
- Canister inserted into PWR basket insert loaded into PWR basket
- Transport configuration identical to current licensed shipping configuration for LWR rods except cask containment is in the leaktight configuration (i.e., all metal seals)



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MOX Fuel Rod Structural and Thermal Evaluation Considerations

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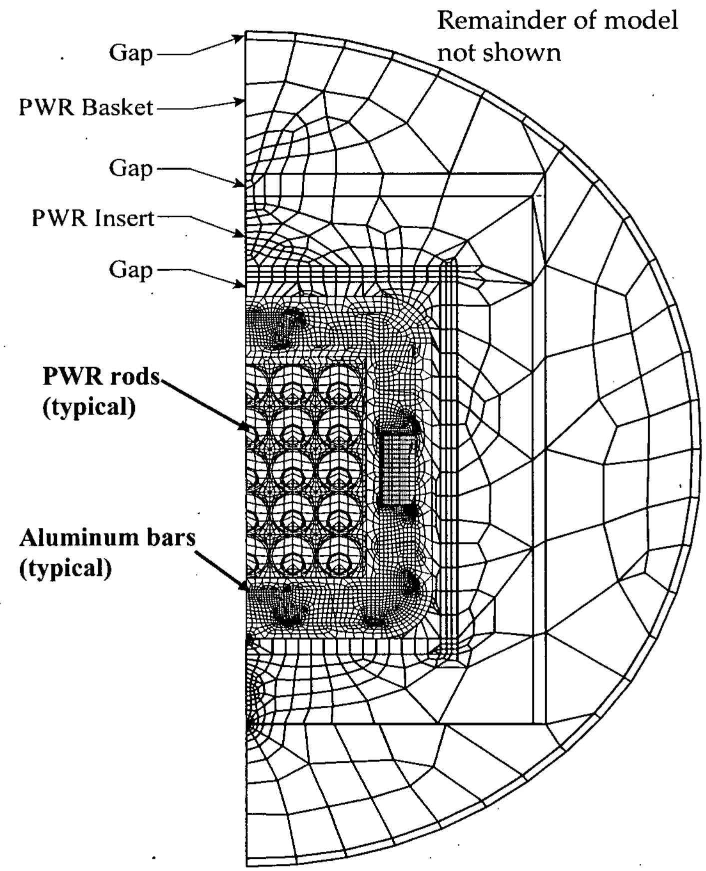
Structural Considerations for MOX Fuel Rods

- The MOX and PWR fuel rod payload is enveloped by the current content (25 PWR or BWR rods) maximum weight
- MOX rods are $\leq$2.75 kg per rod for a total load of < 1,300 lbs for the fuel rods, insert, transport canister and PWR basket spacer
- Current structural evaluations use a bounding load of 1,500 lbs
  - Corresponds to a permissible rod weight of 14 lbs (6.4 kg) per rod
- The proposed MOX fuel rod payload meets geometry requirements (i.e., length, diameter, etc.) of previous LWR rod evaluations
- Therefore, no change to the SAR structural evaluations were required

Thermal Considerations for MOX Fuel Rods

- Maximum heat load of 143 W per rod with a peaking factor of 1.1
- Total heat load for the MOX/PWR fuel rod contents is 16×143 W = 2.3 kW
- Maximum number of MOX rods is 16 in a 5x5 fuel rod insert
- Standard conditions are applied for the NAC-LWT thermal analysis:
  - Helium backfill in cask cavity
  - Package loaded in an ISO container
  - Condition 1 in SAR Section 3.4.1.7
- Current licensed condition for PWR high burnup rods is for 25 rods with a maximum heat load of 2.3 kW



ANSYS half-symmetry model of the cross-section of the 25-rod basket

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Thermal Considerations for MOX Fuel Rods
(continued)

- Evaluation in Section 3.4.1.7 Rev. 38 of the NAC-LWT SAR applied a 2-D ANSYS model
  - Assigned 160 W heat load to each of the 25 rods (4 kW total)
  - Modeled 160 W heat load included a peaking factor for axial flux shape
  - Table 3.4-10 reports a maximum clad temperature of 671°F < 752°F (meets ISG 11, Revision 3)
- MOX amendment revised Section 3.4.1.7 (Normal) and Section 3.5.1.2 (Fire Accident) to provide justification that:
  - 143 W high burnup MOX/UO_2 rods, with a peaking factor of 1.1, are bounded by the heat load applied in the previous analysis (143 W x 1.1 = 158 W < 160 W
  - Removal of 9 fuel rods at 160 watts per rod (1.44 kW total) significantly reduces fuel temperatures (no significant effect on system conductance)
  - Effect of reduced MOX thermal conductivity versus UO_2 is not significant

Summary of Nuclear Evaluations
MOX Fuel Rods

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MOX Fuel Nuclear Evaluations

- Containment
  - Cask configuration to use metallic seals to providing leaktight containment
  - Pressure calculations account for maximum MOX fuel rod fission gas release
- Shielding
  - SAS2H source term generation for MOX elements
    - Included light element activation of plenum springs
    - Evaluated various plutonium compositions ranging from weapons grade (WG) to power grade (PG)
  - MCNP shielding evaluation with revised source terms
  - Generate minimum cool time table – constraint by heat load
- Criticality
  - MCNP evaluations using ENDF/B-VI libraries
  - Applying maximum reactivity rod pitch configuration

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Containment/Pressure Evaluation
MOX Fuel Rods

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NAC-LWT Containment Considerations

- Based on recommendations of NUREG-1617, Supplement 1, MOX Fuel Rod Contents will be loaded into a NAC-LWT with a leaktight containment
- Containment openings (i.e., closure lid and vent and drain port covers) will be sealed with metallic O-ring seals
- Containment design will be identical to that utilized and certified for TPBAR transports
- The lid and Alternate B port covers will each be individually leak tested to verify a helium leakage rate of less than or equal to 2×10^{-7} cm^3/s
- Therefore, there will be no leakage of radioactive material from the cask under normal or hypothetical conditions of transport

NAC-LWT Pressure Considerations

- System pressure evaluated (30% fission gas release)
  - Normal condition (3% rod failure) system pressure 17.2 pisg
  - Accident condition (100% rod failure) system pressure 80.0 psig
- Failure of 13 rods during normal transport at 100% fission gas release required to reach 50 psig limit (structural analysis basis)
- Failure of all 16 MOX rods at 75% fission gas release produces maximum normal condition pressure of 48.5 psig

MOX Shielding Evaluation

- Source generation duplicates LWR UO_2 rod source generation currently in NAC-LWT SAR
- Generated maximum fissile material mass fuel pin hybrid
  - Pellet OD 0.3805 inch, Active Fuel Length 153.5 inches
  - 2.63 kg HM per rod
- Source term evaluated using the SAS2H sequence
  - Range of plutonium compositions from WG/MOX Services (93.5% ^{239}Pu) to PG (62% ^{239}Pu)
    - Lower limit ^{239}Pu applied to each Pu composition to maximize shielding source
  - Cool time from 90 days in 10-day increments
  - Burnups evaluated up to 70 GWd/MTHM (maximum requested average rod burnup of 62.5 GWd/MTHM)
  - Light element source at 5g ^{60}Co/kg of plenum spring

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MOX Shielding Evaluation (continued)

- Minimum cool time generated for various plutonium contents
  - Standard configurations from MOX review plan plus MOX Services (MS) specific configuration (similar to WG)
  - Added uranium oxide fuel for comparison and shipment with the MOX rods
    (UO_2 rods at 80 GWd/MTU to conform to currently licensed contents)
- Analysis shown in presentation based on a range of 2 wt% to 7 wt% fissile Pu content for all grades
  - 0.2 wt% ^{235}U depleted uranium matrix
    (conservatively reduced fissile material)
  - Overall low fissile content for burnups considered

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MOX Shielding Evaluation (continued)

- With the exception of power grade (low quality Pu), minimum cool time is *90 days*
  - Power grade Pu requires 120 days
- Required cool time increases with increased fissile Pu content while source increases with decreased fissile Pu content

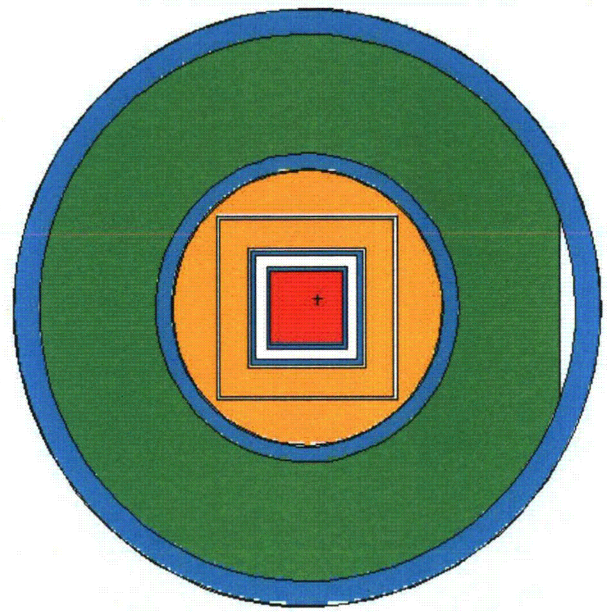
WG Source Term Magnitudes at 70 GWd/MTHM and 90 Days Cool	Heat [watts/rod]	Neutron [n/sec/rod]	Gamma [γ/sec/rod]
2% Fissile	118.1	4.34E+07	7.11E+14
3% Fissile	122.4	3.28E+07	7.12E+14
4% Fissile	126.7	2.59E+07	7.09E+14
5% Fissile	129.0	2.14E+07	7.06E+14
6% Fissile	129.3	1.83E+07	7.03E+14
7% Fissile	128.6	1.60E+07	7.00E+14

Burnup (GWd/MTHM) Fissile Material Type	80 LEU	70 WG	70 FG	70 PG	70 MS
7% Fissile Content	<90	<90	<90	120	<90
6% Fissile Content	<90	<90	<90	120	<90
5% Fissile Content	<90	<90	<90	110	<90
4% Fissile Content	<90	<90	<90	100	<90
3% Fissile Content	<90	<90	<90	<90	<90
2% Fissile Content	<90	<90	<90	<90	<90

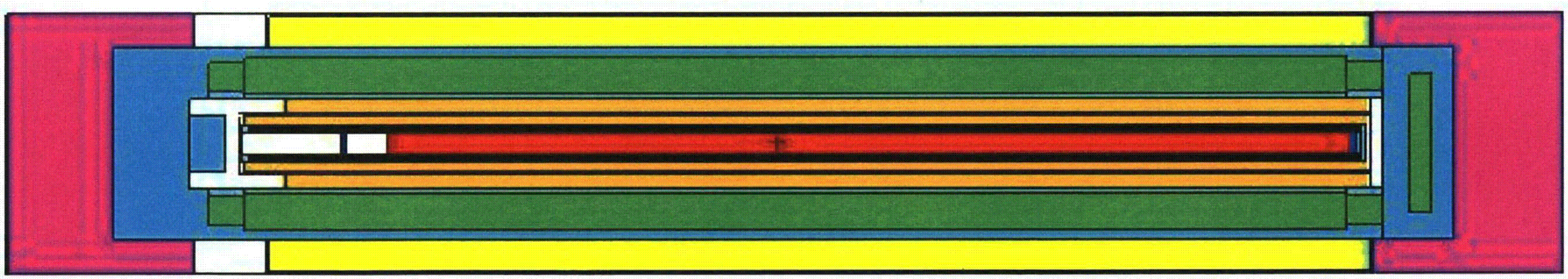
MOX Shielding Evaluation (continued)

- Generated dose profiles in MCNP for each fuel type at 90 days cool time and a burnup of 70 GWd/MTHM
- Discrete cask model
- Accident model contains
  - Lead slump
  - Impact limiter loss
  - Neutron shield loss

Radial Accident



Axial Normal



MOX Shielding Evaluation (continued)

- Dose rates are below limits for all fuel types
  - Therefore, no specific requirement needs to be applied to plutonium composition
- Mixture of UO_2 and PuO_2 rods is allowed
- Zirconium-based nonfuel hardware, such as guide tube and burnable absorber rods, produces no significant source and may be loaded in nonfuel rod locations

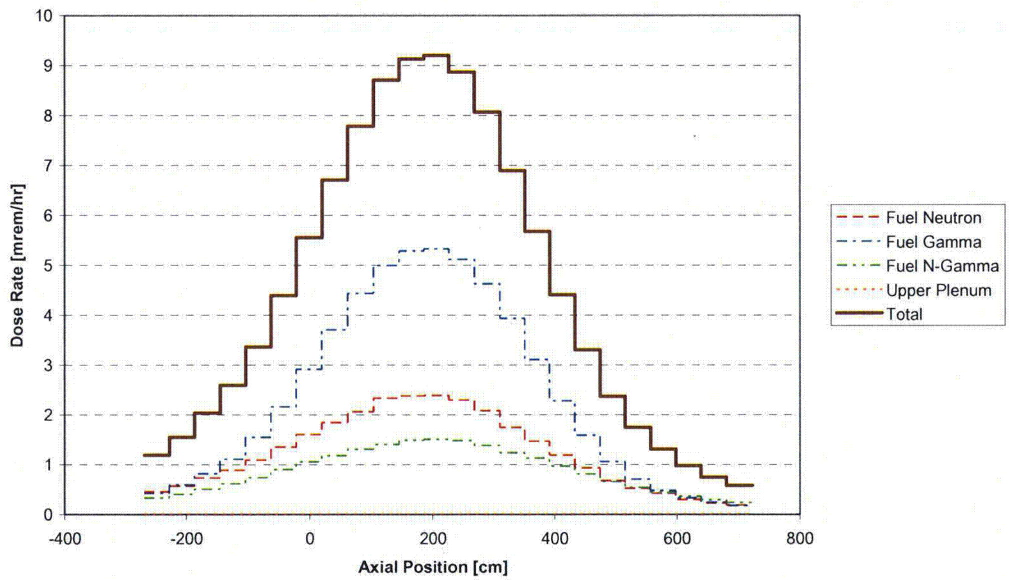
Burnup (GWd/MTHM) **Fuel Material**	**80** **LEU**	**70** **WG**	**70** **FG**	**70** **PG**	**70** **MS**
Normal Surface	91.6	85.0	87.8	109.6	86.3
Normal 1 meter	23.6	22.1	22.7	27.5	22.4
Normal 2 meter	8.1	7.6	7.8	9.2	7.7
Accident 1 meter	362	344	347	373	345

Dose rates in mrem/hr

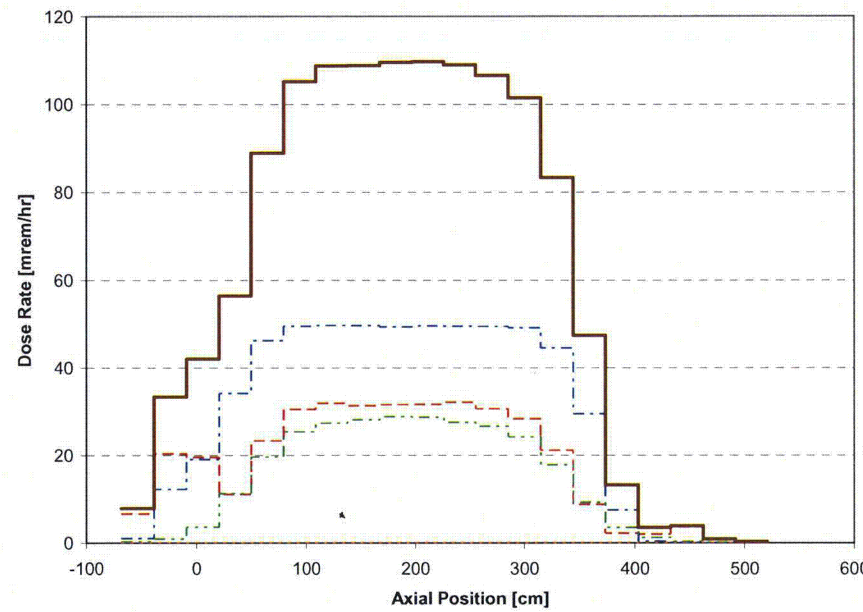
MOX Shielding Evaluation (continued)

- Cask dose rate profiles (PG Material, 70 GWd/MTU, 90 days cool time)

2-meter from conveyance



Cask surface



Plenum contribution is ~ 0 mrem/hr (i.e., no significant hardware source)

MOX Shielding Evaluation Summary

- Up to 16 UO_2 and MOX rods with a heat load up to 143 W/rod may be loaded
- A limit of 62 GWd/MTHM is applied consistent with NRC guidance on maximum allowed burnup (rod clad performance)
- Rods may be loaded at a minimum cool time of 90 days
  - Exception Power Grade Pu (<86% ^{239}Pu) at 120 days due to heat load limit

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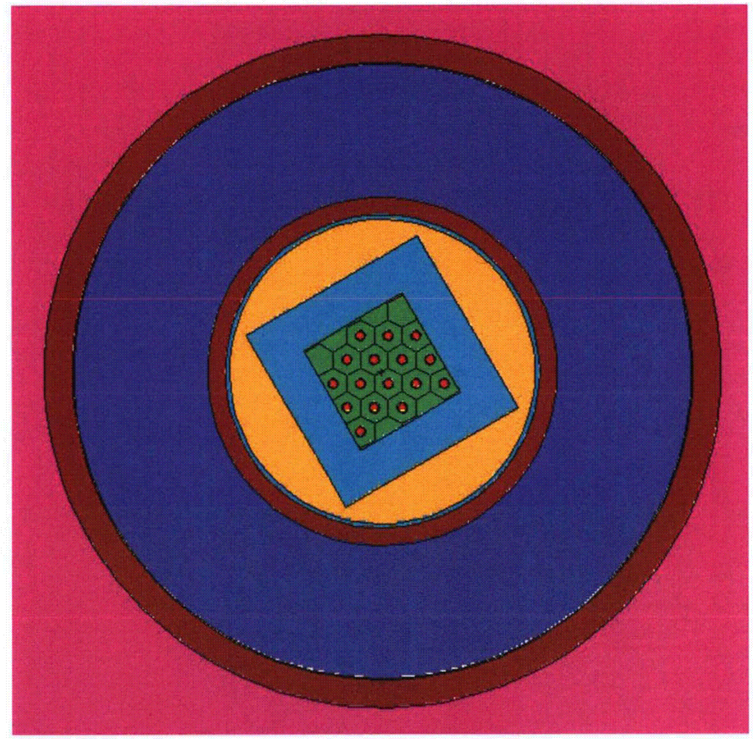
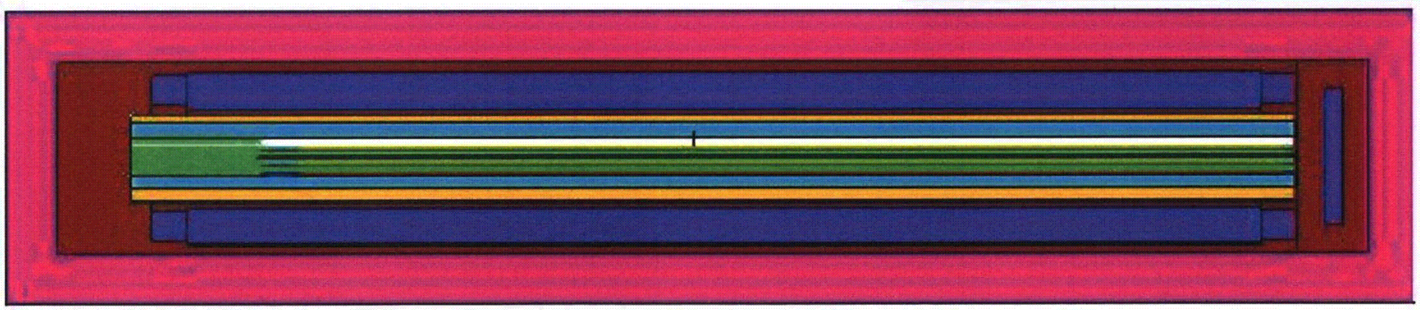
MOX Criticality Evaluations

- MOX fuel rod shipping configuration is identical to previously evaluated LWR rod geometry
- Reactivity calculations for MOX fuel rods are performed using MCNP versus CSAS (KENO-Va) models employed in previous LWR evaluations
- Model changes from previous undamaged LWR rod evaluations are limited to:
  - Revising fuel material composition (max. 7 wt% fissile Pu)
    - Including all fissile isotope (^{239}Pu and ^{241}Pu) evaluations
  - Allow partial flooding of the canister
    (used in NAC-LWT SAR LWR damaged fuel evaluations)
- Addition of MOX specific MCNP validation (USL)

MOX Criticality Evaluation (continued)

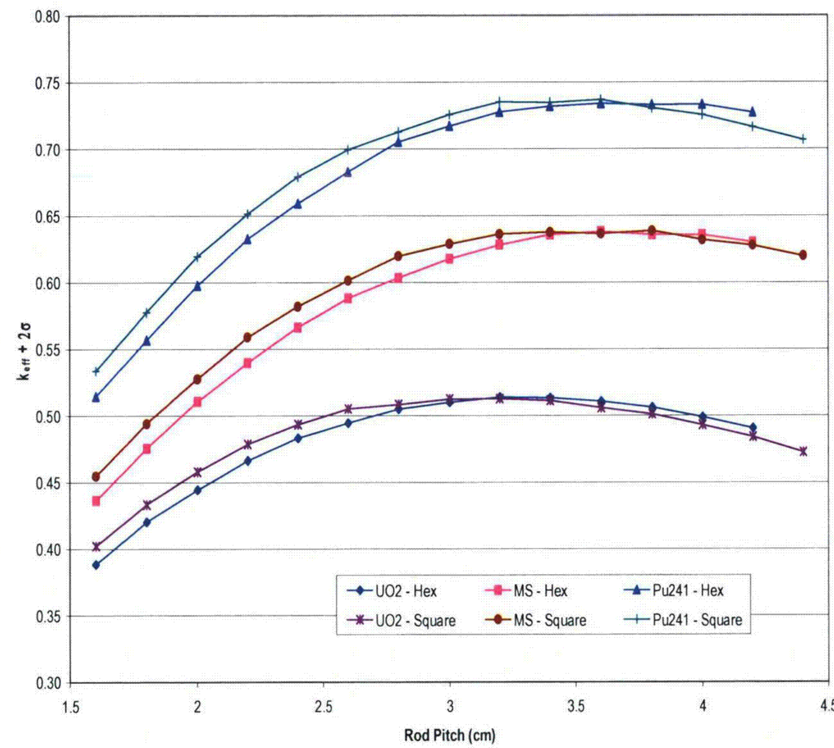
- Model Summary
  - Finite cask model
  - Infinite array of casks
  - Accident condition
    - Loss of neutron shield
    - Loss of impact limiter
  - Maximum reactivity rod configuration





MOX Criticality Evaluation (continued)

- Evaluation performed at various rod pitches to determine optimum configuration – square rod pitch and triangular (hex) pitch
  - Bounding results for 7 wt% fissile Pu and 0.7 wt% ^{235}U
- No credit taken for rod holder, can, or can insert
  - No geometry constraints from components
  - No parasitic absorption



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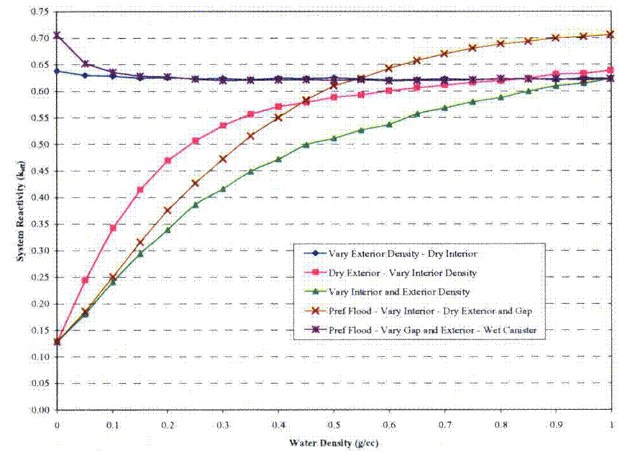
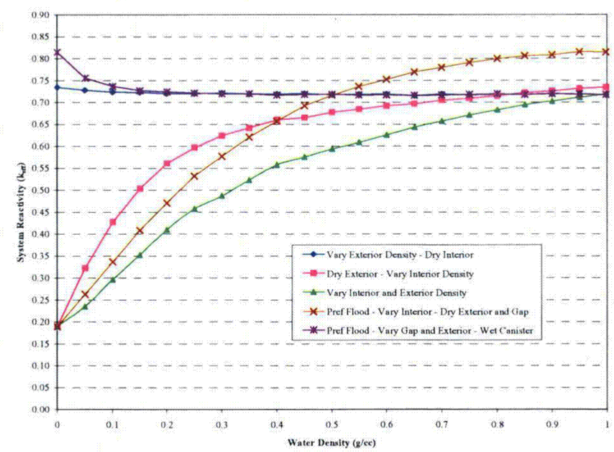
MOX Criticality Evaluation (continued)

- Optimum Moderator Studies
  - Including preferential flooding of system
  - Most reactive configuration
    - Flooded rod region
    - Dry cask cavity
    - Dry cask exterior
  - Bounding for 7 wt% fissile Pu and 0.7 wt% ^{235}U
  - Conservatively evaluated pure ^{241}Pu isotope curves to demonstrate no specification of Pu distribution is required

MS Fuel Material



^{241}Pu Fuel Material



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MOX Criticality Bias (USL) Calculation

- NUREG/CR-6361 based analysis effort
- Establish Upper Subcritical Limit (USL) based on code bias and uncertainty
- MOX critical benchmarks obtained from "International Handbook of Critical Experiments"
  - Models based on direct inputs and experiment description
  - 59 experiments selected based on plutonium enrichment and pin (rod) geometry
- Established bias trends versus neutron energy, moderator, and isotope content
- USL for MOX material is 0.9338 (5% administrative margin) similar to the USL of 0.9372 for low enriched (max. 5 wt% ^{235}U) uranium oxide
- Adequacy of administrative margin tested by USLSTATS Method 2 and found acceptable
- No indication of significant code bias in either fuel material. Fuel material is not mixed but exits as distinct rods within basket. Therefore, code bias calculation with a mixed rod set not required (note that MOX material contains ^{235}U/^{238}U mixture)
- Large margin to USL even with conservative ^{241}Pu payload and removal of tube structure constraints (Δk>0.1 versus code bias and uncertainty in the range of 0.01 to 0.02)

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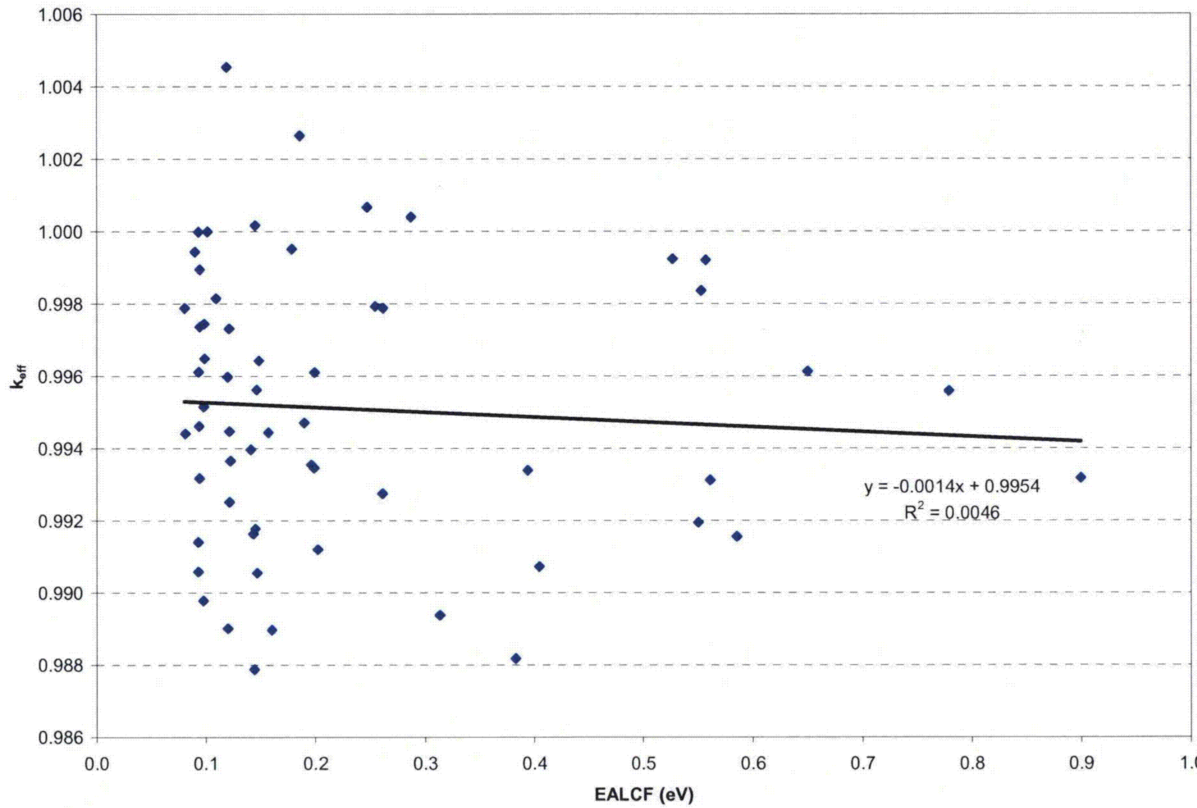
MOX Criticality Bias (USL) Calculation (continued)

- Sample distribution of k_{eff} versus EALCF
- No statistical trend (low correlation coefficient)
- USLSTATS test normal distribution
- Lowest USL applied from any correlation



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MOX Criticality Evaluation Summary

- System reactivity significantly below Upper Subcritical Limit (USL) considering conservative assumptions of:
  - No credit for rod holder and canister structure
  - Preferential flooding of canister (designed to drain freely) in a cask demonstrated not to leak
  - Infinite array of casks under accident conditions
  - Fresh fuel
- Constraints on the MOX or UO_2 rods loaded are limited to:
  - Maximum Pellet OD of 0.3805 inch (No minimum)
  - Maximum Active Length of 153.5 inches (No minimum)
  - Maximum heavy metal mass of 2.63 kg (No minimum)

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PWR MOX Fuel Rod Shipment Schedule

- Intent is to ship PWR MOX and PWR UO_2 fuel rods to Post Irradiation Examination as soon as possible after cycle completion
- Minimum 90 days cooling per amendment request
- Loading as early as October 2008
- CoC required by September 1, 2008

Other NAC-LWT Licensing Activities

- LEU TRIGA Cluster Rod Amendment Request Supplement based on February 6, 2008 NAC/NRC Meeting submitted week of February 25, 2008
- ANSTO damaged fuel amendment (FRR) anticipated for 3rd Quarter 2008
- LWT SAR Revision 39 to incorporate LEU TRIGA Cluster Rods and MOX; may include ANSTO damaged fuel