Browns Ferry Nuclear Plant

Extended Power Uprate License Amendment Request Probabilistic Risk Assessment

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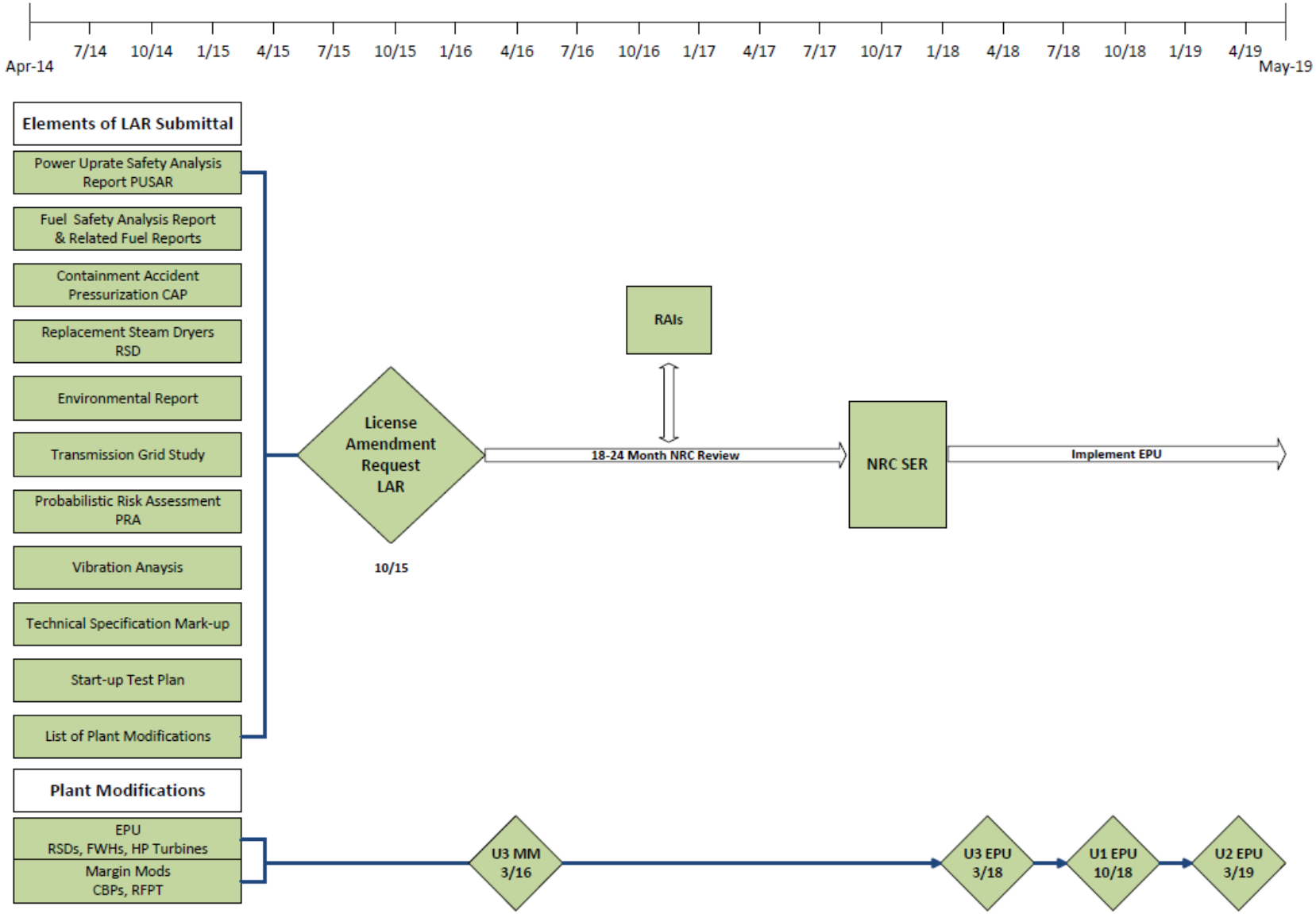
BFN EPU – Agenda

Introductions	G. Doyle
Overview and Schedule	G. Doyle
Browns Ferry Nuclear Plant Probabilistic Risk Assessment (PRA)	D. Kearnaghan
Questions/Comments	G. Doyle

BFN EPU – Overview and Schedule

- New consolidated Browns Ferry Nuclear Plant (BFN) Extended Power Uprate (EPU) License Amendment Request (LAR) submittal
  - Supersedes previous BFN EPU submittals
    - Addresses current BFN conditions and licensing basis (e.g., AREVA ATRIUM 10XM fuel type)
  - Uses the format of RS-001, Review Standard for Extended Power Uprates
  - Addresses previous applicable NRC Requests for Additional Information (RAIs)
  - Applies improved submittal verification process to ensure completeness and accuracy

BFN EPU – Overview and Schedule



BFN EPU – Overview and Schedule

- We are here to present and discuss our approach to developing the PRA portion of the BFN EPU LAR
  - The current BFN PRA models were developed assuming EPU conditions
    - To determine the delta Core Damage Frequency (ΔCDF) and delta Large Early Release Frequency (ΔLERF) values for the BFN EPU LAR, changes to the existing PRA models were necessary
    - The purpose of this meeting is to discuss the approach used for changing the existing PRA models to allow calculation of the Current Licensed Thermal Power (CLTP) CDF and LERF values

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Background

- BFN is pursuing a power uprate
  - CLTP 3458 MWth
  - EPU 3952 MWth
- Constant Pressure Power Uprate
  - 1050 psia Steam Dome Pressure
- Maximum Extended Load Line Limit Analyses power/flow map is retained
- Feedwater and Steam Flow Increased

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Background (continued)

Browns Ferry Current and EPU Operating Conditions

Parameter	Current Value	EPU Value
Thermal Power	3458 MWth	3952 MWth
Vessel Steam Flow	14.1 Mlbm/hr	16.44 Mlbm/hr
Core Flow	85 - 105%	99 - 105%
Steam Dome Pressure	1050 Psia	1050 Psia
Steam Header Pressure	980 Psia	962 Psia
Feedwater Flow	14.07 Mlbm/hr	16.39 Mlbm/hr
Feedwater Temperature	380.6 degrees F	394.5 degrees F

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Scope of Risk Evaluation

- At-Power Risk
  - Internal Events
    - Transients
    - Loss of Coolant Accidents (LOCAs)
    - Anticipated Transients without Scram (ATWS)
  - Internal Flooding
  - Internal Fires
  - Seismic Events
  - Other External Events
- Shutdown Risk

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Methodologies

- Quantitative Methodologies
  - Internal Events
  - Internal Fires
  - CDF and LERF calculated for EPU and CLTP conditions
  - Delta risk calculated
- Qualitative Methodologies
  - Seismic Events
  - Other External Events
  - Shutdown Risk
  - CDF and LERF estimated using conservative methods

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Quantitative Risk Evaluation Process

Internal Events and Fires Only

- Define PRA scope for EPU and CLTP
- Review EPU changes for PRA Impact
  - Physical modifications
  - Procedure changes
  - Setpoint adjustments
  - Plant operating conditions
- Identify PRA model elements impacted
- Evaluate EPU and CLTP thermal hydraulics
- Revise models as necessary
- Quantify results

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Internal Events Model

- EPU Model
  - Considered EPU modifications scheduled for implementation post-EPU License issuance
  - Thermal Hydraulic (T/H) Analysis performed at 120% Original Licensed Thermal Power (OLTP) (MAAP 4.0.7)
  - Operator action times are shorter due to higher decay heat
  - Increased probability of stuck open relief valves assumed
  - Higher human error probabilities
  - Increased dependencies for Human Error Probabilities (HEPs)
  - None of the EPU modifications resulted in a PRA logic model change
- CLTP Model
  - Included EPU modifications implemented prior to EPU License issuance
  - Used current BFN PRA Model of Record as basis
  - T/H Analysis performed at 105% OLTP (MAAP 4.0.7)
  - Increased allowable operator action times

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Fire PRA Model

- Developed to support National Fire Protection Association (NFPA)-805 Transition
- EPU Model
  - Credits Emergency High Pressure Makeup Pump and other Fire Risk Modifications
  - T/H Analysis performed at 120% OLTP (MAAP 4.0.7)
  - Operator action times are shorter due to higher decay heat
  - Increased probability of stuck open relief valves assumed
  - Higher human error probabilities
  - None of the EPU modifications resulted in a PRA logic model change
- CLTP model
  - Credits Emergency High Pressure Makeup Pump and other Fire Risk Modifications
  - Included EPU modifications implemented prior to EPU License issuance
  - T/H Analysis performed at 105% OLTP (MAAP 4.0.7)
  - Increased operator action times with less decay heat

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Qualitative Risk Evaluation Process

- Seismic and Other External Events
  - Review existing Individual Plant Examinations for External Events (IPEEEs)
  - Determine EPU impact on initiators
  - Determine if new vulnerabilities exist
  - Assess risk for CLTP and EPU conditions
- Shutdown Risk
  - Initiating events
  - Success criteria
    - Time to Boil
    - Time to Core Uncovery
  - Human reliability
  - Assess risk for CLTP and EPU conditions

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Aggregation of Risk

- Summed individual contributions of CDF and summed individual contributions of LERF
  - Quantified Internal Events and Fire Values
  - Developed estimates for Seismic and External Events

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PRA Quality

- PRA Models have been peer reviewed
  - ASME/ANS RA-Sa-2009 PRA Standard as endorsed by Revision 2 of Regulatory Guide (RG) 1.200, An Approach for Determining the Technical Adequacy of PRA Results for Risk-Informed Activities
  - Part 2 for Internal Events – Peer review conducted in 2009
    - Additional focused scope peer review of internal events planned for 2015
  - Part 4 for Fire PRA – Peer review conducted in 2012
    - Additional focused scope peer review of fire events conducted May 2015
- Application of models consistent with:
  - RS-001, Review Standard for Extended Power Uprates
  - NUREG-0800, Standard Review Plan, Chapter 19.2, Appendix D, Use of Risk Information in Review of Non-risk-informed License Amendments
- Evaluation of change in risk consistent with:
  - RG 1.174, An Approach for Using PRA in Risk-Informed Decisions on Plant Specific Changes to the Licensing Basis

Facts and Observations

Facts and Observations (F&Os)

- F&Os were generated during prior peer reviews
  - All F&Os dispositioned
  - No F&Os impact the EPU conclusions
  - Capability Category II is met with disposition of the F&Os
- Focused scope peer reviews to close F&Os
  - Expect to substantially reduce the number of F&Os

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Total Risk Results

CDF

UNIT	Total CDF (EPU)	Total CDF (CLTP)	Δ CDF
1	6.08E-5	5.91E-5	1.69E-6
2	6.14E-5	5.96E-5	1.74E-6
3	6.64E-5	6.47E-5	1.67E-6

LERF

UNIT	Total LERF (EPU)	Total LERF (CLTP)	Δ LERF
1	8.73E-6	7.96E-6	7.74E-7
2	8.65E-6	7.99E-6	6.63E-7
3	7.72E-6	7.18E-6	5.45E-7

Frequencies are units of “per reactor-year”

Conclusion: The change in CDF and LERF for BFN Units 1, 2, and 3 due to transitioning to EPU power results in a small and acceptable increase in risk (i.e., RG 1.174, Region II of Figures 4 and 5)

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Key Risk Insights

- Small change in risk due to EPU transition
  - Change in risk driven primarily by fire sequences
- Factors in risk increase
  - Increased decay heat
  - Shortened time for important operator actions
- Dominant sequences (Internal Events and Fires)
  - Involve loss of inventory makeup in which the reactor pressure remains high
- Important Operator Actions
  - Manual control of reactor level with high pressure systems
  - Manual depressurization of reactor vessel

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Key Risk Insights (continued)

- Seismic risk
  - Minimal EPU impact on seismic risk
  - External event…no impact on seismic initiating event frequency
  - Proposed EPU modifications qualitatively reviewed to verify no seismic risk impact
- Shutdown risk
  - Minimal EPU impact on shutdown risk
  - Decay heat is higher…shorter times to boil and uncover core
    - However, system time windows to perform operator actions are long (hours)
- Other external events (high winds, tornados, transportation, etc.)
  - Minimal EPU impact on external event risk

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Sensitivity Analyses

- Internal Events PRA
  - Increased Failure Probabilities
    - Screening HEPs
    - RPV overpressure probability
  - Increased Initiating Event Frequencies
    - General Transients
    - LOCAs
- Fire PRA
  - Increased HEPs
  - Increased Frequency of Lube Oil Fire Scenarios
    - Conservative fire severity factors were used for:
      - Condensate pumps
      - Condensate booster pumps
      - Feedwater pumps
- Conservative sensitivity cases did not result in changes to risk conclusions
  - RG 1.174 CDF/LERF Acceptance Criteria met (Region II)

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Conclusions

- BFN PRA models are technically adequate for this non-risk informed EPU application
- EPU impact on BFN CDF and LERF is small and within Region II of RG 1.174 Acceptance Guidelines
- Based on small risk impact, EPU does not create special circumstances that challenge the presumption of adequate protection to the health and safety of the public

BFN EPU – Acronyms

- ANS – American Nuclear Society
- ASME – American Society of Mechanical Engineers
- ATWS – Anticipated Transients Without Scram
- BFN – Browns Ferry Nuclear Plant
- CDF – Core Damage Frequency
- CLTP – Current Licensed Thermal Power
- EPU – Extended Power Uprate
- F – Farenheit
- F&Os – Facts and Observations
- HEPs – Human Error Probabilities
- IPEEEs – Individual Plant Examinations for External Events
- LAR – License Amendment Request
- LERF – Large Early Release Frequency
- LOCAs – Loss of Coolant Accidents
- Mlbm/hr – Million pounds mass per hour
- MWth – Megawatts thermal
- NFPA – National Fire Protection Association
- OLTP – Original Licensed Thermal Power
- psia – pounds per square inch absolute
- PRA – Probabilistic Risk Assessment
- RAIs – Requests for Additional Information
- RG – Regulatory Guide
- T/H – Thermal Hydraulic

BFN EPU – Questions/Comments