

**North Anna Power Station  
Criticality Analysis Checklist  
New Fuel Storage Rack and Spent Fuel Pool  
Proposed License Amendment Request**

| Subject  | Included | Justification / Explanation                               |
|--|----------|---|
| <b>1.0 Introduction</b>                                |          |   |
| <b>Purpose of submittal</b>                            | YES      | Increase enrichment to 5 w/o                              |
| <b>License changes requested</b>                       | YES      |   |
| Summary of physical changes                            | YES      | Two regions, remove cell blockers                         |
| Summary of analytical scope                            | YES      | New and spent fuel racks                                  |
|  |          |   |
| <b>2.0 Acceptance Criteria and Regulatory Guidance</b> |          |   |
| <b>Summary of requirements and guidance</b>            | YES      |   |
| Requirements documents referenced                      | YES      |   |
| Guidance documents referenced                          | YES      |   |
| Acceptance criteria described                          | YES      |   |
|  |          |   |
| <b>3.0 Storage Rack Description</b>                    |          |   |
| <b>New fuel storage rack description</b>               | YES      |   |
| Nominal and tolerance dimensions                       | YES      |   |
| <b>Spent fuel storage rack description</b>             | Yes      |   |
| Nominal and tolerance dimensions                       | YES      |   |
|  |          |   |
| <b>4.0 Fuel Design Description</b>                     |          |   |
| <b>Describe all fuel in pool</b>                       | YES      | Range of key parameters all past and present fuel designs |
| Nominal and tolerance dimensions                       | YES      |   |
| <b>Describe future fuel to be covered</b>              | NO       | None proposed   |
| <b>Describe all fuel inserts</b>                       | YES      |   |
| Nominal and tolerance dimensions                       | YES      |   |
| <b>Describe non-standard fuel</b>                      | YES      |   |
| <b>Describe non-fuel items in fuel cells</b>           | YES      |   |
| Nominal and tolerance dimensions                       | YES      | Bounding approximation                                    |
|  |          |   |
| <b>5.0 Overview of the Method of Analysis</b>          |          |   |
| <b>New fuel rack analysis description</b>              | YES      |   |
| Storage geometries                                     | NO       | Single region, no blocked cells                           |
| Bounding assembly design(s)                            | YES      |   |
| Integral absorber credit                               | NO       |   |
| Accident analysis                                      | YES      | Flooded & Optimum Moderation                              |
| <b>Spent fuel storage rack analysis description</b>    | YES      |   |
| Storage geometries                                     | YES      | Two regions   |
| Bounding assembly design(s)                            | YES      | Bounds old and new fuel designs                           |
| Soluble boron credit                                   | YES      |   |
| Boron dilution analysis                                | NO       | Previously approved analysis referenced                   |

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| <b>Spent fuel storage rack analysis description (cont'd.)</b>    |          |   |
| Burnup credit  | YES      | One burnup curve  |
| Decay time credit  | YES      | One burnup curve  |
| Integral absorber credit   | NO       |   |
| Other credit   | NO       |   |
| Fixed neutron absorbers  | NO       |   |
| Aging management program   | NO       |   |
| Accident analysis  | YES      |   |
| Temperature increase   | YES      |   |
| Assembly drop  | YES      |   |
| Multiple misload   | YES      | Bounding accident   |
| Boron dilution   | YES      |   |
| Other  | NO       |   |
| Fuel out of rack analysis  | YES      |   |
| Handling   | YES      |   |
| Movement   | YES      |   |
| Inspection   | YES      |   |
|  |          |   |
| <b>6.0 Cross Sections, Computer Codes, and Validation</b>        |          |   |
| <b>Code/Modules Used for Calculation of <math>k_{eff}</math></b> | YES      | SCALE6.0/CSAS5 – KENO V.a                                 |
| Cross section library  | YES      | ENDF/B-VII 238 Group                                      |
| List all the isotopes used                                       | YES      | Section 8.0   |
| Convergence checks   | YES      | Source, histories, trends                                 |
| <b>Code/Module Used for Depletion Calculation</b>                | YES      | SCALE6.0/T5-depl – KENO V.a                               |
| Cross section library  | YES      | ENDF/B-VII 238 Group                                      |
| List all the isotopes used                                       | YES      | All SCALE 6.0 (T5-DEPL addnux=3)                          |
| Convergence checks   | YES      | Step size, histories, rack $k_{eff}$                      |
| <b>Validation of Depleted Fuel Isotopic Content</b>              | YES      | Use ISG 2010-01 (5% burnup worth)                         |
| <b>Validation of Code and Library</b>                            | YES      |   |
| Major Actinides and Structural Materials                         | YES      | Appendix A  |
| Minor Actinides and Fission Products                             | YES      | 1.5% bias (NUREG/CR-7109)                                 |
|  |          |   |
| <b>7.0 Criticality Safety Analysis of the New Fuel Rack</b>      |          |   |
| <b>Rack model</b>  | YES      | Full storage area (126 cells plus structure and concrete) |
| Boundary conditions  | YES      | Void  |
| Source distribution  | NO       | Uniform in fissile material                               |
| Geometry restrictions  | NO       |   |

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| <b>Limiting fuel design</b>                |          |  |
| Fuel density                               | YES      | Bounding high  |
| Grids                                      | NO       | Not modeled  |
| Burnable Poisons                           | NO       | No credit  |
| Fuel dimensions                            | YES      | Multiple recent designs considered, bounding                       |
| Axial blankets                             | NO       | No blankets have been used   |
| Fuel plenum and end plug region            | NO       | No credit, modeled as moderator                                    |
| <b>Limiting rack model</b>                 |          |  |
| Storage area walls                         | YES      | Bound-water concrete   |
| Temperature                                | YES      | Flooded 32° to 100°F<br>Optimum Moderation 32° to 100°F            |
| Multiple regions                           | NO       | New 5.0 w/o fuel allowed in all cells                              |
| Flooded                                    | YES      | Bias and uncertainty calculated                                    |
| Low density moderator                      | YES      | Bias and uncertainty calculated                                    |
| Asymmetric fuel placement                  | YES      | Offset all assemblies towards middle of storage area in rack model |
| <b>Tolerances</b>                          |          |  |
| Fuel geometry                              |          |  |
| Fuel pin pitch                             | YES      |  |
| Fuel pellet OD                             | YES      |  |
| Fuel clad ID                               | YES      |  |
| Fuel clad OD                               | YES      |  |
| Guide tube ID                              | YES      |  |
| Guide tube OD                              | YES      |  |
| Axial fuel position                        | YES      |  |
| Axial Fuel Length                          | YES      |  |
| Fuel content                               |          |  |
| Enrichment                                 | NO       | 5.0 w/o is bounding  |
| Dish and Chamfer                           | NO       | Included in Density  |
| Density                                    | YES      |  |
| Rack geometry                              |          |  |
| Rack pitch                                 | YES      |  |
| Cell wall thickness                        | YES      |  |
| Concrete Composition                       | NO       | Bounding Composition   |
| Code uncertainty                           | YES      | EALF extrapolation   |
| Absorber geometry and content              | NO       | No absorber credit   |
| <b>Biases</b>                              |          |  |
| Temperature                                | YES      | From code benchmarking   |
| Code bias                                  | YES      | EALF extrapolation   |
| Absorber geometry and content              | NO       | No absorber credit   |
| <b>Accident analysis</b>                   |          |  |
| Flooding (water and low density moderator) | YES      |  |

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| <b>8.0 Depletion Modeling and Burnup Effects</b> |          |  |
| <b>TRITON Depletion Model Considerations</b>     |          |  |
| Time step verification                           | YES      | Adequate for isotopic convergence  |
| Convergence verification                         | YES      | More neutron histories than required for depletion $k_{eff}$ convergence   |
| Simplifications                                  | YES      | Described and justified (grids)  |
| Non-uniform enrichments                          | NO       | None present   |
| Nodalization                                     | YES      | 18 nodes depleted independently  |
| Fuel clad creep and grid growth                  | YES      | Evaluated as a bias  |
| <b>Limiting depletion parameters</b>             |          | Past and present cycles  |
| Burnable Absorbers                               | YES      | Bounding, except for Pyrex (only used in initial cycles)   |
| Integral absorbers                               | NO       | BPRA bounds WABA and IFBA (WABA plus IFBA not analyzed)  |
| Soluble Boron                                    | YES      | Bounds all burnup average boron  |
| Fuel and Water Temperature                       | YES      | Node-specific values based on bounding high power history fuel assembly, TS minimum flow, 18 node burnup (power) shape, SIMULATE fuel temp tables      |
| Specific power                                   | YES      | Includes all core power uprates, bounding high power assembly history, reduced 50% for last 40 days of depletion, proportional to 18 node burnup shape |
| Control rod insertion                            | NO       | Bounded by BPRA insertion  |
| Axial burnup shapes                              | YES      | Uniform and NUREG/CR-6801  |
| Grids  | YES      | Max. volume Zircaloy grids   |
| <b>Depleted fuel content nuclide selection</b>   |          |  |
| Number of nuclides                               | YES      | All TRITON nuclides  |
| Volatile fission products                        | YES      | Reduced based on release fractions   |
| Decay time                                       | YES      | 5 days (base burnup curve) and 3 years (decay time credit)   |
|  |          |  |
| <b>9.0 Spent Fuel Rack Analysis</b>              |          |  |
| <b>Rack model</b>                                | YES      | Two configurations (Regions), both infinite lattice (6x6 model with asymmetric fuel placement)   |
| Boundary conditions                              | YES      | Periodic X-Y, mirror Z   |
| Source distribution                              | NO       | Uniform in fissile material  |
| <b>Geometry restrictions</b>                     | YES      | 2 out of 4 Region 1, Region interface requirements   |

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| <b>Limiting fuel design</b>             |          |  |
| Fuel density                            | YES      | Bounds all fuel batches  |
| Grids                                   | YES      | Min. volume Zr grids   |
| Burnable Poisons                        | NO       | No credit  |
| Fuel assembly inserts                   | YES      | With and without depleted BPRA   |
| Fuel dimensions                         | YES      | All fuel designs in SFP considered   |
| Axial blankets                          | NO       |  |
| Configurations considered               | YES      | Regions 1 (2/4 fresh 5.0 w/o fuel) and 2 (4/4 with burnup credit)  |
| Borated                                 | YES      | Partial bias and tolerance calculations, extra 50 ppm boron, both regions  |
| Unborated                               | YES      | Full bias and tolerance calculations for fresh fuel, most bias and tolerances calculated for depleted fuel, both regions |
| Multiple rack designs                   | NO       | All racks are the same Boraflex flux trap design   |
| Alternate storage geometry              | NO       |  |
| <b>Axial burnup shapes</b>              |          |  |
| Non-uniform with justification          | YES      | NUREG/CR-6801, except shape 9  |
| Uniform                                 | YES      | 0 to 20 GWd/MTU  |
| Region interface effects (mixed shapes) | YES      | Analyzed uniform and non-uniform shapes at minimum and maximum burnup  |
| <b>Tolerances</b>                       |          |  |
| Fuel geometry                           |          |  |
| Fuel pin pitch                          | YES      |  |
| Fuel pellet OD                          | YES      | Fresh fuel, applied to all burnups   |
| Fuel clad ID                            | YES      | Fresh fuel, applied to all burnups   |
| Fuel clad OD                            | YES      | Fresh fuel, creep bias for depleted  |
| Guide tube ID                           | YES      | Fresh fuel, applied to all burnups   |
| Guide tube OD                           | YES      | Fresh fuel, applied to all burnups   |
| Axial fuel position                     | YES      |  |
| Fuel stack height                       | YES      | Fresh fuel, applied to all burnups   |
| Burnup worth                            | YES      | 5% of burnup worth   |
| Measured burnup                         | YES      | 4% of burnup worth   |
| Fuel content                            |          |  |
| Enrichment                              | YES      |  |

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| <b>Tolerances (cont'd.)</b>               |          |  |
| Rack geometry                             |          |  |
| Cell wall thickness                       | YES      |  |
| Rack cell pitch                           | YES      |  |
| Boraflex wrapper thickness                | YES      |  |
| Boraflex wrapper height                   | YES      | Captured via axial fuel position variation                                 |
| Rack tie plate thickness and width        | YES      |  |
| Rack cell pitch                           | YES      |  |
| Code uncertainty                          | YES      |  |
| KENO case uncertainty                     | YES      | 2 standard deviations  |
| <b>Biases</b>                             |          |  |
| Fuel geometry                             |          |  |
| Clad creep                                | YES      |  |
| Grid growth (pin pitch)                   | YES      |  |
| Minimum grid volume                       | YES      |  |
| Minor actinides and fission product worth | YES      | 1.5% of worth (NUREG/CR-7109)  |
| Code bias                                 | YES      |  |
| Temperature                               | YES      | 32 F to 170 F plus code benchmark temperature bias                         |
| Low power at EOL                          | YES      |  |
| Horizontal burnup tilt                    | YES      |  |
| Incore thimble depletion effect           | YES      |  |
| NRC administrative margin                 | YES      | 1% $\Delta k$  |
| <b>Modeling simplifications</b>           |          |  |
| Axial reflectors                          | YES      | Water reflectors above and below active fuel region                        |
|   |          |  |
| <b>10.0 Interface Analysis</b>            |          |  |
| <b>Region interface effects</b>           | YES      | Calculated   |
| Region 1 interface requirements           | YES      | Specified  |
|   |          |  |
| <b>11.0 Normal Conditions</b>             |          |  |
| Fuel handling equipment                   | YES      | Bounding analysis  |
| Administrative controls                   | YES      | Minimum boron, fuel handling restrictions, fuel qualification process, etc |
| Fuel inspection equipment or processes    | YES      | Bounding analysis  |

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| <b>12.0 Accident Analysis</b>                |          |  |
| <b>Boron dilution</b>                        | YES      | 0 ppm $k_{eff} < 1.0$ including biases and uncertainties   |
| Normal conditions                            | YES      | $k_{eff} < 0.95$ with minimum dilution analysis boron  |
| Accident conditions                          | YES      | $k_{eff} < 0.95$ with TS minimum SFP boron   |
| <b>Multiple fuel misload</b>                 | YES      | Fresh 5.0 w/o fuel in all cells  |
| <b>Dropped assembly</b>                      | YES      | Not limiting   |
| <b>Heavy load drop</b>                       | YES      | Not limiting   |
| <b>Temperature</b>                           | YES      | 32 F to 212 F  |
| <b>Seismic event</b>                         | NO       | Infinite lattice with no rack spacing credit, Region 1 contained within rack modules, benign Region boundaries |
|  |          |  |
| <b>13.0 Summary and Conclusions</b>          |          |  |
| <b>Summary of results</b>                    | YES      |  |
| Burnup curve interpolation                   | YES      | Bounding cubic equation  |
| <b>New administrative controls</b>           | NO       | None anticipated   |
| <b>Technical Specification markups</b>       | YES      |  |
|  |          |  |
| <b>Appendix A Computer Code Validation:</b>  |          |  |
| <b>Code validation methodology and bases</b> | YES      | NUREG 6698 Method  |
| New Fuel                                     | YES      |  |
| Depleted Fuel                                | YES      |  |
| MOX critical                                 | YES      | Included for spent fuel  |
| HTC critical                                 | YES      | Included for spent fuel  |
| High temperature criticals                   | YES      | Included, added bias   |
| Convergence                                  | YES      | Source, histories, trends  |
| Trends                                       | YES      |  |
| Bias and uncertainty                         | YES      |  |
| Range of applicability                       | YES      |  |