Beaver Valley Power Station Unit No. 2
Spent Fuel Pool Rerack Project
Pre-submittal Meeting

FirstEnergy

FENOC

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FirstEnergy Nuclear Operating Company

Agenda

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LAR Purpose

Tom Lentz

- Unit 2 License Amendment 165 approved in May, 2008 extends existing rack storage capacity until the end of 2010.
  - Revised criticality analysis, storage arrangement
- Proposed Unit 2 License Amendment Request will extend projected storage capacity through 2024.
  - The modification will replace the spent fuel pool racks with Holtec high density storage racks.

Proposed Schedule

Tom Lentz

■ Submit License Amendment Request	March, 2009
■ NRC Acceptance Review (Projected)	April, 2009
■ NRC issues Amendment (Requested)	April, 2010
■ Start modification implementation	May, 2010
■ Complete modification implementation	December, 2010
■ Unit 2 refueling outage	Spring, 2011

Key Design Features

Kevin Rogers

- The spent fuel pool presently contains 1088 storage cells in seventeen spent fuel storage racks.
- The seventeen will be removed and replaced by fifteen high density freestanding racks designed by Holtec International.
- Storage capacity will be increased to 1690 cells.
- The high density racks are non-flux-trap and are designated in a mixed–zone three region array, loading patterns are used to help control criticality.

Key Design Features (continued)

- All the storage racks are freestanding and self-supporting
- The principal materials of the racks are stainless steel sheet.
- The only non-stainless material utilized in the high density racks is the neutron absorber material – Metamic.
- During the high density rack installation phase, a high density rack and supporting platform will be temporarily placed in the Cask Pit to facilitate necessary fuel movements.

Structural/Mechanical Analyses

Nate Walker

- Structural/Seismic Analysis Methods
  - Have been used previously at many nuclear plants worldwide.
  - The Whole Pool Multi-Rack (WPMR) analysis simulates the dynamic behavior and performs a stress analysis of the complex spent fuel storage rack configuration.
  - The 3-D rack model handles an array of variables:
    - Interface Coefficient of Friction, Rack Beam Behavior, Impact Phenomena, Fluid Coupling

Structural/Mechanical Analyses (continued)

- Structural/Seismic Evaluation
  - Synthetic time-histories in three orthogonal directions (N-S, E-W, and vertical) were generated in accordance with the provisions of Section 3.7.1 of the Standard Review Plan.
    - The Holtec-proprietary code GENEQ was utilized in order to prepare an acceptable set of acceleration time-histories.
  - Stress Limit Evaluations- Normal, Upset, and Faulted conditions were evaluated with results in the form of dimensionless stress factors less than the limit of 1.0.

Structural/Mechanical Analyses (continued)

- Structural/Mechanical Evaluation
  - The results from the DYNARACK program are provided by extracting the worst case values from the parameters of interest:
    - Displacements, support pedestal forces, impact loads, and stress factors
  - Other analyses were performed to develop and evaluate structural member stresses, which are not determined by the DYNARACK postprocessor
    - Pedestal thread shear stresses, weld stresses, buckling
  - All safety factors were determined to be greater than 1.0.

Structural/Mechanical Analyses (continued)

- Rack Fatigue Margin
  - Alternating stresses in metals produce metal fatigue if the amplitude of the stress cycles is sufficiently large.
  - The cumulative damage factor has been determined to be less than the ASME Code limit of 1.0.

Structural/Mechanical Analyses (continued)

- Cask Pit Platform Analysis
  - A single rack analysis was performed in order to evaluate the seismic loads induced by a single rack on the supporting cask pit rack platform.
  - All safety factors were determined to be greater than 1.0.

Structural/Mechanical Analyses (continued)

- Rack Bearing Pad Analysis
  - Rack bearing pads are placed between rack pedestals and the spent fuel pool floor to reduce the stresses in the spent fuel pool concrete slab by spreading the load of each pedestal over a larger concrete contact area.
  - This evaluation demonstrated that under maximum vertical forces in seismic events, the average compressive stress in the underlying concrete remains below the allowable value permitted by the American Concrete Institute, ACI-349.

Structural/Mechanical Analyses (continued)

- Pool Liner Integrity Analysis
  - Rack pedestal friction loads must not tear the pool liner and must not cause liner seam welds to rupture. The liner is also evaluated for fatigue.
  - Under the maximum rack pedestal loads, the pool liner plates and seam welds are acceptable, and fatigue failure does not occur

Structural/Mechanical Analyses (continued)

- Spent Fuel Pool Structure
  - The BVPS-2 spent fuel pool is similar to the BVPS-1 pool in terms of the storage locations and the elevation of the slab and the confining walls.
  - A comprehensive evaluation of the pool structure was performed previously for the BVPS-1 spent fuel pool in support of the rerack Amendment 178 issued on November 1, 1993.
  - The bounding load cases are compared between the BVPS-1 and BVPS-2 spent fuel pools and a corresponding linear interpolation of the BVPS-1 SFP safety factors is performed. The safety factors are all greater than 1.0

Structural/Mechanical Analyses (continued)

- Conclusions
  - All Structural, Seismic, and Mechanical analyses produce acceptable results within the required design codes for the new spent fuel racks

Safety Analyses
Criticality Analysis

Paul Messman

- Overview
  - Purpose
  - Summary of Kopp Memorandum
  - Review of Lessons Learned from Previous LAR
  - Proposed Criticality Analysis
  - Human Performance Aspects
  - Conclusion

Criticality Analysis (continued)

- Purpose
  - Based upon NUREG-0800,
    - Ensure that effective neutron multiplication factor (keff) is less than 1.0 when considering fuel design and parameters that maximize reactivity in unborated water for normal and accident conditions including margin for uncertainties and manufacturing tolerances.
    - Ensure that keff is less than 0.95 in borated water including margin for uncertainties and manufacturing tolerances.

Criticality Analysis (continued)

- Summary of Kopp Memorandum
  - keff is determined using conservative fuel rod and fuel assembly parameters.
  - Methods and computer codes are appropriate for criticality analyses and have been adequately benchmarked.
  - Abnormal and accident conditions are considered, including natural events (e.g. earthquakes).
  - Proposed racks adhere to keff < 1.0 with unborated water and keff < 0.95 with some credited amount of borated water.
  - Dilution accident is considered.
- Criticality Analysis is consistent with the guidance outlined by the Kopp Memorandum.

Criticality Analysis (continued)

- Review of Lessons Learned from previous LAR
  - Some generic inputs were not explicitly determined to be applicable to BVPS-2.
  - Core operating parameters were not selected to maximize plutonium production and increase reactivity of the spent fuel.
  - Burnup uncertainty methodology was different than that specified by the Kopp Memorandum.
  - Specific analysis to demonstrate the limiting temperature bias was not determined for each storage configuration.
- New criticality analysis incorporates lessons learned from previous submittal that were reviewed.

Criticality Analysis (continued)

- Proposed Criticality Analysis
  - Methodology
    - Fuel is depleted with CASMO-4 to determine isotopic concentration. CASMO-4 is an acceptable code by the Kopp Memorandum.
    - The maximum keff is determined from the MCNP4a calculated keff, the calculational bias, the temperature bias, and all applicable uncertainties and tolerances. Benchmark calculations of MCNP4a against measured critical data and KENO5a are provided within the criticality analysis.

Criticality Analysis (continued)

- Assumptions
  - Pool moderator analyzed at temperature corresponding to the highest reactivity.
  - Neutron absorption in minor structural members neglected.
  - Reactivity effect of spacer grids in borated water analyzed.
  - keff of infinite radial array of fuel used (neutron leakage neglected), except for the assessment of certain accident/abnormal conditions and conditions where neutron leakage is important.
  - No axial blankets credited.
  - Burnable absorber poison length conservatively modeled as same length as active fuel.
  - Reactivity of fuel maximized (no Xe-135, peak post-shutdown build-up of Pu-239, no post-shutdown build-up of Sm-149).
  - Fuel pellets modeled as solid cylinders with maximum allowable density.

Criticality Analysis (continued)

- Assumptions (continued)
  - Guide tubes dimensions set to minimum thickness.
  - Burnable absorbers neglected in fresh fuel (no credit taken for fixed burnable absorbers), but spectral hardening effects of burnable absorbers accounted for in spent fuel.
  - Segmented axial burnup profile modeled; confirmed to bound all previous plant-specific burnup shapes.
  - Uprated core operating parameters used to maximize reactivity of depleted fuel (i.e., plutonium content) based upon plant-specific data.
  - Target reactivity set to 0.995 (instead of 1.0) for unborated water and set to 0.945 (instead of 0.95) for borated water.
  - Rack-to-rack interfaces explicitly accounted for in criticality analysis.
  - All applicable fuel and rack manufacturing tolerances explicitly included in criticality analysis.

Criticality Analysis (continued)

- Human Performance Aspects
  - Installed storage racks
    - Four configurations with different burnup versus enrichment requirements, and may also be dependent upon initial IFBA loading and decay time.
  - Proposed high density storage racks
    - The high density storage racks have a Mixed-Zone Three Region (MZTR) configuration based solely upon initial enrichment and burnup combination.
    - The high density storage racks will improve human performance with its distinct, simplified configurations compared to the current storage racks, which have configurations with multiple parameter requirements.
  - Consequences of misplaced fuel assembly
    - Worst case misplaced fuel assembly scenario was evaluated with acceptable results.

Criticality Analysis (continued)

- Conclusion
  - Conservative fuel design chosen that bounds all previously used fuel at BVPS-2.
  - Criticality analysis is consistent with Kopp Memorandum.
  - All configurations both normal and abnormal/accident conditions, borated and unborated, satisfy the acceptance criteria.
  - Human factors are enhanced due to a simpler three-region configuration based only on burnup and enrichment.

Safety Analyses (continued)
Mechanical Accidents

Nate Walker

- Analysis Requirements
  - The analyses were carried out to demonstrate the regulatory compliance of the proposed racks under postulated accidental drop of a fuel assembly, a fuel rack and a gate.
- Analysis Methodology
  - Used in many Holtec wet storage projects accepted by NRC
  - The velocity of the dropped object is computed for the condition of underwater free fall, and then a finite element model for each drop event is prepared with LS-DYNA.

Mechanical Accidents (continued)

- <u>Results of Analysis</u>
  - Shallow Fuel Drop
    - The shallow drop event will produce some localized plastic deformation in the top of the storage cell, but the region of permanent strain is limited to the portion of the rack structure situated above the top of the active fuel region.
  - Gate Drop
    - The gate drop accident is bounded by the shallow drop event in terms of the depth of permanent deformation measured from the top of the rack.

Mechanical Accidents (continued)

- Results of Analysis (continued)
  - Deep Fuel Drop
    - The downward displacement of the rack baseplate is limited, and a secondary impact of the fuel assembly with the pool liner would not occur. The maximum lowering of the baseplate is considered in the criticality evaluations.
  - Rack Drop
    - The rack drop analysis shows that the concrete slab can maintain its structural integrity under the postulated impact of the heaviest rack in the pool.

Mechanical Accidents (continued)

- Results of Analysis (continued)
  - Fuel to Fuel Drop Event
    - It was demonstrated that the damage to the fuel assembly rods from the fuel to fuel impact drop is satisfactory.
  - Uplift Force Evaluation
    - The rack uplift force evaluation shows that configuration of the fuel and neutron absorber (Metamic) is not compromised from the configurations analyzed in the criticality evaluations.

Mechanical Accidents (continued)

- Conclusions
  - The results of the postulated drop accidents are acceptable and are in accordance with the "OT Position for Review and Acceptance of Spent Fuel Storage and Handling Applications"

Safety Analyses (continued)
Thermal & Hydraulic Analyses

Mike Unfried

- Spent Fuel Pool Gamma Energy Deposition Calculation
- Spent Fuel Pool Bulk Thermal Analysis
- Spent Fuel Pool Local Temperature Analysis
- Cask Pit Local Thermal Analysis

Thermal & Hydraulic Analyses (continued)

Spent Fuel Pool Gamma Energy Deposition Calculation

- Methodology includes generation of the gamma source term and calculation of the gamma energy deposition rate in fuel, fuel cladding, fuel assembly end fitting, water, spent fuel pool (SFP) stainless steel liner and fuel pool concrete.
- Source term calculations were performed using SAS2H and ORIGEN-S for a single Westinghouse Electric PWR 17 x 17 standard fuel assembly, which covers all BVPS-2 past & present assemblies.
- For SFP structure gamma heating, reflective boundary conditions were applied and run in MCNP 4A with the minimum distance from the rack to the SFP liner.

Thermal & Hydraulic Analyses (continued)

Spent Fuel Pool Gamma Energy Deposition Calculation (continued)

- Heating rates were calculated in mW/g for 36 one inch thick slabs (to 3' of thickness) and constant energy deposition rates (equivalent to the value at 3') for locations more than 3' from the surface.
- Calculated Gamma energy deposition rates are used to calculate maximum concrete temperatures and temperature gradients.

Thermal & Hydraulic Analyses (continued)

Spent Fuel Pool Bulk Thermal Analysis

- Cases run include:
  - Evaluation of thermal-hydraulic performance of the SFP heat exchanger.
  - Calculation of the pseudo-steady-state and transient decay heat loads in the SFP, based on all storage locations filled, for normal and abnormal full core offload scenarios.
  - Calculation of the maximum bulk temperature in the SFP for the normal and abnormal full core offload scenarios.
  - Calculation of the minimum time-to-boil after a complete loss of forced cooling coincident with the maximum SFP bulk temperatures. The boil off rate and the time for the water level to reach 10 feet above the top of the racks are also computed.

Thermal & Hydraulic Analyses (continued)

<u>Spent Fuel Pool Bulk Thermal Analysis (continued)</u>

- SFP water temperature acceptance criteria (unchanged from the current EPU acceptance criteria) are met.
- SFP time to boiling provides sufficient time for remedial actions to be taken.

Thermal & Hydraulic Analyses (continued)

Spent Fuel Pool Local Temperature Analysis

- The local temperature analysis evaluates water natural circulation through the use of a computational fluid dynamics analysis (utilizing FLEUNT) to demonstrate that the local SFP water and maximum cladding temperatures do not reach the local saturation temperature of water.
- The calculated fuel assembly hydraulic resistance parameters are increased by 10%.

Thermal & Hydraulic Analyses (continued)

Spent Fuel Pool Local Temperature Analysis (continued)

- No downcomer flow is assumed to exist between the SFP storage racks or the assemblies they hold. With every storage position considered full, all modeled downcomer flow is in the space between the SFP racks and the SFP walls.
- The peak local water temperature and peak fuel cladding temperature are less than the local saturation temperature of water.

Thermal & Hydraulic Analyses (continued)

Cask Pit Local Thermal Analysis

- Methodology is the same as for the local temperature analysis.
- The SFP cask pit rack is assumed to contain fuel assemblies cooled at least 18 months.
- The peak local water temperature and peak fuel cladding temperature are less than the local saturation temperature of water.

Safety Analyses (continued)
Radiological Analysis

Mike Unfried

- The design inputs for the fuel handling accident remain unchanged.
- The current analysis remains valid for the high density racks.

Technical Specifications

Steve Sarver

Current Technical Specifications

- LCO 3.7.14, Spent Fuel Pool Storage
  - Table 3.7.14-1B for “All Cells” or Design Features Section 4.3.1.1 for other configurations.
- Design Features Section 4.3.1.1
  - If an assembly is not within the limits of Table 3.7.14-1B, use WCAP-16518-P, “Beaver Valley Unit 2 Spent Fuel Rack Criticality Analysis,” for other configurations.

Technical Specifications (continued)

<u>Proposed Technical Specifications</u>

- LCO 3.7.14, Spent Fuel Pool Storage
  - Table 3.7.14-1B specifies three regions based solely on enrichment and burnup.
- Design Features Section 4.3
  - Specifies the storage requirements within each region.
  - Change SFP to boron requirement.
  - Change to the center to center distance between fuel assemblies.
  - Changes storage capacity limit from 1088 to 1690 fuel assemblies.

Technical Specifications (continued)

Design Features Section 4.3.1.1

Region 1 storage cells are located on the periphery of each rack (outer row only) and are therefore separated from other Region 1 cells in adjacent racks by the gap between the racks.

Region 1 cells are also to be separated from other Region 1 cells within the same rack by Region 2 cells.

Since Region 1 cells are qualified for the storage of fresh fuel, any fuel assembly (fresh or burned) meeting the enrichment requirement may be stored in a Region 1 location.

Technical Specifications (continued)

Design Features Section 4.3.1.1

Region 2 cells are located on the rack periphery (outer row) interspaced with separating Region 1 cells and are also located in the second row of cells (from the outside of the rack) separating the Region 1 cells from the Region 3 cells.

Technical Specifications (continued)

Design Features Section 4.3.1.1

Region 3 cells are located on the interior of the rack, at least three rows in from the rack periphery.

The Region 3 cells are not permitted to be located in the outer two rows of the rack.

Technical Specifications (continued)

- Transitioning to the revised Technical Specifications
  - The current and revised Technical Specifications will both be in place during the installation of the high density racks.
  - The spent fuel cask pit area will be used to temporarily store some assemblies during the installation of the high density racks.
  - The type of rack, high density vs. existing, will be identified on the applicable Technical Specifications.
  - Following installation of the high density racks, only the Technical Specifications applicable to the high density racks will remain.

Summary/Follow-up

Tom Lentz

- Summary
- Follow-up
  - Four months following submittal
  - Eight months following submittal

Questions and Discussion