St. Lucie Unit 2
Fuel Transition Project

Control Rod Ejection RAI – SNPB-RAI-1

June 11, 2015

NRC Concerns Expressed in the RAI

- **"The application of the above methodology [XN-NF-78-44] to AREVA's CE 16x16 fuel is considered as an expansion of the applicability of this Topical Report."**

NRC Concerns Expressed in the RAI

- **PIRT for PWR rod ejection accident identifies certain properties of the fuel design under high burnup conditions:**
  - Fuel thermal conductivity, gap conductance, clad conductivity (including oxide layer), transient cladding-to-coolant heat transfer coefficient, heat capacities of fuel and cladding, and other applicable parameters.
  - "It is not evident from your submittal on the CR ejection analysis whether a modern fuel performance code is used to compute the fuel and clad properties."

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NRC Concerns Expressed in the RAI

- **"The margin to the centerline temperature (CLT) for 20% and 65% rated thermal power (RTP) has been substantially reduced for beginning of cycle (BOC)."**

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SNPB-RAI-1

- In view of the above, the NRC staff requests that the licensee and AREVA perform a plant-specific analysis of CR Ejection accident for St. Lucie 2 using an alternate methodology that was proposed to the staff during the pre-submittal meeting on November 3, 2014. By performing the alternate analysis using the combination of latest fuel performance methodology and the proposed supplement to the ARCADIA reactor analysis system methodology, the licensee may provide additional information that is necessary for determining the acceptability of the applicability of XN-NF-78-44(NP)(A) to AREVA CE 16x16 fuel design.

Proposed Approach for RAI Response

- **Comparison to another approved method**
  - Part of the basis for the original approval of the XN-NF-78-44 Topical Report was NRC comparison to other approved methods.
- **Comparison of 16 x 16 results**
  - Quantitative comparison of 16 x 16 results (St. Lucie Unit 2) to the analysis results for other fuel types provided in ANP-3396P.
  - The recently-approved St. Lucie-2 EPU rod ejection Analysis of Record (deposited enthalpy cases), performed by the current fuel vendor, could be modeled with the XN-NF-78-44 method for comparison of results to the currently approved method.

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Background

- **The St. Lucie Unit 2 HTP fuel transition control rod ejection accident analysis was performed using the following AREVA approved methodologies for the applicable SRP acceptance criteria:**
  - XN-NF-78-44(NP)(A), "A Generic Analysis of the Control Rod Ejection Transient for Pressurized Water Reactors," 1983.
  - EMF-2310(P)(A), Revision 1, "SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors," 2004.

Background

- XN-NF-78-44(NP)(A), “A Generic Analysis of the Control Rod Ejection Transient for Pressurized Water Reactors,” 1983.
  - Used in conjunction with current SRP criteria (more conservative than as approved in topical report)
  - Peak radial average fuel enthalpy
    - 230 cal/g for fuel coolability
    - 150 cal/g for HZP conditions
  - PCMI failure criterion - a change in radial average fuel enthalpy greater than the corrosion-dependent limit

- EMF-2310(P)(A), Revision 1, “SRP Chapter 15 Non-LOCA Methodology for Pressurized Water Reactors,” 2004.
  - Fuel failure limits from DNB and FCM for core coolability and radiological analysis

Applicability to CE 16x16 Fuel (XN-NF-78-44)

- **Key input parameters are calculated with NRC-approved Neutronics methods:**
  - Reactivity worth of ejected control rod, power peaking factor, reactivity coefficients, and delayed neutron fraction
  - Explicitly models the CE 16x16 reactor and fuel geometry

- **Deposited enthalpy calculation is independent of fuel pin dimensions or array**
  - Function of ejected rod worth, effective delayed neutron fraction, and Doppler Temperature Coefficient (based on Nordheim-Fuchs model)

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Applicability to CE 16x16 Fuel (XN-NF-78-44)

- The approved methodology has been applied for 14x14, 15x15, and 17x17 fuel.
- Application to 16 x 16 followed the same approach as for other fuel types.

- Quantitative comparison of 16 x 16 results (St. Lucie Unit 2) to the analysis results for other fuel types provided in ANP-3396P.

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Applicability to CE 16x16 Fuel (XN-NF-78-44)

See FPL Letter L-2015-091 dated March 23, 2015

PIRT Parameters for Rod Ejection (EMF-2310 Method)

- **S-RELAP5 used in the transient analysis of the non-LOCA events, including Rod Ejection, covers the impact of high burnup to explicitly account for the effects of thermal conductivity degradation, as stated in Section 2.7 of ANP-3347P. The parameters include:**
  - Fuel thermal conductivity
  - Heat capacity
  - Fuel pellet-to-clad gap coefficient

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Margin to DNB and FCM (EMF-2310 Method)

- S-RELAP5 determines the core average transient response, the hot spot fuel centerline temperature and the thermal-hydraulic boundary conditions for subsequent XCOBRA-IIIC MDNBR calculations.
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- The S-RELAP5 model explicitly accounts for the St. Lucie-2 plant and fuel dimensions.

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Margin to DNB and FCM (EMF-2310 Method)

- **Key neutronic parameters are conservatively biased**
  - Doppler reactivity feedback
  - moderator reactivity
  - ejected CEA worth (maximized to mitigate the event on Doppler feedback prior to reactor scram)
  - power peaking factors
  - fuel rod exposures

Margin to DNB and FCM (EMF-2310 Method)

- **The S-RELAP5 calculation contains other conservative assumptions**
  - Conservative reactor protection system setpoints and delays
  - minimum Technical Specification RCS flow
  - maximum core inlet temperature are used to increase the challenge to MDNBR
  - core average pellet-to-cladding gap coefficients are maximized resulting in decreased Doppler feedback and increased core power
  - hot spot pellet-to-cladding gap coefficients are minimized resulting in increased fuel centerline temperatures
  - Conservative biasing of fuel thermal properties for the average core and hot spot

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Margin to DNB and FCM (EMF-2310 Method)

- Summary:
  - In the S-RELAP analyses, key parameters are intentionally biased based on available margin to ensure that cycle-by-cycle variations are bounded.
  - Each cycle, the values for these key parameters are checked to ensure that limits are not exceeded (or to re-analyze if necessary)
  - For St. Lucie Unit 2, the radiological dose analyses support up to 9.5% fuel failure due to DNB and 0.5% fuel failure from fuel centerline melt.
    - Since the there are no failures predicted in the AREVA analyses, significant margin is maintained to the fuel failure limits based on DNB and fuel centerline melt.

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Summary and Recommendations

- A Supplement to the LAR (ANP-3396P) provides justification of applicability of XN-NF-78-44 to CE 16x16 fuel.
  - *The recently-approved St. Lucie-2 EPU control rod ejection case could be modeled with XN-NF-78-44, for comparison to the currently approved results, to provide additional justification for applicability of XN-NF-78-44 to CE 16x16 fuel.*
- The NRC concerns regarding PIRT parameters and margin to DNB and FCM are covered by the EMF-2310 portion of the analysis, which addresses the effects of high burnup.

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