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Recent Materials Inspections of PWR Reactor Internals

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NRC RIC Meeting
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Topics

- Quick Overview of MRP-227-A Inspections Approach
- Reactor Internals Inspection Results to Date
- Observations

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Basic Approach of Guidelines

- Combine detection of aging effects with focus on safety function
- Credit and coordinate with existing ASME Code inspections
- Manage less active mechanisms by sampling, expand to additional scope based on results
- Make the inspection consistent with component and its safety function

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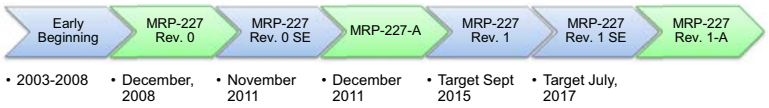
Basic Approach of Guidelines

- Convey most requirements via simple tables
- Ensure guideline is generally applicable to all PWRs
- Needed and Mandatory requirements applicable to all US PWRs through NEI 03-08 initiative
- Make the guideline a living document through reporting of results, review and update process
- Engineering evaluation of relevant conditions guided by companion document, WCAP-17096, developed by PWROG

Development and Evolution of MRP-227



- Four major stakeholders influenced development under NEI 03-08
  - Owners, NRC, EPRI, NSSS Vendors
- Extensive interaction among stakeholders during development
- Implementation began in 2009 and continues each outage season
- Results to date show no unexpected issues
- ***MRP-227 continues as a living document***

B&W MRP-227-A RV Internals Primary Scope

- Lower Core Barrel Bolts (UT)
- Baffle-to-Former Bolts (UT)
- Flow Distributor Bolts (UT)
- Plenum Cover Weldment Rib Pads Support Flange and Core Support Shield Top Flange (VT3)
- Core Support Shield Vent Valve Top & Bottom Retaining Rings (VT-3)
- Upper Core Barrel Bolt Locking Devices/Welds (VT-3)
- Lower Core Barrel Bolt Locking Devices/Welds (VT-3)
- Baffle Plates (VT-3)
- Baffle-to-Former Bolt Locking Devices/Welds (VT-3)
- Internal Baffle-to-Baffle Bolt Locking Devices/Welds (VT-3)
- Flow Distributor Bolt Locking Devices (VT-3)
- Alloy X-750 Dowel-to-Guide Block Welds (VT-3)
- Incore Monitoring Guide Tube Spiders & Lower Grid Rib Welds (VT-3)
- Control Rod Guide Tube Spacer Castings and Cap Screws (VT-3)

CE MRP-227-A RV Internals Primary Scope

- Core Shroud Bolts (Bolted Design) (UT)
- Core Shroud Plate-Former Plate (Welded Design) (EVT-1)
- Welded Shroud Plates (Full Height Design) (EVT-1)
- Core Shroud Assembly [Bolted (VT-3); Welded (VT-1)]
- Core Barrel Upper Flange Weld (EVT-1)
- Core Barrel Lower Cylinder Girth Welds (EVT-1)
- Core Support Column Welds (VT-3)
- Core Barrel Lower Flange (TLAA or EVT-1)
- Core Support Plate (TLAA or EVT-1)
- Fuel Alignment Plate (Full Height Design) (TLAA or EVT-1)
- Instrument Guide Tubes (in CEA Shroud Design) (VT-3)
- Lower Structure Beams (Full Height Design) (EVT-1)

Westinghouse MR-227-A Primary Scope

- Control Rod Guide Card wear inspections (VT-3)
- Lower Control Rod Guide Tube (CRGT) Lower Flange welds (EVT-1)
- Baffle Former Bolts (UT)
- Baffle Former Assembly (including seams) (VT-3)
- Baffle Former Edge Bolts (VT-3)
- Upper Core Barrel Flange to Shell Weld (EVT-1)
- Lower Core Barrel Flange Weld (EVT-1)
- Thermal Shield Flexures (VT-3)
- Core Barrel Cylinder Girth Welds (EVT-1)
- Internals Hold-Down Spring (if applicable material type) (measurement)

Examples of Inspected Components

W Lower CRGT Flange Welds

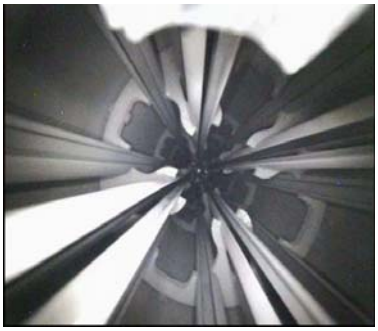
Thermal Shield Flexures (VT-3)

VT-3/Measurement W Control Rod Guide Cards

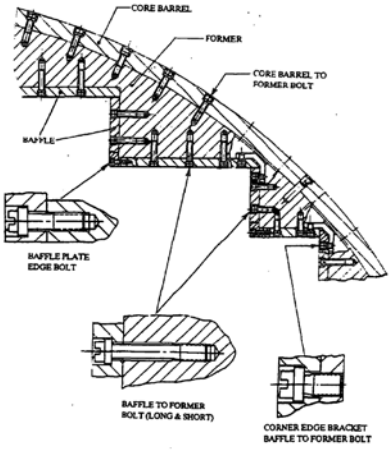
Acceptable

Observed Wear

VT-3 of B&W Control Rod Guide Tube (CRGT) Spacer Castings and Cap Screws

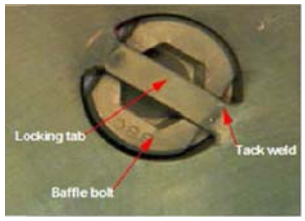


Baffle-Former Assembly Bolts

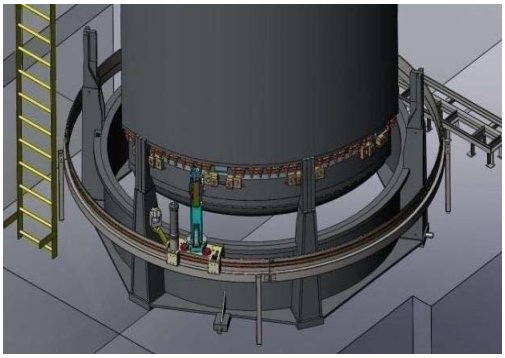


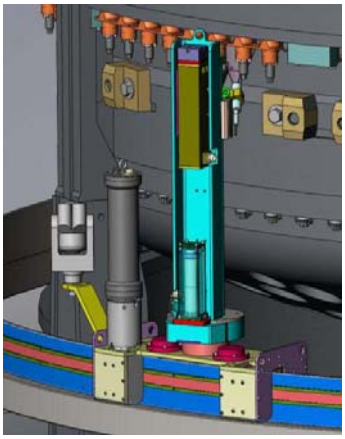
External Hex

Internal Hex

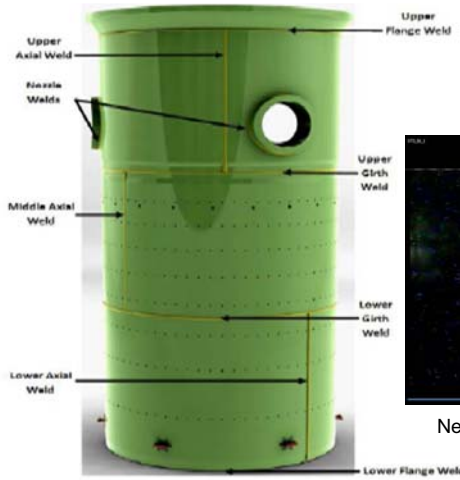


B&W Lower Barrel and Flow Distributor Bolts



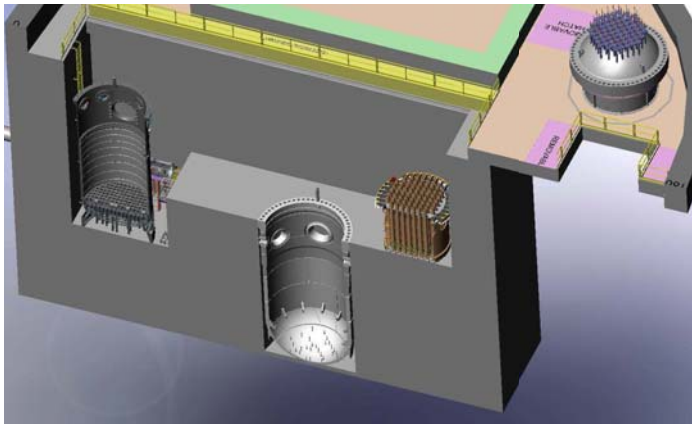


Core Barrel Welds



Neutron Panel and lower girth weld

Inspection Implementation



Inspection Implementation

- Some inspections best performed with core barrel in vessel
- Others require core barrel removal
- Common to split inspections over two or more outages
- Typically integrated with ASME Section XI exams
- Special tooling often required
- Vendor crew of roughly 20 specialists required 24/7
- Vendor crew typically experienced on both PWRs and BWRs
- Owner oversight

Inspection Results

Inspections by Plant Design – as of Fall 2014

Design	Initial Ops	Bfl Blts	CB Bolts	CRGT Spc	BMI Spdr	
BW	1973	2012F	2012F	2012F	2012F	
BW	1973	2013S	2013S	2013S	2013S	
BW	1974	2014S	2014S	2014S	2014S	
3 of 6 total						
		Bfl Blts	CRGT Wld	CB Wlds	Gd Cards	LCS
CE	1971		2014S	2014S	2014S	2014S
1 of 12 total		Bfl Blts	CRGT Wld	CB Wlds	Gd Cards	
W2	1969	2011S	2011S	2011S	2011S	
W2	1970	2013S	2013S	2013S	2013S	
W2	1973	2014S	2014S		2014S	
W2	1974	2014F		2014F		
W2	1974	2013F				
W3	1970	2013F		2013F	2012S	
W3	1972	2010F	2012S	2013F	2012S	
W3	1972			2014S		
W3	1973	2011S	2012S	2014S	2012S	
W3	1973			2014F		
11 of 48 total						

Results to Date

- Initial full inspections at W and B&W and partial CE NSSS designs have not identified any major issues of concern
- Current results reduce uncertainty in mechanism activity
- Issues of greatest concern not seen
  - SCC of austenitic welded components not observed
    - Cracking currently limited to high strength bolting
  - IASCC of welds not observed, indications limited to bolts
  - Macroscopic effect of void swelling not observed

By the Numbers*

- 15 units begun or completed MRP inspections
- 959 W guide tube flange welds inspected
- 2427 inches of irradiated welds inspected (approx.)
- 9125 inches of non-irradiated welds inspected (approx.)
- 2226 CASS items inspected
- 8887 baffle bolts UT inspected**
- 1654 B&W high strength bolts UT inspected**
- 108 B&W baffle plates inspected

* All numbers approximate. Includes reported inspections through Fall 2014; some data includes retired plant; additional data may affect results slightly

** Includes retired unit

By the Numbers*

- Zero Guide Tube Flange weld indications
- Zero irradiated girth weld indications
- One non-irradiated weld indication
- One CASS VT-3 indication
- 136 baffle bolt indications (1.5% of total)
- 20 B&W high strength bolt indications (1.2% of total)

* All numbers approximate. Includes reported inspections through Fall 2014 ; additional data may affect results slightly

Trends and Observations

- Almost no observed austenitic SS stress corrosion cracking (one indication reported)
- Irradiation Assisted SCC is extremely limited
  - Currently limited to bolts
  - Explained in part by irradiation stress relaxation
  - High barrier to initiation in PWR environment
  - Compared to other plant designs, major benefit from coolant chemistry

Trends and Observations

- No macroscopic effects of void swelling
  - No distortions, cracking, or excessive bolting failure
- High-strength nickel alloy clevis insert bolting failures
  - However, not in safety function load path
- Guide card wear will require monitoring
  - MRP Interim guidance MRP-2014-006 issued

Trends and Observations

- Sampling approach to inspections very successful
  - Spectrum of plant designs, materials, heats
  - Transition to more focused sampling for guide cards
- Efficiency could be increased, and is being pursued
- Integrated fleet management strategies are possible

MRP-227-A Experience Summary

- Exam results show few instances of service-induced degradation flaws, as expected
- Overall uncertainty in aging mechanism activity reduced
- Implementation by owners is thorough, but exams are difficult, as well as resource and dose intensive
- Some adjustments and efficiencies are needed, as expected with a ‘living’ program
- Lessons learned incorporated into MRP-227 Rev. 1

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