# Path Forward on Fuel Burnup Extension

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U.S.NRC
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# Outline

- Operating Experience
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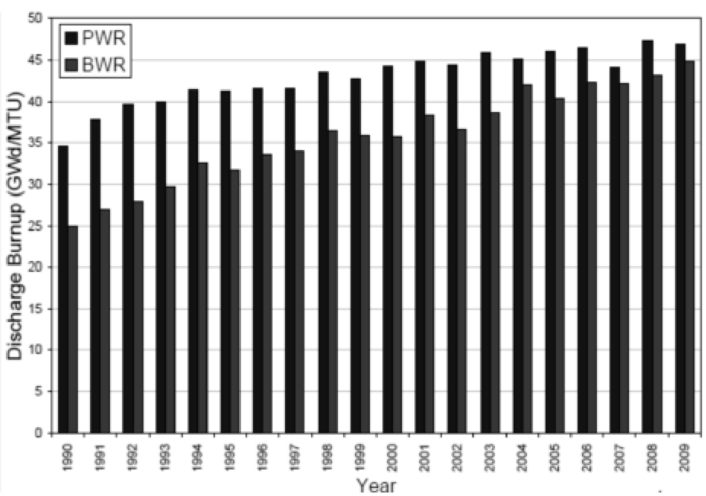
- Updates to Regulations and Guidance
- Barriers to BU Extension
- Shared Responsibility
- Path Forward
- Legacy Issues
- Proposed Approach

# Operating Experience

- Current approved fuel rod BU limits have been in effect for over 25 years
- Longer operating cycles, higher power cores, and advanced computational methods have led to more aggressive fuel utilization
- Assembly average discharge BU has increased

**Figure 1: Average US discharged assembly burn-up trends**




Source: EPRI.

- Advancements in fuel assembly design and materials have allowed this more aggressive fuel utilization and achieved significant improvements in fuel reliability
- ATF may provide more latitude.

# Lessons Learned

While plants continue to operate safely, many new burnup-related phenomena have been identified since approval of existing fuel burnup limits.

- Impact of absorbed hydrogen on cladding properties
  - Zirconium hydrides on cladding mechanical properties
  - Hydrogen on cladding post-quench microstructure and properties

- Evolution of fuel pellet microstructure and composition
  - Enhanced fission gas release
  - Degradation in fuel thermal conductivity
  - Rim region
  - Gaseous swelling

# Lessons Learned

- Transient fuel fragmentation
  - Transient fission gas release
  - Axial fuel relocation
  - Fuel dispersal
- Impact of irradiation-induced grid spring relaxation on crush strength and seismic performance
- Control rod (and blade) swelling and cracking
- BWR channel distortion due to shadow corrosion
- PWR guide tube growth and assembly distortion
- Crud-induced accelerated corrosion
- Crud-induced axial offset anomaly

# Updates to Regulations and Guidance

- Innovations in fuel design and utilization have prompted updates to NRC regulations and guidance
- Updates to SRP Section 4.2, “Fuel System Design,” Revision 3 (March 2007):
  - New guidance related to BWR shadow corrosion-induced channel distortion and control blade interference (Section II.1.A.v). This new guidance necessitated by longer, higher power BWR operating cycles which require more frequent, deeper control blade insertion to hold down excess reactivity.
  - New guidance related to cladding lift-off, hydride reorientation, and DNB propagation (Section II.1.A.vi). This new guidance necessitated by higher fuel rod burnup and associated higher rod internal gas pressure.
  - New guidance related to defining mechanical and nuclear lifetimes for control rod/blade designs (Section II.1.A.viii). This new guidance necessitated by longer, higher power BWR operating cycles which require more frequent, deeper control blade insertion to hold down excess reactivity.

# Updates to Regulations and Guidance

- Revised guidance related to defining AOO overpower cladding strain failure threshold (Section II.1.B.vi). This revised guidance necessitated by longer, higher power operating cycles and associated cladding corrosion and hydrogen uptake.
- Revised guidance related to steady-state fission product inventory (Section II.1.C.ix). This revised guidance necessitated by longer, higher power operating cycles. Revised radionuclide inventories are presented in DG-1199 (draft revision to RG 1.183).
- Revised guidance related to high temperature cladding failure thresholds during reactivity-initiated accidents (Appendix B, Section B). This revised guidance necessitated by higher fuel rod burnup and associated higher rod internal gas pressure.
- New guidance related to pellet-cladding mechanical interaction (PCMI) cladding failure thresholds during reactivity-initiated accidents (Appendix B, Section B). This new guidance necessitated by longer, higher power operating cycles and associated cladding corrosion and hydrogen uptake.
- Revised guidance related to core coolability criteria during reactivity-initiated accidents (Appendix B, Section C). This revised guidance necessitated by higher fuel rod burnup.
- Revised guidance related to fission product inventory (i.e., transient fission gas release) during reactivity-initiated accidents (Appendix B, Section D). This revised guidance necessitated by higher fuel rod burnup.

# Updates to Regulations and Guidance

- NRC actively updating the following regulations and guidance to reflect current fuel utilization
  - RG 1.183, Alternate Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors
  - DG 1327, Pressurized Water Reactor Control Rod Ejection and Boiling Water Reactor Control Rod Drop Accidents
  - 10 CFR 50.46, Acceptance Criteria for Emergency Core Cooling Systems for Light Water Nuclear Power Reactors

# Barriers for Extended BU

- Past experience with approving extended fuel rod burnup based on incomplete technical bases

- Industry's reluctance to update approved models and methods based on operating experience and research findings

- Existing regulatory framework and backfit hurdle to update "forever" approved models and methods

**Comprehensive and irrefutable empirical database needed to justify burnup extension**

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# Shared Responsibilities

- Licensees have sole responsibility to operate nuclear power plants in a safe manner in accordance with the design and licensed bases
  - Fuel vendors have responsibility to maintain conservative models and methods

- NRC has responsibility to maintain regulations and guidance, as well as oversight and enforcement.

**Credible operating experience or research findings need to be included in models and methods**

# Path Forward

- All legacy issues and deficiencies must be addressed

- Establish a regulatory process for periodic self-assessment of fuel related models and methods
  - Mandatory confirmation and reporting
  - May include a streamlined approval process

- Licensees would voluntarily implement all necessary corrective actions and new requirements

# Legacy Issues

- New ECCS performance embrittlement mechanisms
  - Implement 50.46c rule, or
  - Implement research findings along with 50.46 exemption
- Revised RIA guidance
  - Implement revised CRE/CRDA cladding failure thresholds, coolability criteria, and transient FGR
- Fuel fragmentation, relocation, and dispersal (FFRD)
  - Develop a strategy to address FFRD
- State-of-the-art analytical models and methods
  - Properly account for BU-effects (e.g., TCD, rim, gaseous swelling)
  - Established statistics and sampling
  - Established BU and fluence limits
    - Peak pellet
    - Average fuel rod(s) and/or assembly
    - Non-fuel component fluence

# Legacy Issues

- Fuel assembly seismic and LOCA applied loads models and methods
- Expanded COLR
  - Captures fuel assembly designs
  - Burnup limits
  - Burnup-dependent fuel peaking factors credited in safety analyses
- Inconsistent and out-of-date fuel design change processes

# SECY-15-0148

*The research and assessments completed to date indicate that near-term regulatory action is not needed to address FFRD phenomena at this time. However, this conclusion is closely linked with current fuel design limits and assumptions on how high-burnup fuel is operated….*

*Research has shown that as burnup exceeds 62 GWd/MTU, fuel becomes increasingly susceptible to FFRD.*

# Proposed Approach

- Agreement on BU limit

- Each fuel vendor would submit for review and approval a single topical report detailing changes to existing, approved models and methods needed to address BU extension.

- Separate topical report supplements may be needed to address **legacy issues**:
  - Fuel rod thermal-mechanical model and application methods
  - Fuel assembly mechanical design
  - ECCS model and application methods
  - Fuel assembly seismic/LOCA applied loads
  - CRE / CRDA model and application methods

# Proposed Approach

- Each licensee would submit a license amendment request for extended burnup.
  - Add Extended BU Topical Report and any necessary supplements to existing Topical Reports into COLR references
  - Update USFAR Chapter 15 safety analyses, as necessary
  - Update TS and COLR (e.g., BU-dependent peaking factor surveillances)
  - Address all peripheral, burnup-dependent issues (e.g., EIS, dry cask, SFP cooling, LTC, Lower Mode time-to-boil, etc.)

- Conditional approval requiring periodic self-assessment and reporting, as necessary to address gaps and uncertainty in empirical database