APPENDIX C: CRITICALITY ANALYSIS CHECKLIST

The criticality analysis checklist is completed by the applicant prior to submittal to the NRC. It provides a useful guide to the applicant to ensure that all the applicable subject areas are addressed in the application, or to provide justification/identification of alternative approaches.

The checklist also assists the NRC reviewer in identifying areas of the analysis that conform or do not conform to the guidance in NEI 12-16. Subsequently, the NRC review can then be more efficiently focused on those areas that deviate from NEI 12-16 and the justification for those deviations.

Subject	Included	Notes / Explanation
1.0 Introduction and Overview		
Purpose of submittal	YES	Increase enrichment, update methods & codes, include gadolinium.
Changes requested	YES	Change Tech. Spec burnup curve, change maximum enrichment, add empty cell requirement to NFSA
Summary of physical changes	YES	No physical changes
Summary of Tech Spec changes	YES	Change burnup curve, change maximum enrichment, add burnable absorber requirement
Summary of analytical scope	YES	SFP and new fuel storage criticality safety analysis including normal storage and fuel handling, abnormal conditions, boron dilution analysis, and accompanying code benchmarking analysis
2.0 Acceptance Criteria and Regulatory Guidance		
Summary of requirements and guidance	YES	
Requirements documents referenced	YES	Multiple
Guidance documents referenced	YES	Mainly RG 1.240
Acceptance criteria described	YES	
3.0 Reactor and Fuel Design Description		
Describe reactor operating parameters	YES	Bounds historical and anticipated
Describe all fuel in pool	YES	
Geometric dimensions (Nominal and Tolerances)	YES	
Schematic of guide tube patterns	YES	15x15 PWR fuel and four 17x17 assemblies (>30 years old)
Material compositions	YES	
Describe future fuel to be covered	NO	None proposed. Using composite bounding fuel design
Geometric dimensions (Nominal and Tolerances)	NO	None proposed.
Schematic of guide tube patterns	NO	None proposed.

Subject	Included	Notes / Explanation
Material compositions	NO	None proposed.
Describe all fuel inserts	YES	Borosilicate glass, Alumina B_4C, Secondary Sources, Control Rods
Geometric Dimensions (Nominal and Tolerances)	YES	
Schematic (axial/cross-section)	YES	
Material compositions	YES	
Describe non-standard fuel	YES	Fuel Rod Canister for failed fuel rods and reconstituted fuel.
Geometric dimensions	YES	
Describe non-fuel items in fuel cells	NO	Non-fuel items can be stored in cells that can store fuel. Therefore, non-fuel items displace fuel
Nominal and tolerance dimensions	NO	
4.0 Spent Fuel Pool/Storage Rack Description		
New fuel vault & Storage rack description	YES	Two storage options: -4 out of 4 for enrichments ≤4.35% -3 out of 4 for enrichments >4.35%
Nominal and tolerance dimensions	YES	
Schematic (axial/cross-section)	YES	Rack diagrams
Material compositions	YES	
Spent fuel pool, Storage rack description	YES	One rack type, two storage regions Region 1: Takes burnup credit Region 2: No burnup credit
Nominal and tolerance dimensions	YES	
Schematic (axial/cross-section)	YES	Rack diagrams
Material compositions	YES	
Other Reactivity Control Devices (Inserts)	NO	No installed rack inserts.
Nominal and tolerance dimensions	NO	
Schematic (axial/cross-section)	NO	
Material compositions	NO	
5.0 Overview of the Method of Analysis		
New fuel rack analysis description	YES	
Storage geometries	YES	Two storage options: -4 out of 4 for enrichments ≤4.35% -3 out of 4 for enrichments >4.35%
Bounding assembly design(s)	YES	
Integral absorber credit	NO	No absorber material credited
Accident analysis	YES	- Flooded with water - Flooded with optimum density water - Dropped/misplaced assembly - Seismic event
Spent fuel storage rack analysis description	YES	
Storage geometries	NO	All regions are 4 out of 4. No empty cells are required.
Bounding assembly design(s)	YES	

Subject	Included	Notes / Explanation
Soluble boron credit	YES	
Boron dilution analysis	YES	
Burnup credit	YES	Region 1 credits burnup Region 2 does not credit burnup
Decay/Cooling time credit	NO	The criticality analysis does not credit cooling time (Decays to 100 hours for all cases). The dose assessment analysis requires 150 days of cooling for Region 1. This analysis is not changing this requirement.
Integral absorber credit	NO	
Other credit	NO	
Fixed neutron absorbers	NO	No neutron absorber material installed in the racks
Aging management program	NO	
Accident analysis	YES	
Temperature increase	YES	
Assembly drop	YES	Into racks and outside of racks
Single assembly misload	NO	No empty cells required. Fresh, 5.0wt% assemblies in all cells meet regulatory limits with normally spaced cells.
Multiple misload	NO	No empty cells required. Fresh, 5.0wt% assemblies in all cells meet regulatory limits with normally spaced cells.
Boron dilution	YES	
Other	YES	Cask drop analysis. Modeled by moving all of the Region 1 assemblies and pins towards each other until optimum moderation.
Fuel out of rack analysis	YES	
Handling	YES	
Movement	YES	
Inspection	YES	
6.0 Computer Codes, Cross Sections and Validation Overview		
Code/Modules Used for Calculation of k_{eff}	YES	SCALE 6.2.3 / CSAS5 - KENO V.a
Cross section library	YES	238 group ENDF/B-VII
Description of nuclides used	YES	233 isotopes used
Convergence checks	YES	Convergence tests run on all cases
Code/Module Used for Depletion Calculation	YES	SCALE 6.2.3 / Triton t5-depl (depletion) and ORIGAMI (decay)
Cross section library	YES	238 group ENDF/B-VII
Description of nuclides used	YES	233 isotopes used
Convergence checks	YES	Test cases displayed convergence

Subject	Included	Notes / Explanation
Validation of Code and Library	YES	Appendix A is the validation of CSAS5 Appendix B is the validation of TRITON/ORIGAMI
Major Actinides and Structural Materials	YES	
Minor Actinides and Fission Products	YES	1.5% bias (NUREG/CR-7109)
Absorbers Credited	YES	Soluble boron
7.0 Criticality Safety Analysis of the New Fuel Rack		
Rack model	YES	Full storage area with structure and concrete.
Boundary conditions	YES	Void
Source distribution	YES	Uniform in fissile material
Geometry restrictions	YES	Two storage options: -4 out of 4 for enrichments ≤4.35% -3 out of 4 for enrichments >4.35%
Limiting fuel design	YES	
Fuel density	YES	Bounding high
Burnable Poisons	NO	No credit taken
Fuel dimensions	YES	Composite bounding design
Axial blankets	NO	No credit taken
Limiting rack model	YES	
Storage vault dimensions and materials	YES	
Temperature	YES	
Multiple regions/configurations	NO	Only one region / type of rack
Flooded	YES	
Low density moderator	YES	
Eccentric fuel placement	YES	
Tolerances	YES	
Fuel geometry	YES	
Fuel pin pitch	YES	
Fuel pellet OD	YES	
Fuel clad OD	YES	
Fuel content		
Enrichment	YES	
Density	YES	
Integral absorber	NO	No credit
Rack geometry		
Rack pitch	YES	
Cell wall thickness	YES	
Storage vault dimensions/materials	YES	
Code uncertainty	YES	
Biases	YES	
Temperature	YES	
Code bias	YES	

Subject	Included	Notes / Explanation
Moderator Conditions	YES	
Fully flooded and optimum density moderator	YES	
8.0 Depletion Analysis for Spent Fuel		
Depletion Model Considerations	YES	
Time step verification	YES	Verified (similar to prior LARs).
Convergence verification	YES	Verified (similar to prior LARs).
Simplifications	YES	Bounding high grid volume homogenized in fuel lattice water, constant depletion conditions (except reduced power for final 40 days).
Non-uniform enrichments	NO	
Post Depletion Nuclide Adjustment	YES	Reduced volatile fission product content (same as prior LARs).
Cooling Time	YES	Only peak reactivity decay used (100 hours)
Depletion Parameters	YES	
Burnable Absorbers	YES	Bounding Alumina B_4C discrete burnable absorber used.
Integral Absorbers	NO	IFBA and Gad tested and shown to be bounded by Alumina B_4C discrete burnable poison. Rules set up for use mixture of discrete BP with integral BP (similar to prior LARs).
Soluble Boron	YES	Bounding high boron concentration used. 1 unbounded assembly justified.
Fuel and Moderator Temperature	YES	Calculated using bounding high fuel assembly power history and bounding high core moderator exit temperature
Power	YES	Bounding high power reduced near end of depletion to maximize depleted fuel reactivity.
Control rod insertion	NO	Shown to be bounded by the bounding burnable poison
Atypical Cycle Operating History	YES	Bounded or justified.
9.0 Criticality Safety Analysis of Spent Fuel Pool Storage Racks		
Rack model	YES	Two rack models. Region 1 models the entire region while Region 2 is an infinite array.
Boundary conditions	YES	Region 1: Reflective with large amount of water and concrete between fuel and boundary. Region 2: Reflective
Source distribution	YES	Uniform in fissile material
Geometry restrictions	NO	No required empty cells or low reactivity cells
Design Basis Fuel Description	YES	Composite bounding design.

Subject	Included	Notes / Explanation
Fuel density	YES	Bounds all fuel assemblies.
Burnable Poisons	NO	Burnable poison credit not utilized
Fuel assembly inserts	NO	Control rod credit not utilized
Fuel dimensions	YES	Present, past, and anticipated future designs bounded
Axial blankets	NO	Axial blanket credit not utilized.
Configurations considered	YES	Evaluated with and without boron.
Borated	YES	
Unborated	YES	
Multiple rack designs	NO	Only one rack type present in SFP
Alternate storage geometry	NO	No required empty cells or low reactivity cells
Reactivity Control Devices	NO	
Fuel Assembly Inserts	NO	Control rod credit not utilized
Storage Cell Inserts	NO	
Storage Cell Blocking Devices	NO	No empty cells required
Axial burnup shapes	YES	
Uniform/Distributed	YES	NUREG/CR-6801 shapes and uniform. Justified with Surry shapes.
Nodalization	YES	NUREG/CR-6801 - 18 nodes.
Blankets modeled	NO	No credit.
Tolerances/Uncertainties	YES	
Fuel geometry	YES	
Fuel rod pin pitch	YES	
Fuel pellet OD	YES	
Cladding OD	YES	
Axial fuel position	YES	
Fuel content	YES	
Enrichment	YES	
Density	YES	
Assembly insert dimensions and materials	NO	No inserts used
Rack geometry	YES	
Flux-trap size (width)	NO	No flux trap racks
Rack cell pitch	YES	
Rack wall thickness	YES	
Neutron Absorber Dimensions	NO	No neutron absorber material
Rack insert dimensions and materials	NO	No rack inserts used
Code validation uncertainty	YES	
Criticality case uncertainty	YES	
Depletion Uncertainty	YES	EPRI 3002016888 method used (calculated depletion uncertainty)
Burnup Uncertainty	YES	5% of measured burnup. From NEI 12-16 and justified using Surry measurement uncertainties.

Subject	Included	Notes / Explanation
Biases	YES	
Design Basis Fuel design	YES	
Code bias	YES	
Temperature	YES	
Eccentric fuel placement	YES	
Incore thimble depletion effect	YES	Incore thimble included in fuel depletion model.
NRC administrative margin	YES	
Modeling simplifications	YES	
Identified and described	YES	
10.0 Interface Analysis		
Interface configurations analyzed	YES	
Between dissimilar racks	NO	Only one type of rack in SFP
Between storage configurations within a rack	YES	Region 1 (burned fuel) – Region 2 (fresh fuel) interface analyzed
Interface restrictions	NO	Benign interface
11.0 Normal Conditions		
Fuel handling equipment	YES	
Administrative controls	YES	
Fuel inspection equipment or processes	YES	
Fuel reconstitution	YES	Evaluated and limitations applied
12.0 Accident Analysis		
Boron dilution	YES	0 ppm $k_{eff} < 1.0$ including bias and uncertainties
Normal conditions	YES	$k_{eff} < 0.95$ with minimum boron dilution analysis boron concentration
Accident conditions	YES	$k_{eff} < 0.95$ with TS boron concentration
Single assembly misload	YES	Bounded by cask drop accident
Fuel assembly misplacement	YES	Bounded by cask drop accident
Neutron Absorber Insert Misload	NO	No neutron absorbing material
Multiple fuel misload	YES	Bounded by cask drop accident
Dropped assembly	YES	Bounded by cask drop accident
Temperature	YES	Between racks. Bounded by cask drop accident
Seismic event/other natural phenomena	YES	No interface effect from shifting racks due to racks being fastened to the SFP floor.
13.0 Analysis Results and Conclusions		
Summary of results	YES	
Burnup curve(s)	YES	Bounding polynomial coefficients
Intermediate Decay time treatment	NO	No decay credit utilized.
New administrative controls	NO	
Technical Specification markups	YES	

Subject	Included	Notes / Explanation
14.0 References	YES	
Appendix A: Criticality Computer Code Validation:		
Code validation methodology and bases	YES	NUREG 6698 Method
New Fuel	YES	
Depleted Fuel	YES	
MOX	YES	
HTC	YES	
Convergence	YES	
Trends	YES	
Bias and uncertainty	YES	
Range of applicability	YES	
Analysis of Area of Applicability coverage	YES	
Appendix B: Depletion Computer Code Validation:		
Code validation methodology and bases	YES	EPRI 3002010613 (Benchmark Report) EPRI 3002016888 (Utilization Report)
Convergence	YES	
Trends	YES	
Bias and uncertainty	YES	
Range of applicability	YES	