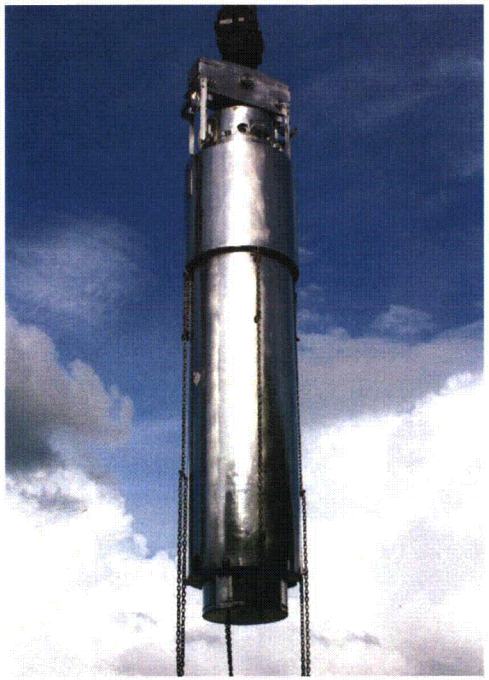
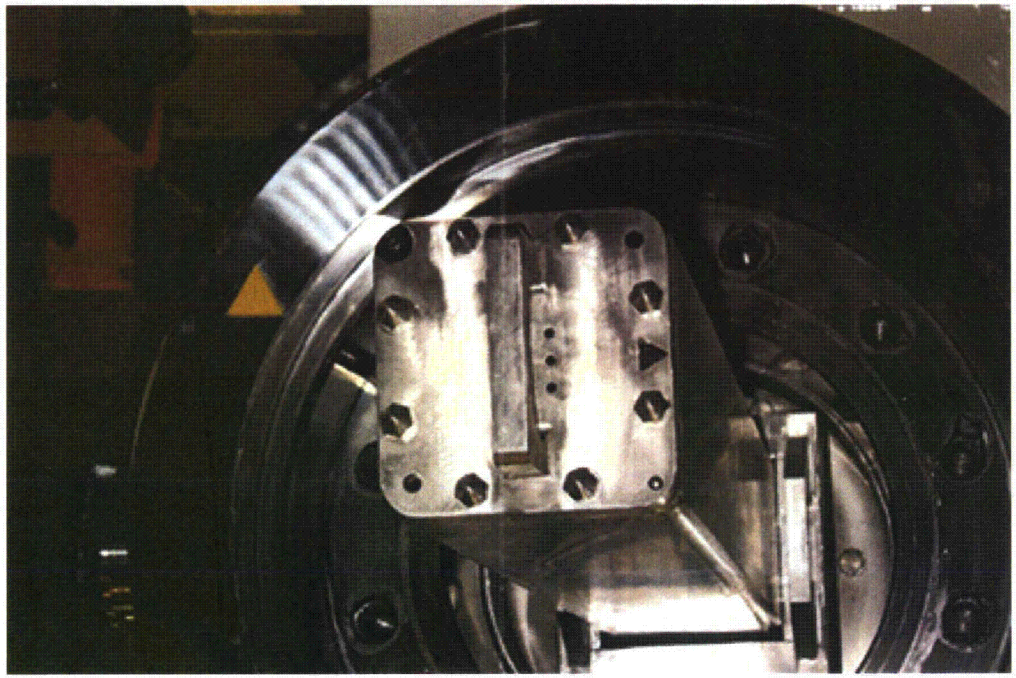
NAC-LWT TRIGA Cluster Rod SAR Amendment





February 6, 2008

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LEU TRIGA Application

NAC-LWT Legal Weight Truck

Spent Fuel Transport Cask

Docket #71-9225

TRIGA Transport to Support DOE's NNSA Foreign Research Reactor (FRR) Program

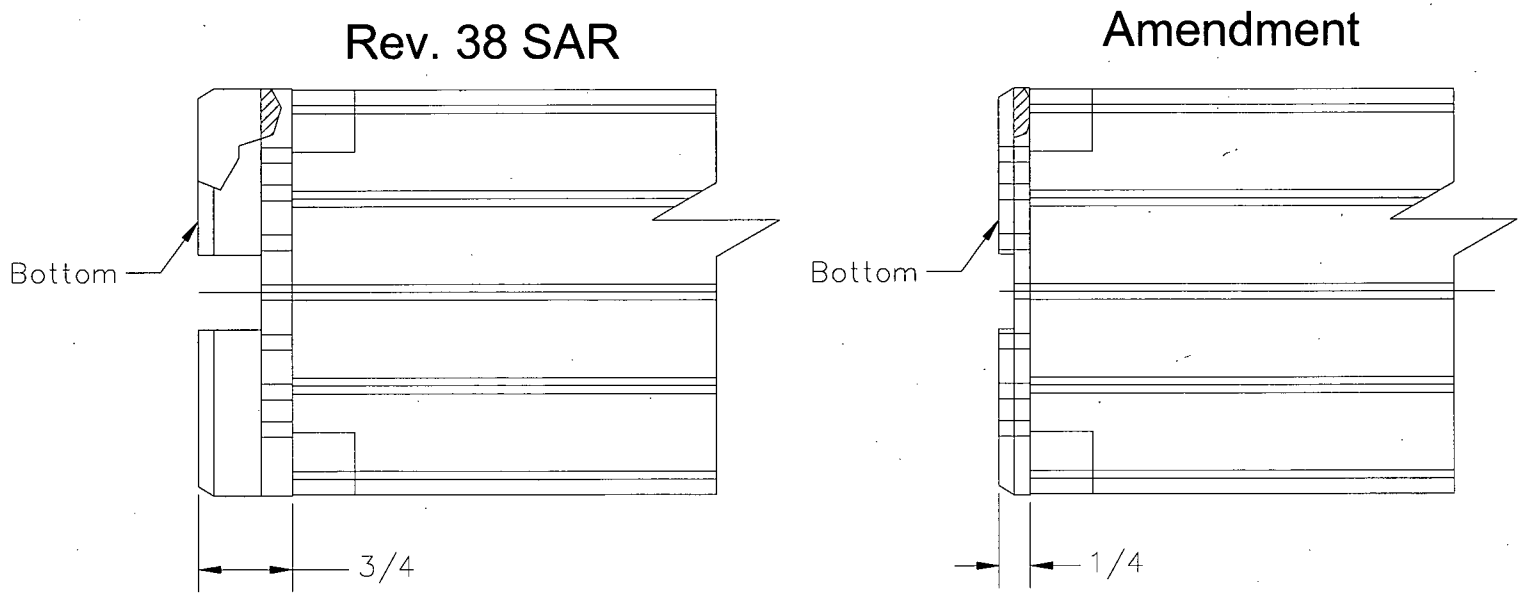
LEU TRIGA Amendment Summary

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

- LEU TRIGA cluster rod contents having a slightly higher ^{235}U mass
  - Revision 38 SAR contains only HEU cluster rods
- Revised H/Zr Ratio
  - Increased H/Zr ratio to 1.7 from 1.6 (specified fuel hydrogen content by a combination of H/Zr ratio and minimum uranium weight percent or zirconium mass)
- Applied consistent HEU and LEU mass limits to nuclear evaluations
- Allow loading of structurally damaged TRIGA cluster rods in screened canister
- Modify basket insert to allow for a slight increase in rod length (eliminates operational requirement for clipping of rod ends) - ALARA

Basket Insert Modification

- Reduction in TRIGA cluster rod base to increase available cavity height
- No effect on safety evaluations
- ALARA change to eliminate fuel cropping – reduction in personnel exposure



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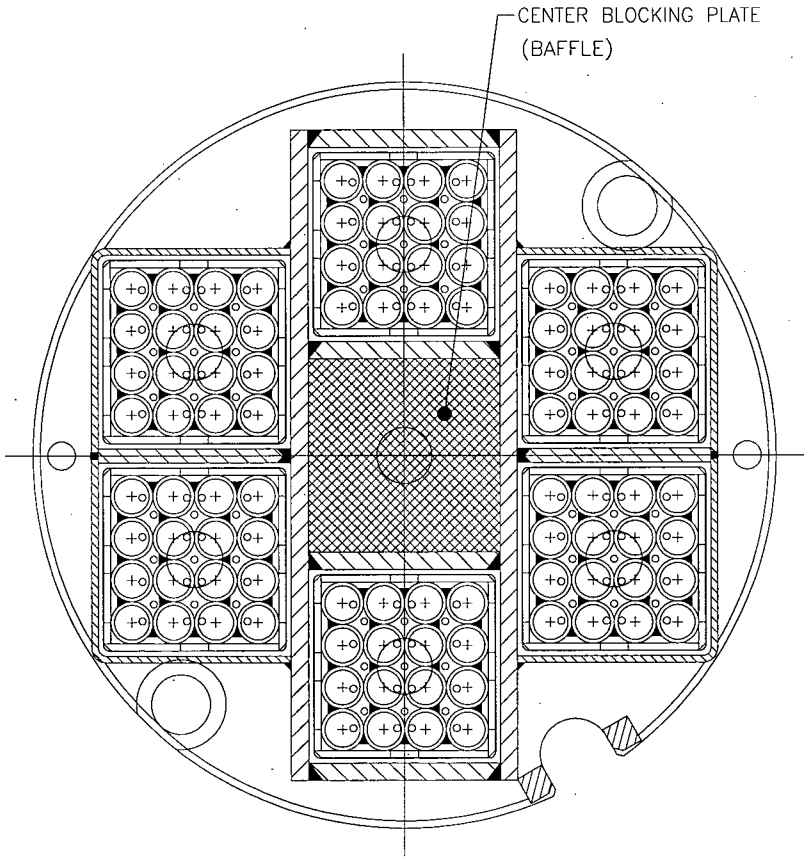
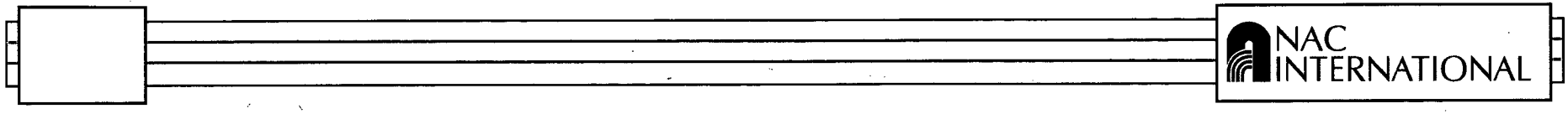
TRIGA Fuel Cluster Rod Configuration

- Up to 480 LEU and HEU TRIGA Fuel Cluster Rods may be transported in a nonpoisoned TRIGA Fuel Basket / 560 rods in poisoned basket
- Standard five module TRIGA basket stack to be utilized with a TRIGA fuel rod insert installed in each of the basket cells
- For nonpoisoned basket, the center cell of each of the seven cell basket modules will be physically blocked to prevent loading of the center cell
- The transport configuration will be identical to that currently certified for HEU TRIGA Fuel Cluster Rods



Structural And Thermal Evaluation TRIGA Cluster Fuel Rods



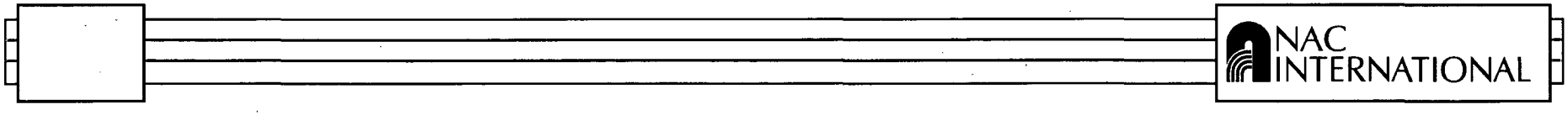
Structural and Thermal Evaluations

- Structural
  - No change in bounding weight per basket opening
  - No change in maximum temperatures
  - No structural calculations required
- Thermal
  - No change in fuel geometry
  - No change in heat load
  - No thermal calculations required

TRIGA Fuel Nuclear Evaluations

- Containment
  - Standard non-metallic seal vent port configuration
  - Updated for revised source term (per shielding calculation)
- Shielding
  - SAS2H source term generated for TRIGA cluster rods
  - Generate minimum cool time table – constraint by heat load
  - SAS1 shielding evaluation with revised source terms at minimum heat load
- Criticality
  - CSAS25 criticality evaluations
  - Applying maximum reactivity configuration from previously licensed HEU cluster rod analysis

Containment Evaluation
TRIGA Fuel Rods



NAC-LWT Containment Considerations

- Apply maximum burnup (455 GWd/MTU HEU and 151 GWd/MTU LEU) nuclide inventory to NUREG/CR-6487 containment method
  - No change in method from NAC-LWT Rev. 38 SAR
- The lid and port covers will each be individually leak tested to verify a allowable leakage rate of less than or equal to 5.5×10^{-7} cm^3/s versus a calculated allowable leakage rate of 1.36×10^{-5} cm^3/s calculated for the TRIGA cluster rods

LEU TRIGA Cluster Rod Shielding Evaluations

- Revision 38 submittal analysis based on:
  - SCALE 4.3 SAS2H source terms
  - SCALE 4.3 1-D (SAS1) shielding evaluations
    - Calculated minimum cool time required to reach heat load limit (1.875 W) or;
    - 1-D dose rate of larger 1.5" OD TRIGA rod calculation (4.5 mrem/hr)
    - While normal condition dose rates are bounding above minimum burnup levels, a justification is provided that based on a large margin in dose rates, that heat load may be applied as the sole limit – CoC limit assigned accordingly

LEU TRIGA Cluster Rod Shielding Evaluations (continued)

- Revised analysis
  - HEU cluster rod SCALE 4.3 SAS2H models are modified to reflect a LEU fissile material payload
    - Include revised HEU payload for consistency with criticality evaluations
  - Generate minimum cool times required to meet a maximum allowed heat load of 1.875 watts per rod
  - Revise SCALE 4.3 HEU 1-D models to contain LEU source terms
  - Summarize dose rates to demonstrate that heat load may be applied as sole payload limit
    - Update HEU analysis to contain similar data – relevant data not currently in SAR

LEU TRIGA Cluster Rod Shielding Evaluations (continued)

- Evaluated fuel characteristics

Parameter	HEU	LEU
Rod Cladding	Incoloy 800	
Clad Thickness, in	0.016	
Active Fuel Length, in	22	
Fuel Diameter, in	0.51	
^{235}U Mass, grams	46.5	55.0
Minimum ^{235}U Enrichment, wt %	92	19
Uranium Mass, grams	50.5	289.4
Fuel Uranium Fraction, wt %	10	45
Hydrogen to Zirconium Ratio	1.6	

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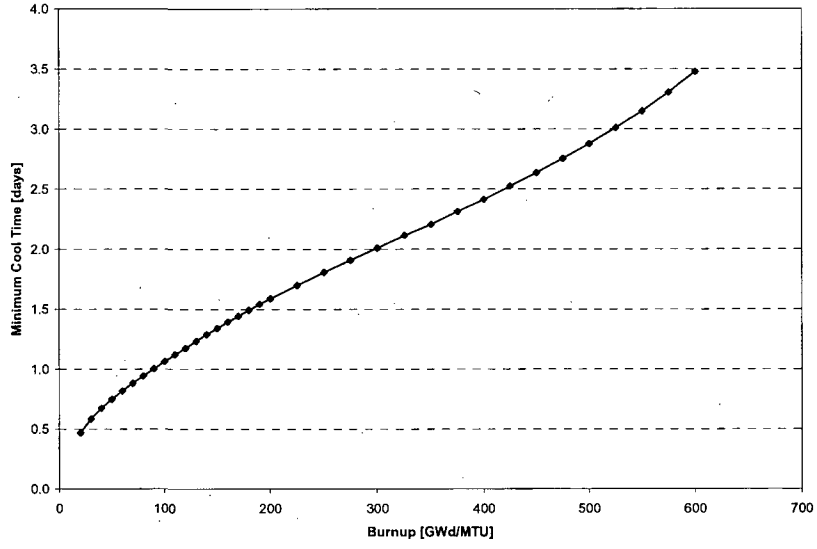
TRIGA Shielding Evaluation (continued)

- Generated minimum cool time for 1.875W heat load limits per rod for LEU and HEU rods
- At each minimum cool time, evaluated one-dimensional (SAS1) at 1 meter, 2 meter normal and 1 meter accident condition dose rates for each fuel type
  - Cask surface dose rates not evaluated as TRIGA evaluations demonstrated significant margin to limits
- Demonstrate that dose rates are below regulatory limits at all locations
  - Evaluations presented in Revision 38 of the SAR demonstrate that one-dimensional dose rates are conservative (lower than) three-dimensional dose rates (evaluation based on standard TRIGA rods)

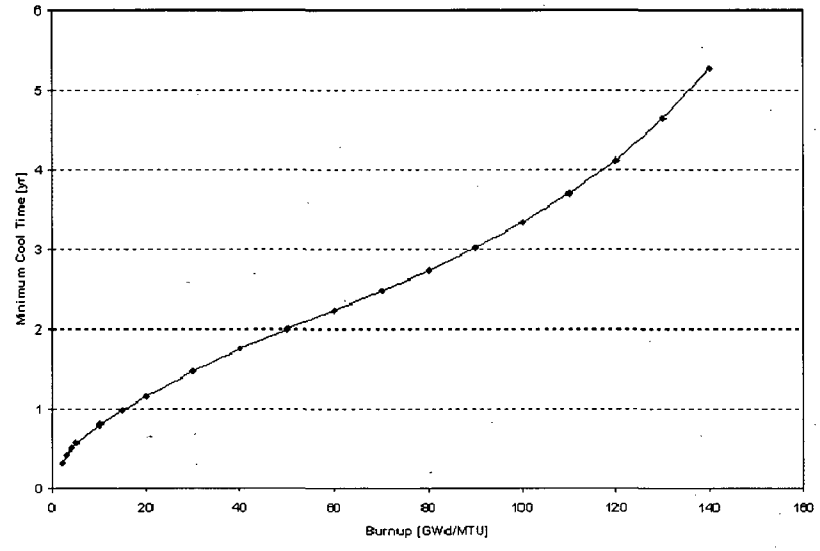
TRIGA Shielding Evaluation (continued)

- Cool time tables on which dose rate calculations are based

HEU



LEU



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TRIGA Shielding Evaluation (continued)

- Sample maximum dose rate evaluation (HEU)

Case	Burnup [GWD/MTU]	Depletion [% U235]	Cool Time [days]	Dose Rate [mrem/hr]		
				clst_acc_1m	clst_nrm_2mc	clst_nrm_1m
clst_b200e2	20	2.8%	170.5	11.4	2.4	7.2
clst_b300e2	30	4.1%	213.4	14.6	3.1	9.2
clst_b400e2	40	5.6%	246.4	17.5	3.7	11.0
clst_b500e2	50	6.9%	273.8	19.9	4.3	12.6
clst_b600e2	60	8.4%	298.7	21.9	4.7	13.8
clst_b700e2	70	9.7%	322.6	23.6	5.1	14.9
clst_b800e2	80	11.2%	344.6	24.9	5.3	15.7
clst_b900e2	90	12.5%	366.9	26.0	5.6	16.4
clst_b100e3	100	14.0%	388.2	26.8	5.7	16.9
clst_b110e3	110	15.3%	410.1	27.4	5.9	17.3
clst_b120e3	120	16.8%	429.5	27.9	6.0	17.6
clst_b130e3	130	18.1%	451.0	28.2	6.0	17.7
clst_b140e3	140	19.6%	471.4	28.4	6.1	17.8
clst_b150e3	150	20.9%	490.1	28.5	6.1	17.9
clst_b160e3	160	22.2%	510.0	28.5	6.1	17.9
clst_b170e3	170	23.7%	527.6	28.5	6.1	17.9
clst_b180e3	180	25.0%	545.3	28.5	6.1	17.8
clst_b190e3	190	26.5%	563.4	28.3	6.0	17.7
clst_b200e3	200	27.8%	580.6	28.2	6.0	17.6
clst_b225e3	225	31.3%	620.7	27.8	5.9	17.4
clst_b250e3	250	34.7%	660.3	27.3	5.8	17.0
clst_b275e3	275	38.1%	697.4	26.8	5.6	16.6
clst_b300e3	300	41.4%	734.5	26.2	5.5	16.2
clst_b325e3	325	44.8%	772.7	25.5	5.3	15.8
clst_b350e3	350	48.3%	806.1	25.1	5.2	15.4
clst_b375e3	375	51.5%	845.3	24.5	5.1	15.0
clst_b400e3	400	55.0%	881.8	24.0	5.0	14.6
clst_b425e3	425	58.2%	922.6	23.4	4.8	14.2
clst_b450e3	450	61.4%	963.2	23.0	4.7	13.8
clst_b475e3	475	64.7%	1005.8	22.6	4.6	13.5
clst_b500e3	500	67.9%	1051.3	22.2	4.4	13.1
clst_b525e3	525	71.1%	1099.4	21.9	4.3	12.8
clst_b550e3	550	74.4%	1150.5	21.7	4.2	12.6
clst_b575e3	575	77.6%	1207.2	21.6	4.2	12.3
clst_b600e3	600	80.6%	1269.6	21.6	4.1	12.1

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TRIGA Cluster Rod Criticality Evaluations

- Current analysis based on:
  - SCALE 4.3 CSAS evaluations
    - nonpoisoned and poisoned basket
    - Undamaged (intact) and damaged fuel
  - Damaged fuel in sealed cans
  - Maximum reactivity configuration based on
    - System geometry – including damaged fuel cans
    - Optimum moderation – including preferential flooding of cans

LEU TRIGA Cluster Rod Criticality Evaluations (continued)

- Revised analysis
  - HEU cluster rod SCALE 4.3 CSAS models modified to reflect LEU fissile material payload
    - Evaluated nonpoisoned baskets
      - Demonstrated in SAR revision 38 to bound poisoned basket
    - Most reactive geometry for intact and damaged fuel configurations determined for HEU models are applicable to both HEU and LEU configurations
  - Applied 1.7 H/Zr ratio to both HEU and LEU TRIGA cluster rod evaluations (1.6 in previous models)
  - Debris / significantly damaged fuel in screened or sealed canisters is equal to a maximum of 6 undamaged fuel rods
  - Allow full set of 16 fuel rods with clad breaches in screened canister (with insert) provided fuel retains its structural integrity

TRIGA Cluster Rod Criticality Evaluations

- Fuel characteristics based on manufacturer summary report

Parameter	HEU	LEU	Evaluation
HEU Max. Enrichment (wt % ^{235}U)	93.33	--	95
HEU Min. U in Fuel Meat (wt %)	10.0	--	9.51
HEU Max. ^{235}U Per Rod (g)	45.4	--	46.5
LEU Max. Enrichment (wt % ^{235}U)	--	19.99	20
LEU Min. U in Fuel Meat (wt %)	--	43	432
LEU Max. ^{235}U Per Rod (g)	--	54	55
Maximum Hydrogen to Zirconium Ratio	1.6	1.70	1.70
Pellet Diameter (inch)	0.53	0.51	0.53
Clad Thickness (inch)	0.015	0.015	0.015
Active Fuel Length (inch)	22.5	20	22.5

[1] Equivalent to 457 grams zirconium

[2] Equivalent to 357 grams zirconium

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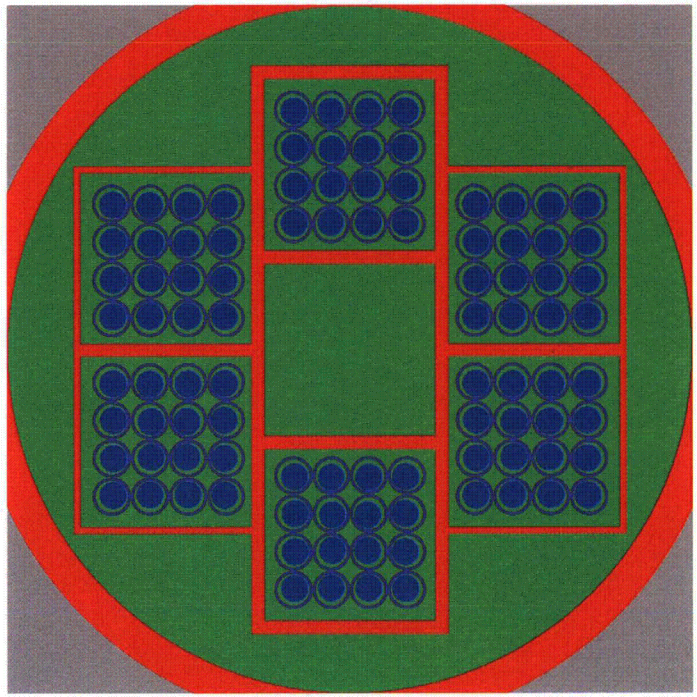
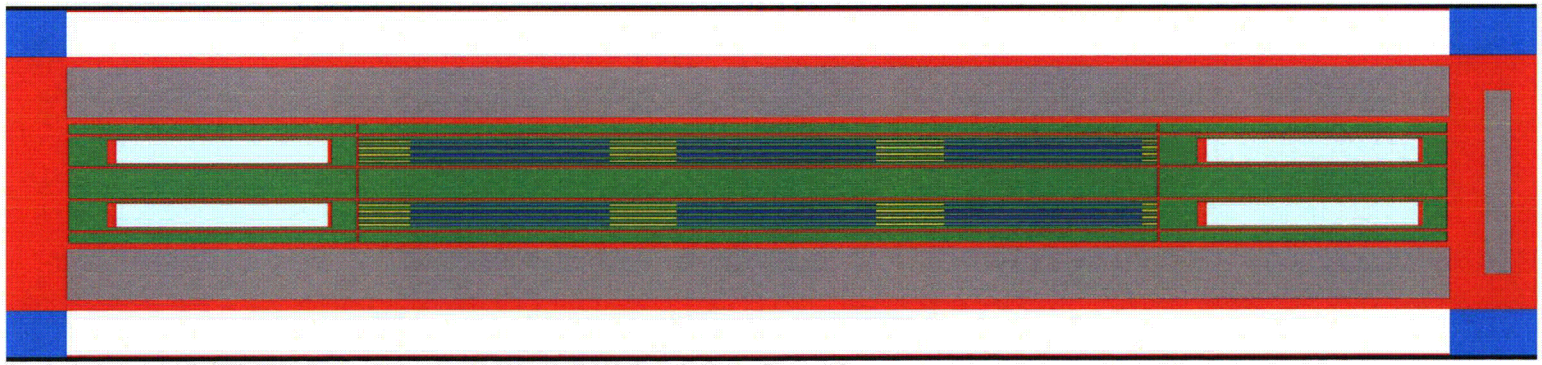
TRIGA Criticality Evaluation (continued)

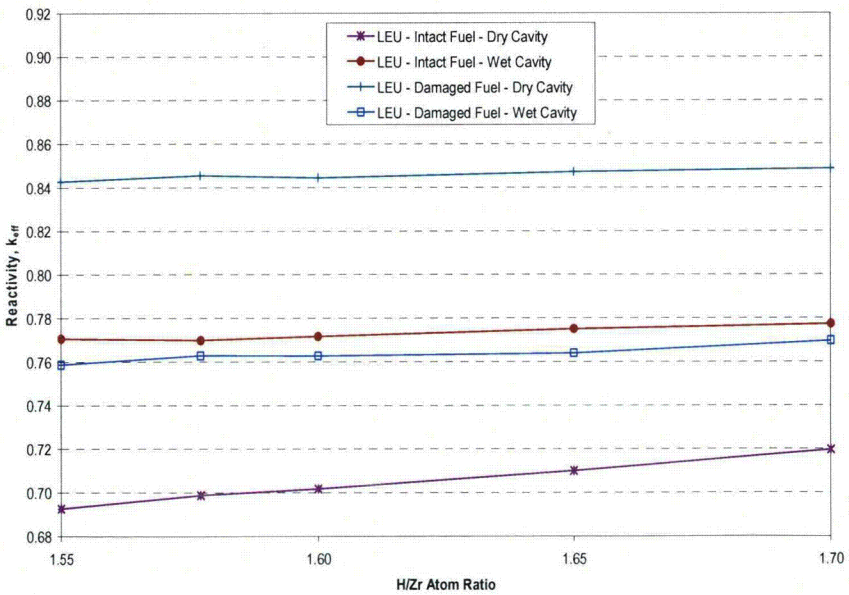
- Model Summary
  - Finite cask model
  - Infinite array of casks
  - Accident condition
    - Loss of neutron shield
    - Loss of impact limiter
  - Maximum reactivity basket configuration

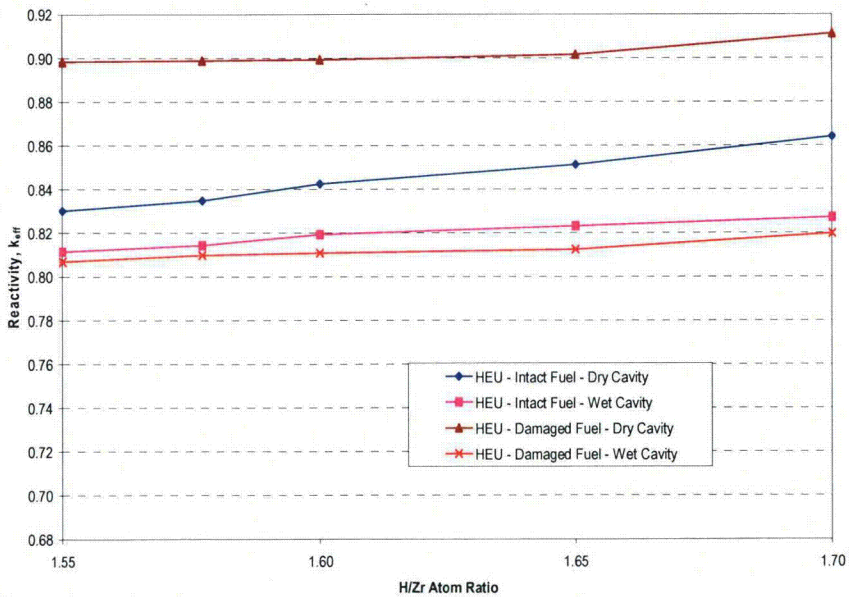




TRIGA Criticality Evaluation (continued)

- Evaluation performed at H/Zr ratios in the range of 1.55 to 1.70 (manufacturer specified range for the TRIGA cluster rod fuel material)
- For both intact and damaged fuel configurations, a higher H/Zr ratio (increased moderator) increases system reactivity





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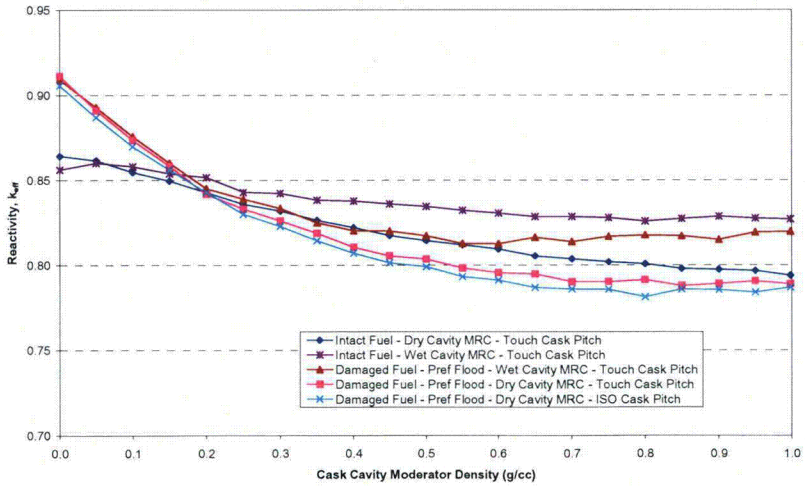
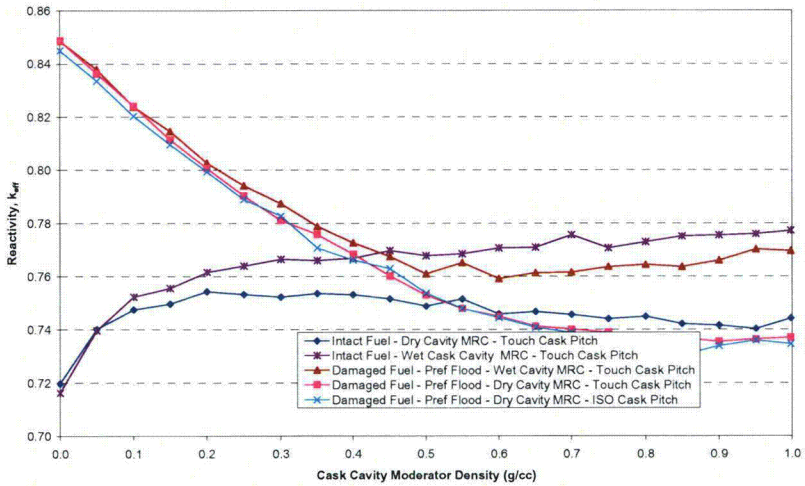
TRIGA Criticality Evaluation (continued)

- Reactivity evaluated as a function of cask internal moderator
  - Evaluations with fuel located in most reactive configuration for flooded cask cavity (rods shifted out) and most reactive configuration for dry cask cavity (rods shifted in)
- Maximum reactivity for LEU and HEU fuel achieved in dry cask model
- Differences in behavior for LEU and HEU fuel at lower reactivity configurations (in particular between intact and damaged fuel configurations)





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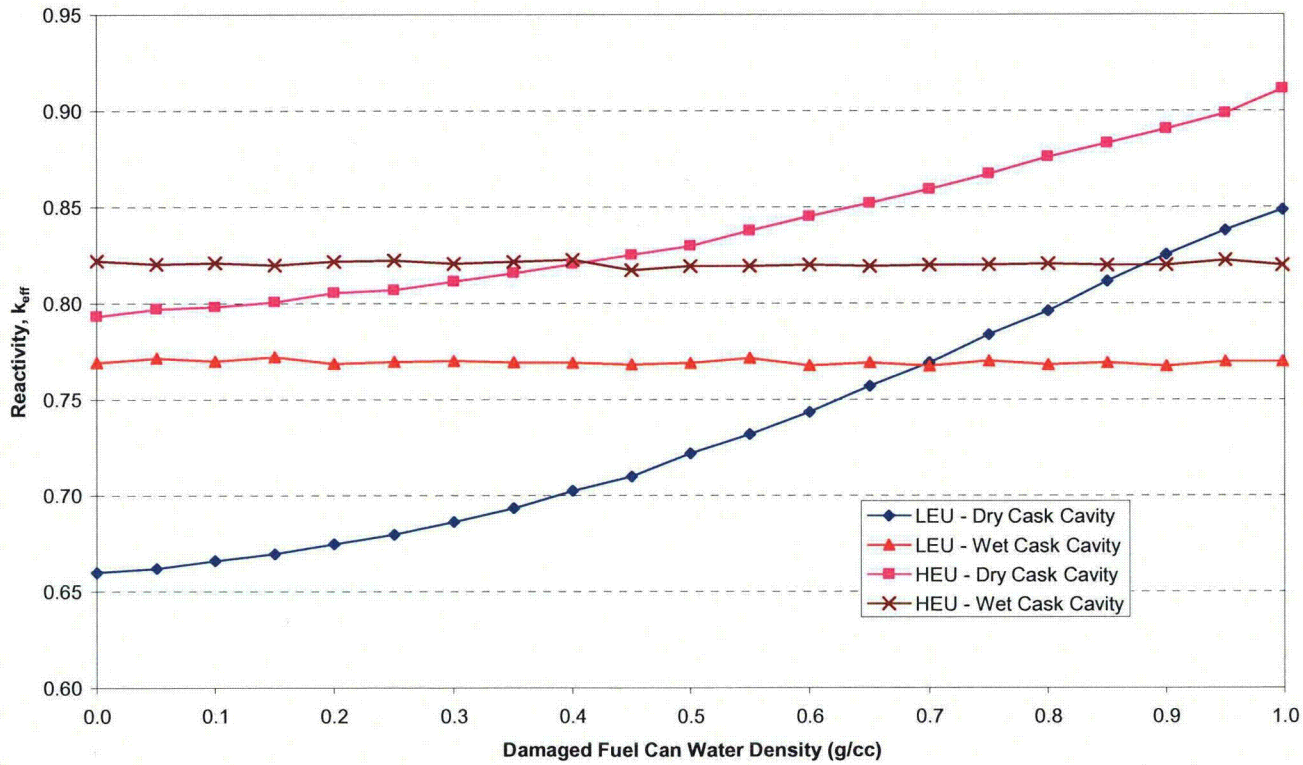
TRIGA Criticality Evaluation (continued)

- Evaluations of damaged fuel can preferential flooding clearly demonstrate maximum reactivity for dry cask cavity with flooded canister



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TRIGA Criticality Evaluation Summary

- System reactivity significantly below 0.95 including:
  - Maximum reactivity fuel rod and basket configuration
  - Preferential flooding of canister (designed to drain freely) in a cask demonstrated not to leak
  - Infinite array of casks under accident conditions
  - Fresh fuel

Fuel Material	HEU			LEU		
Configuration	k_{eff}	σ	k_s	k_{eff}	σ	k_s
Single Cask Fully (Water) Reflected	0.74059	0.00120	0.75979	0.71063	0.00117	0.72977
Normal Array – Preferentially Flooded	0.74210	0.00132	0.76154	0.71750	0.00123	0.73676
Normal Array – Dry	0.56007	0.00114	0.57915	0.44760	0.00094	0.46628
Accident Array – Preferentially Flooded	0.91119	0.00117	0.93033	0.84872	0.00109	0.86770

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NAC-LWT LEU TRIGA Shipment Schedule

- FRR Shipment scheduled for July 2008
- 3-4 months required for (four countries) foreign competent authorities approvals
- CoC required by March 31, 2008

Other NAC-LWT Licensing Activities

- MOX Amendment Request submitted January 25, 2008
  - Meeting scheduled for February 25, 2008
- ANSTO damaged fuel amendment anticipated for 3rd Quarter 2008
- LWT SAR Revision 39 to incorporate LEU TRIGA Cluster Rods and MOX; may include ANSTO damaged fuel