ASME Code Update & Reactor Vessel and Internals Overview

February 28, 2013

(Redacted Version)

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Agenda

- Objectives
- ASME Code Update
  - Key Design Features Overview
  - Component Design perspective
    - Code cases
  - Systems Design perspective
  - 48 Month Fuel Cycle Impacts on Testing and Inspections
- Reactor Vessel Update
  - Changes to support arrangement
- Reactor Internals Update
  - Core Support
  - Upper Internals
  - CRDM update
- Flow Induced Vibration (FIV) Evaluation and Testing
- Conclusions

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Objectives

- Update the NRC staff on B&W interactions with ASME Committees
- Provide an overview of key changes to the reactor vessel and internals design and testing plans

ASME Code Update

Key Design Features Overview

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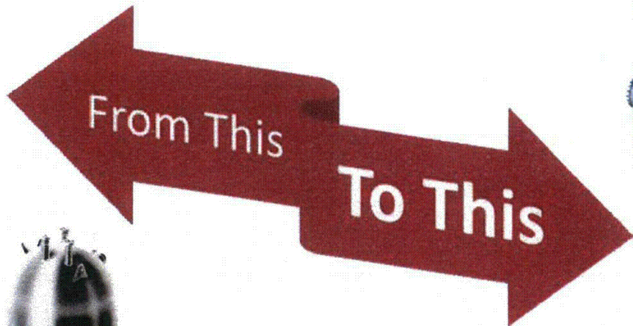
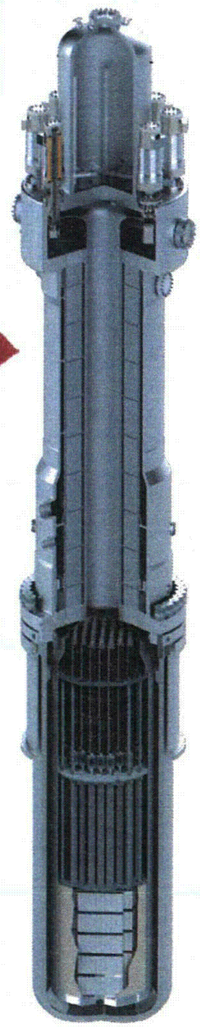
B&W mPower^{TM} Reactor





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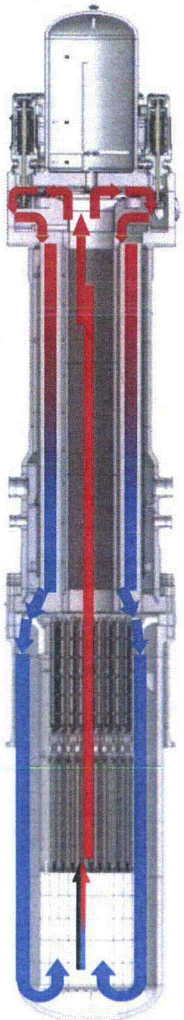
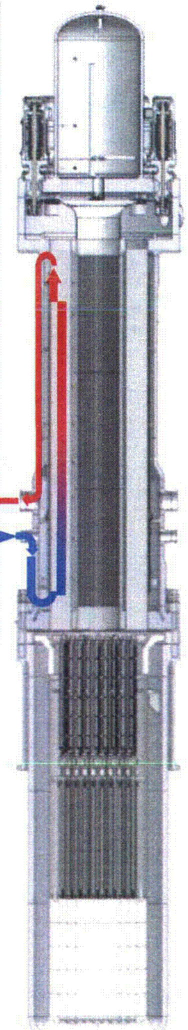
B&W mPower Reactor



Primary Loop



Secondary Loop

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B&W mPower Reactor

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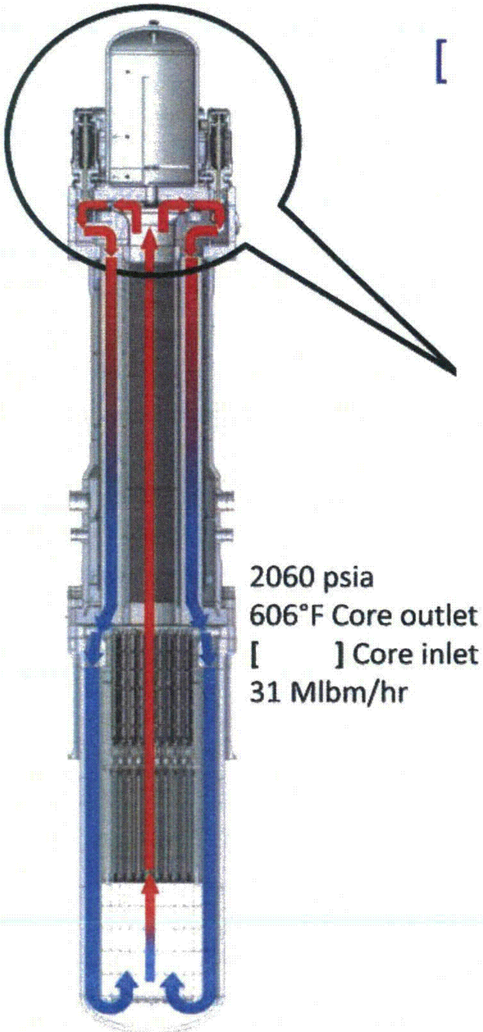
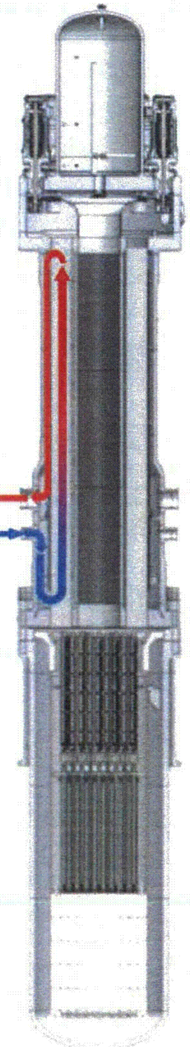


Primary Loop



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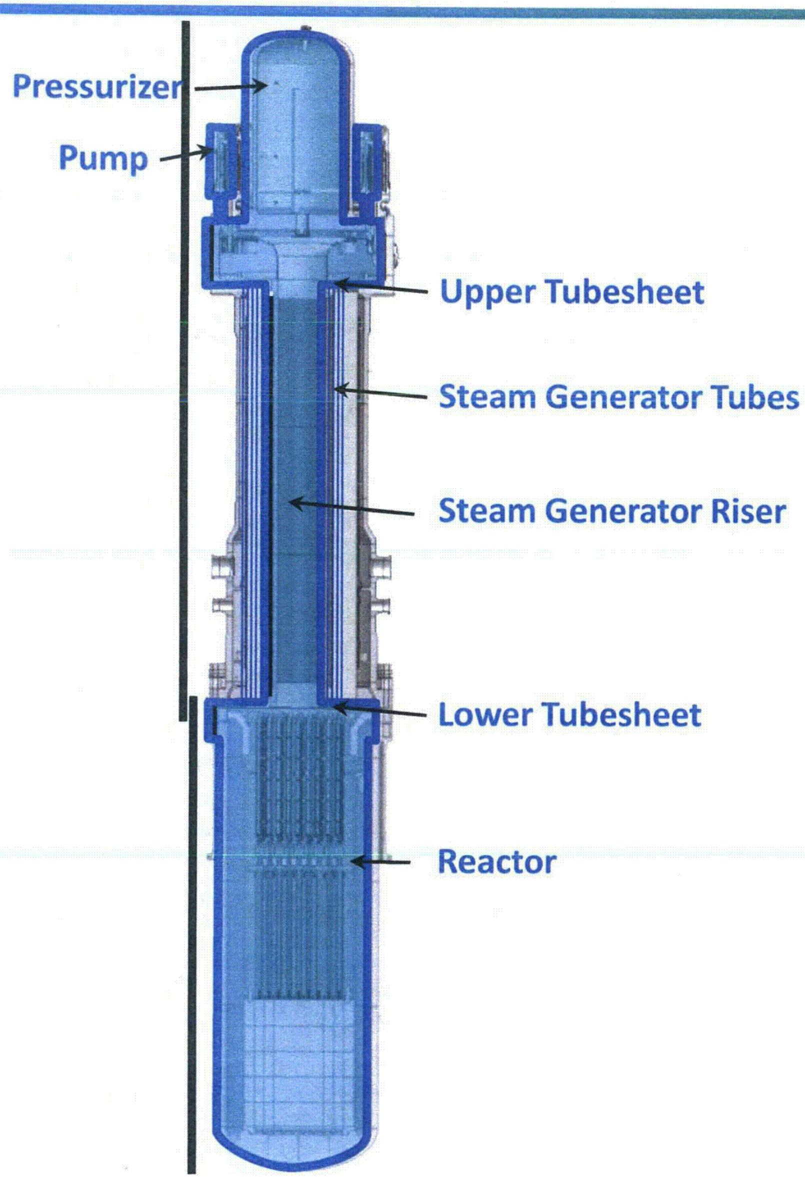
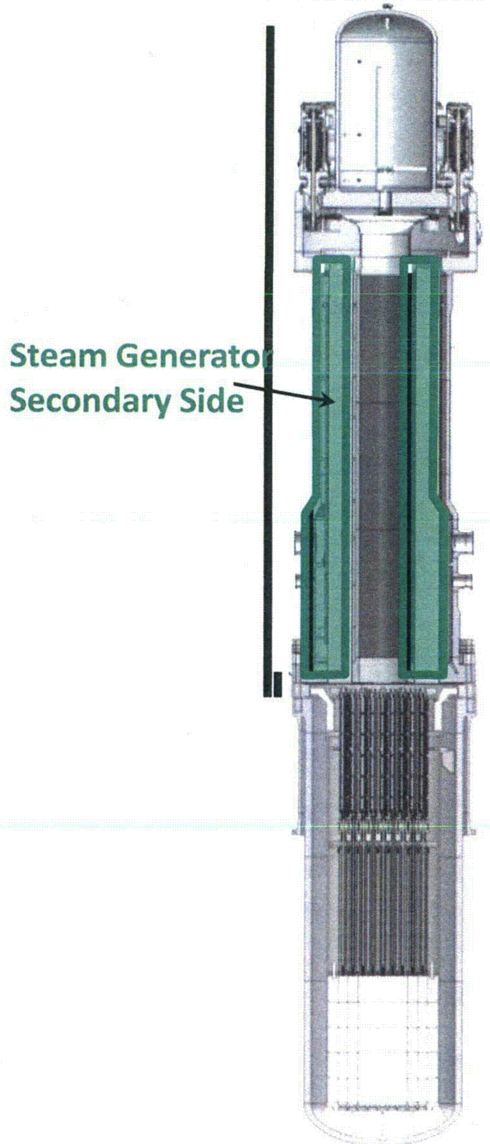
Secondary Loop

Pressure Boundary



Primary



Secondary

Interactions with ASME

- mPower Reactor Overviews for ASME
  - Keep ASME informed of mPower reactor design
- Presentations
  - ASME Executive Committee on Strategy (8/11/11)
  - ASME 2011 SMR Symposium, Plenary Session (9/29/11)
  - ASME Section XI Committee (2/6/12)
  - ANSI-NIST NESCC Meeting (7/17/12)
- ASME Engagement
  - B&W mPower continues to increase participation on ASME Code committees
- Component Code Jurisdiction Established

Interactions with ASME (cont.)

- Anticipated Code Cases
  - Case N-782, Use of Code Editions, Addenda, and Cases Section III, Division 1
- Possible Code Cases
  - Case N-60-5, Material for Core Support Structures Section III, Division 1
  - Case N-62-7 Internal and External Valve Items, Classes 1, 2, and 3 Section III, Division 1
  - Case N-284-2 Metal Containment Shell Buckling Design Methods, Class MC Section III, Division 1
  - Case N-71-18, Additional Materials for Subsection NF, Class 1, 2, 3, and MC Supports Fabricated by Welding Section III, Division I
  - Case N-249-14 Additional Materials for Subsection NF, Class 1, 2, 3, and MC Supports Fabricated Without Welding Section III, Division 1

48 Month Surveillance Cycle

Background

- Regulations, Codes, Technical Specifications, etc. Stipulate a Variety of Periodic Surveillances – for Example:
  - Instrument Calibrations and Channel Checks
  - Condition (Parameter) Verifications
  - Component Operability Tests
  - Weld Examinations
  - Leak Rate Tests
  - System Functional Tests
  - Steam Generator Tube Inspections
- Current Outage Related Surveillance Frequencies Based on Standard 24-Month Fuel Cycle
- B&W mPower Reactor Designed for 48-Month Fuel Cycle

Applicable Requirements

- Technical Specifications
- ASME Section XI
- 10 CFR 50, Appendix J (Containment Leak Rate Testing)
- EPRI (Steam Generator Tube Inspection Guidelines)
- ASME OM Code

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Technical Specifications

- Safety Systems Surveillances
  - Instrument Channel Calibrations
  - Instrument Response Time Testing
  - Instrument Channel Functional Tests
  - Visual Inspections
  - Component Functional Tests
  - System Functional Tests
- Path Forward
  - Some Standard TS 24-Month Intervals ⇒ 48-Months

ASME Section XI

- Additional Surveillances
  - Pressure Boundary Visual and Non-Destructive Examinations
  - Component Support Visual and Non-Destructive Examinations

⇒ Typically @ 100% / 10-Years

- Path Forward
  - DC: Conform to ASME Section XI – perform 10-year ISI at 8- intervals
  - In Parallel:
    - Evaluating risk-informed intervals based on Section XI, Div. 2 in progress
    - Request a code case allowing 12-year intervals

Containment Leak Rate Testing

- Containment Surveillances
  - Appendix J, Option A
    - Type A (Containment Integrated Leak Rate) = 3 / 10-Years
    - Types B & C (Local Leak Rate) = Each Refueling Shutdown, Not to Exceed 2 Years
  - Appendix J, Option B (Via RG 1.163)
    - Type A ≤ 10 Years, Following Two Consecutive Successful Tests
    - Type B ≤ 10 Years, Following Two Consecutive Successful Tests
    - Type C ≤ 5 Years, Following Two Consecutive Successful Tests

- Options
  - Evaluating technical basis for exemption to allow 4 year frequency for Type B and C tests
  - Evaluating feasibility of mid-cycle shutdown to address 2 year frequency for Type B and C tests

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Steam Generator Inspection

- Steam Generator Surveillances
  - Typical TS for Operating Plant Programs Are Based on Inspecting 33% of Tubes Every 24 EFPM or Each Refueling Outage (Whichever Occurs First), such that 100% of Tubes Are Inspected Every 60 EFPM
  - Current EPRI Guidelines for Replacement Steam Generators Require Inspection of 100% of Tubes at First Refueling Outage following SG Replacement (Within 18-24 EFPM of SG Replacement), then 100% of Tubes Sequentially Thereafter at 144, 108, 72 and 60 EFPM
- Path Forward
  - Inspect 100% of tubes each refueling outage (48 months)

ASME OM

- Additional Surveillances
  - Pump and Valve Testing
  - Snubber Testing

⇒ Complex Frequency Specifications

- Options
  - Class 1 Pressurizer Safety Valves (24 month test frequency)
    - Evaluating technical bases for relief request or feasibility of mid cycle shutdown to perform testing
  - Position Indication Testing (24 month test frequency)
    - Evaluating technical bases for on-line testing options
  - Leakage testing of Category A valves, other than containment isolation valves (PIVs)
    - Evaluating technical bases for on-line testing options

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Reactor Vessel Update

B&W mPower Reactor

Design Characteristics	
Reactor Type	PWR
Core Outlet	530 MWt
Reactor Height	[ ]
Reactor Diameter	13ft (At the Flanges)
Reactor Dry Weight	[ ]
Fuel Cycle	4 Years
Design Life	60 Years
RCP Quantity	8
Rail Shippable	Factory built

[ ]

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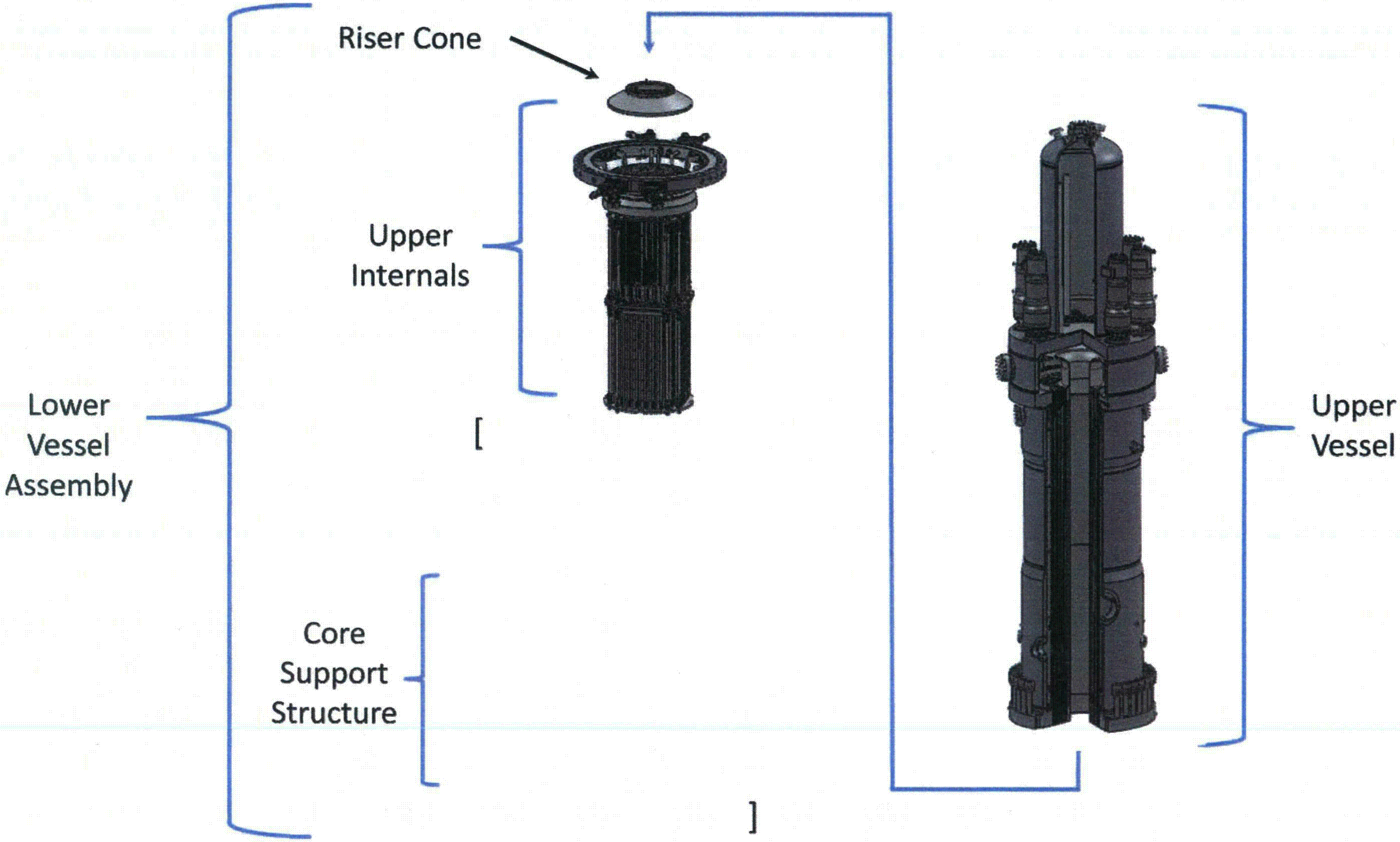
Reactor Component Breakdown



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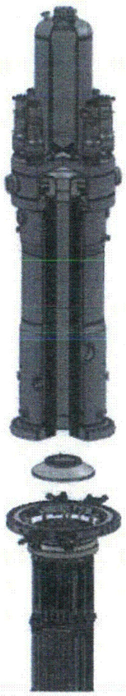
Lower Vessel



Components	Lower Vessel
Height	[ ]
Flange OD	13’
Vessel ID	[ ]
Weight	≈ [ ]
Penetrations	In the flange, well above the core
All Pressure Boundary	[ ]
Core Support Gussets	[ ]

[

]

]

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Lower Reactor Vessel Support

Vessel support arrangement

- Improved ease of fabrication / cost reduction
- Improved ease of installation
- Preferable seismic responses
- Inclusion of additional [ ] enables revised arrangement

Upper Reactor Vessel Support

[

]

Lower Reactor Vessel Support

[

]

Reactor Internals Update

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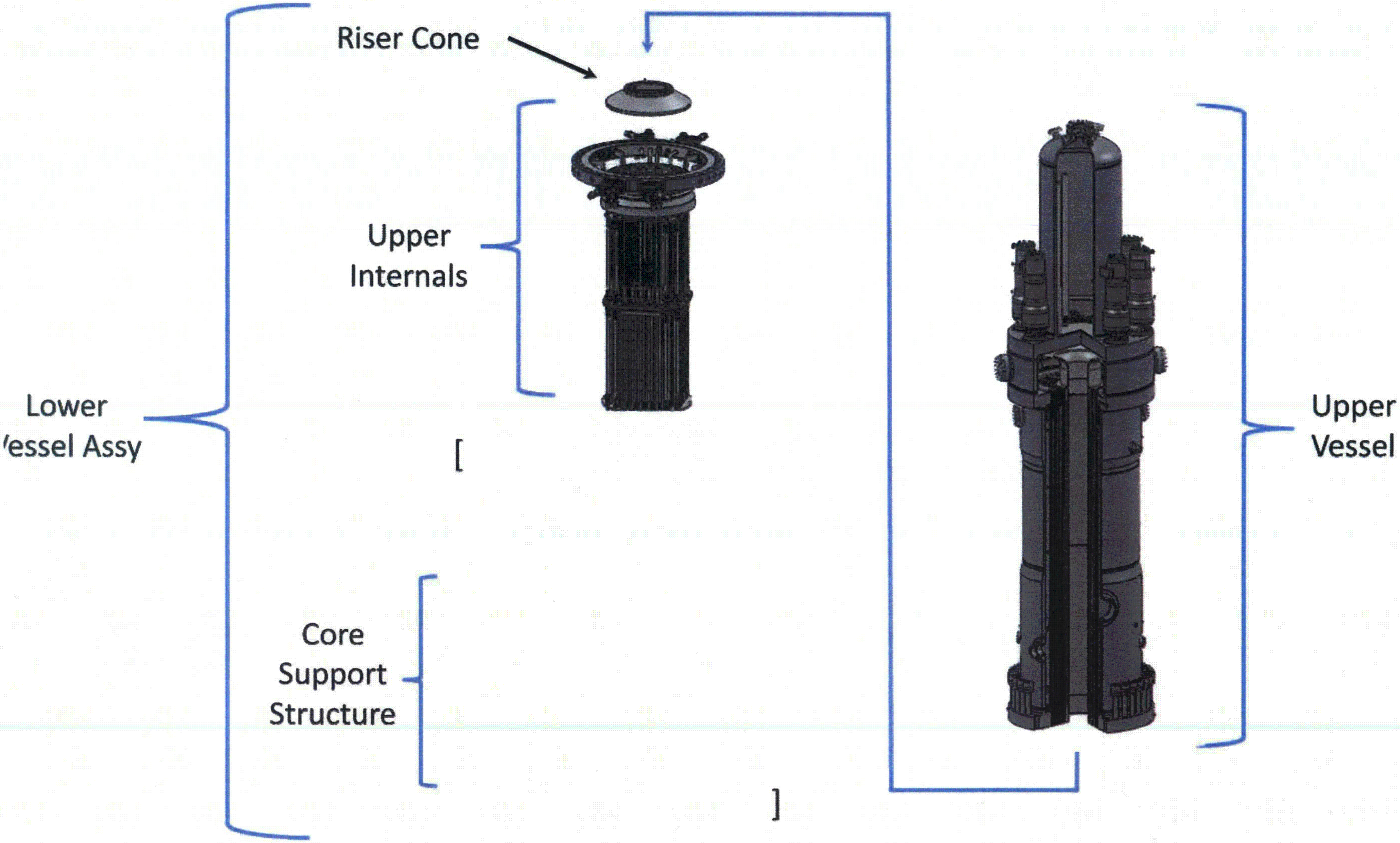
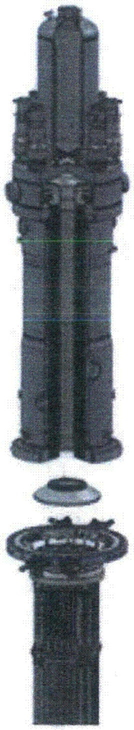
Reactor Component Breakdown



Core Support Structure



Components	Core Basket Core Former
Height	[ ]
Basket Diameter	[ ]
Basket Thickness	[ ]
Basket Material	[ ]
Former Material	[ ]
Weight	[ ]

[

]

]

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In-core Detector Routing

[

• [

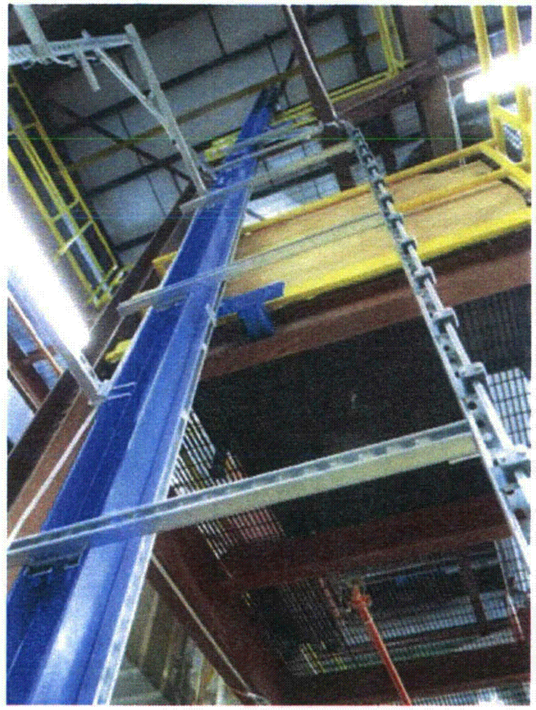
] [

• Insertion testing
  - Proof of concept

]]

In-core Detector Testing

Test Objectives	• [
Equipment	
Test Conditions	
Testing	]



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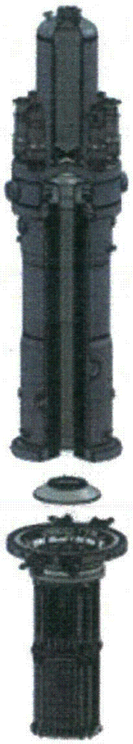
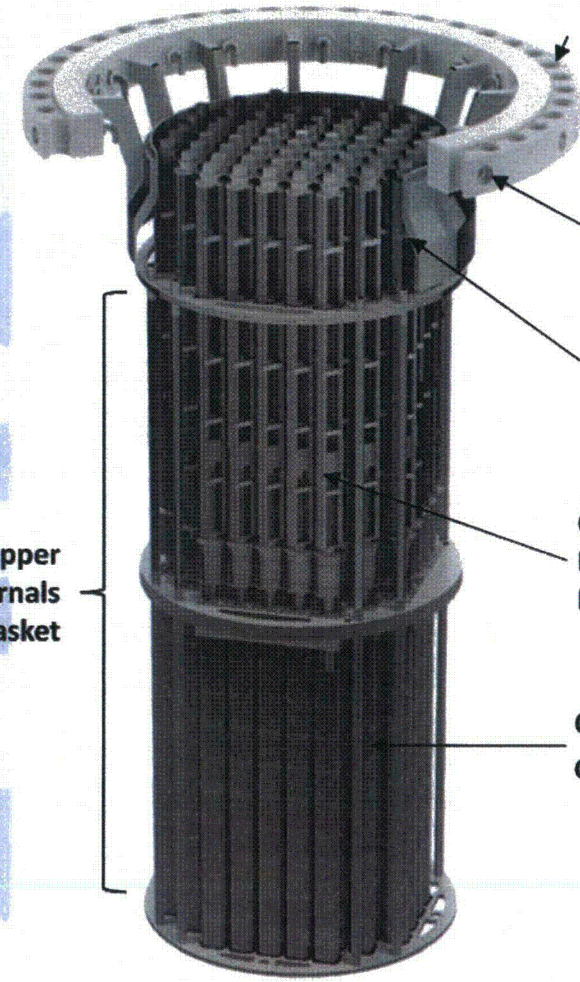
mPower Upper Internals



Components	Mid flange UI basket CRDMs Guide frames
Penetrations	[ ]
Height	[ ]
Flange OD	13'
Flange Height	[ ]
Flange Material	[ ]
Upper Internals Basket Material	[ ]
Upper Internals Weight	≈ [ ]



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Control Rod Drive Mechanism Update

- [ ] Control Rod Drive Mechanism
  - 69 internal CRDMs, [ ] inches of stroke
- [ ] latching mechanism
- High temperature motor
  - [ ]
- Lead screw [ ]

[

]

Overall Mechanism

Fully Inserted

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Overall Mechanism

Fully Withdrawn

]

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Latching System

Fully Inserted - Disengaged

Cutaway Broken View

[

Latching System

Fully Engaged

]

Latching System

Fully Withdrawn

Latching System

Fully Scrammed

CRDM Program Status

- [

]

CRDM Testing

[

]

CRDM Testing

[

]

CRDM Testing

[

]

Flow Induced Vibration (FIV) Evaluation and Testing

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FIV Evaluation and Testing

FIV Evaluation and Testing Approach

- Conform to RG 1.20
- Design with FIV in mind
- Analytical evaluation
  - CFD prediction of velocity distribution
  - B&W FIV codes
  - Commercial structural codes + manual calculations
- Test Program
  - Test at increasingly prototypical conditions
  - Vessel model flow tests
  - FOAK reactor instrumentation
- Comprehensive program document is being written
- Generally, FIV is less an issue in mPower because of lower coolant velocities
- Plan to engage industry FIV experts

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FIV Related Testing

- Integral Control Rod Drive Line (ICRDL)
  - Increasingly prototypical test conditions
- Vessel model flow tests
  - [ ]
  - Primarily to validate CFD predictions
- FOAK Reactor Instrumentation
  - Accelerometers, strain gauges, etc. installed in first reactor for hot functional testing
  - [ ]

ICRDL Test Program

[

- Test program includes
  - [

]

- Components include
  - [

]

]

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ICRDL Test Program

Static Test Facility (STF)

- Largely used for scoping tests
- Test data may be used for safety analyses
- Multiple design iterations tested quickly

→

Cold Flow Test Loop (CFTL)

- May be used for scoping tests
- Largely used for safety-related tests
- Test data used to benchmark safety analyses
- Meant for proven designs

(first occurrence of ICRDL being brought together)

→

Hot Test Facilities

HFTL

- Used for safety related tests
- Test data used to validate safety analyses
- Used for life & wear tests
- Meant to validate proven designs

Autoclave 3

- Used for safety related tests
- Used for life & wear tests
- Meant to validate proven designs

Static Test Facility

[

Location	Lynchburg, VA
Material	[
Design Conditions	
Capabilities	
Components Accommodated	
Testing	]

]

Cold Flow Test Loop (CFTL)

[

Location	BWRC / Barberton, OH
Material	[
Design Conditions	
Capabilities	
Components Accommodated	
Online	
Testing	]

]

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Autoclave 3 Test Facility

Location	NOG - E / Euclid, OH
	Autoclave 3
Design Conditions	[
Capabilities	
Components Accommodated	
Online	
Testing	]

[

]

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Hot Flow Test Loop (HFTL)

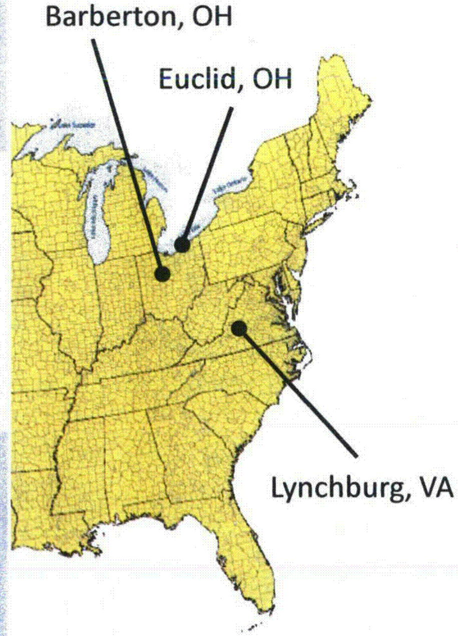
Location	TBD
	HFTL
Design Conditions	[
Capabilities	
Components Accommodated	
Online	
Testing	]

[

]

Component Test Locations

Location	Testing
Barberton, OH • Cold Flow Test Loop • Small autoclaves • Vessel Model Flow • Hot Flow Test Loop (tentative)	• Penetrations / Connectors • ICRDL Test Program • Fuel assembly hydraulic testing • In-core insertion testing
Euclid, OH • Large autoclaves (Air & Hot Tests)	• CRDM Motor and Latch • ICRDL Test Program • ICRDL life & wear testing • Fuel assembly life & wear testing
Lynchburg, VA • Static Test Facility • Fuel Assembly mechanical test system • Instron & Fixtures • CAER - Integrated System Testing (IST)	• ICRDL Test Program • Fuel assembly and component mechanical testing • Integrated Systems • Operational simulations



Vessel Model Flow Test (VMFT) Program

Test Program	Objective	Status	Possible Location(s)
Lower Vessel Model Flow Test Program	• [ ]	Initial Planning Stage	Barberton Research Center or Vendor
Upper Vessel Model Flow Test Program	• [ ]	Initial Planning Stage	Barberton Research Center or Vendor

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B&W VMFT History

- B&W 177 and 205 VMFT facilities existed at the Alliance Research Center
- 1/6th geometrically scaled model of the B&W 177 and 205 PWRs
- 2-2,000 GPM pumps used giving a total flow capacity of 4,000 GPM @ a total head of 350 feet
- Extensive testing conducted: Gross Flow Distribution, Pressure Drop, FIV, Gross Mixing of Fluid Entering Core, Vent Valve Closing Forces
- Testing started ~1968 and ended ~1980
- Unit decommissioned after the B&W 205 program ended

Figure 1-7. Cross Section of One-Sixth-Scale Model Final Design — Vessel Pressure Drop Taps

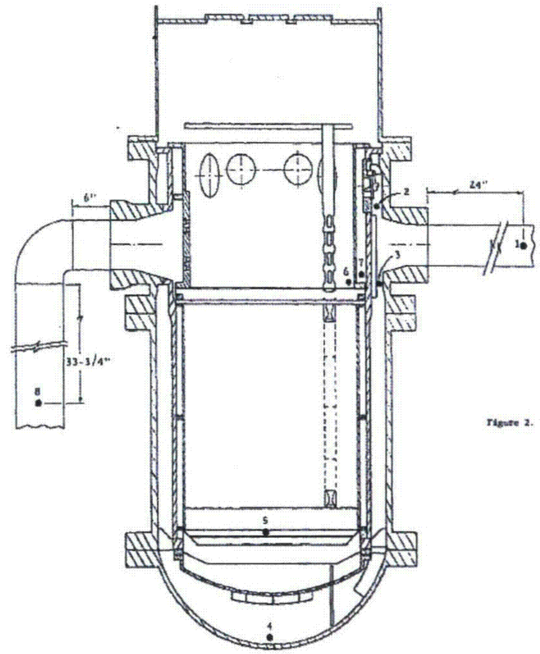
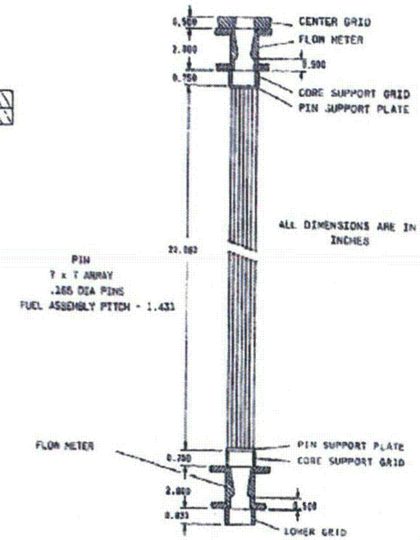
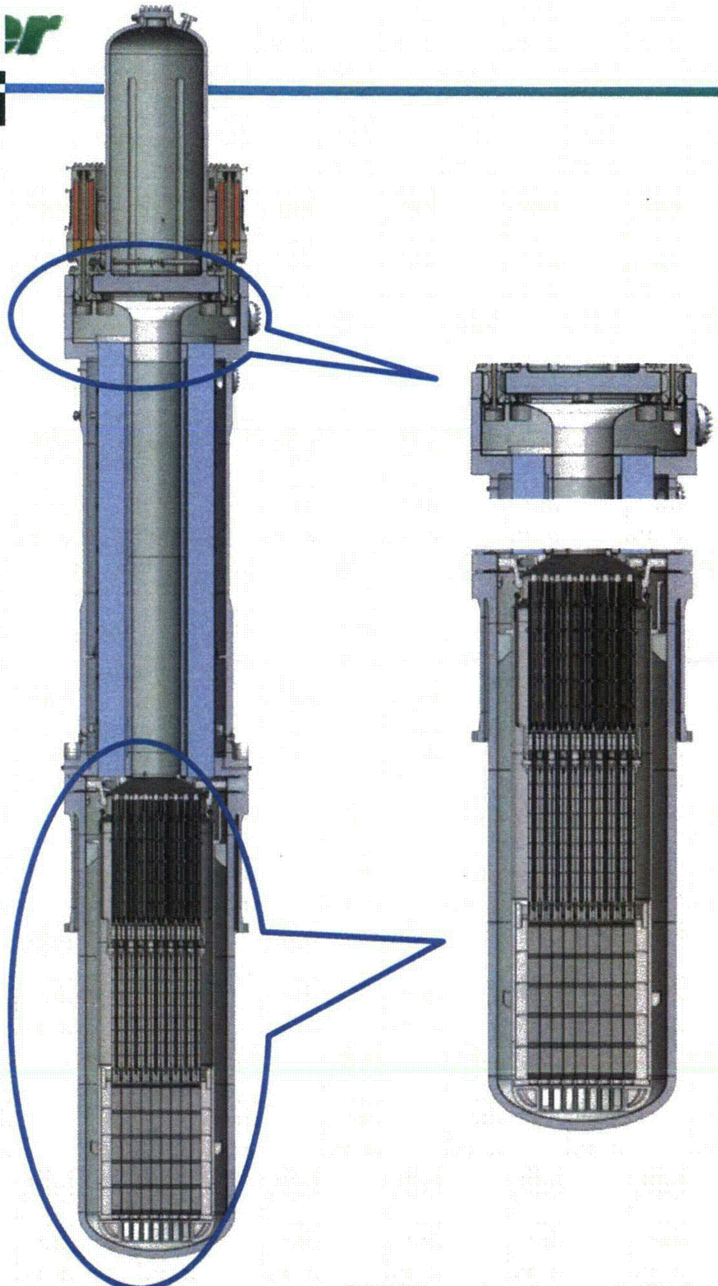


Figure 2. Schematic Drawing of Modeled Fuel Assembly



VMFT Focus Areas



Pump Plenum Area

- First of a Kind Design
- Verification of Computational Fluid Dynamic (CFD) model flow characteristics
- Verification of anticipated pressure drops in the area
- Instrumentation type and location in vessel

Lower Vessel Assembly

- First of a Kind Design
- Verification of Computational Fluid Dynamic (CFD) model flow characteristics.
- Verification of anticipated pressure drops in the area
- Identification of areas of interest in regards to Flow Induced Vibrations (FIV)
- Instrumentation type and location in vessel

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Conclusions

- B&W ASME Interfaces Active and Focused
- Vessel and Internals Design Progress Progressing as Planned
- Key Testing has been Identified, Prioritized and Plans are Active