Revised TRIGA Contents
NAC-LWT Shipment

February 26, 2009

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TRIGA Amendment Application

NAC-LWT Legal Weight Truck

Spent Fuel Transport Cask

Docket #71-9225

Content Conditions

- NAC-LWT currently authorized to transport the following contents:
  - **TRIGA Fuel Elements (1.5 inch OD typical)**
  - **TRIGA Fuel Cluster Rods (0.5 inch OD typical)**
- NAC to request authorization to ship mixed contents of TRIGA elements and TRIGA cluster rods
- Revise characteristics of TRIGA elements
- Include handling can within TRIGA sealed damaged fuel can

Summary of Structural and Thermal Discussions for the Revised TRIGA Contents

- Thermal
  - No change in per fuel element/rod heat load or physical configuration of payloads beyond mixing of element and cluster rod payloads
  - Mixture of standard fuel elements and cluster rods (mixed loading not permitted within same basket opening but permitted in same basket module) has no effect on system maximum temperatures
  - TRIGA fuel elements thermal evaluations are conservative as they include large gaps enveloping the refined finite element TRIGA cluster rod model.
- Structural
  - No increase in payload weight
  - Basket evaluated for bounding payload (80 lb per basket opening)
    - Licensing Drawing 314-40-084 Note 4
  - No structural analysis required

Containment Summary

- NAC-LWT (including TRIGA) payloads defined to be transported in a leaktight (no credible leakage) configuration
- ANSI N.14.5-1997 leak testing invoked in current SAR operating procedures
- No changes to containment chapter

Shielding Evaluations

- Address increased fissile material mass for LEU elements
- Add in HEU at 93+ wt% ^{235}U enrichment (currently licensed at 70 wt% ^{235}U)
- Address reduction in enrichment from design basis nominal values (augmentation of current SAR analysis)
- Include justification for mixed content shipping

Shielding Evaluation Scope

- Currently certified TRIGA elements

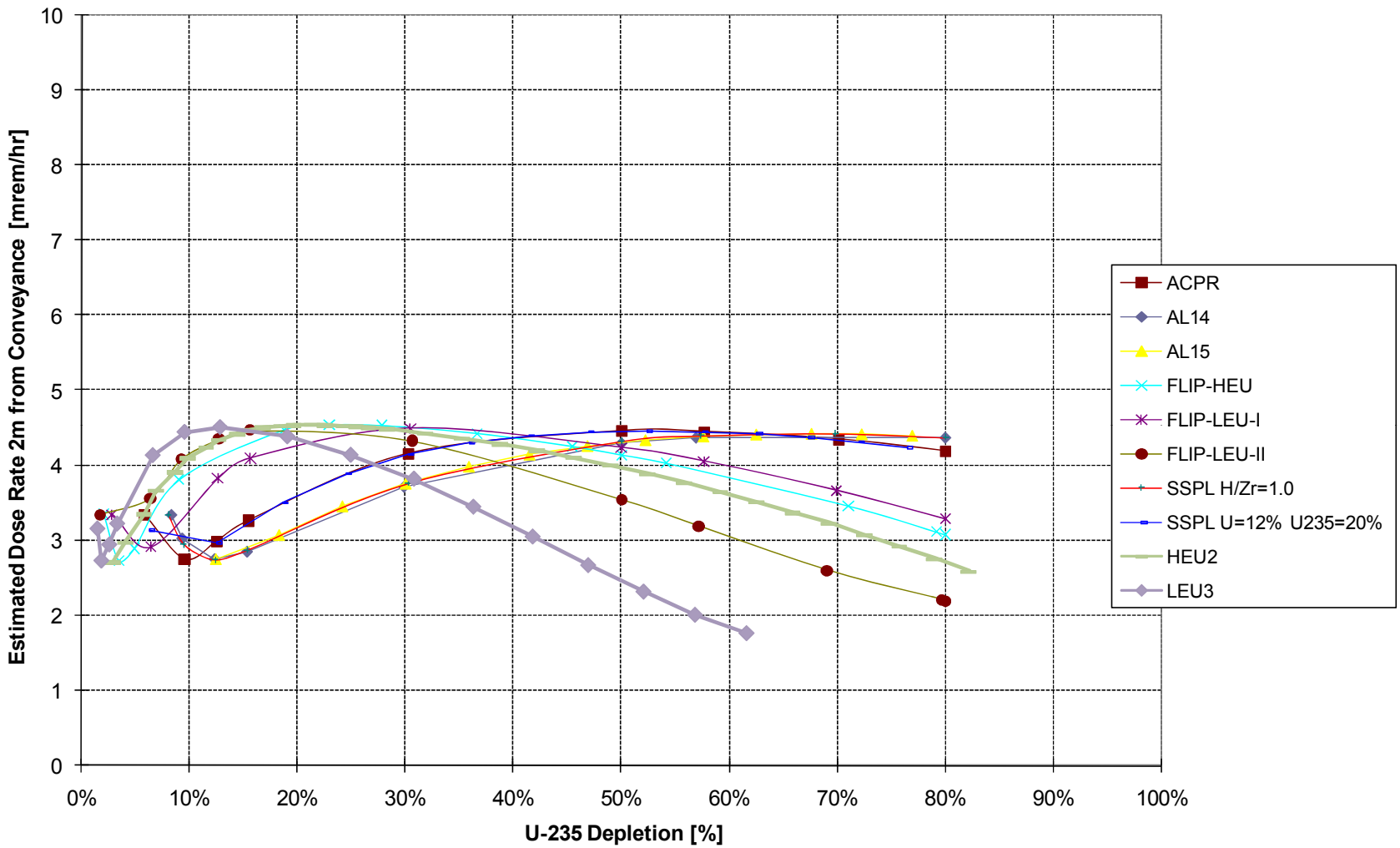
ID	U-235 Mass [g]	Enrichment [wt. %]	U Mass [wt. % Fuel]	Fuel Mass [g]
ACPR	56.9	20%	12.0%	2370
AL14	40.0	20%	8.5%	2350
AL15	41.0	20%	8.5%	2412
FLIP-HEU	144.0	70%	8.5%	2420
FLIP-LEU-I	106.0	20%	20.0%	2650
FLIP-LEU-II	173.4	20%	30.0%	2890
SSPL	41.0	20%	8.5%	2410
SSPL	56.0	20%	12.0%	2334

- Additional HEU and LEU elements

ID	U-235 Mass [g]	Enrichment [wt. %]	U Mass [wt. % Fuel]	Fuel Mass [g]
HEU2	173	93%	8.5%	2189
LEU3	273	20%	44.0%	3103

- Use of licensed methodology to generate one-dimensional dose rates based on 7.5 W per fuel element heat load

Normal Condition 2-Meter Dose Rates



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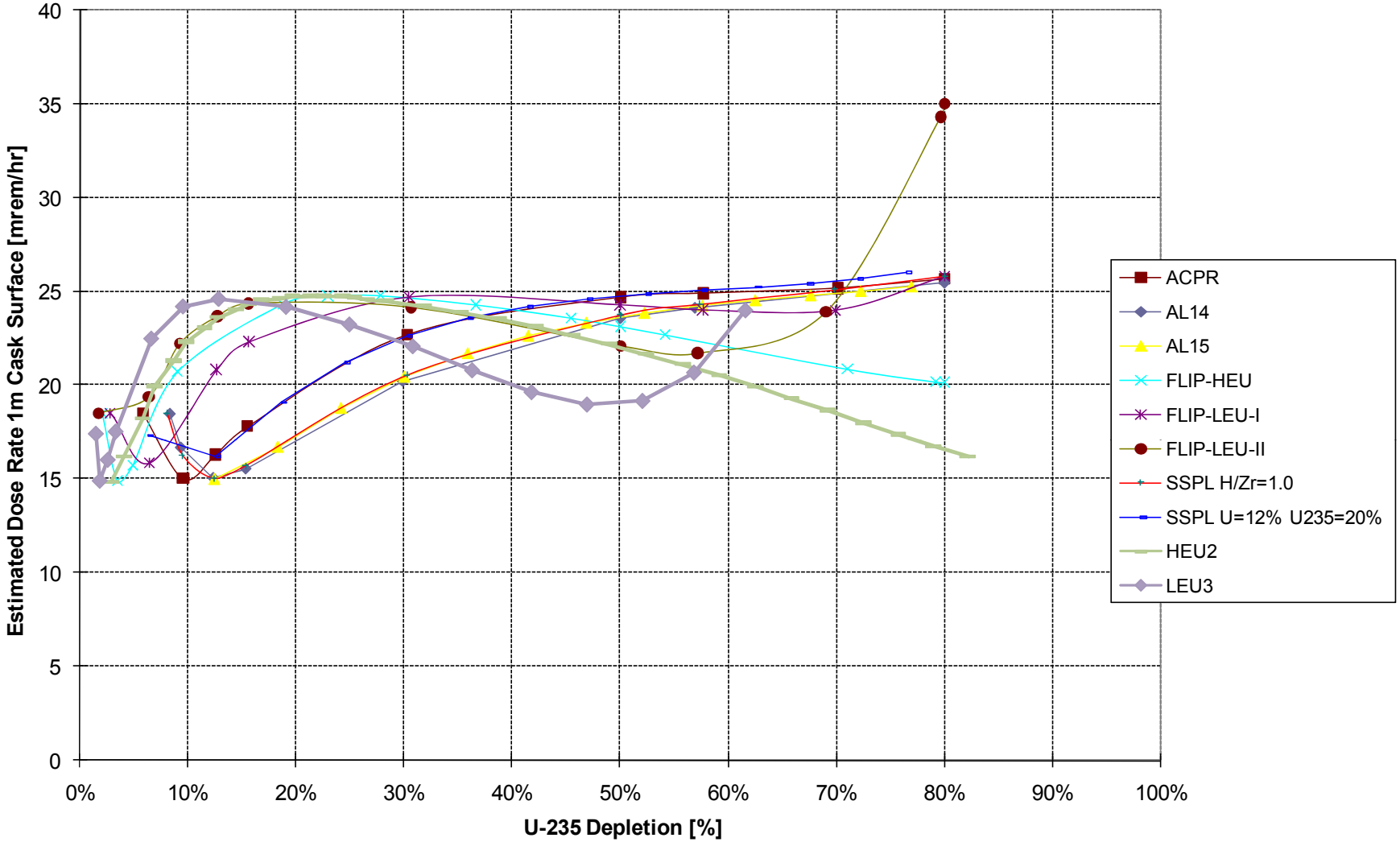
Accident Condition 1-Meter Dose Rates



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Nominal Enrichment Discussion

- Evaluation added to assess impact of reduced initial enrichment (manufacturing tolerances)
  - Minor source effects primarily on neutron source for LEU fuel
    - (fuel gamma source effect <2%)
  - Normal conditions
    - Neutron dose not significant; increase in source does not increase dose rates
    - Minimal increase in gamma source; no increase in dose rates
  - Accident conditions
    - Neutron dose increases for bounding ACPR (LEU) fuel element by approximately 5 mrem/hr; estimated total dose of 40 mrem/hr << 1000 mrem/hr allowable
    - Minimal increase in gamma source; little impact on total dose rate

Shielding Conclusions

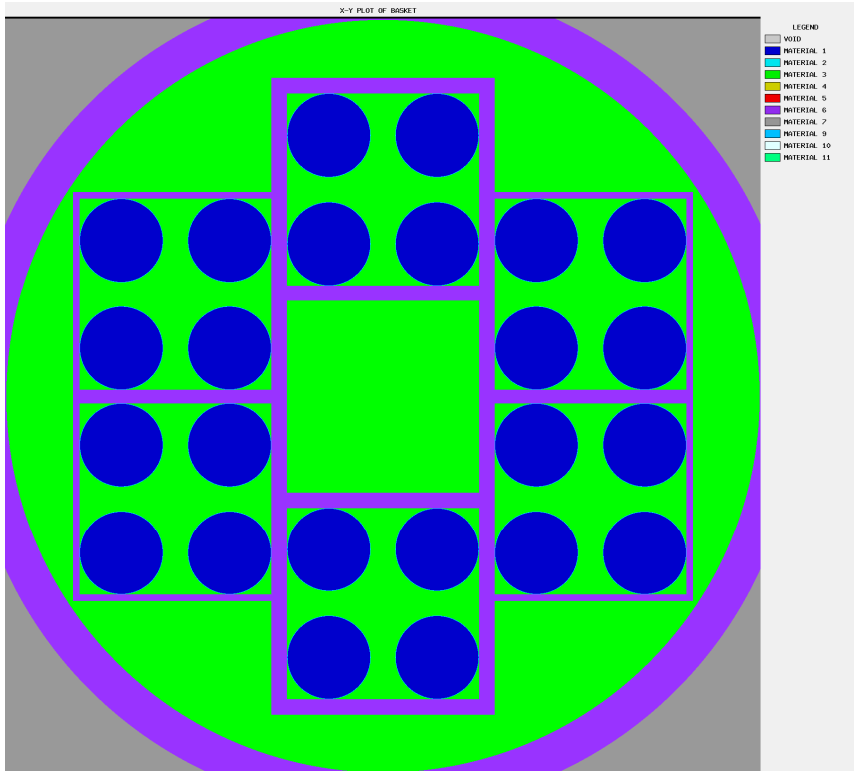
- Modified payload characteristics
  - Demonstrated to be bounded by currently certified payloads
  - As expected, 90+ wt% ^{235}U HEU materials produce significantly lower sources than design basis with correspondingly lower dose rates
  - At a fixed heat load, maximum dose from increased mass LEU element no higher than design basis element
  - Increased mass LEU payload limited to 60% depletion to minimize spike in source at high depletion percentage
- Mixed payload of TRIGA elements and cluster rods
  - Same fuel material composition; no secondary effects on source production due to mixture of fuel types

Criticality Evaluations

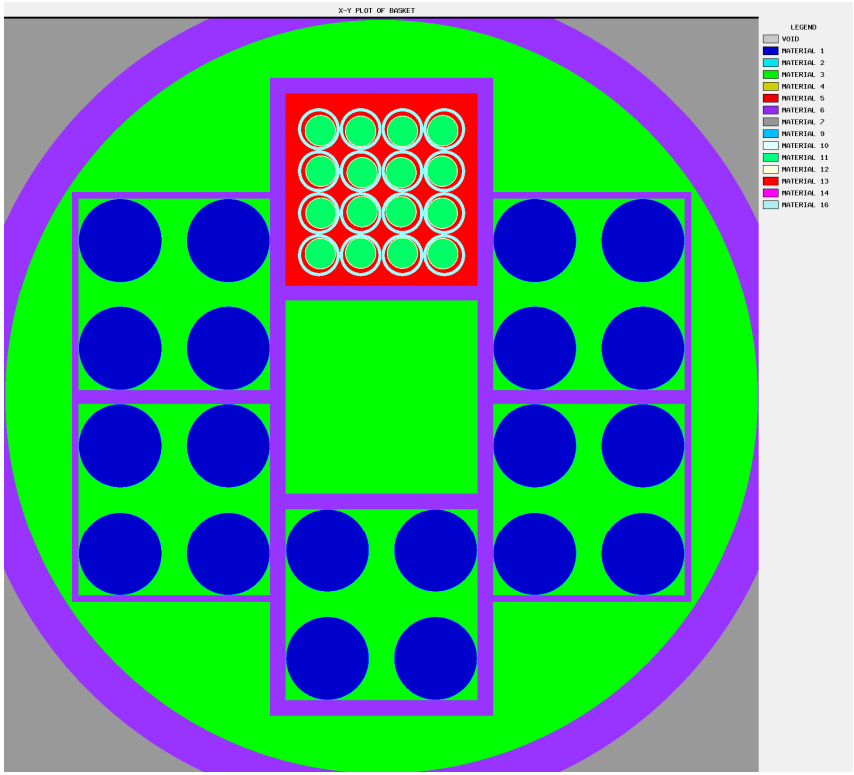
- SCALE (CSAS/KENO Va) basket specific evaluations for:
  - Modify fissile TRIGA element enrichment (manufacturing tolerance adjustments)
    - Increase HEU in enrichment for existing licensed payload 70 wt% to 71 wt%
    - Increase LEU in enrichment for existing licensed payload 20 wt% to 25 wt% (not bounding – higher delta used)
  - Add HEU 95 wt% ^{235}U fuel type
  - Increase fissile material content of LEU fuel from 169 to 271 g ^{235}U
  - Mixing fuel types

Criticality Evaluations (Sample Models)

TRIGA Element Model

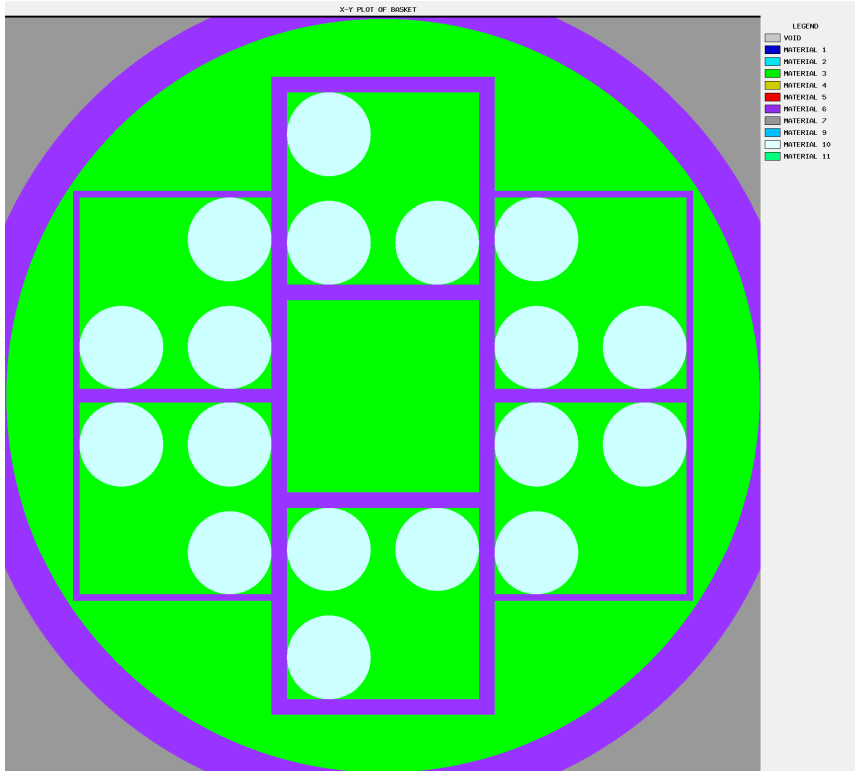


Insertion of TRIGA Cluster Rod



Criticality Evaluations (Sample Models)

Reduced Payload Sample Model



Criticality Evaluations

- Baseline model from currently licensed configuration
  - Maximum zirconium content
  - Maximum H/Zr ratio (2.0)
  - Max rod outer diameter of 1.5 inches
  - Minimum clad thickness
  - Maximum fuel outer diameter, minimum inner diameter and removed central rod
  - Wet can
  - Fuel shifted to maximum reactivity location
  - No neutron shield
  - $k_s = k_{eff} + 2\sigma + 0.0168$ (bias uncertainty)

Criticality Evaluations

- Stage 1 Analysis
  - Updated the LEU from 20 to 25 wt% ^{235}U
    Max bias adjusted reactivity (k_s) of 0.9320
  - Updated the HEU from 70 to 71% wt% ^{235}U - Max k_s of 0.94760
  - Updated HEU fuel from 137 to 138g ^{235}U (71 wt% U^{235}) -
    Max k_s of 0.94897
- Stage 2 Analysis
  - Updated LEU to 275g ^{235}U - Max k_s of 0.97310 - Exceeds limits
  - Restricted 275g ^{235}U LEU to single basket with 71 wt% 138g ^{235}U
    HEU loading rest of cask - Max k_s of 0.97772 - Exceeds limits
  - Restricted to 3 rods per basket opening - Max k_s of 0.94560

Criticality Evaluations

- Stage 3 Analysis
  - Single basket 95 wt% 175g ^{235}U HEU
    Remainder of cask at 71 wt% ^{235}U
    Max k_s of 0.99223
  - Restricted to 3 rods per basket opening for 95 wt% payload - Max k_s of 0.94836
- Stage 4 Analysis
  - Mixed payloads
  - Merge basket of TRIGA cluster rods (intact and damaged fuel can maximum reactivity configuration) into TRIGA element model
  - No increase in reactivity

Criticality Evaluations

- Conclusion
  - Minor revisions on enrichment and fissile material mass of 70 wt% ^{235}U TRIGA fuel type – no significant change in system reactivity
  - High mass LEU and increased enrichment (bounding 95 wt% ^{235}U evaluated) TRIGA fuel types require limitation to 3 rods per basket opening (rather than 4 in a full cask configuration)
  - Mixed loading is allowed as there is no reactivity effect of cross-loading

License Drawing Updates

- Limited to assembly drawings associated with the combined cluster rod / fuel element transport configuration

Questions?