Enclosure 4
Core/Fuel Mechanical Design
(Redacted)

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B&W mPower^{TM} Reactor Core, Fuel Mechanical Design, Analysis, Testing Overview

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May 21, 2013

(Redacted Version)

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This is a pre-application document and includes preliminary B&W mPower Reactor design or design supporting information and is subject to further internal review, revision, or verification.

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B&W mPower™ Introduction and Objectives

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Introduction and Objectives

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- The objective of the meeting is to provide information and elicit feedback from the Staff such that the topical reports on the overall Fuel Assembly Design and Design Criteria have sufficient information to be licensed
- The material presented during this meeting will provide the Staff with a sound understanding of:
  - Fuel Assembly Mechanical Design
  - Control Components
  - Analysis Code and Methodology
  - Fuel Rod Performance Code and Analysis Methodology
  - Fuel Assembly Seismic Code and Analysis Methodology
  - Fuel System Testing
- Overall licensing and testing deliverables are identified, and submittal dates are provided

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Core Design Overview

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Outline

- Introduction
- Assembly Design
- Core Configuration
- Cycle Results
- Summary

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Introduction

- The B&W mPower reactor core is designed to generate 530 MWt for up to 4 years with a 95% capacity factor
- Key features include:
  - Industry standard 17x17 fuel assembly[ ]
  - < 5% enriched U-235
  - Internal control rods
  - No soluble boron
- Designed with eye toward maximizing thermal margins within operating space to ensure safe operation
  - Core average linear heat generation rate[ ]
  - Peak linear heat generation rate[ ]
  - Maximum enthalpy rise factor[ ]
- State of the art software used in core design process
  - CASMO-5/SIMULATE-3
  - MCNPX 2.7.0

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Assembly Design

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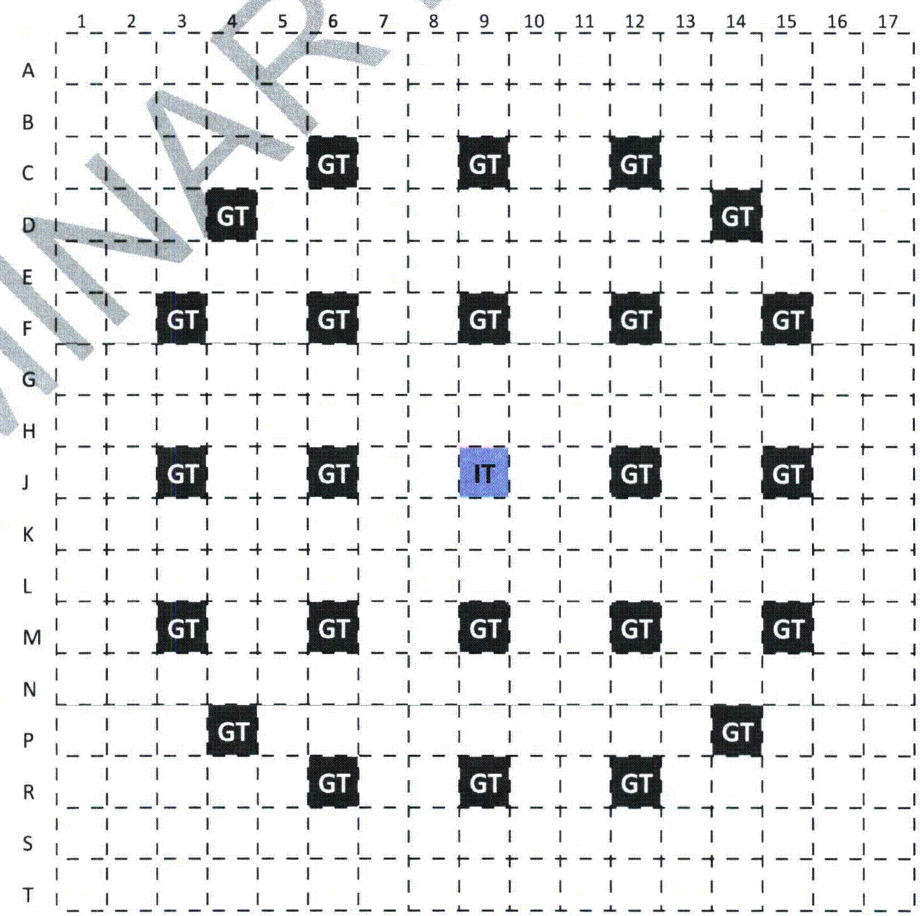
- Fuel assembly conceptually similar to a conventional 17x17 square lattice PWR, except shorter
- 24 guide tubes (GT) for AIC control rod fingers
- 1 central instrument tube (IT)
- 264 positions for fuel (UO_2(-Gd_2O_3)) and burnable poison rods (Al_2O_3-B_4C)
- Enrichment of ^{235}U in UO_2-Gd_2O_3 pins reduced to [ ] of the main lattice enrichment
- BPRs have axial zones with different B_4C wt%

[ ]



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Lattice Nomenclature

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Sample Lattice Layout

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Core Assembly Types

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Core Assembly Map

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Control Rod Sequences

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Assembly Average Relative Radial Power Distribution at BOC

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Assembly Average Relative Radial Power Distribution at MOC

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Assembly Average Relative Radial Power Distribution at EOFP

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Axial Power Distributions at BOC

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Axial Power Distributions at MOC

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Axial Power Distribution at EOC

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Assembly Average Exposures at EOC

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Assembly Axial Burnup Distributions at EOC

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Core Operating Cycle Metrics Summary

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- End-of-cycle core exposure: [ ] GWD/MTU
- Operating cycle length: 1391 EFPD
- Cycle capacity factor: 95%
- Estimated full power capability: [ ] GWD/MTU
- Nodal peaking:
  - Max nodal peaking: [ ] during full power operations
  - Increases slightly to [ ] during coast down
- Axial Offset:
  - Axial offset: < +15 % during full power operations
  - Increases above +15% only during coast down

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Questions?

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B&W mPower^{TM} Fuel Assembly Mechanical Design

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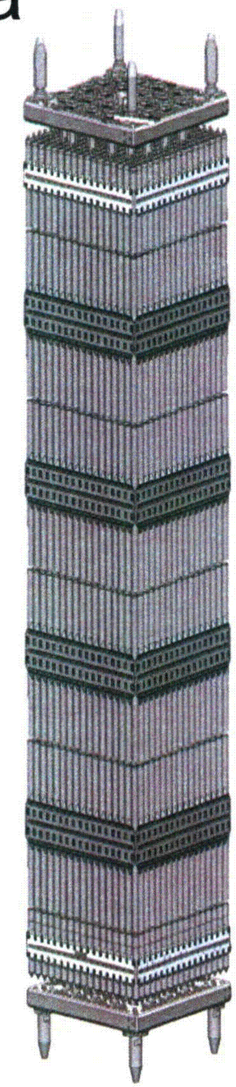
Fuel Mechanical Design - Agenda

- Fuel Assembly Overview
- Pre-Prototype FA Build / Lessons Learned
- Industry "Best Practice" Design Features
- Fuel Component Overview
  - Guide tube assembly
  - Upper and lower end fitting assemblies
  - End and mid grid assemblies
  - Threaded joints and locking mechanisms
  - Cage welded joints / grid restraints
  - Fuel and burnable poison rods
- Structural Analysis



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General Fuel Mechanical Design Objectives

- Fuel rods, burnable poison rods, fuel assemblies and in-core control components shall be designed to:
  - Maintain coolable geometry and control component insertability under all anticipated operational occurrences (AOOs) and postulated accidents (PAs)
  - Ensure that fuel system is not damaged as a result of normal operation and AOOs
  - Provide a means for safe handling and structural integrity (no damage) during transport, refueling and storage operations
- The designs shall account for the effects of temperature, pressure, irradiation, fission products, static and dynamic loads, and changes in the physical and chemical characteristics of the constituent materials

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Fuel Assembly Design

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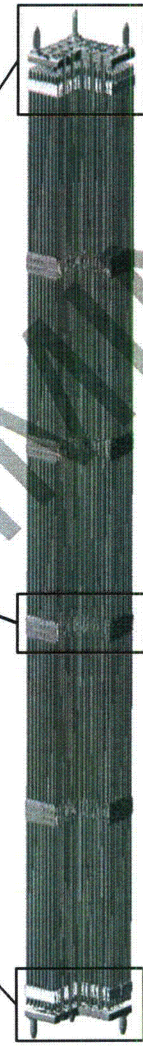

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Fuel Assembly Attributes

- 17 x 17 Fuel Rod Array
  - 264 Zircaloy-4 cladding (SRA) Fuel Rods and Burnable Poison Rods (BPRs)

[ ]

- Structural Cage Assembly
  - 24 Zircaloy-4 Control Rod Guide Tube Assemblies (RXA)

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Pre-Prototype FA Build / Lessons Learned

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Industry "Best Practice" Design Features

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Features Incorporated

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Guide Tube Assembly Design

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Guide Tube (GT) Assembly Attributes

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Upper End Fitting Design

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Upper End Fitting (UEF) Attributes

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Nickel Alloy 718 End Grid Design

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End Grid Attributes

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Zircaloy-4 Mid Grid Design

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Mid Grid Attributes

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Lower End Fitting Design

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Lower End Fitting (LEF) Attributes

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FA Cage Threaded Joints

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FA Cage Threaded Joints

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FA Cage Weld Joints

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Fuel Rod Design

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Burnable Poison Rod Design

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BP Rod Attributes

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FA/Component Structural Approach

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- Analytical Methods
  - Finite Element Analysis (ANSYS) modeling
  - Classical hand calculations
  - Bounding load-cases (i.e. BOL/EOL, S&H, operation, temperature, irradiation, etc.)
- Analysis to correlate Test Results
  - Full size FA testing
  - Individual component testing

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B&W mPower™ Control Components

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Reactivity Control Components

- Burnable Poison (BP) Rods
  - Power suppression early in cycle
- The B&W mPower Reactor uses two In-core control components:
  - Control Rod Assemblies (CRAs)
    - Controls reactor power during operation
    - Emergency shutdown function
  - Neutron Source Rods (Primary and Secondary)
    - Primary neutron source
      - Initial reactor startup
      - Ex-core monitoring
    - Secondary neutron source
      - Reactor startup for nth cycle
      - Ex-core monitoring

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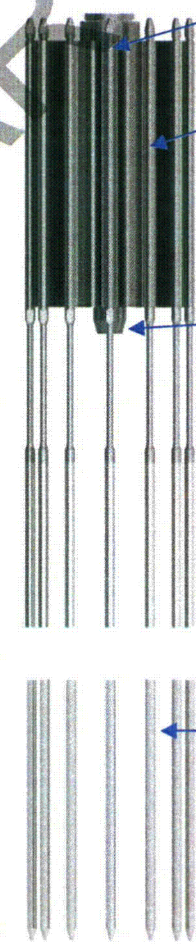
Control Rod Assembly Design

- 69 CRAs per Core (one CRA per FA)
- 24 Control Rods per CRA
  - Except for locations with Neutron Source Rods
- 80Ag-15In-5Cd absorber rods
- 304L SS Spider with tungsten ballast
  - Additional weight needed to meet scram times
- CRA drops under gravity upon scram
- J-lock coupling at top of Spider Hub mates to CRDL Connecting Rod
- Spider is heavier than typical PWR spider due to the non-scramming lead screw
- Impact Limiter at bottom of Spider Hub minimizes scram impact loads on FA



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Spider Assembly Design

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Control Rod Design

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Control Rod Attributes

- Design similar to existing Control Rods used for PWRs using 17x17 fuel

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Burnable Poison Rod Design

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BP Rod Attributes

- Mechanically identical to Fuel Rods, but with $Al_2O_3 - B_4C$ absorber pellets

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- BP Rod design utilizes axial zones to optimize power suppression
- BP rod design optimization:
  - Helium gas release
  - Pellet swelling

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Burnable Poison Pellet Swelling Model

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Burnable Poison Rod Performance

Preliminary Performance Analyses Conducted for BP Rods

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Approach To Critical – Startup Neutron Sources

- Neutron sources installed to provide adequate source of neutrons so that the neutron population can be raised to a point where the SRMs present a true picture of the reactor conditions even though it may be completely shutdown with all CRAs inserted
  - [ ] ^{252}Cf Source (1st Startup)
    - ^{252}U spontaneous fission source
    - The ^{252}Cf located in four symmetric assemblies on the core periphery
  - [ ] Regenerative Neutron Sources
    - Sb-Be regenerative neutron sources will located in four symmetric assemblies near the core periphery (first cycle) for activation
    - Subsequent cycle's regenerative sources will be located on the periphery

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Approach To Critical – Startup Neutron Sources

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Fuel Analysis Methodology Development

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Fuel Assembly Mechanical Design Analyses

- Utilize "hand" calculations and FEA for most structural analyses
  - Use selected mechanical tests to benchmark analyses
- Develop and Validate Computer Codes for More Complex Analyses
  - Fuel Assembly Growth Analysis
  - Cladding Creep Collapse Analysis
  - Fuel Rod Bow Analysis
  - Control Rod Drop Analysis
- All computer codes developed under NQA-1 Compliant Procedure for code V&V
  - Requirements Phase, Test Plan Phase, Software Design Phase, Coding Phase, Verification Phase, Validation Phase, & Software Release Phase

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Fuel Assembly Growth Analysis - Purpose

Why It Is Important

- Can create forces on vessel internals
- Can distort fuel assembly
  - Can affect reactor shut-down
  - Can affect fuel handling
  - Can affect fuel movement/shuffling
- Can influence overall mechanical design
  - Grid design (target spring force)
  - Gap between LEF and fuel rods
  - Gap between UEF and fuel rods
  - Location of grid relative to flux

Design Criteria

- Maintain gap between fuel assembly and the reactor core internals
- Maintain gap between rod end plugs and end fittings

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Fuel Assembly Growth Analysis – Methodology

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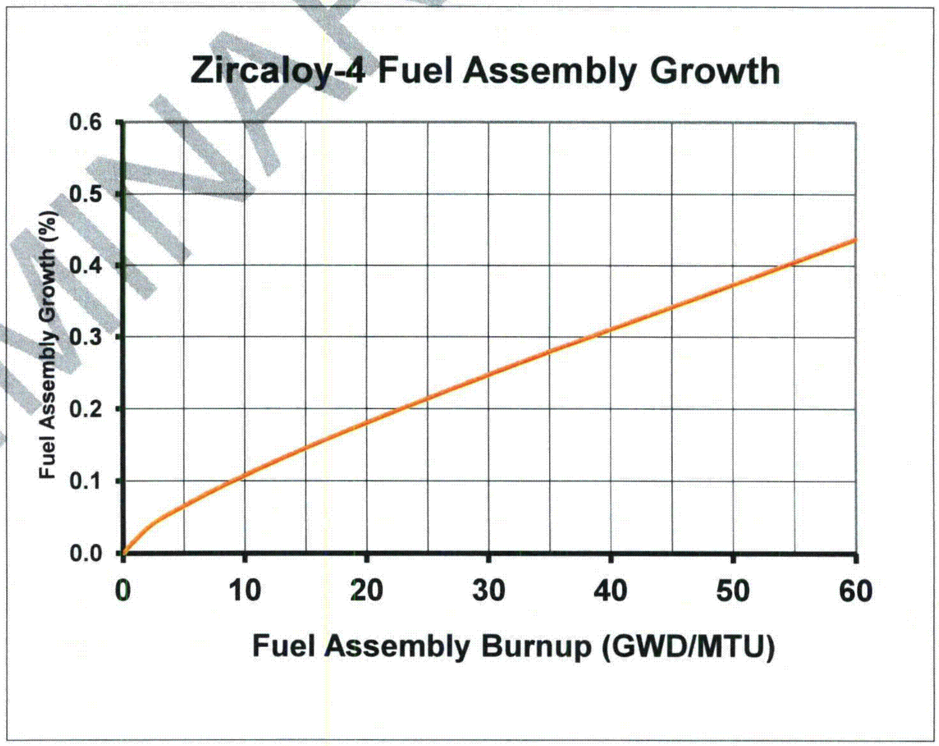
Fuel Assembly Growth Analysis – Result Goals

Statistical Response of

- Fuel Assembly Growth = f(Burnup)
- GT Stress = f(Burnup)

Analysis to Confirm Design Criteria

- Gap between fuel assembly and the reactor core maintained
- Gap between rod end plugs and end fittings maintained



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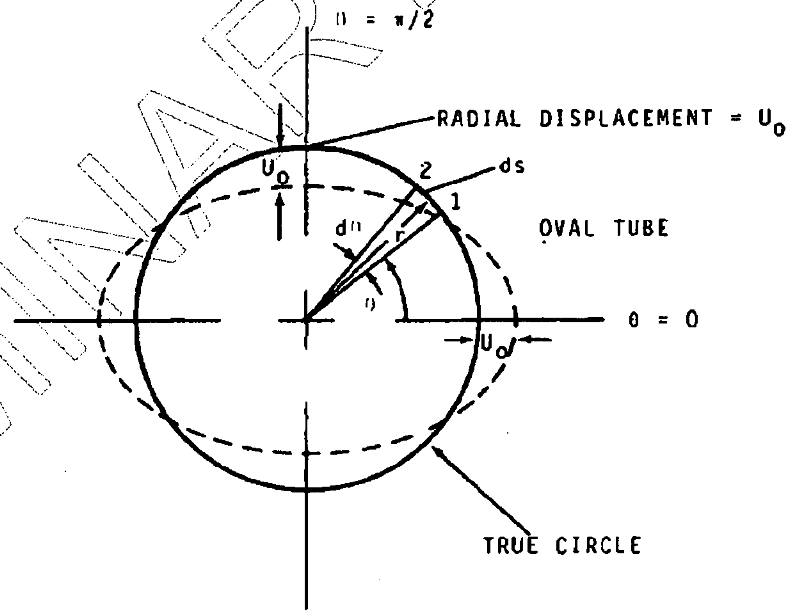
Cladding Creep Collapse Analysis - Purpose

Why It Is Important

- Potential for Elastic Buckling
- Potential for Plastic Deformation
- Can Influence
  - Helium backfill pressures
  - Cladding tube thickness
  - Fuel column axial gaps
  - Maximum tube ovality
  - Cycle lifetime



Design Criteria

- Preclude Cladding Collapse

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Cladding Creep Collapse Analysis – Methodology

B&W Finite Difference Creep Collapse Code

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Cladding Creep Collapse Analysis – Result Goals

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Statistical Response of

- Collapse Time= f(Initial Ovality)
- Collapse Time= f(mPower Geometry)
  - Fuel Rods, BP Rods, Control Rods

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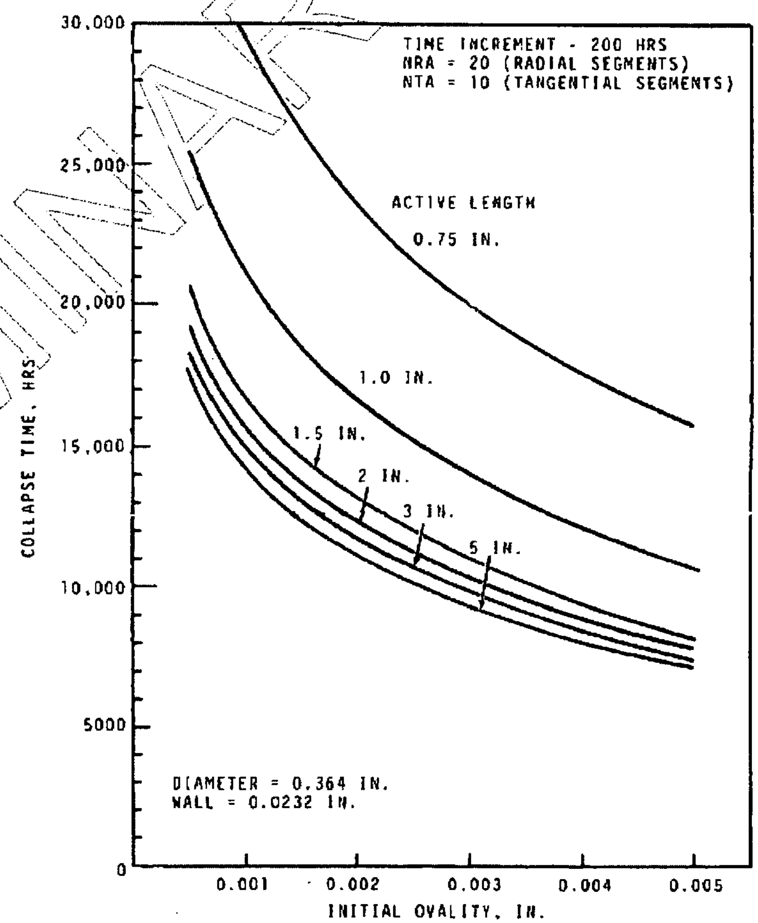
- High density pellets
- Adequate helium pre-pressurized



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Fuel Rod Bow Analysis - Purpose

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What Is It

- Deflection of fuel rods between grids
- Decreases water channel width

What Can Affect It

- Fuel assembly geometry
- Number of grids
- Axial shape
- Pressure differentials
- Linear heat rate
- Spring grip forces
- Creep influences
- Flow characteristics

Design Criteria

- Effect of fuel rod bow does not exceed thermal limits

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Fuel Rod Bow Analysis – Methodology

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Fuel Rod Bow Analysis – Result Goals

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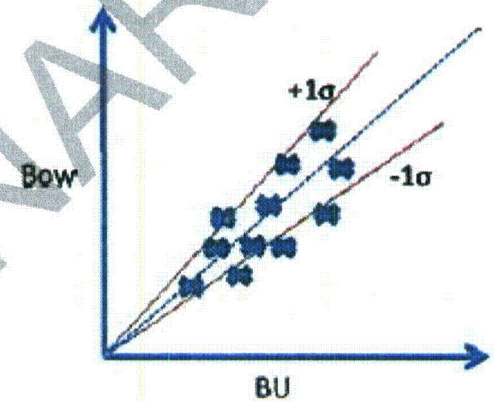
Statistical Response of

- Bow = f(burnup, span)
- Bow = f(geometry)



Design Criteria ...

- Effect of fuel rod bow does not exceed thermal limits

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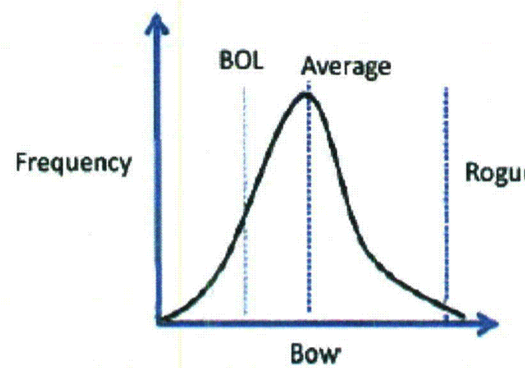

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Control Rod Drop Analysis - Purpose

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Why It Is Important

- Impacts SCRAM times
- Impacts Control Rod System Design
- Impacts stresses in Upper End Fitting

Design Criteria

- Acceptable SCRAM Times
- Complete Control Rod Insertion
- Acceptable Maximum Stresses

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Control Rod Drop Analysis – Methodology

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Control Rod Drop Analysis – Result Goals

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Statistical Response of
- Distance vs. Time
- Pressure vs. Time
- Velocity vs. Time

Design Criteria
- Acceptable SCRAM Times
- Complete Control Rod Insertion
- Acceptable Maximum Stresses

Control Rod Benchmarking
- Drag Load Testing
- Drop Time Testing

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Fuel Assembly Mechanical Design Analyses

- Robust Statistical Analytic Predictions
  - Fuel Assembly Growth Analysis
  - Cladding Creep Collapse Analysis
  - Fuel Rod Bow Analysis
  - Control Rod Drop Analysis
- Mechanical Testing with Prototypes
  - Control Rod Drop Tests
- Empirical mPower PIE Data as Available
  - Fuel Assembly Growth Data
  - Fuel Rod Bow Data
  - Control Rod Drop Data

→ ***Safe, Robust, Predictable mPower Mechanical Design***

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B&W mPower™ Fuel Rod Performance Code and Analysis Methodology

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Fuel Performance Analyses - Agenda

- Fuel Performance Codes
- Brief Overview of Design Analysis Methodology
- Preliminary Results

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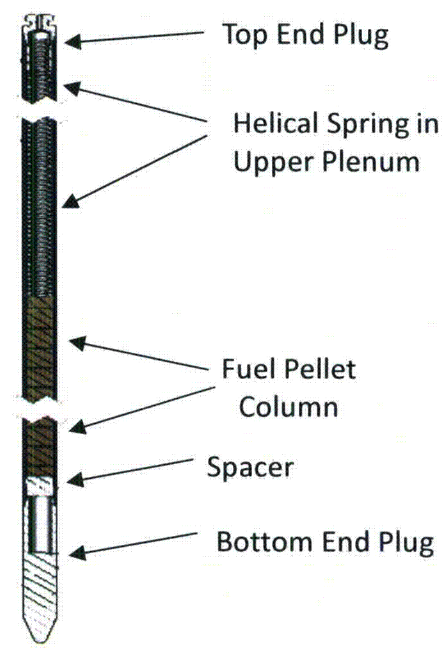
FRAPCON-BW & FRAPTRAN-BW

- B&W Conducted Review of Several Industry Fuel Performance Codes
  - Appropriate models for mPower fuel design & Op conditions
    - Supported by modern fuel database
    - ≤5 w/o UO_2, ≤ 8 w/o Gad, Zirc clad, ≤ 62 GWd/T, PWR, SS & AOOs
  - Established peer-reviewed industry tools
  - Experienced users
  - Reliable results
    - Accuracy & convergence
  - Thorough documentation
  - Fast run time
    - Can support deterministic and statistical analyses
- FRAPCON & FRAPTRAN chosen



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FRAPCON-BW & FRAPTRAN-BW V&V

- B&W Creating Appendix B Versions of FRAP Codes
  - QA review of documentation
  - Detailed check of source coding
  - Testing of subroutines
  - Development of test cases
  - Quantification of uncertainties
  - Demonstration of appropriateness for mPower design & operating conditions
  - Updates of documentation and coding
  - Addition of pre- and post- processors
- Proprietary Versions of FRAPCON-BW & FRAPTRAN-BW Developed Under mPower QA Program

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Fuel Performance Analyses

- Fission Gas Release / Rod Internal Pressure Analyses
- Fuel Heat Rate to Melt Analyses
- Fuel Creep, Stress and Strain Analyses
- Cladding Oxide/Hydride Analyses
- Analyses of fuel rod response during transients
  - Loss of flow
  - Over-cooling
  - Control rod withdrawal
- Inputs to Other Analyses
  - Fuel temperatures, dimensions, etc.

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Statistical Analyses Methodology

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Rod Internal Pressure

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Demonstrate that fuel rod internal pressure remains below clad lift-off pressure at power and 1200 psia in SFP

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Cladding Transient Strain

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Demonstrate that entire core cladding hoop strain remains less than 1% SRP limit for AOO analyses

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Centerline Fuel Melt

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Demonstrate that fuel melting is precluded in entire core for AOO analyses

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Cladding Waterside Corrosion

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Demonstrate that local oxide thickness remains below 100 micron limit

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Preliminary Fuel Performance Results

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Conclusions

- B&W Employing State-of-the-Art FRAP-BW Codes
- Coupled with Modern Statistical Methods
- Topical Report to be Submitted
  - Description of models
  - Code validation benchmarks
  - Quantification of Code Uncertainties
  - Description of design methodology
  - Sample results for each proposed application

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B&W mPower^{TM} Fuel Assembly Seismic Analysis

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Fuel Assembly Seismic (and LOCA) Analysis

- Agenda
  - Design basis and criteria
  - Event description
  - Reactor and fuel design summary
  - Historical linear-elastic, finite-difference code
    - B&W mPower QUAKE Code
  - Non-Linear, FEA-based code development
  - Statistical methodology for analysis

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Fuel Assembly Seismic (and LOCA) Analysis

- Design Basis – For combination of SSE and LOCA events:
  - Ensure safe shutdown of reactor
  - Maintain core coolability
- Applicable Design Criteria
  - Spacer grid deformation shall not prevent insertion of control rods
  - Spacer grid deformation shall not result in unacceptable FR peak clad temperatures and stresses
  - Stress in fuel assembly components shall be less than the allowable stress intensity based on ASME Code, Section III (guidance)
  - Control rod guide tubes shall not buckle due to imposed axial loads

(Source: NUREG-0800, Section 4.2, Appendix A)

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Fuel Assembly Seismic (and LOCA) Analysis

Event Description:

- Transient dynamic excitation of reactor vessel (RV) may induce significant loads acting on fuel assemblies and their components:
  - Earthquake events – horizontal and vertical motions of reactor upper and lower internals and core former
    - Horizontal motions induce impacts between intermediate spacer (mid) grids of adjacent assemblies or between spacer grids and core former
    - Vertical motions may cause impacts between fuel assembly upper and lower end fittings and reactor upper and lower internals, respectively
  - LOCA events – hydraulic pressure wave acting on fuel assembly grids and components
    - Pressure wave causes loads on fuel assembly components
    - Pressure wave may cause fuel assembly to bounce – impact between end fittings and reactor upper and lower internals

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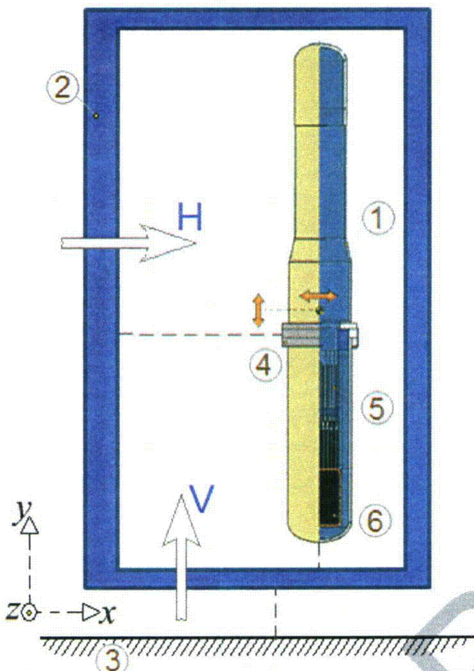
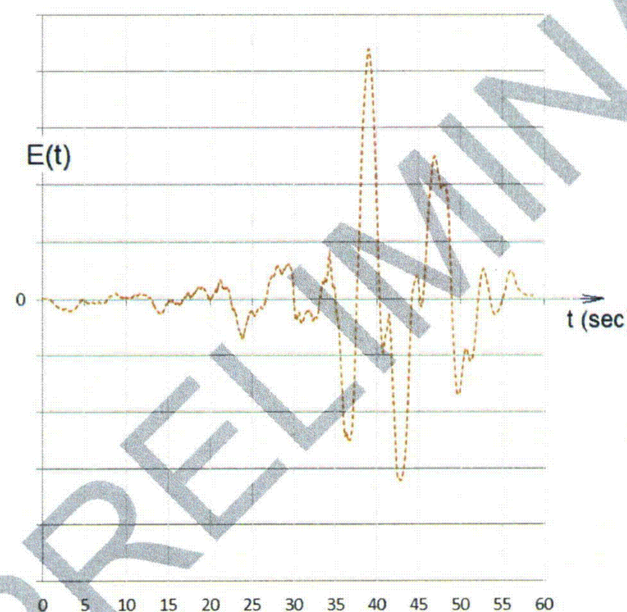
Fuel Assembly Seismic (and LOCA) Analysis

Event Description (cont'd):





Captions:

- **1 – Reactor Vessel**
- **2 – Reactor Building ("Civil Structure")**
- **3 – Soil (ground) Base Plate**
- **4 – Reactor Vessel Flange**
- **5 – Core Upper Internals**
- **6 – Fueled Core (69 FAs)**
- **"H" – Horizontal (lateral) excitation direction (SRSS combination of "X" and "Z" direc's)**
- **"V" – Vertical (axial) excitation direction ("Y" direction)**
- **"E(t)" – Core Plate Excitation:**
  - **(displacement TH of Lower Core Plate, Core Former and Lower Hanger Plate)**

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Fuel Assembly Seismic (and LOCA) Analysis

Reactor and Fuel Design Summary:

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Fuel Assembly Seismic (and LOCA) Analysis

Lateral Seismic Analysis:

- Fuel Assembly (FA) and component loading conditions addressed in faulted evaluations associated with horizontal seismic/LOCA excitations
  - Seismic Excitation – Provided in the form of displacement-time histories (from reactor vessel seismic analysis) for the following:
    - Lower Core Support Plate (or "LCP")
    - Upper Internals Interface (Lower Hanger Plate, also referred to the "Upper Core Plate" for other reactor designs)
    - Core Former (or typically referred to as "Baffle")
  - LOCA Excitation – N/A, addressed in vertical analysis
- Analysis performed using special-purpose, custom computer codes (topical)
  - Linear-elastic, finite-difference code – "QUAKE"

[ ]

- FA and component structural models for codes are developed and benchmarked using fuel assembly and component test data:

[ ]

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Fuel Assembly Seismic (and LOCA) Analysis

Vertical Seismic and LOCA Analysis:

- Fuel assembly and component loading conditions addressed in faulted evaluations associated with vertical seismic/LOCA excitations
  - Seismic Excitation – Provided in the form of vertical displacement or acceleration time histories (from reactor vessel seismic analysis) at LCP and LHP.
  - LOCA Excitation – caused by vertically oriented pressure surge along FAs
    - Provided in form of equivalent axially-oriented force distributed along FA due to hydraulic pressure gradient
- Analysis will be performed using commercially available computer code

  [ ]
- Similar to the lateral analysis, FA and component structural properties are developed and benchmarked using fuel assembly and component test data:

  [ ]

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Fuel Assembly Seismic (and LOCA) Analysis

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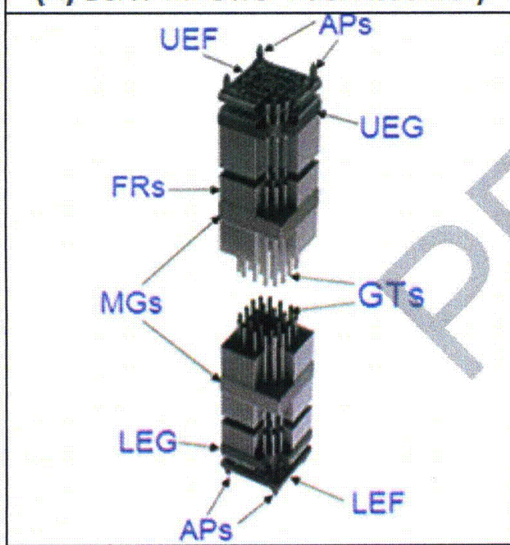
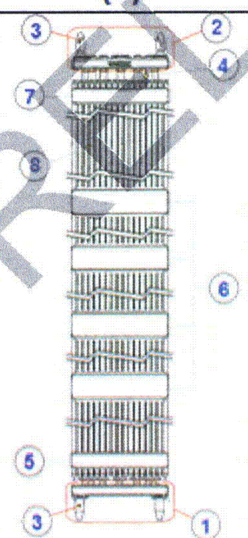
B&W QUAKE Code:

- Typical of past industry practice
- One-beam FA model ("1-beam') – GTs & FRs bundled together
  - Based on finite-difference integration algorithm
  - Each span represented with a single beam element, with distributed mass lumped at grid elevations
  - Each end fitting is lumped together with adjacent end grid

(A) B&W mPower Fuel Assembly	(B)	(C) 1-beam FA FD-model	Captions:
		[ ]	○ "APs", 3 – Alignment Pins. ○ "LEF", 1 - Lower End Fitting. ○ "UEF", 2 - Upper End Fitting. ○ "GTs", 4 – Guide Tubes (24/25). ○ "LEG", 5 – Lower End Grid. ○ "MGs", 6 – Mid Grids (4). ○ "UEG", 7 – Upper End Grid. ○ "FRs", 8 – Fuel Rods (264).

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Fuel Assembly Seismic (and LOCA) Analysis

B&W QUAKE Code (cont'd):

- Horizontal seismic analyses are based on SRSS combination of maximum grid impact forces in two orthogonal directions for three combinations of mutually perpendicular directions (slices of 5, 7 and 9 FAs in a row)

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Fuel Assembly Seismic (and LOCA) Analysis

B&W QUAKE Code (cont'd):

- Example from scoping analysis:
  - Figures below illustrate shape of laterally deflected FAs (row of 9) relative to the left (1) and right (2) CF plates at time instant of about 3 sec of the seismic excitation TH (20 sec. long). The correlated integration progression is illustrated with moving slide ("A")
  - Red highlights in the left figure illustrate occurrence of mid grid contacts between neighboring FAs and/or peripheral FA and core former inner surface

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Fuel Assembly Seismic (and LOCA) Analysis

B&W QUAKE Code (cont'd):

- Example from scoping analysis:
  - Characteristic grid impact force vs. time signature for 4 grids, and two orthogonal directions ("X" and "Z"). Typically, maximum impacts do not occur simultaneously in all grids
  - Example: preliminary scoping seismic analysis indicate maximum impact forces for EOL grid relaxation condition, assuming no grid swelling (to reduce gaps between grids in adjacent FAs):
  - Illustrative values: FX = 5,690 lb @ mid grid 3, FA-9 AT 37.9030 SEC
    FZ = 4,037 lb @ mid grid 3, FA-1 AT 38.6371 SEC

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Fuel Assembly Seismic (and LOCA) Analysis

B&W Non-linear, FE-based Code:

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Fuel Assembly Seismic (and LOCA) Analysis

B&W Non-linear, FE-based Code (cont'd):

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B&W mPower^{TM} Fuel System Test Program

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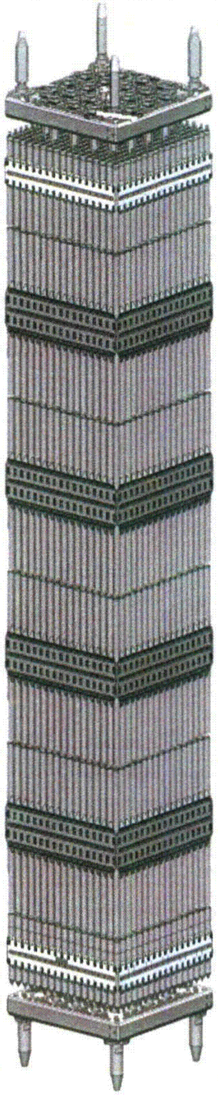
Fuel System Mechanical & Hydraulic Testing



- Extensive mechanical and hydraulic testing being conducted to support fuel system development and licensing
  - Fuel system component-level mechanical tests
  - Fuel assembly mechanical tests

    [

    ]
  - Fuel system hydraulic tests

    [

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Fuel Assembly Component Mechanical Test

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Fuel Assembly Component Mechanical Test

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Fuel Assembly Component Mechanical Test

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Spider Assembly Component Mechanical Test

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Fuel Assembly Mechanical Tests

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Fuel Assembly Mechanical Tests

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Fuel Assembly Mechanical Testing

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Fuel System Hydraulic Testing

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Fuel System Hydraulic Testing

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Fuel System Hydraulic Testing

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Fuel System Hydraulic Testing

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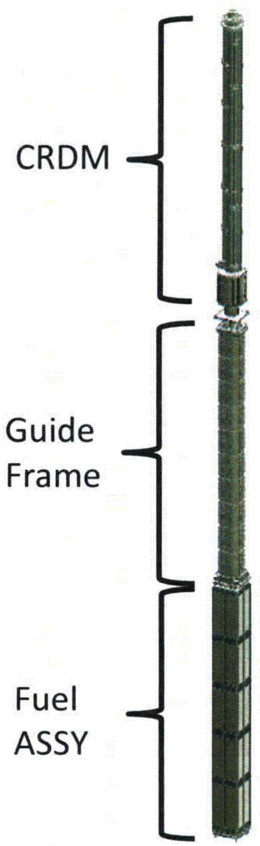

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Cold-flow Test Loop (CFTL)

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Hot-flow Test Loop (HFTL)

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Fuel System Hydraulic Testing

Hot-flow Test Facility (HFTL) Test Program

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Fuel System Performance Validation

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- B&W expects to conduct a significant Post-irradiation Examination (PIE) program [ ] to:
  - Verify performance of the fuel
  - Provide data to generate improved irradiation-dependent material property and performance correlations used as analysis inputs
  - Provide data to validate analysis predictions and benchmark codes (and "tune" codes, if necessary)
- PIE data obtained for fuel assemblies may include:
  - Fuel assembly growth
  - Fuel assembly distortion
  - Shoulder gap between fuel rods and LEF flow plate (rod growth)
  - Water channel at middle of each span (measure of rod bow)
  - Mid grid envelop (grid growth), strap oxide and hydrogen pick-up
  - Guide tube oxide thickness and mechanical properties

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Fuel System Performance Validation

- PIE data obtained for Fuel Rods and BP Rods may include:
  - Rod surface condition (CRUD, oxide character, ridging, etc)
  - Rod length, clad OD profilometry
  - Rod internal pressure, gas release/composition, internal volume
  - Clad oxide thickness, hydrogen content, hydride orientation, inner surface character (fuel-clad interactions, blisters)
  - Clad mechanical properties
  - Pellet diameter, length, density, swelling, open porosity
  - General pellet condition (cracks, microstructure, etc)
  - B^{10} depletion (for BP pellets)
  - Gamma scanning (FR axial BU profile, stack gaps)

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Fuel Technology Center

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Fuel Technology Center Objectives

- Optimize the mPower fuel design for manufacturing
- Develop and qualify the key manufacturing processes
- Fabricate production representative licensing test components and assemblies
- Perform component and assembly testing
- Production ready processes to support mPower deployment

A tremendous opportunity!

Capturing 40 years of experience and lessons learned

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The Facility

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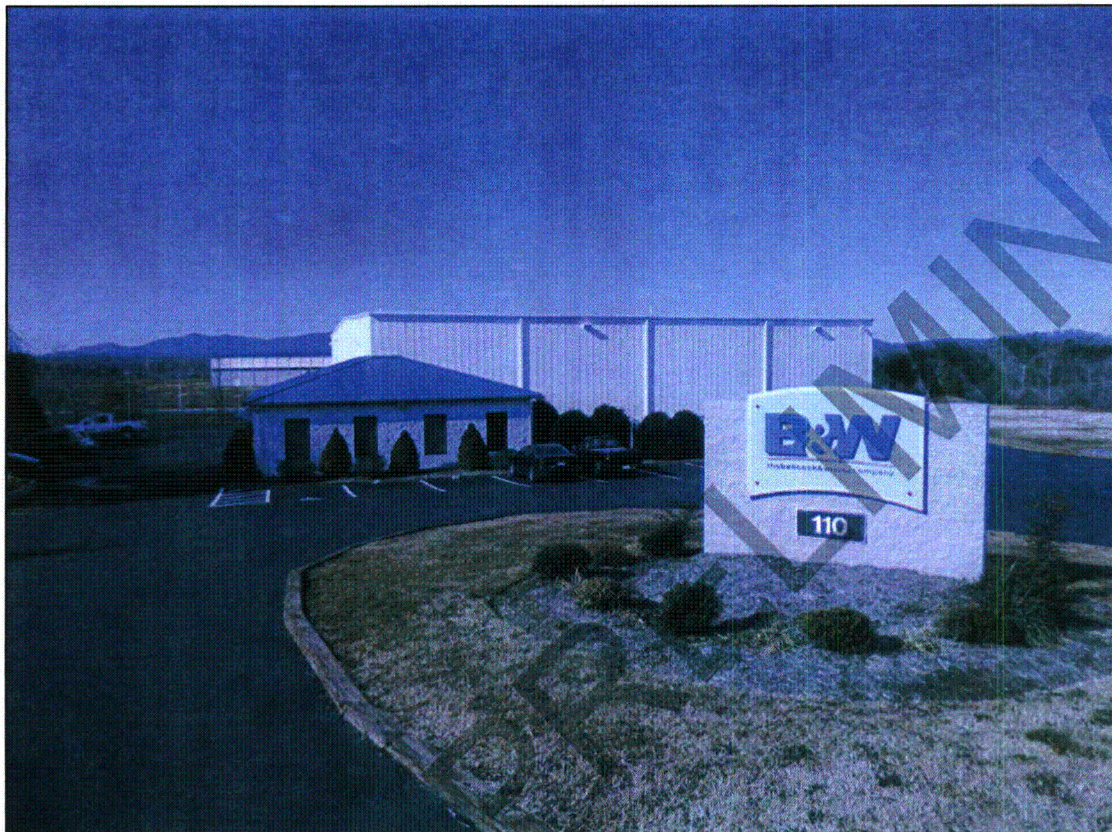

- Located adjacent to the mPower NSSS design office In Lynchburg, VA

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The Initial Projects ....

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Fuel Rod Welding

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The Initial Projects ....

[

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Spacer Grid Welding

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The Initial Projects ....

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Guide Tubes, Cage, and Assembly Fabrication

- Large granite surface tables for guide tube, cage, and fuel assembly fabrication

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The Initial Projects ....

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Fuel Assembly Inspection

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The Initial Projects ....

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Inspection Operations

- Dimensional inspection systems
- Gauges and measurement equipment
- Destructive testing equipment

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Current Status

[ ]

- Focus on long term requirements

- Building our nuclear safety culture from the start
  - Lean six sigma is our culture enabler
- Completing phase 1 capital projects

[ ]

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- Beginning execution of second phase capital and R&D projects

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B&W mPower™ Conclusions and Licensing Schedule

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Agenda

- Key Conclusions
- Overall Licensing/Testing Schedule

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Key Conclusions

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- Fuel Assembly Mechanical Design:
  - The overall fuel mechanical design is very similar to existing fuel used in conventional PWR reactors, other than the overall length
  - The overall fuel design accounts for industry lessons learned and incorporates state-of-the-art design concepts to preclude issues
  - With the lower flow rates and relatively lower T_{hot} operating temperatures, it is not anticipated that the fuel will experience flow induced vibration, fretting, or corrosion issues

- Control Components:
  - The Control Rod Assembly design is similar to existing designs in conventional reactors but also incorporates state-of-the-art design concepts to accommodate the SMR configuration
  - Very conservative assumptions for swelling and gas release have been built into the design of control components
  - The Burnable Poison Rod design is consistent with current industry designs
  - Primary and Secondary Source Assemblies are double encapsulated and consistent with current industry designs

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Key Conclusions (cont.)

- Analysis Code & Methodology:
  - Since the fuel design uses similar materials and design concepts to existing fuel in the industry, the conservative analysis methodology does not introduce challenges to fuel performance
  - Many of the mechanical tests being conducted on the fuel to confirm predicted performance behavior

[ ]

- Fuel Rod Performance Code & Analysis Methodology:
  - The fuel rod design is consistent with existing fuel that is and has been used in the industry
  - The fuel performance code is a recognized industry standard that has been shown to predict well the fuel behavior for existing fuel in the industry from various vendors
  - The fuel performance code will be handled under an Appendix B QA program
  - The fuel performance methodology is consistent with that used in the industry by other vendors

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Key Conclusions (cont.)

- Fuel Assembly Seismic Code & Analysis Methodology:
  - The seismic analysis will use both current industry practices and state-of-the-art methods to assess the seismic and LOCA behavior of the fuel assemblies[ ]
  - Confirmatory testing of the fuel design will be conducted to substantiate the analysis methodology (inclusive of BOL and simulated EOL conditions)

- Fuel System Testing

[ ]

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Overall Licensing/Testing Schedule

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Overall Licensing/Testing Schedule (cont.)

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Enclosure 5
NSSS Design Update
(Redacted)