Pre- Submittal Meeting for Palo Verde Unit 1, 2, and 3 Updated Spent Fuel Pool Criticality Analysis

May 11, 2015

Purpose

- Present and discuss planned licensing changes
  - Update spent fuel pool (SFP) criticality analysis
  - Add neutron absorbing inserts to SFP racks

Objectives

- Updated criticality analysis will
  - Provide basis for replacing non-conservative Technical Specification (TS) caused by missed power uprate impact
  - Include Next Generation Fuel (NGF) not bounded by current analysis
    - Account for reactivity effects of integral fuel burnable absorber (IFBA)
  - Maintain full core offload capability

Borated Aluminum Inserts

- Additional reactivity hold down is required to meet 10 CFR 50.68
  - Thermal hydraulic, seismic, structural, and pool cooling calculations will be updated as needed
  - Add a coupon surveillance program to monitor material performance

TS Changes

- 3.7.17 - Spent Fuel Assembly Storage
  - Incorporate new burnup and enrichment curves
  - Display information graphically with the polynomial explicitly stated
  - Include diagrams of approved arrays

TS Changes (cont.)

- 4.3.1.1 – Design Features
  - Incorporate new arrays
  - Update boron concentration
  - Reduce radially averaged enrichment from 4.8 wt% to 4.65 wt%

New TS

- 5.5.21 - Spent Fuel Storage Rack Neutron Absorber Monitoring program
  - Information will include:
    - Periodicity for coupon testing
    - Description of coupon testing procedure
    - Definition of acceptance criteria, including what constitutes an adverse condition
    - Description of process and acceptance criteria for B-10 loading analysis
    - Description of actions to address failure to meet acceptance criteria
  - Consider license extension
  - Consider plant decommissioning

Implementation

- Prior to NGF implementation in each unit
- Considering installation inserts under 10 CFR 50.59
- Considering a license condition for a specified period of time to transition between TS

Methodology

- Based on
  - ISG-2010-01, "Staff Guidance Regarding the Nuclear Criticality Safety Analysis for Spent Fuel Pools"
  - NEI 12-16, "Guidance for Performing Criticality Analyses of Fuel Storage at Light-Water Reactor Power Plants", Revision 1
  - EPRI Depletion Benchmark Reports
  - NUREGs 7109, 6698, 6760, etc.

Recent Licensing Actions

- Methodology similar to:
  - Comanche Peak
  - Prairie Island
- Insert material similar to:
  - LaSalle
  - Peach Bottom
  - Quad Cities
- Criticality code usage similar to:
  - Millstone 2

ISG Item 1 - Fuel Assembly Selection

- Palo Verde will demonstrate that variations in design are adequately accounted for in a single fuel assembly design
  - CE Standard Fuel
  - CE Value Added Pellet
  - Westinghouse NGF
  - AREVA Advanced CE-16 HTP
- Single, limiting, assembly will be used to create burnup requirements

ISG Item 2 – Depletion Analysis

- Depletion parameters will impact the isotopic inventory of burned fuel
- Major depletion inputs
  - Fuel type
  - Axial burnup
  - Moderator temperature
  - Reactor power
  - Soluble boron
  - Burnable absorbers

ISC Item 2.a – Depletion Uncertainty

- The EPRI methodology will be used to demonstrate the 5% depletion uncertainty is conservative for Palo Verde

- Fission product uncertainty explicitly considered

ISG Item 2.b – Reactor Parameters

- Limiting axial moderator temperature profiles derived past, present, and anticipated profiles
  - Same methodology employed at Comanche Peak
- Analysis performed at 4070 MWth
- Licensee controls include verification of radial power distribution and T-cold

ISG Item 2.c – Burnable Absorbers

- Palo Verde has used the following integral burnable absorbers
  - B_4C rods in CE STD Fuel
  - Erbia in CE STD Fuel and Value Added Pellet
  - Integral Fuel Burnable Absorber (IFBA) in NGF
  - Gadolinia in AREVA Fuel
- Analysis will not credit Erbia, B_4C, or Gadolinia
- NGF fuel modeled with IFBA in all 236 pins for depletion analysis only
  - Pool model assumes no burnable absorbers

ISG Item 2.d – Rodded Operation

- Palo Verde does not operate with control rods inserted
  - Guide tube wear program

- End of cycle check will ensure that fuel assemblies experienced an insignificant amount of rodded operation at hot full power

ISG Item 3 - Criticality Analysis

- SCALE 6.1.2 will be used in the analysis
  - KENO V.a solves the eigenvalue (k_{eff}) problem in 3D using the Monte Carlo method
  - 238 Group ENDF/B-VII will be used as the library
  - Millstone LAR used SCALE 6.0 with the KENO V.a module and 238 Group ENDF/B-VII library

ISG Item 3.a – Axial Burnup Profile

- Bounding axial burnup profiles selected from past, present, and anticipated profiles
  - Cycle specific licensee controls include checks on cutback regions (blanket), fuel design, and moderator temperature

ISG Item 3.b – Rack Model

- Dimensions and tolerance of racks are traceable to design documents

- B-10 areal density conservatively modeled at quantity less than minimum certified areal density

ISG Item 3.c - Interfaces

- All interfaces will be evaluated
  - Palo Verde has only one rack design
  - No gaps modeled between rack modules
  - Limiting interfaces will be analyzed

ISG Item 3.d – Normal Conditions

- Analysis demonstrates that $k_{eff} \leq 0.95$ at less than the TS required boron concentration for:
  - Fuel movement
  - Fuel inspection and reconstitution
  - Foreign Object Search and Retrieval
  - Limiting normal condition to initiate accident identified

ISG Item 3.e – Accident Conditions

- Analysis demonstrates that $k_{eff} \leq 0.95$ at less than the TS required boron concentration for
  - Misloaded or dropped single fresh fuel assembly into, outside of, or on top of spent fuel racks
  - Multiple misloaded fuel assemblies
  - Loss of SFP cooling
  - Seismic events

ISG Item 3.e (contd.)

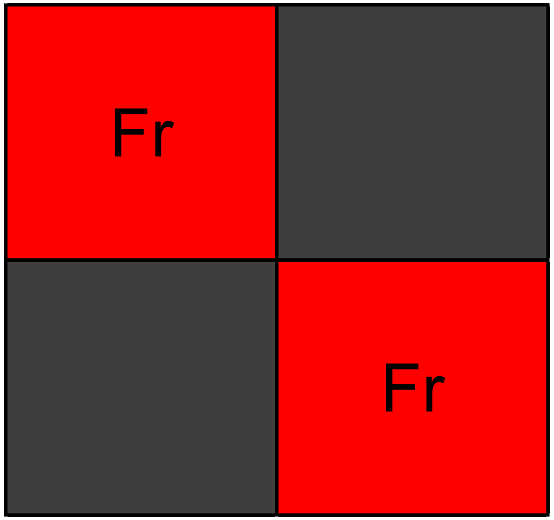
- Limiting dilution event reduces pool boron from 2150 ppm to 1900 ppm
- TRM requires boron concentration to be maintained at 4000 ppm

ISG Item 4 – Code Validation

- Will perform criticality code validation in accordance with NUREG/CR-6698
  - Data carefully considered to identify trends consistent with NUREG-1475
  - HTC experiments will be included
- Fission products will be explicitly accounted for
  - No lumped fission products will be used

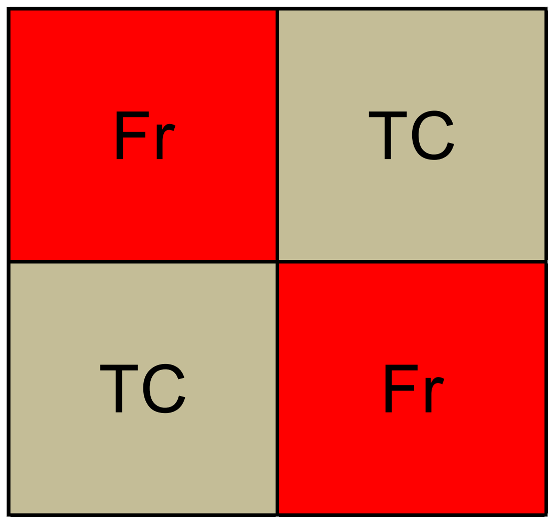
Palo Verde Arrays

- Infinite array of 2 fresh fuel assemblies (Fr) with two blocked locations and no inserts



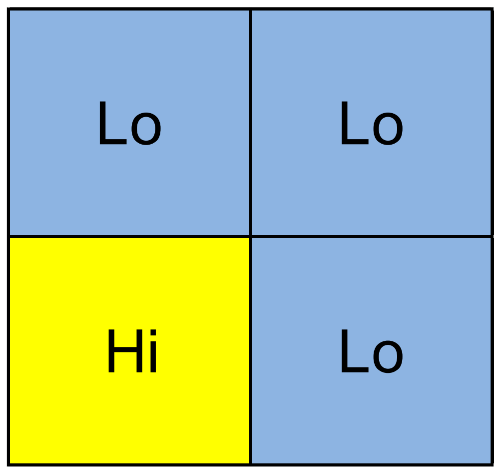
Palo Verde Arrays

- Infinite array of 2 fresh fuel assemblies (Fr) with two trash cans (TC) and two inserts



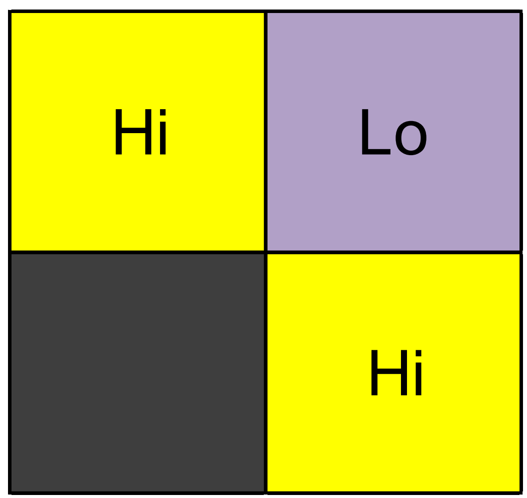
Palo Verde Arrays

- Infinite array of 3 low reactivity fuel assemblies (Lo) and 1 high (Hi) reactivity fuel assembly with 2 inserts



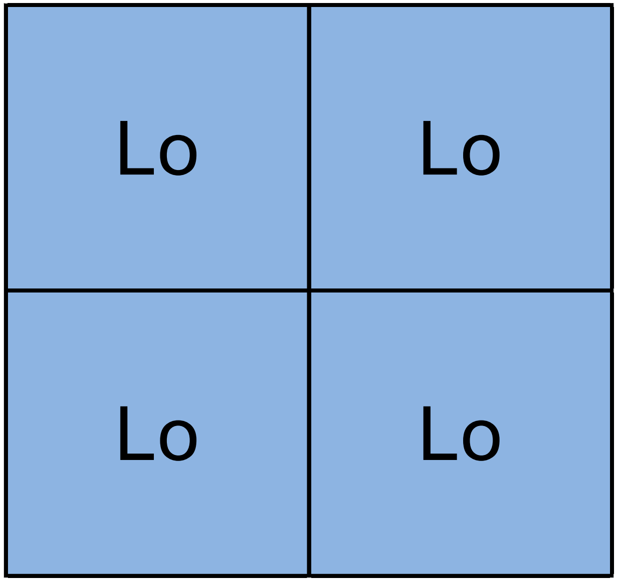
Palo Verde Arrays

- Infinite array of 2 high reactivity fuel assemblies (Hi) and one low reactivity fuel assembly (Lo) with one blocked cell and one insert



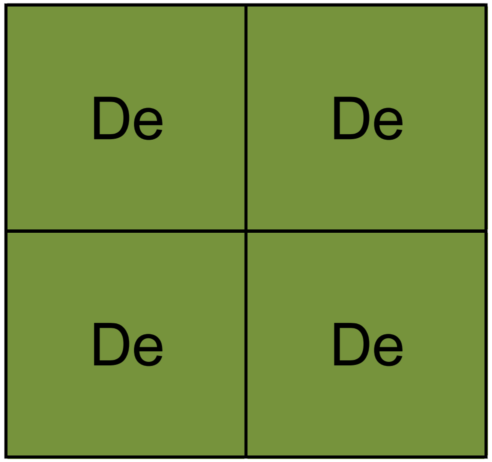
Palo Verde Arrays

- Infinite array of 4 low reactivity fuel assemblies (Lo) with one insert



Palo Verde Arrays

- Infinite array of 4 depleted fuel assemblies (De) with no inserts



Margin Maintenance

- Palo Verde will monitor the margin identified in the analysis
- Cycle specific checks of key input parameters
- 0.005 Δk additional margin reserved by Palo Verde
  - Burnup and enrichment curves will be for $k_{eff} = 0.99$

Conclusion

- Palo Verde is proposing an acceptable methodology for performing SFP criticality analysis
- Permanently installed borated aluminum inserts will be credited in the analysis
- Submit LAR by Nov 2015
- Request NRC approval in 18 – 24 months