AREVA MELLLA+ Methods Applicability Presentation
(Non-Proprietary Version)

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AREVA MELLLA+ Methods Applicability

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AGENDA

- Overview of the AREVA MELLLA+ Methods Applicability Document
  - History of AREVA experience in licensing and testing
- Enhanced Option III
- AREVA application of fuel specific limitations and conditions from generic MELLLA+ topical NEDO-33006A

Applicability of AREVA Methods in MELLLA+

- **The applicability of AREVA methods to MELLLA+ conditions is described in the Methods Applicability Report (ANP-3108)**
  - **Address AREVA topical reports**
    - Review all SE restrictions for applicability to MELLLA+
    - Review that the codes have been appropriately benchmarked to cover expected MELLLA+ operation
  - **Describes the AREVA modeling of bypass voiding**
  - **Describes AREVA implementation of any methodology deviations**
    - i.e. AREVA's approach to thermal conductivity degradation
  - **Content of this report covers methodologies needed to support the necessary fuel specific analyses that AREVA is performing for Brunswick MELLLA+**
  - **This report will be submitted with the Brunswick MELLLA+ LAR**

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Applicability of AREVA Methods in MELLLA+

- Topical Report Review
  - No SER restrictions on power level or flow in AREVA topical reports
  - No SER restrictions on the parameters most impacted by the increased power level: steam flow, feedwater flow, jet pump M-ratio, and core average void fraction
- AREVA methodologies are characterized by technically rigorous treatment of phenomena and are very well benchmarked
- Recent experience is tabulated on the following slides
  - For comparison Power/Flow ratio is used as the figure of merit

AREVA Experience Base

Plant	Class	Rated Power MWt	Min Core Flow at Rated Power (Mlb/hr) (estimated)	Power/Flow MW/Mlb/hr
Brunswick EPU	BWR4	2923.00	76.23	38.34
Brunswick EPU and EFW	**BWR4**	**2923.00**	**65.45**	**44.66**
Chinshan	BWR4	1840.00	42.02	**43.79**
Susquehanna	BWR4	3952.00	99.00	39.92
Grand Gulf	BWR6	3833.00	84.38	**45.43**
River Bend	BWR6	3091.00	70.14	**44.07**
Kuosheng	BWR6	2894.00	63.38	**45.66**

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AREVA Experience Base

- **Applicability of AREVA Methods**
  - As can be seen from this information, the power / flow ratio in this experience base exceeds that associated with MELLLA+ for Brunswick
  - The validity of AREVA methods to the Brunswick core design are further illustrated by combining both test data and assembly conditions used in the qualification of MICROBURN-B2 and compared on the next slide
  - The data is presented in terms of the key physical phenomena (e.g. fluid exit quality and assembly flow) as they relate closely to the exit void fractions

AREVA Experience Base

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Applicability of AREVA Methods in MELLLA+

- AREVA licensing methodology is required to push the limits to the Safety Limit conditions
  - This approaches boiling transition for the worst assembly regardless of the core conditions
- Pressure drop testing is performed as close as possible to the point of boiling transition
- Void measurements are performed as close as possible to the point of boiling transition
- AREVA models are qualified to the point of boiling transition

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Applicability of AREVA Methods in MELLLA+

- **AREVA uses conservative methods to address the potential for boiling in the bypass / Water Channel regions**
  - **Water Channels /Rods are modeled explicitly and separately from the bypass region in the areas of potential bypass voiding**
  - **[**

    ]
  - **For the LPRM detector response analyses are performed with CASMO-4 to determine the sensitivity to water density in the bypass region and appropriate penalties are applied to the OPRM setpoints.**

Applicability of AREVA Methods in MELLLA+

- **AREVA uses Zubar-Findlay drift flux model for predicting void fraction**
  - **[ ] void correlation is used in nuclear design, frequency domain stability, and nuclear AOO transient and accident analyses**
  - **Ohkawa-Lahey void correlation is used in thermal-hydraulic design, system transient AOO and accident, and loss of coolant accident**
  - **Both correlations have been validated against the FRIGG experiments, as well as void fraction measurements for ATRIUM-10 and ATRIUM 10XM at the KATHY test facility**
  - **ATRIUM 10XM tests measured void fractions up to [ ]**

Applicability of AREVA Methods in MELLLA+

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Applicability of AREVA Methods in MELLLA+

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Applicability of AREVA Methods in MELLLA+

- **Void quality correlations have been benchmarked using ATRIUM-10 and ATRIUM 10XM data**
  - **[ ] matches data with very little bias**
  - **Ohkawa-Lahey exhibits some bias in the 0.5-0.8 void fraction range**
    - Still within 5% of measured void
  - **Sensitivity studies performed with a modified void-quality correlation to remove the bias**
    - Also performed analyses with a void-quality correlation that was biased by ±5%
    - Analyses with the best-estimate void quality correlation showed an insignificant change in results
    - Impact of the ±5% bias to correlation was shown to be bound by the conservatism built into the method

Thermal Conductivity Degradation

- **Fuel thermal conductivity degradation with exposure has been evaluated**
  - **Halden ultra-high-burnup experiment indicated steady degradation in the thermal conductivity of uranium fuel pellets with increasing exposure**
  - **NRC expressed concern that some vendors might still be using codes for safety analyses that do not account for this phenomenon and therefore may produce non-conservative results**
  - **AREVA uses RODEX4 for thermal-mechanical analyses (which contains models for TCD)**
  - **Methodologies based on RODEX2/2a are affected**
    - AOO transient methodology (COTRANSA2/XCOBRA/XCOBRA-T)
    - LOCA (RELAX/RODEX2/HUXY)
    - Overpressurization (COTRANSA2/RODEX2)
    - Fire Event (RELAX/RODEX2/HUXY)

Thermal Conductivity Degradation

- **AOO Transient Methodology (COTRANSA2/XCOBRA/XCOBRA-T)**
  - **Benchmarking to Peach Bottom Turbine Trip did not include conductivity degradation**
  - **AURORA-B was used to determine the sensitivity to conductivity degradation**
    - AURORA-B is RODEX4 based
    - AURORA-B sensitivity studies show that the impact of fuel thermal conductivity degradation with exposure results in a decrease in the ΔCPR of [
      ] increase in the transient LHGR excursion
    - For Brunswick MELLLA+ LHGR evaluation will be done with RODEX4 so thermal conductivity degradation is already accounted for
    - Effect is small and within the conservatism of the methodology
    - MCPR and LHGR limits are not impacted

Thermal Conductivity Degradation

- **LOCA (RELAX/RODEX2/HUXY)**
  - **Degraded thermal conductivity in the fuel will increase centerline temperature increasing the fuel stored energy**
    - Following the loss of coolant, the heat transfer is driven by the degraded heat transfer to the coolant
    - Temperature profile in the pellet is very flat so RELAX and HUXY models are not sensitive to conductivity
  - **RODEX4 was used to determine the change in stored energy**
  - **Used to increase the RODEX2 calculated stored energy to account for conductivity degradation**
    - Very conservative since RODEX2 was designed to produce conservatively high stored energy for AREVA Appendix K LOCA calculations
  - **Brunswick MELLLA+ LOCA analyses were evaluated for the effect of thermal conductivity degradation**
    - BOL remains limiting when no conductivity degradation has yet occurred

Thermal Conductivity Degradation

- **Overpressurization (COTRANSA2/RODEX2)**
  - **ASME Overpressurization**
    - 30% reduction in fuel thermal conductivity showed a slight reduction in peak pressure
    - No credit taken for this reduction
  - **ATWS Overpressurization**
    - 30% reduction in fuel thermal conductivity increased the pressure increase by [ ]
  - **The effects of thermal conductivity on overpressurization analyses will be tracked and applied each reload**
- **Fire event (RELAX/RODEX2/HUXY)**
  - **Effect of thermal conductivity similar to LOCA**
  - **However, PCT is much lower than LOCA**
  - **Similar to LOCA, PCT is limiting at BOL**

LOCA Analysis Approach

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Enhanced Option III

- **AREVA has performed the fuel specific analyses required to support Enhanced Option III (EO-III)**
  - Enhanced Option III is an extension of the original Option III Long Term Stability Solution to the MELLLA+ domain
    - Original Option III methodology maintained
    - An additional automatic scram region to protect against single channel oscillations was introduced to maintain applicability of Option III in MELLLA+
  - EO-III approved for MELLLA+ application in ANP-10262PA Rev 0
  - Approval of EMF-3028PA Volume 2 Rev 4 formally approved use of RAMONA5-FA in MELLLA+ and removed the interim 10% penalty on RAMONA5-FA MELLLA+ results
  - AREVA will provide channel exclusion region boundaries and OPRM setpoint calculations
    - Provided in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))

Review of Generic MELLLA+ Limitations and Conditions

- **The restrictions for fuel dependent analyses presented in NEDO-33006A were reviewed for applicability to AREVA methods**
  - **Most restrictions have been applied**
  - **Some restrictions are specific to the methodology being used**
  - **Methodology specific restrictions were adapted to provide a comparable AREVA result**
  - **Methodology independent restrictions are applied**
  - **Summary of fuel specific implementation of MELLLA+ limitations and conditions from Section 12 of the SE to NEDO-33006A follows**

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Review of Generic MELLLA+ Limitations and Conditions

Section 12.1: GEXL-PLUS

- **Requirement: Plant-specific application will confirm that for operation within the boundary defined by the MELLLA+ upper boundary and maximum CF range, the GEXL-PLUS experimental data base covers the thermal-hydraulic condition the fuel bundles will experience**
  - AREVA licensing methods are programmed to determine whether assembly conditions fall outside of the approved range for the CHF correlation
  - If conditions are outside of approved range the codes impose the approved corrective actions
  - The implementation of AREVA correlations is discussed in Methods Applicability Report ANP-3108P
- **Requirement:** In addition, the plant-specific application will confirm that the experimental pressure drop database for the pressure drop correlation covers the pressure drops anticipated in the MELLLA+ range.
  - The range of the experimental database was shown in a previous slide and is documented in Methods Applicability Report ANP-3108P

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Review of Generic MELLLA+ Limitations and Conditions

- **Section 12.3: Concurrent changes**
  - **Requirement:** If a new GE fuel product line or another vendor's fuel is loaded at the plant, the applicability of any generic sensitivity analyses supporting the MELLLA+ application shall be justified in the plant-specific application. If the generic sensitivity analyses cannot be demonstrated to be applicable, the analyses will be performed including the new fuel.
    - New analyses are being provided for any analysis that is potentially impacted by fuel
- **Section 12.4: Reload Analysis Submittal**
  - **Requirement:** The plant-specific MELLLA+ application shall provide the plant-specific thermal limits assessment and transient analysis results.
    - Provided in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))
  - **Requirement:** Additionally, the SRLR for the initial MELLLA+ implementation cycle shall be submitted for NRC staff confirmation
    - The Reload Safety Analysis Report for the initial MELLLA+ implementation cycle will be submitted when available

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Review of Generic MELLLA+ Limitations and Conditions

▶ Section 12.6: SLMCPR Statepoints and CF Uncertainty

- **Requirement:** Until such time when the SLMCPR methodology (References 40 and 41) for off-rated SLMCPR calculation is approved by the staff for MELLLA+ operation, the SLMCPR will be calculated at the rated statepoint (120 percent P/100 percent CF), the plant-specific minimum CF statepoint (e.g., 120 percent P/80 percent CF), and at the 100 percent OLTP at 55 percent CF statepoint
  - AREVA performs SLMCPR analyses to bound the full power/flow domain
  - Performed analyses at 100%P/104.5%F, 100%P/85%F, and 55% core flow and highest licensed power level
  - Results for all three statepoints are provided in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))
- **Requirement:** The currently approved off-rated CF uncertainty will be 'used for the minimum CF and 55 percent CF statepoints. The uncertainty must be consistent with the CF uncertainty currently applied to the SLO operation or as NRC-approved for MELLLA+ operation.
  - SLO core flow uncertainty applied to the 85% and 55% core flow analyses

Review of Generic MELLLA+ Limitations and Conditions

- **Section 12.6: SLMCPR Statepoints and CF Uncertainty**
  - **Requirement:** The calculated values will be documented in the SRLR
    - Provided results for all calculated power/flow points in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))
  - **Analyses showed that the limiting statepoint is the 55% core flow point**
  - **A 0.01 increase in SLMCPR is required for MELLLA+**
    - MELLLA+ SLMCPR for TLO is 1.09

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Review of Generic MELLLA+ Limitations and Conditions

Section 12.10: ECCS-LOCA Off-Rated Multiplier

- **Requirement:** The plant-specific application will provide the 10 CFR Part 50, Appendix K, and the nominal PCTs calculated at the rated EPU power/rated CF, rated EPU power/minimum CF, at the low-flow MELLLA+ boundary (Transition Statepoint). For the limiting statepoint, both the upper bound and the licensing PCT will be reported
  - Analyses performed at Rated power/ [ ] consistent with definition of the transition statepoint from SE section 4.3.1.3
  - Appendix K PCTs reported in the Break Spectrum Report (ANP-3105P)
- **Requirement:** The M+SAR will justify why the transition statepoint ECCS-LOCA response bounds the 55 percent CF statepoint
  - The transition statepoint is defined per Section 4.3.1.3 of the SE to NEDO-33006A
  - Discussion of the transition statepoint given in the Break Spectrum Report (ANP-3105P)

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Review of Generic MELLLA+ Limitations and Conditions

▶ Section 12.10: ECCS-LOCA Off-Rated Multiplier

- **Requirement:** The COLR and the SRLR will contain confirmation that the off-rated limits assumed in the ECCS-LOCA analyses bound the cycle-specific off-rated limits calculated for the MELLLA+ operation
  - Confirmation that the limits assumed in the LOCA analysis is bounded by cycle-specific limits is provided in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))
- **Requirement:** Off-rated limits will not be applied to the minimum CF statepoint
  - [ ] as discussed in the Break Spectrum Report (ANP-3105P)

Review of Generic MELLLA+ Limitations and Conditions

- **Section 12.11: ECCS-LOCA Axial Power Distribution Evaluation**
  - **Requirement:** For MELLLA+ applications, the small and large break ECCS-LOCA analyses will include toppeaked and mid-peaked power shape in establishing the MAPLHGR and determining the PCT
    - Both top and mid-peaked results are provided in the Break Spectrum Report (ANP-3105P)
  - **Requirement:** The plant-specific applications will report the limiting small and large break licensing basis and upper bound PCTs
    - Results for a broad range of break sizes (encompassing both small and large break) is provided in the Break Spectrum Report (ANP-3105P)

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Review of Generic MELLLA+ Limitations and Conditions

Section 12.12: ECCS-LOCA Reporting

- **Requirement:** Both the nominal and Appendix K PCTs should be reported for all of the calculated statepoints
  - AREVA LOCA methodology is Appendix K based and no nominal PCTs are available
  - Appendix K PCTs for all calculated statepoints are provided in the Break Spectrum Report (ANP-3105P)
- **Requirement:** The plant-variable and uncertainties currently applied will be used, unless the NRC staff specifically approves a different plant variable uncertainty method for application to the non-rated statepoints
  - Uncertainties were applied per the AREVA approved methodology as described in the Break Spectrum Report (ANP-3105P)

Review of Generic MELLLA+ Limitations and Conditions

Section 12.13: Small Break LOCA

- **Requirement:** Small break LOCA analysis will be performed at the MELLLA+ minimum CF and the transition statepoints for those plants that: (1) are small break LOCA limited based on small break LOCA analysis performed at the rated EPU conditions; or (2) have margins of less than or equal to [[ ]] relative to the Appendix K or the licensing basis PCT
  - Results for all statepoints for a broad range of break sizes (encompassing both small and large break) is provided in the Break Spectrum Report (ANP-3105P)

Section 12.14: Break Spectrum

- **Requirement:** The scope of small break LOCA analysis for MELLLA+ operation relies upon the EPU small break LOCA analysis results. Therefore, the NRC staff concludes that for plants that will implement MELLLA+, sufficient small break sizes should be analyzed at the rated EPU power level to ensure that the peak PCT break size is identified
  - The full break spectrum analysis performed for EPU/MELLLA+ is documented in the Break Spectrum Report (ANP-3105P)

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Review of Generic MELLLA+ Limitations and Conditions

Section 12.15: Bypass Voiding Above the D-Level

- **Requirement:** Plant-specific MELLLA+ applications shall identify where in the MELLLA+ upper boundary the bypass voiding greater than 5 percent will occur above the D-level
  - The maximum bypass voiding at LPRM Level D is given in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))

Section 12.16: RWE

- **Requirement:** Plants operating at the MELLLA+ operating domain shall perform RWE analyses to confirm the adequacy of the generic RBM setpoints
  - AREVA performs RWE on a cycle-specific basis
  - Results of the RWE analysis is given in the MELLLA+ Reload Safety Analysis Report (ANP-3280(P))

Review of Generic MELLLA+ Limitations and Conditions

- **Section 12.24: Limitations from Fuel Dependent Analyses RAI Evaluations**
  - **Requirement:** For EPU/MELLLA+ plant-specific applications that use TRACG or any code that has the capability to model in-channel water rod flow, the supporting analysis will use the actual flow configuration
    - AREVA will utilize explicit water rod models in methodologies that support the capability
    - Discussed in the Methods Applicability Report ANP-3108P
  - **Requirement:** The EPU/MELLLA+ application would provide the exit void fraction of the high-powered bundles in the comparison between the EPU/MELLLA+ and the pre-MELLLA+ conditions
    - Maximum exit void for Brunswick Unit 1 Cycle 19 MELLLA+ operation given in the MELLLA+ Fuel Cycle Design Report (ANP-3013P)
    - Maximum exit void for Brunswick Unit 1 Cycle 19 MELLLA operation given in the MELLLA Fuel Cycle Design Report (ANP-3005P)

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Applicability of AREVA Methods in MELLLA+

▶ Summary

- The steady state and transient neutronics and thermal-hydraulic analytical methods and code systems supporting MELLLA+ are within NRC approved applicability ranges
  - the conditions for MELLLA+ application are equivalent to existing core and assembly conditions in other plants for which the AREVA methodology was benchmarked
- The calculational and measurement uncertainties applied in MELLLA+ applications are valid
  - the conditions for MELLLA+ application are equivalent to existing core and assembly conditions for which the AREVA methodology was benchmarked
- The assessment database and uncertainty of models used to simulate the plant response at MELLLA+ conditions are equivalent to core and assembly conditions for which the AREVA methodology was benchmarked
- Applicability of approved AREVA methods to Brunswick MELLLA+ established
- AREVA analyses will comply with the fuel-specific limitations and conditions from the generic MELLLA+ SE to NEDO-33006A
  - Analysis reports will be submitted as part of the LAR