AP1000 Fuel Design & Core Operations

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Introduction

- **AP1000** Reactor Design
  - Achieves simplicity through the use of passive safety systems
    - Results in
      - Significant Reduction in capital and O&M costs
      - Large margins to safety limits while using proven technologies
  - Certified by the NRC
- **AP1000** Fuel design
  - Adaptation of the 17X17 RFA design that has significant worldwide operating experience
  - Further enhancements to provide higher thermal and mechanical margins
- **AP1000** Core design & Operations
  - 69 Control Rods provide high level of reactivity control
    - No requirement for Boron adjustment during load follow and power maneuvers
      - Strategy Designated as Mechanical Shim (MSHIM)
- **AP1000** Core Monitoring
  - BEACON ™ used to provide core related technical specification monitoring and operational support

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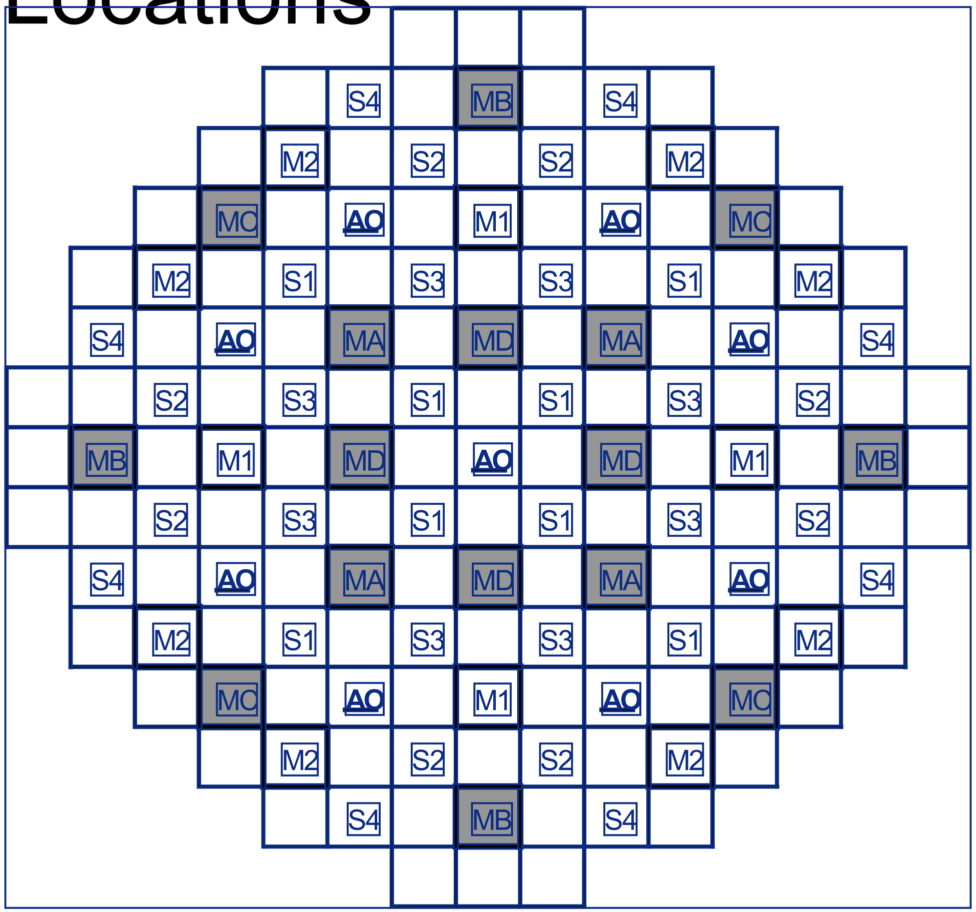
AP1000 Critical Fuel Parameters Selected to be Within Experience Base

AP1000 Control and Shutdown Bank Locations



69 Total Control Rods

M-Bank
MA : 4
MB : 4
MC : 4
MD : 4
(Gray)
M1 : 4
M2 : 8
(Black)

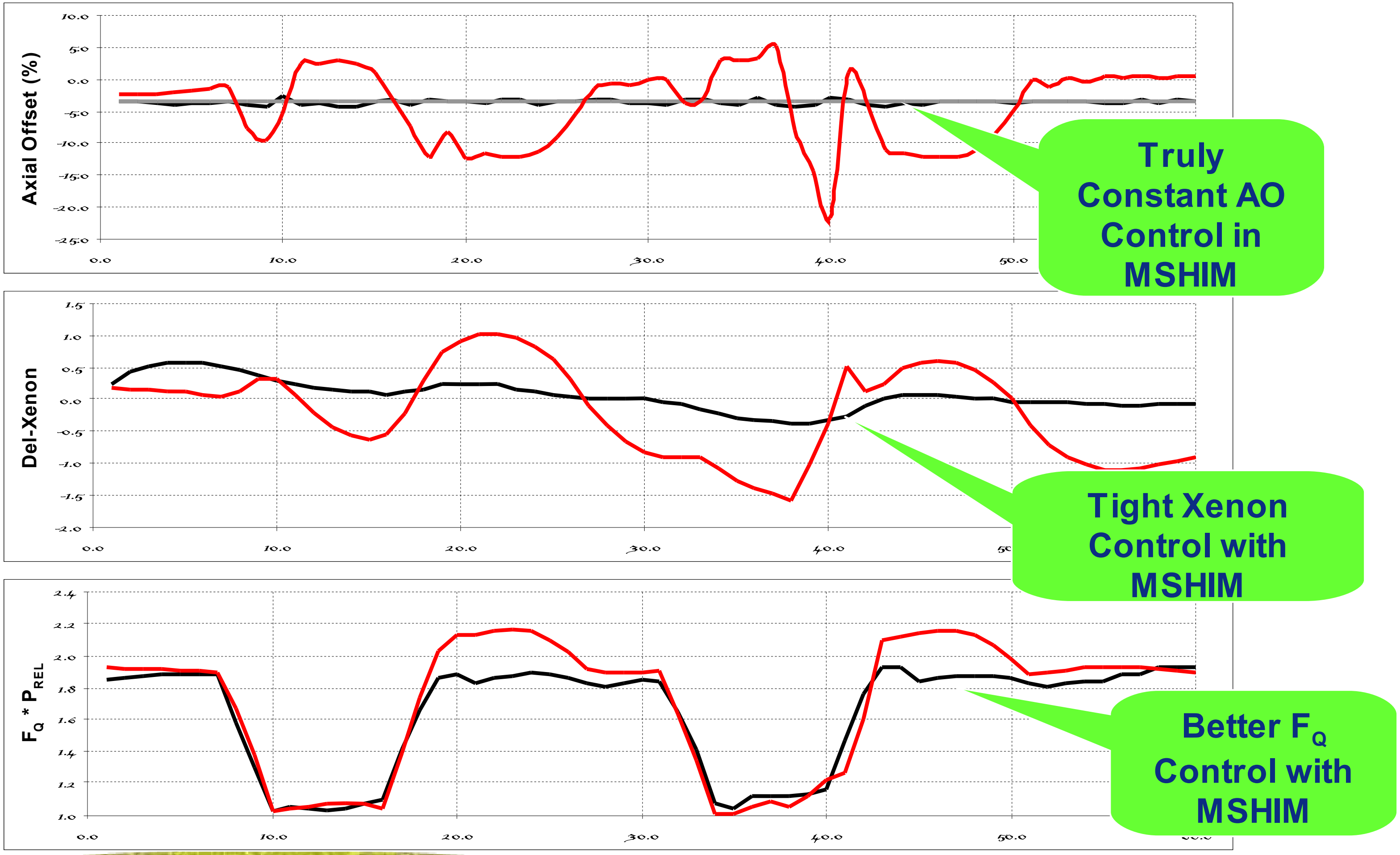
AO-Bank
AO : 9
(Black)

Shutdown-Bank
S1 : 8
S2 : 8
S3 : 8
S4 : 8
(Black)

AP 1000 Reactivity Control System Description

- Existing plants use the same control bank for both overall reactivity / temperature control and Axial Power Distribution control, along with changes in RCS Boron concentration
  - Leads to high variation in local power distributions and propensity for Xenon transients
- **AP1000** Uses two separate sets of Banks – no changes in RCS Boron for load follow or power maneuvers
  - M banks for Reactivity/ Temperature control
  - AO banks for Axial Power Distribution Control
- M banks include lower worth rods (Gray rods)
  - Allow boron-adjustment free load-follow operation

MSHIM Operation Provides Tighter Power Distribution Control



AP1000 First Cycle -- Daily Load Follow 100% to 50% Power at Near MOL (Black Line = MSHIM, Red Line = CAOC)

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AP1000 Fuel Design & Operational Experience

- **AP1000** Fuel design
  - Adaptation of the 17X17 Robust Fuel Assembly (RFA) design that has significant worldwide operating experience
  - Further enhancements to increase thermal and mechanical margins
- Substantial field experience with this design
  - In Operation since 1997
  - Over 12,700 assemblies (~3.3 million fuel rods) and 221 reloads have operated in 47 plants worldwide since 1997
  - Lead rod burnups close to regulatory limit of 62 GWD/MTU
- Further enhancements to improve mechanical robustness and thermal margins
  - Intermediate Flow Mixing Grids
  - Enhanced RFA mid-grid design
  - Addition of bottom plenum to improve Rod Internal Pressure margins
  - Westinghouse Integral Nozzle (WIN)
  - Ability to use either discrete or a variety of Integral Burnable Absorber Designs

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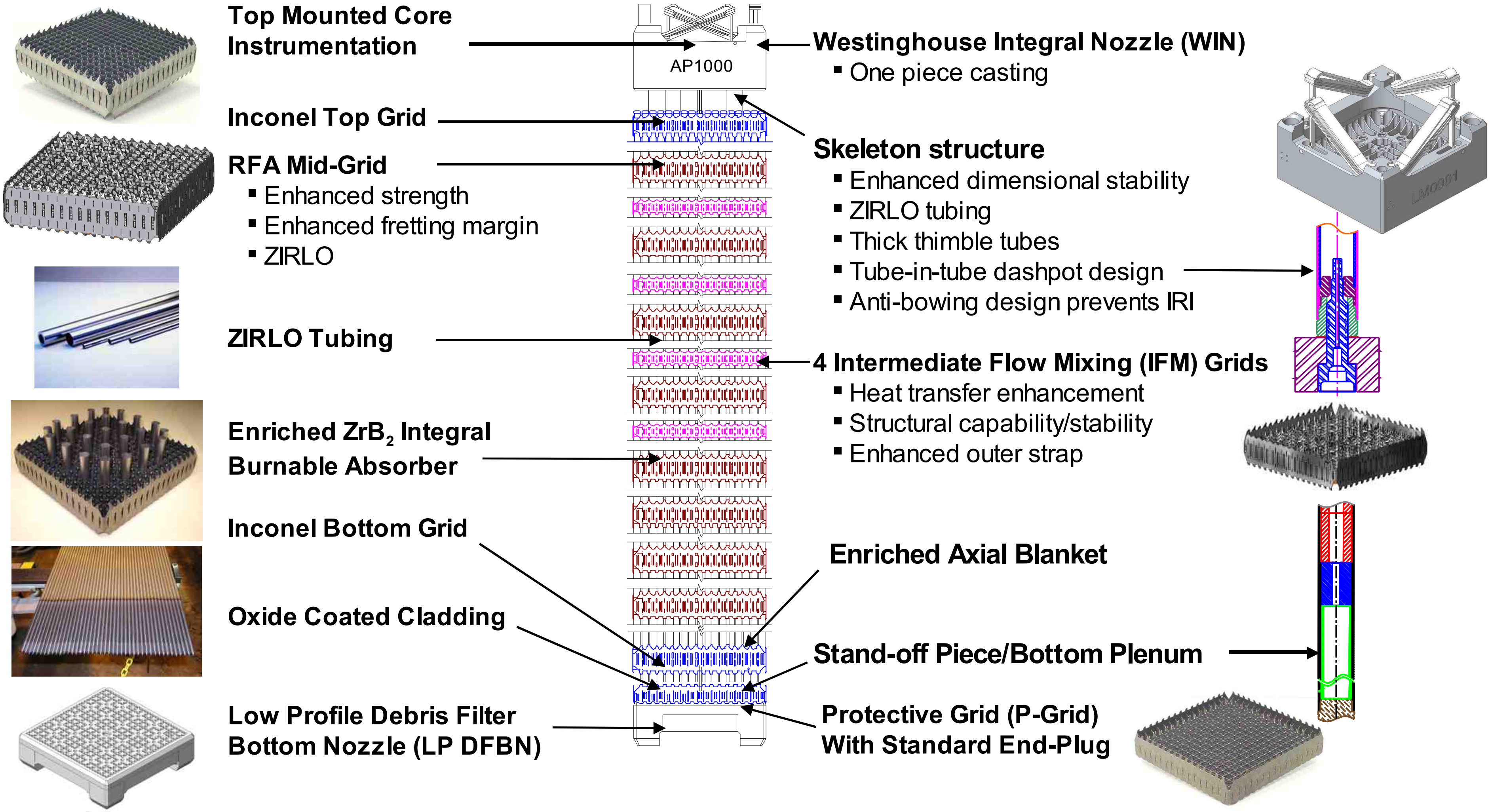
AP1000 Fuel Assembly Design Features



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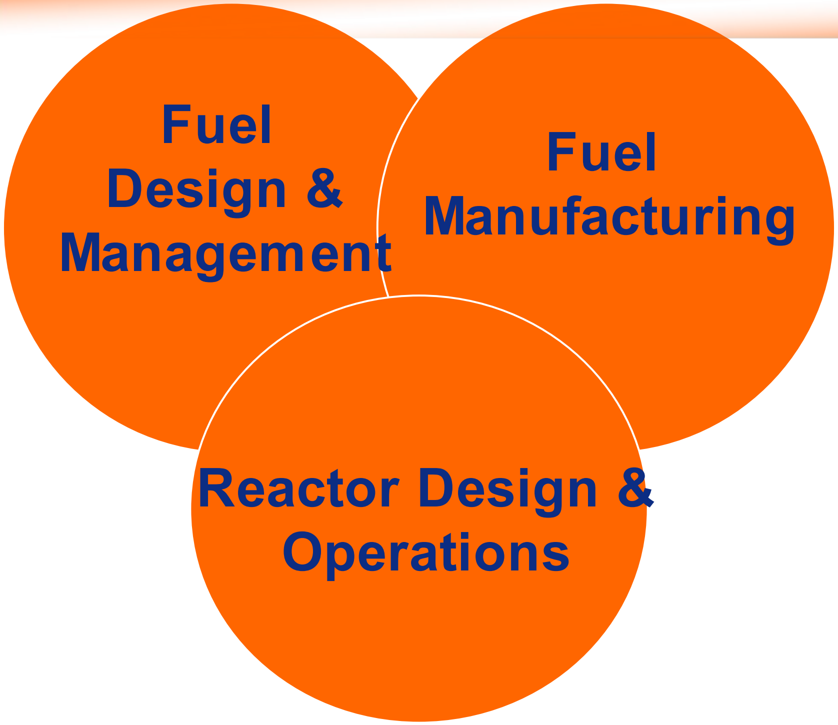
AP1000 Fuel Reliability Program – "Zero from the Start"



- **Address plant design issues during design finalization that can adversely impact fuel performance**
- **Implement design features and manufacturing processes to maximize margins to failure**
- **Specify bounds of reactor operation and monitor using BEACON™ software**
- **Specify and implement a robust PIE program to obtain early feedback on fuel performance**

Specific INPO 2010 Focus Areas

- INPO 2010 requires specific attention to the following areas
  – PWR Grid-to-rod fretting
  – Crud induced corrosion
  – PCI induced failures
  – Debris related failures
  – Manufacturing related failures

- Specific focus also on Post Irradiation Exams (PIE) on healthy fuel for early identification of potential issues

*Significant Attention Paid to of All of the Above Issues During the **AP1000** Fuel Design Finalization Process*

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Reactor Design –Key Aspects Designed to Improve Fuel Reliability

- Core Shroud Design
  - All welded design that does not require baffle bolts for assembly
    - Removes potential for baffle jetting failures
- Addition of inlet Flow skirt
  - Provides significantly better inlet flow distribution and minimizes the potential for inlet flow distribution anomalies
- Orientation of Gray banks
  - Optimized to minimize power peaking

Highlights of Steps Taken to Address Specific Failure Mechanisms

- PWR Grid-to-rod fretting
  - Grid to rod-contact areas significantly increased for additional margin
  - Extensive testing to ensure excellent performance
- Crud induced corrosion
  - Thermal parameters selected to ensure boiling duties are within experience base
  - Zinc injection will be implemented during hot functional testing
- PCI induced failures
  - MSHIM designed to provide extremely tight power distribution control

to black rods

Highlights of Steps Taken to Address Specific Failure Mechanisms

- Debris related failures
  - Aggressive debris prevention and system cleanup being implemented during plant construction through procedural requirements
  - Full complement of Westinghouse fuel debris features
    - Debris Filter Bottom Nozzle, Protective Grid and Oxide Coating
- Manufacturing related failures
  - 100% eddy current testing to pick up cladding flaws or surface defects
  - Tighter pellet chip acceptance criteria to maximize margins to PCI failures
  - Incorporation of an automated system for pellet diameter inspection
  - Pellet Drying prior to rod loading to minimize the probability of primary hydride failures
- Specific focus also on Post Irradiation Exams (PIE) on healthy fuel for early identification of potential issues

AP1000 Power Distribution Monitoring System Description

- Uses the Westinghouse BEACON™ system
  - Utilized in over sixty reactors over the world
- BEACON™ signals generated by seven section fixed incore detectors utilizing long life Vanadium emitters
  - Detailed power distribution input used to continuously update and deplete a 3D Core Neutronics model
- BEACON™ allows
  - Online Core Thermal margin Monitoring (DNBR and Linear Heat Rate)
  - Core Reactivity and Shutdown margin monitoring
  - Input to Control Room alarms
  - Excore detector calibration
  - General core diagnostic and predictive simulation capability

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Summary

- **AP1000** Fuel Design and Core Operations utilizes proven technologies while enhancing thermal and operational margins
- Operational & safety margins within current W experience base
- MSHIM Operational strategy allows load follow & power changes without Boron concentration changes
  - provides significantly enhanced power distribution control
- The **AP1000** fuel reliability program aims for "Zero from the Start"
- Use of the BEACON™ system allows for improved operational as well as safety margins

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