

# Industry Plans to Address Core Barrel Operating Experience



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# RAI 29 – Impact of Recent Core Barrel OE

## NRC RAI 29

*During the 2018 Materials Information Exchange Meeting, the EPRI MRP reported that, during the spring 2018 outage, a domestic Combustion Engineering (CE) plant identified cracks on the outer diameter (OD) surface of the core barrel in the belt-line elevation using enhanced visual (EVT-1) examination (ML18142A394). EPRI indicated that one crack-like indication was found in base-metal adjacent to the middle-girth weld, which is a primary component in MRP-227-A (ML120170453), and that several crack-like indications were found in base-metal adjacent to the middle-axial weld, which is an expansion component in MRP-227-A. EPRI stated that industry established joint EPRI/PWROG Focus Group similar to Baffle-Former-Bolt Focus Group that was established in 2016, with the intent to provide generic assessment of impact of OE to industry.*

*Describe how this operating experience will be addressed in MRP-227, Rev.1.*

# Current MRP-227, Revision 1 Primary Requirements (Including RAI Response Changes)

Primary Item	Applicability	Effect (Mechanism)	Expansion Link	Examination Method / Frequency	Examination Coverage
<b>W3.Core Barrel Assembly</b> Upper flange Weld (UFW)	All plants	Cracking (SCC)	UGW, LFW, UAW, and lower support forging or casting	Enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	A minimum of 25% of one side of the circumference of the surface of the UFW and adjacent base metal shall be examined. (Notes 8, 10, 11)
<b>W4.Core Barrel Assembly</b> Lower girth weld (LGW)	All plants	Cracking (SCC, IASCC), Aging Management (IE)	UCP, Lower support column bodies (cast, non-cast), MAW, LAW	Enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	A minimum of 25% of the OD circumference of the LGW and adjacent base metal shall be examined. This 25% sample must include the accessible portion of the weld OD with the highest accumulated neutron fluence. (Notes 8, 10, 11)

8. Examination coverage requires 25% of the circumference of either the ID or the OD of the weld.

10. The stated coverage requirement is the minimum if no significant indications are found. However the Examination Acceptance criteria in Section 5 require that additional coverage must be achieved in the same outage if significant flaws are found. This contingency should be considered for inspection planning purposes.

11. Inspections subsequent to the first 25% sampling inspection must cover weld length that was not inspected during previous examinations. A minimum of 20% out of the 25% inspection coverage of each subsequent inspection must include previously un-inspected weld length as possible within the limitation of the remaining accessible un-inspected weld.

# Current MRP-227, Revision 1 Primary Requirements (Including RAI Response Changes)

Primary Item	Applicability	Effect (Mechanism)	Expansion Link	Examination Method / Frequency	Examination Coverage
<b>C5.Core Support Barrel Assembly</b> Upper flange weld (UFW)	All plants	Cracking (SCC)	UGW LGW/LFW UAW lower core support beams	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	A minimum of 25% of the circumference of the UFW and adjacent base metal shall be examined. (Notes 5, 6, and 7)
<b>C6.Core Support Barrel Assembly</b> Middle Girth Weld (MGW)	All plants	Cracking (SCC, IASCC), Aging Management (IE)	MAW LAW	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	A minimum of 25% of the OD circumference of the MGW and adjacent base metal shall be examined. This 25% sample must include the accessible portion of the weld OD with the highest accumulated neutron fluence. (Notes 5, 6, and 7)

5. Examination coverage requires a minimum of 25% of the circumference of either the ID or the OD of the weld.
6. The stated coverage requirement is the minimum if no significant indications are found. However the Examination Acceptance criteria in Section 5 require that additional coverage must be achieved in the same outage if significant flaws are found. This contingency should be considered for inspection planning purposes.
7. Inspections subsequent to the first 25% sampling inspection must cover weld length that was not inspected during previous examinations. A minimum of 20% out of the 25% inspection coverage of each subsequent inspection must include previously un-inspected weld length as possible within the limitation of the remaining accessible un-inspected weld.

# Notes on Current MRP-227, Revision 1 Requirements

- Changes proposed in response to RAI 5 were included
  - Addition of Notes (7 for CE and 11 for WEC) on selection of inspection sample
  - Focus of LGW inspection on accessible high fluence areas
  - Transmitted in response to RAI 5 on 1/30/2018 (ML18038A875)
- Expansion welds require higher coverage levels (minimum of 75%) due to presence of active degradation mechanism

# Summary of Technical Basis Previously Presented

- Reduced examination scope and coverage (RAI 5)
  - Sampling strategy employed by MRP-227, Revision 1
  - Statistical evaluation of previous inspection results
  - Probabilistic evaluation of likelihood to detect a flaw
  - Expected physical distribution of degradation susceptibility
  - Functionality evaluation of the impacts of catastrophic barrel failure
  - Industry response to relevant conditions that are detected
- Revised Primary and Expansion components (RAI 26)
  - Improved weld nomenclature
  - Relative degradation levels expected between Primary and Expansion (due to stress, location, etc.)

# Summary of Spring 2018 OE

- Domestic CE plant identified cracks on OD surface of core support barrel
  - Detected through MRP-227-A EVT-1 inspection
  - Located in the core belt-line elevation
    - One indication in base metal adjacent to MGW (Primary component)
    - Multiple indications in base-metal adjacent to MAW (Expansion component)
    - Indications were perpendicular to the weld, and appear similar to “off-axis cracking” previously identified in BWR units
  - Notified the industry and NRC during refueling outage
- Utility elected to perform supplemental inspections
  - Performed EVT-1 and UT inspections, consistent with BWR guidance
  - Provided further characterization of indications and extent of condition
  - Confirmed that none of the indications were through-wall
- Engineering analysis performed using WCAP-17096-NP-A method
  - Station identifying and planning utility-specific actions for fall 2019

# Industry Response to Spring 2018 OE

- Established joint MRP/PWR Owners Group Focus Group
  - Similar to Baffle-Former Bolt FG that was established in 2016
  - Intent is to provide generic assessment of impact of OE to industry
- Developed focus areas and timeline for interim guidance
  - Focus areas: extent of condition, causal evaluations, inspections/NDE, OE evaluation, interim guidance, MRP-227 updates
  - OE notification letter issued by EPRI MRP 2018-028, dated 8/9/2018
  - Interim guidance planned for first quarter 2019
- EPRI-MRP and PWROG projects to support industry
  - Prepare interim guidance including technical basis for the guidance
  - Investigation of potential factors causing the cracking



# Plans for Core Barrel Interim Guidance

- Project will address areas necessary for IG development
  - Inspection type
  - Inspection coverage
  - Timing of initial and subsequent inspections
  - Expansion requirements and links
- Examples of items that may be considered
  - Extend allowable inspection methods to include eddy current and/or ultrasonic examination for inspection credit in MRP-227
  - Revise amount of base metal to inspect
  - Revise Expansion trigger (length of indication)
  - Revise which welds are Primary and Expansion
  - Continue to limit coverage to one surface of the weld
    - ID surface behind baffle-assembly is inaccessible

# Impact of Spring 2018 OE on Previous Basis

Previous Technical Basis	Impact of OE
<b>Reduced examination coverage (RAI 5)</b>	
Sampling strategy employed by MRP-227, Revision 1	Sampling strategy still applicable, but OE impacts sample size needed
Statistical evaluation of previous inspection results	Case with relevant inspection results impacts statistical argument based on sample size
Probabilistic evaluation of likelihood to detect a flaw	Sampling strategy still applicable, but OE impacts sample size needed
Expected physical distribution of degradation susceptibility	Initial look at results consistent with previous argument (OD, highest dose, distributed)
Functionality evaluation of the impacts of catastrophic barrel failure	Not impacted by the OE
Industry response to relevant conditions that are detected	Not impacted by the OE (and even demonstrates the expected response)
<b>Revised Primary and Expansion components (RAI 26)</b>	
Improved weld nomenclature	Not impacted by OE
Relative degradation levels expected between Primary and Expansion	Location of indications not completely consistent with expected behavior (MAW)

# Proposed Actions for MRP-227, Revision 1 SE

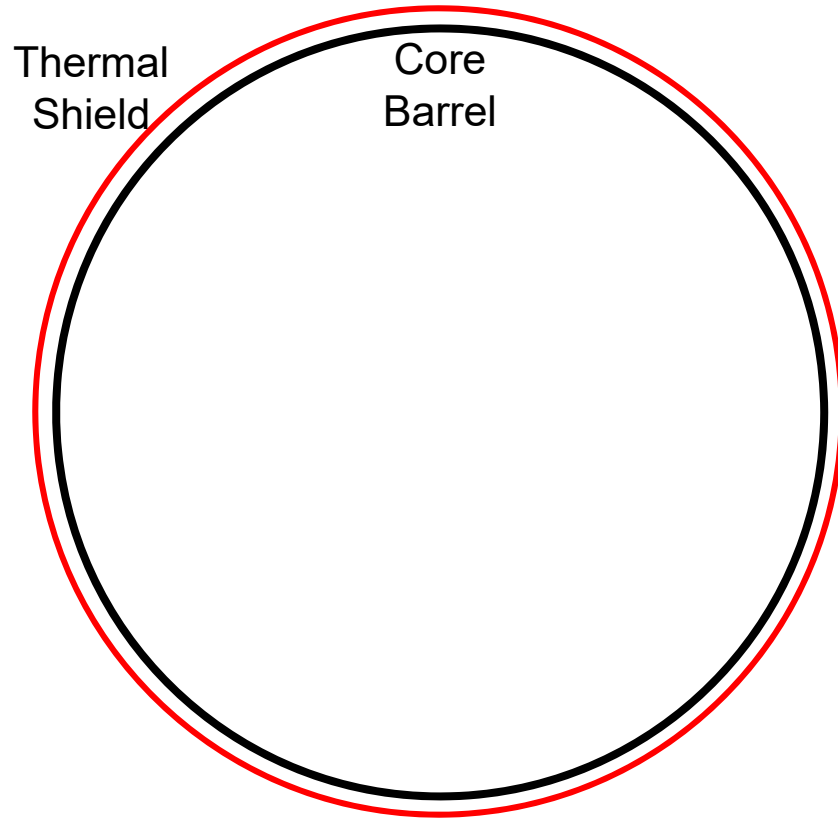
- Keep current MRP-227, Rev. 1 core barrel Primary and Expansion components
- Increase Primary component coverage levels
  - Clarify minimum requirement of 50% rather than 75% is due to the access restrictions of neutron panel plants
  - Access restrictions/difficulties for neutron panel plants and thermal shield plants make it difficult to achieve higher coverage of lower girth welds

# Industry Concerns about Barrel Weld Coverage

- Greater than ~50% coverage of lower barrel welds will require disassembly for neutron panel plants
  - Baffle-former assembly or core shroud completely covers ID
  - Neutron panels cover 40-50 percent of barrel OD (bolted on, no gap)
    - Not all the panels are the same size (plant-specific)
  - Thermal shields also limit OD accessibility and increase difficulty
- Basic assumption in MRP-227 development was component disassembly should be avoided unless absolutely warranted
  - RAI 4-8 on MRP-227, Rev. 0 (MRP 2010-066, ML103160381)
  - Driver should be a safety need
- Disassembly carries serious risks:
  - Personnel safety and dose during disassembly, inspection, and re-assembly (ALARA)
  - Mechanical disassembly and reassembly would have to be performed remotely
  - Potential for damage to the assembly sections
  - Potential for loose parts and debris
  - Inability to re-weld structures
  - Potential need to modify the internals' design (due to accommodating the above)

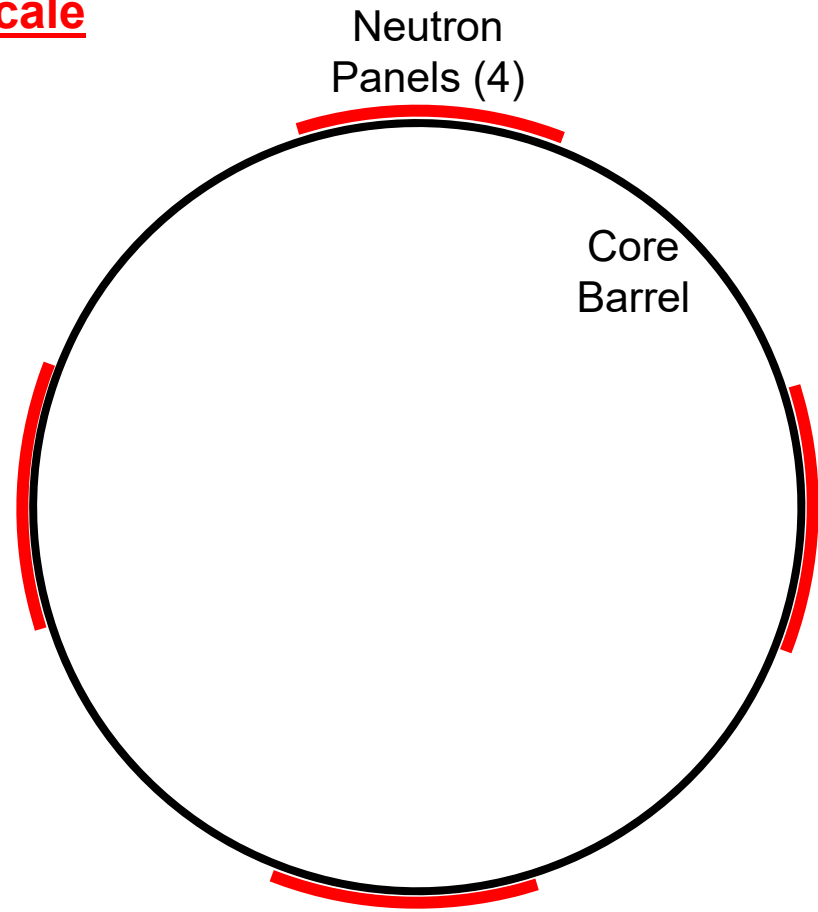
# Sketch of Thermal Shield and Neutron Panel Layout

Not to Scale



Thermal Shield Configuration

~50% of WEC-design PWRs



Neutron Panel Configuration

~50% of WEC-design PWRs

# Example of Neutron Panel Configuration



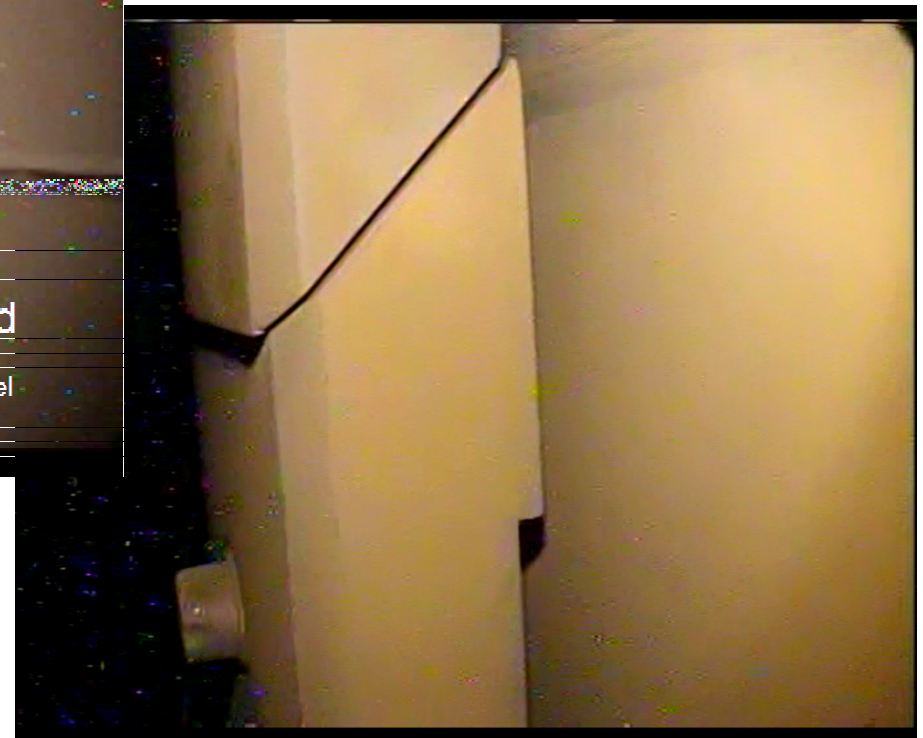
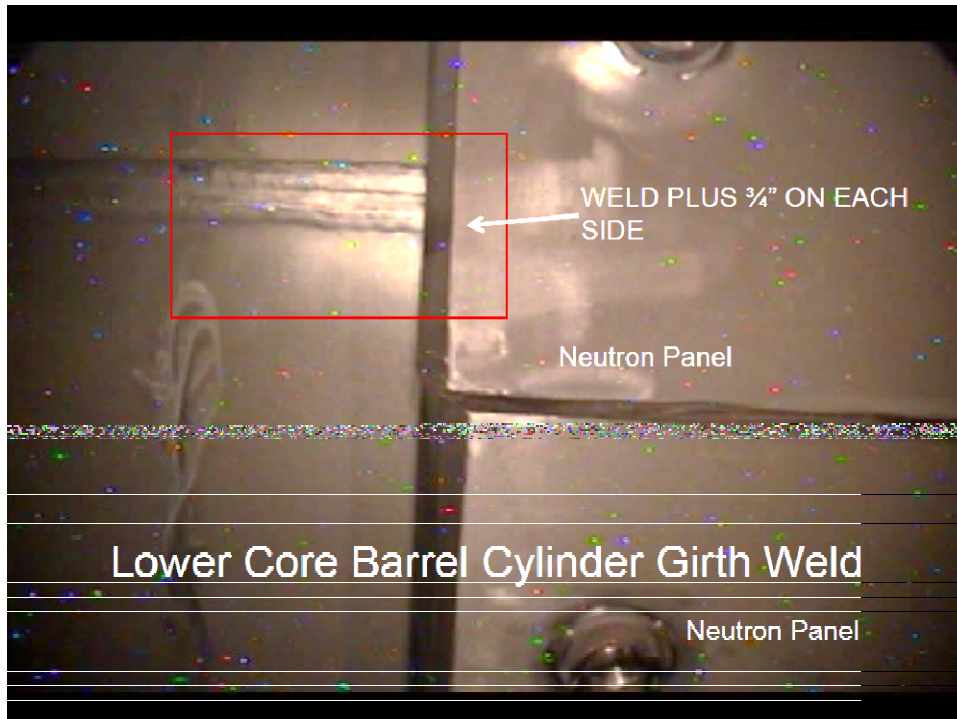
Girth weld

Neutron panel



*Configuration and dimensions  
are plant-specific*

# Example of Neutron Panel Configuration



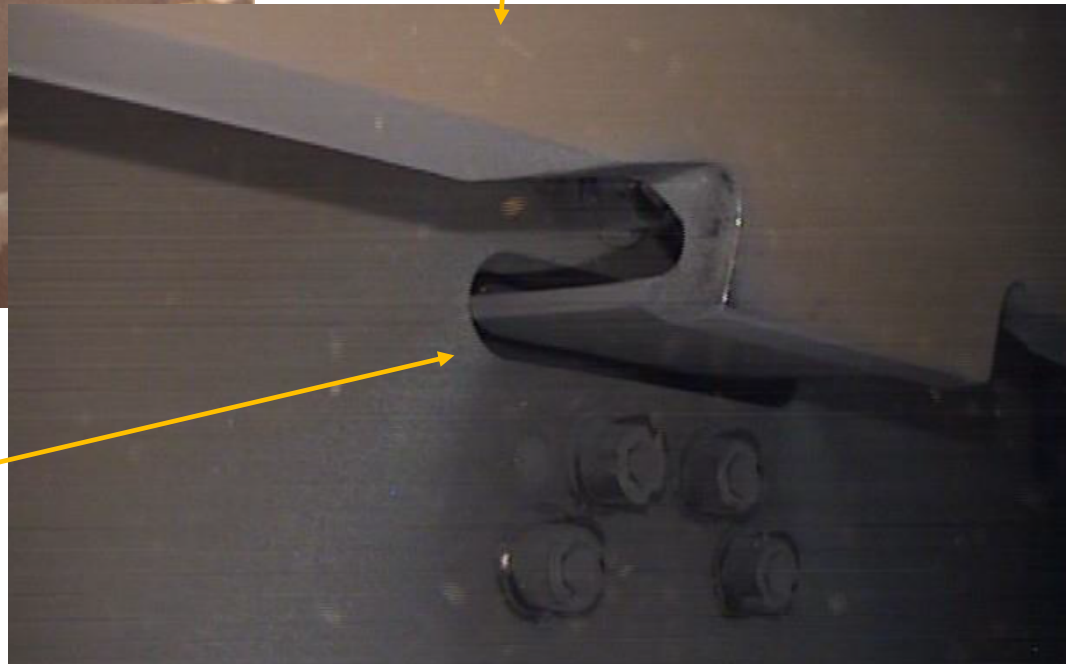
*Configuration and dimensions are plant-specific*

# Example of Thermal Shield Configuration



Thermal shield

*Configuration and dimensions are plant-specific*



Thermal shield flexure



# Proposed CE Primary Requirements

Primary Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
<b>C5.Core Support Barrel Assembly</b> Upper flange weld (UFW)	All plants	Cracking (SCC)	Upper Girth Weld (UGW), Lower Girth/Flange Weld (LGW/LFW), Upper Axial Welds (UAW), Lower core support beams	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	100% of the accessible weld length of one side of the UFW and 3/4" of adjacent base metal shall be examined. (Note 5)
<b>C6.Core Support Barrel Assembly</b> Middle Girth Weld (MGW)	All plants	Cracking (SCC, IASCC) Aging Management (IE)	Middle Axial Weld (MAW), Lower Axial Weld (LAW)	Enhanced visual (EVT-1) examination no later than 2 refueling outages from the beginning of the license renewal period. Subsequent examinations on a ten-year interval.	100% of the accessible weld length of the OD of the MGW and 3/4" of adjacent base metal shall be examined. Note (5)

1. Examination acceptance criteria and expansion criteria for the CE components are in Table 5-2.
5. Examination coverage requires a **minimum of 50% of the weld length** of either the ID or the OD of the weld being examined .

# Proposed CE Expansion Requirements

Expansion Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
<b>Core Support Barrel Assembly</b> C5.1.Lower Girth Weld (LGW)	All plants	Cracking (SCC, Fatigue)	C5.Upper Flange Weld (UFW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of the OD of the LGW and 3/4" of adjacent base metal shall be examined. (Note 3)
<b>Core Support Barrel Assembly</b> C5.2.Upper Girth Weld (UGW) and C5.3.Upper Axial Weld (UAW)	All plants	Cracking (SCC) Aging Management (IE)	C5.Upper Flange Weld (UFW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of one side of the UGW and UAW and 3/4" adjacent base metal shall be examined. (Notes 2 and 3)
<b>Core Support Barrel Assembly</b> C6.1.Middle Axial Weld (MAW), C6.2.Lower Axial Weld (LAW)	All plants	Cracking (SCC, IASCC) Aging Management (IE)	C6.Middle Girth Weld (MGW)	Enhanced visual (EVT-1) examination Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of the OD of the MAW and LAW and 3/4" adjacent base metal shall be examined. (Note 3)

1. Examination acceptance criteria and expansion criteria for the CE components are in Table 5-2.
2. Examination coverage requires examination of either the ID or the OD of the weld.
3. Examination coverage requires a **minimum of 50% of the weld length** for either the ID or the OD of the weld being examined

# Proposed Westinghouse Primary Requirements

Primary Item	Applicability	Effect (Mechanism)	Expansion Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
<b>W3.Core Barrel Assembly</b> Upper flange Weld (UFW)	All plants	Cracking (SCC)	Upper girth weld (UGW), lower flange weld (LFW) (Note 5), upper axial welds (UAW), and lower support forging or casting	Enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	100% of the accessible weld length of one side of the UFW and 3/4" of adjacent base metal shall be examined. (Note 8)
<b>W4.Core Barrel Assembly</b> Lower girth weld (LGW)	All plants	Cracking (SCC, IASCC), Aging Management (IE)	Upper core plate, Lower support column bodies (cast, non-cast), middle axial welds (MAW), lower axial welds (LAW)	Enhanced visual (EVT-1) examination, no later than 2 refueling outages from the beginning of the license renewal period and subsequent examination on a ten-year interval.	100% of the accessible weld length of the OD of the LGW and 3/4" of adjacent base metal shall be examined. (Note 8)

1. Examination acceptance criteria and expansion criteria for the Westinghouse components are in Table 5-3.
5. The lower core barrel flange weld may be alternatively designated as the core barrel-to-support plate weld in some Westinghouse plant designs.
8. Examination coverage requires a **minimum of 50% of the weld length** of either the ID or the OD of the weld being examined

# Proposed Westinghouse Expansion Requirements

Expansion Item	Applicability	Effect (Mechanism)	Primary Link (Note 1)	Examination Method/Frequency (Note 1)	Examination Coverage
<b>Core Barrel Assembly</b> W3.1.Upper Girth Weld (UGW)	All plants	Cracking (SCC)	W3.Upper Core Barrel Flange Weld (UFW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of one side of the UGW and 3/4" of adjacent base metal shall be examined (Notes 2 and 3).
<b>Core Barrel Assembly</b> W3.2.Upper Axial Weld (UAW)	All plants	Cracking (SCC)	W3.Upper Core Barrel Flange Weld (UFW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of one side of the UAW and 3/4" of adjacent base metal shall be examined (Notes 2 and 3).
<b>Core Barrel Assembly</b> W3.3.Lower Flange Weld (LFW)	All plants	Cracking (SCC)	W3.Upper Core Barrel Flange Weld (UFW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection.	100% of the accessible weld length of the OD surface of the LFW and 3/4" of adjacent base metal shall be examined (Note 3)
<b>Core Barrel Assembly</b> W4.2.Middle Axial Welds (MAW) and W4.3.Lower Axial Welds (LAW)	All plants	Cracking (SCC, IASCC) Aging Management (IE)	W4.Lower Girth Weld (LGW)	Enhanced visual (EVT-1) examination. Re-inspection every 10 years following initial inspection	100% of the accessible weld length of the OD of the MAW and LAW and 3/4" of adjacent base metal shall be examined (Notes 3 and 4).

1. Examination acceptance criteria and expansion criteria for the Westinghouse components are in Table 5-3.
2. Examination coverage requires examination of either the ID or the OD of the weld.
3. Examination coverage requires a **minimum of 50% of the weld length** for either the ID or the OD of the weld being examined
4. **Accessibility to the MAW and LAW may be limited by the thermal shield or neutron panels—no disassembly to achieve higher weld length coverage is required.**

# Core Barrel OE Conclusions

- The Spring 2018 core barrel OE has an impact on the requirements of MRP-227, Revision 1
- Industry suggests
  - Keep current MRP-227, Rev. 1 core barrel Primary and Expansion components
  - Increase Primary component coverage levels
- Finalize MRP-227 Rev. 1 SE and prepare “-1-A”
- Industry will develop interim guidance in early 2019
  - Revised guidance could change the Primary and Expansion components and the required coverage
- Additional inspections are planned by PWR plants during the next 3-5 years per existing MRP-227-A requirements
- Incorporate CB interim guidance into MRP-227 Rev.2 in calendar year 2020, as appropriate



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