Palisades-NRC
Pre-submittal meeting

AREVA and Entergy
July 21, 2010

Agenda

- Palisades Status
- Overview and Background
  - This Analysis Plan
  - Programs – KENO, CASMO3
- KENO Benchmarking
  - HTC Benchmarking Efforts for Actinides
  - OECD Fission Product Benchmarks
- Methods of Analysis
  - Basic methods and occurrences evaluated
  - Burnup Credit Methods
  - Selection of Conservative Depletion Parameters (i.e. Harden the spectrum)
  - Pin by Pin analysis versus assembly averaged enrichment
  - The Lumped Fission Product equivalent
  - How the physical changes during depletion are modeled
  - Legacy Fuel Treatment (burnup penalty)
  - Misload assumptions
- Palisades Rack Model
  - Carborundum Poison
  - Rack Distortion and Void
  - Stuck Assemblies

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Palisades Status

- **2009 LAR submittal:**
  - Submitted September 1, 2009
  - Included burnup credit and soluble boron credit
  - No Carborundum credit
  - Included minimal rack voiding; with wall deformation
  - Supplemental information requested by NRC
    - a) Swelling Model
    - b) KENO-V.a validation
    - c) Burnup Credit Methodology
  - LAR Withdrawn on 10/29/09

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Palisades Status

- **Previous LAR submitted on 11/25/08 for SFP Region I:**
  - **Approved February 6, 2009, License Amendment 236**
  - **Fresh fuel assumed with soluble boron**
  - **No Carborundum credit**
  - **Resulted in 2/4 checkerboard pattern**

Palisades Status

ANALYSIS PLAN

Dates of Activity	Activity
7/21/2010	Meeting with NRC to discuss and plan and schedule for LAR
Mid January 2011	Submit LAR
Mid January 2011- Mid February2012	NRC review, RAI's issued and answered, final NRC review
Mid February 2012	Receive SER
Mid February 2012-End of February (2 weeks)	Implement New Technical Specifications
Early March 2012	Fuel Receipt
Early April 2012	Refueling Outage #22

Overview and Background

- **This Analysis Plan**
  - **Include burnup credit and soluble boron credit**
  - **No Carborundum credit**
  - **Maximal rack voiding, with wall deformation; throughout racks**
  - **Added HTC and Fission Product benchmarks for KENO benchmark**
  - **Treat explicitly all available isotopes from CASMO3 depletion**
    - Model 2 lumped fission products as Nd145.

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Overview and Background, Programs

- **KENO-V.a, SCALE 4.4a, with 44 group library**
  - **Bias and uncertainty evaluation will follow similar methods shown in recent submittals**
  - **Guided by NUREG-6698: 100 benchmark problems (including MOX), trending analysis, normality, description of applicability**
  - **Added HTC and limited fission product benchmarks**
    - New bias and uncertainty results will be incorporated
  - **All available benchmarks have been evaluated**
    - Explicit isotope treatments will be used.
    - Only lumped fission products will use an equivalency method
      - ~0.01 of 0.10 delta-kinf
    - CASMO3-Prism and Nemo topical reports demonstrate good performance against reactor operation
    - 5% of reactivity burnup credit is adequate conservatism for this application
    - In addition, 10% measurement uncertainty is included, when applying limits

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Overview and Background, Programs

- CASMO-3
  - Used to generate cross sections for the fuel cycle calculations
  - Will be used for generation of depletion inventories
    - NEMO and PRISM Topical Reports
  - Will not be used for tolerance calculations

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KENO Benchmarking

- **Previous KENO benchmarking included:**
  - 100 LEU fresh fuel benchmarks, including 10 MOX
- **HTC Benchmarking added:**
  - ~156 benchmarks with isotopic concentrations representative of 4.5% enriched PWR fuel burned to 37.5 GWd/MTU, but without any fission products (11 were recommended for exclusion by ORNL, leaving 145)
- **In addition, 3 OECD Fission Product Benchmarks were evaluated:**
  - LCT-050: 149Sm Solution Tank in the middle of water-reflected 4.74 wt% UO2 fuel rod arrays (18 benchmarks)
  - LCT-079: Water-moderated 4.3 wt% UO2 fuel rod lattices containing rhodium foils (10 benchmarks)
  - LMCT-005: STACY: 60cm Diameter Water-reflected tank containing 5 wt% enriched UO2 fuel rods in 6% Uranyl Nitrate solutions poisoned with pseudo-fission-product elements (12 benchmarks)
    - Excluded due to NITAWL issue in SCALE 4.4a, and inapplicability of fissile solution

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KENO Benchmarking (cont'd)

- **Previous Statistical Evaluation of 100 Benchmarks:**
  - Bias, 95/95 uncertainty and lower tolerance limit:
  - -0.00542, 0.00985, 0.98473
- **Statistical Evaluation of HTC Benchmarks:**
  - Bias, uncertainty, and lower tolerance limit:
  - -0.0041, 0.0049, 0.9910
- **Statistical Evaluation of HTC and OECD Benchmarks:**
  - Bias, uncertainty, and lower tolerance limit:
  - -0.0046, 0.0054, 0.9900 including all except 11 (ORNL-recommended)
  - LTL = 0.9931 if also reject 83 benchmarks containing dissolved gadolinium or thick lead or steel reflectors
- **Plan to incorporate new bias and uncertainty**

KENO Benchmarking (cont'd)

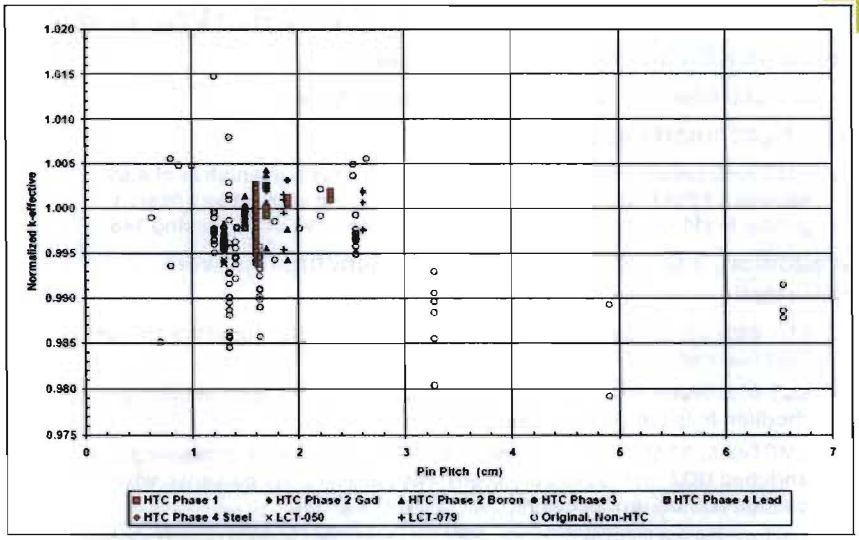

Figure 4-19: Overview of Normalized k_{eff} versus Pin Pitch

KENO Benchmarking (cont'd)

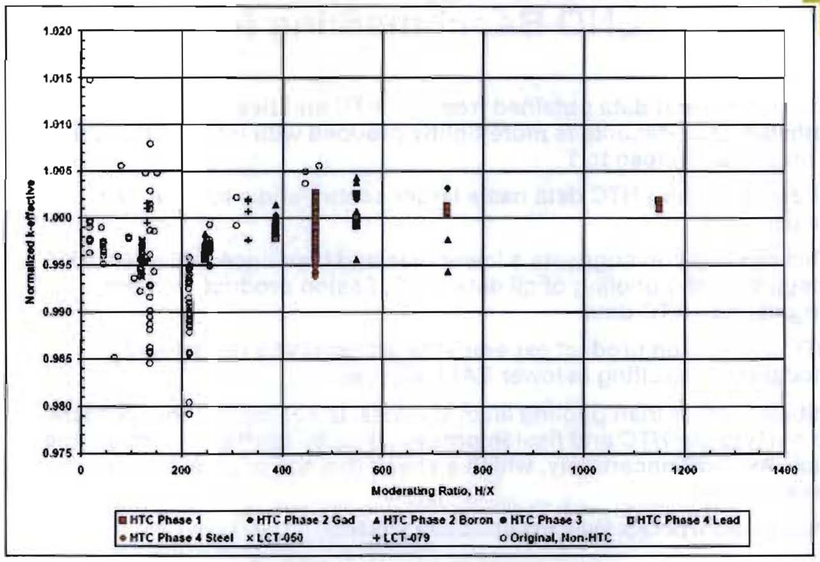

Figure 4-20: Overview of Normalized k_{eff} versus H/X

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KENO Benchmarking (cont'd)

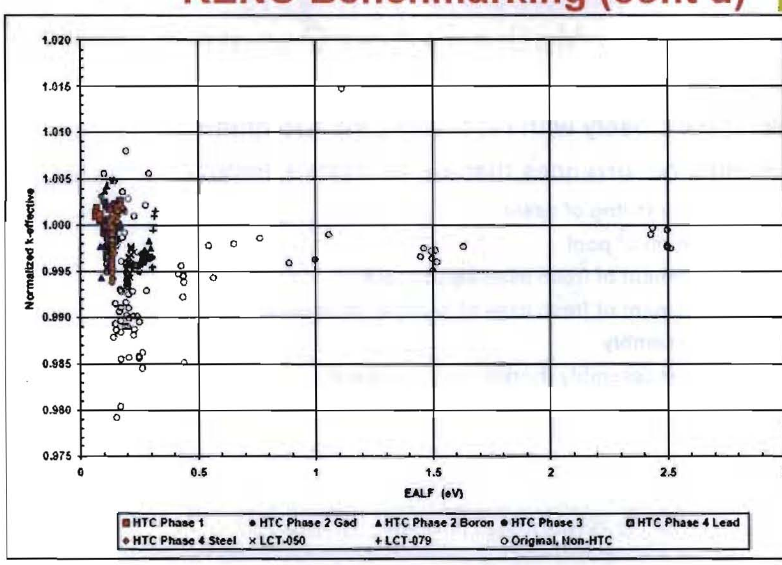

Figure 4-21: Overview of Normalized k_{eff} versus EALF

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KENO Benchmarking (cont'd)

- Normalized keff data obtained from the HTC and fission product criticality experiments is more tightly grouped with less scatter about a mean value close to 1
- The original non-HTC data has a larger scatter and a lower mean value
- This observation suggests a lower bias and bias uncertainty would result from the pooling of all data: HTC, fission product, and the original non-HTC data
- HTC and fission product experiments are generally more highly moderated, resulting in lower EALF values.
- Initially, rather than pooling all of the data, it was considered prudent to analyze the HTC and fission product data by itself to determine the bias and bias uncertainty, which showed that the original bias is conservative
- Plan to incorporate new bias and uncertainty

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Methods of Analysis – Basic Methods and Occurrences

- Will follow closely with recent AREVA submittals.
- Abnormal occurrences that are evaluated, include:
  - Tipping or falling of assembly
  - De-boration of pool
  - Misplacement of fresh assembly in rack
  - Misplacement of fresh assembly adjacent to rack
  - Stuck assembly
  - Off center assembly (horizontal movement)

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Methods of Analysis – Analytical Requirements & Assumptions

- **Burnup credit methods:**
  - **Explicit rack modeling with no leakage, or full reflection.**
  - **Design basis fuel assembly characteristics:**
    - 4.54 w/o
    - active fuel length with no axial blankets
    - no burnable poison bearing fuel rods
  - **Soluble boron credit – 850 ppm, or 1350 ppm for misload accident**
  - **Flat axial burnup profile at low burnups, explicit determination of the "breakpoint", custom burnup profile used above the "breakpoint"**
  - **CASMO depletion performed with conservative parameters**
  - **Uncertainty equal to 5% of reactivity decrement to the burnup of interest**
  - **In addition, 10% measurement uncertainty is included, when applying limits**

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Methods of Analysis – Assembly Selection

- **Selection of limiting assembly type**
- **What is modeled, what is omitted**
  - **End details (top & bottom nozzles) omitted**
  - **Guide bars included**
  - **Grid spacers were evaluated**
- **Conservatively assume uniform, maximum nominal, planar average U235 enrichment, over the axial length and cross sectional area of the assembly**
- **Review of assemblies in the pool, and what is anticipated**
- **Consider special items (pin holders, dummy assemblies, control blades, ...)**

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Analysis Methods – Depletion Parameters

- **Methods of Analysis – Conservative Depletion Parameters**
  - **Selection of Conservative Depletion Parameters (i.e. Harden the spectrum)**
    - See following table. Also,
  - **Spectral affects from operation with control blades fully or partially inserted:**
    - Palisades typically operates with all control blades fully withdrawn, however, certain transients require operation with some control blades partly or fully inserted (Section 2.2 of Core Operation Limits Report)
    - 1 GWD/MTU of each assembly burnup is modeled with adjacent blade fully inserted

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Analysis Methods - Depletion Parameters

Parameter	Value/Model	Comment
Burnup Uncertainty	5% of the reactivity decrement from 0 burnup and the burnup of interest	Standard value consistent with Kopp memo
Measured Burnup Uncertainty	10%	Conservatively large value taken.
Sm	Equilibrium value	More conservative than using peak Sm. Peak Sm is less for low power operation at end of cycle.
Xe	Zero, Decayed to Cs	
Pu239+Pu241 Buildup	• Moderator temperature chosen to maximize Pu production by hardening the spectrum. • All Np-239 is assumed instantly decayed to Pu239.	
Axial Burnup Profile	• 10 axial nodes used. • 3 axial shapes taken from NUREG-6801, validated against core monitoring data.	
Fuel Temperature	• 1260 °F (955.4K). 100 °F higher than maximum predicted fuel temperature.	Conservatively high to increase production of Pu through resonance absorption.
Moderator Temperature	• A bounding axial temperature profile was calculated.	Conservatively high to harden spectrum and increase Pu production.
Soluble Boron Concentration	• Cycle-average concentration of 700 ppm.	
Core Power	• Nominal value of 2565.4 MW	
Operating History	• Nominal, 1 GWD/MTU rodded	
Fixed/Integral Burnable absorbers	• None modeled	Conservative to ignore Gad integral poisons, and lumped burnable poisons are currently not used.

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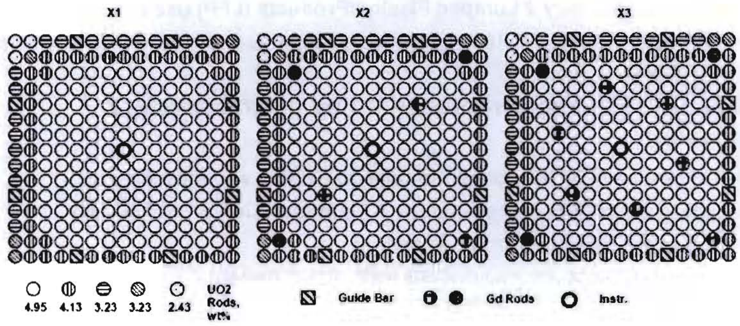
Analysis Methods – Assembly Average Enrichment

- Pin by Pin analysis versus Assembly averaged:

Figure B-5: Pin Arrangements for Batch X Fuel Assemblies



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Analysis Methods – Assembly Average Enrichment (cont.)

- Conservatively assuming uniform, assembly averaged
- Pin by Pin analysis versus Assembly averaged:
- Reported in Appendix B of ANP-2779NP-001 (approved)
- Uniform planar average results were more reactive than pin by pin model results
  - By over 0.01 delta-k, for 4-of-4 loadings in C-rack, and
  - By 0.007 to almost 0.01 for 4-of-4 loadings in E-rack
  - Smaller differences for 3-of-4 and 2-of-4 loadings
  - Considered 8 different assembly orientations, including rotations to maximize reactivity, and offset locations within storage cells

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Analysis Methods – Lumped Fission Product Equivalent

- **Changing to Nd145 equivalent**
  - **To represent only 2 Lumped Fission Products (LFP) used by CASMO-3**
  - **Reference ORNL-TM-1658 (previously submitted to NRC) for LFP isotopic contents**
- **Reduction in what is represented by fission product equivalent**
  - **Takes all available explicit isotopes to KENO - see following list**
  - **Nd145 equivalent represents the 2 lumped fission products, only**
  - **Study has been performed showing:**
    - All fission products: ~0.1 reactivity worth, at high burnup
    - 2 lumped FP: ~0.01 reactivity worth

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Analysis Methods - CASMO-3 with Nd Lumping Versus B10 Lumping

- **Previous models, with B-10 Reactivity Equivalent**

Modeled Explicitly	Modeled as B-10 Equivalent	
U235	U234	Np239
U236	U239	Kr83
U238	Np237	Rh103
Pu239	Pu238	Rh105
Pu240	Pu242	Rh109
Pu241	Am241	Xe131
Sm149	Am242	Cs133
O16	Am243	Cs134
	Cm242	Cs135
	Cm244	Nd143
	Sm147	Nd145
	Sm150	Pm147
	Sm151	Pm148
	Sm152	Pm148m
	Eu153	Pm149
	Eu154	FP Lump 1
	Eu155	FP Lump 2

Note: Should be considered illustrative, subject to minor changes

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Analysis Methods - CASMO-3 with Nd Lumping Versus B10 Lumping

- Current models, with Nd145 Reactivity Equivalent

Modeled Explicitly

U234	Sm147	
U235	Sm149 (incl. Pm149)	
U236	Sm150	
U238	Sm151	
Pu238	Sm152	
Pu239 (incl. U239 & Np239)	Eu153	Rh103=0
Pu240	Eu154	Rh105=0
Pu241	Eu155	Nd143=0
Pu242	Kr83	Pm148=0
Np237	Rh109	Pm148m=0
Am241	Xe131	
Am242	Cs133	
Am243	Cs134	
Cm242	Cs135 (incl. X135, I135)	
Cm244	Pm147	
O16		

Modeled as Nd145 Equivalent

- FP Lump 1
- FP Lump 2

Note: Should be considered illustrative, subject to minor changes

Analysis Methods – Physical Changes with Burnup

- How the physical changes during depletion are modeled
  - Evaluating clad thinning, fuel densification, reduction in fuel pellet/clad gap, and change in active fuel height
  - Sensitivities to all (except fuel height) were included before
  - positive tolerance reactivity effects are related to: increase in rod pitch, %TD, or pellet diameter, and a reduction in the clad OD.
  - Increased density, increased pellet diameter or increased active fuel height increases the mass of fissile material in the assembly, if nothing else is changed, to conserve mass
    - In reality, increased pellet diameter or increased fuel height are concurrent with decreased average density, a compensating change
  - Increased rod pitch or reduced clad OD provides additional water to a generally under-moderated configuration.
    - Change in average rod pitch is not expected
  - Expected density change is bounded by manufacturing tolerance
  - Expected Clad OD decrease is bounded by manufacturing tolerance

Analysis Methods – Legacy Fuel

- **Analysis Assumptions - Legacy Fuel Treatment**
  - Some older assemblies may have had lumped burnable absorber pins, or may have fuel rods replaced with either stainless steel rods or empty pin cells
  - Were examined in previously approved submittal for fresh fuel
  - Empty pin cells may result in a reactivity increase as much as 0.005 Δk
  - Burnup reactivity effects are bounded by an additional 0.005 Δk penalty.
  - A 1.0 GWD/MTU penalty is subtracted from the burnup as indicated by the core monitoring system
  - Determined by examining fuel depletions of similar, lower enrichment
  - This burnup penalty covers approximately 0.01 Δk reactivity bias of these assemblies

Analysis Assumptions - Misload

- **Analysis Assumptions, Misload analysis :**
  - Misload analysis will evaluate a single misload of a fresh assembly in locations expected to produce highest increase in reactivity
  - Credit for soluble boron will be taken
    - 1350 ppm credit, of 1720 ppm tech spec limit
  - Consistent with February 2009 analysis

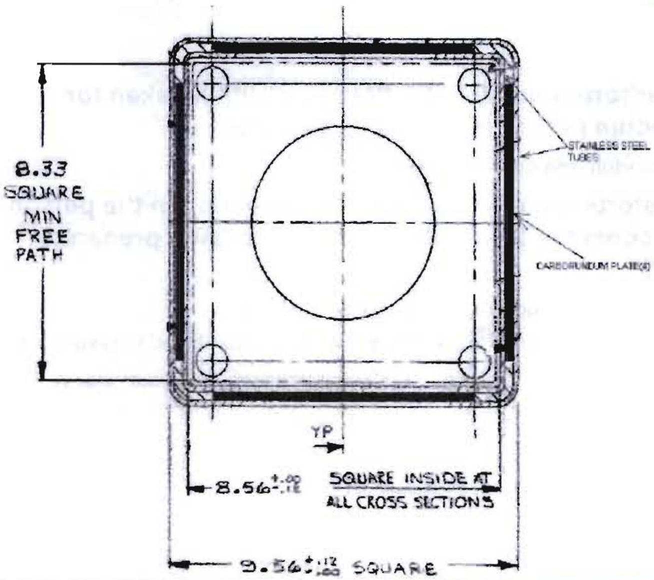
Methods of Analysis - Rack Models

- Due to Carborundum degradation, no credit is taken for Carborundum poison in the spent fuel rack.
  - Carborundum region is completely voided
- Due to distortion and the possibility of voiding in the poison region, a conservative swelling model has been prepared, including:
  - Deformation of structure, with mass conserved
  - Voiding of poison and flux trap regions, and assembly side (exterior to assembly)

Palisades Rack Models

- Will show:
- Nominal geometry of the rack
- Figures showing deformation and voiding assumed for the criticality model
- Will choose deformation with highest k-effective
- This model negates concerns of previous acceptance review question #1

Rack Models - Nominal Design



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Rack Models - Nominal Design

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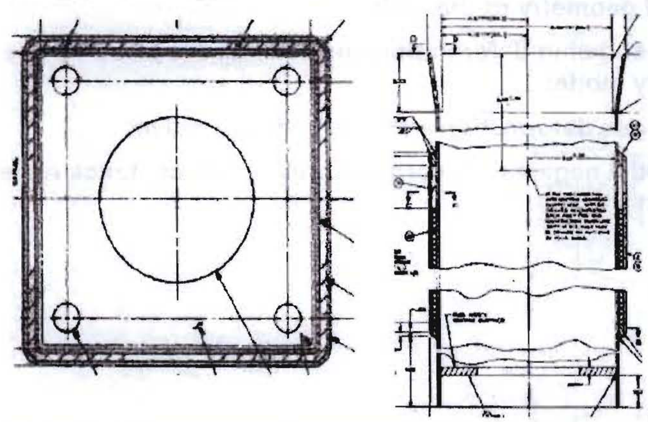
Region I (NUS) Storage Racks



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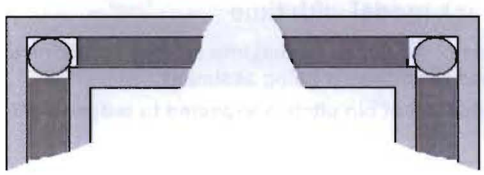
Rack Models - Analysis

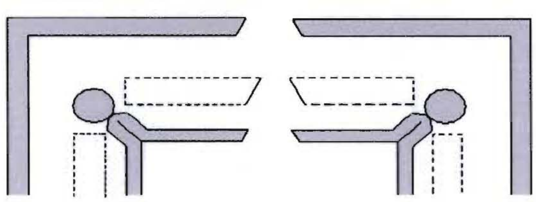
- **For C-racks and the E-rack:**
  - **The entire fuel-to-water gap is voided, and the entire flux trap water gap is voided**
  - **This simulates maximum expansion of the walls to the constraints of contact with the fuel assembly, and contact with other rack walls in the flux trap**
  - **Additionally, using conservation of mass, the two stainless steel panels that enclose the Carborundum material are positioned and thinned on either side of the Carborundum plate, so as to maximize Keff.**
  - **This requires three deviations from nominal dimensions to define the worse case. The following diagrams illustrate the concept for the C-rack.**
  - **The only water in the model is the water within the assembly envelope.**
    - Will be evaluated both with and without the presence of soluble boron.

Rack Models – Nominal versus Modeled

Nominal, C-Rack:



Deformed, Carborundum Voided, C-rack:



Rack Models – Stuck Assemblies

- **Impact of Stuck assemblies**
  - Considered when defining and evaluating acceptable loading patterns
  - Constrains loading of other assemblies around stuck locations
  - Requires additional evaluation
  - Considered for misload analysis
  - Considered when determining assumptions for rack deformation model
  - Precludes misload into stuck locations (no impact on analysis)
  - Requires consideration of possibility of additional locations

Rack Models – Validity with Time

- **Validity of the rack model with time**
  - Fuel assemblies could not be loaded into storage locations if deformation was more than is being assumed
  - Any further reduction of pin pitch is expected to reduce k-eff

Conclusion

Questions?

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