PWR Owners Group

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Josh Morton, Vistra (FG Chair) – Industry Core Barrel Focus Group Update – Presentation #13

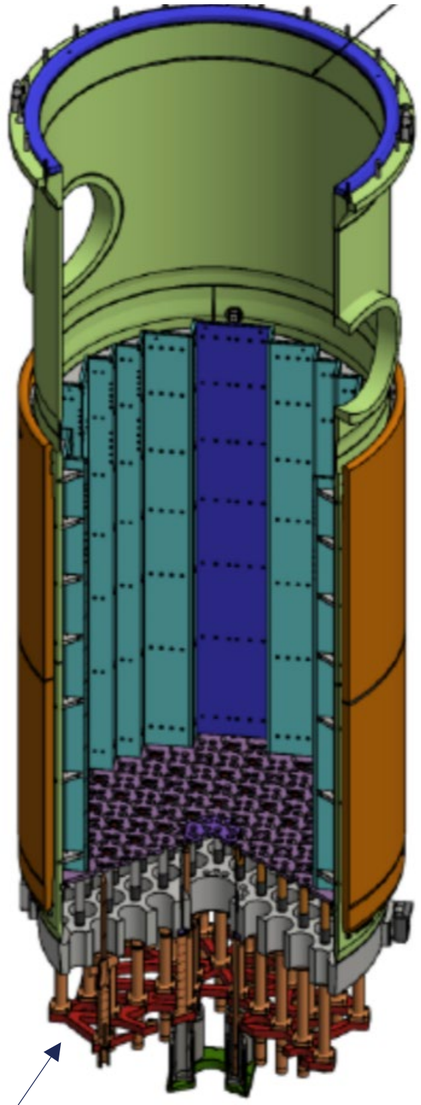
June 2025 NRC/Industry Materials Technical Exchange Meeting

Agenda

- Background: OE and MRP-227
- Industry Core Barrel Focus Group
- Interim Guidance
- Ongoing and Future Work

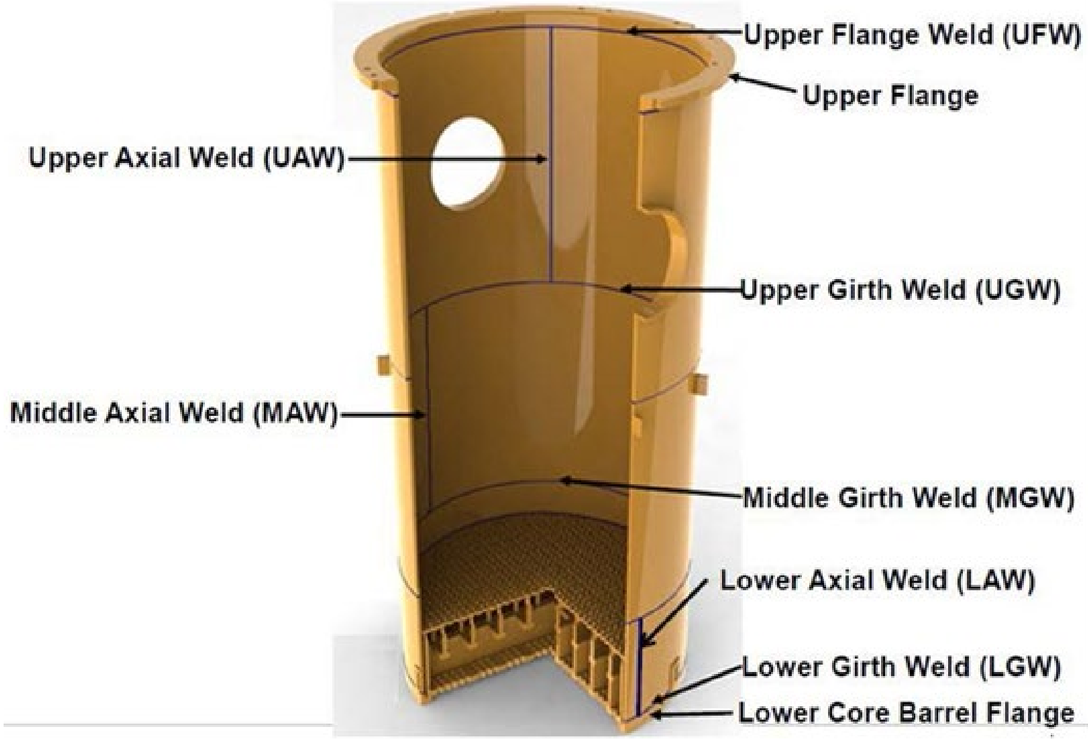
Background

- The primary function of the core barrel (CB) is to support the core
  - It also directs coolant through the fuel
- In the event of failure of a circumferential weld and a complete separation of the CB, a secondary core support structure is in place to protect the core and support maintaining alignment for safe shutdown
  - Downward movement of the lower portion of the CB is limited to ensure continued engagement of the fuel alignment pins with the fuel as well as engagement of the control rods within the fuel.
  - The lower radial keys maintain alignment of the lower portion of the CB with the top portion to ensure the control rods can still be inserted and maintain fuel alignment.
- While design features are in place to support shutdown when initiated, separation of the CB is treated as a potential safety significant condition since prolonged operation with a CB in a separated condition is an unanalyzed condition in the plants design basis.



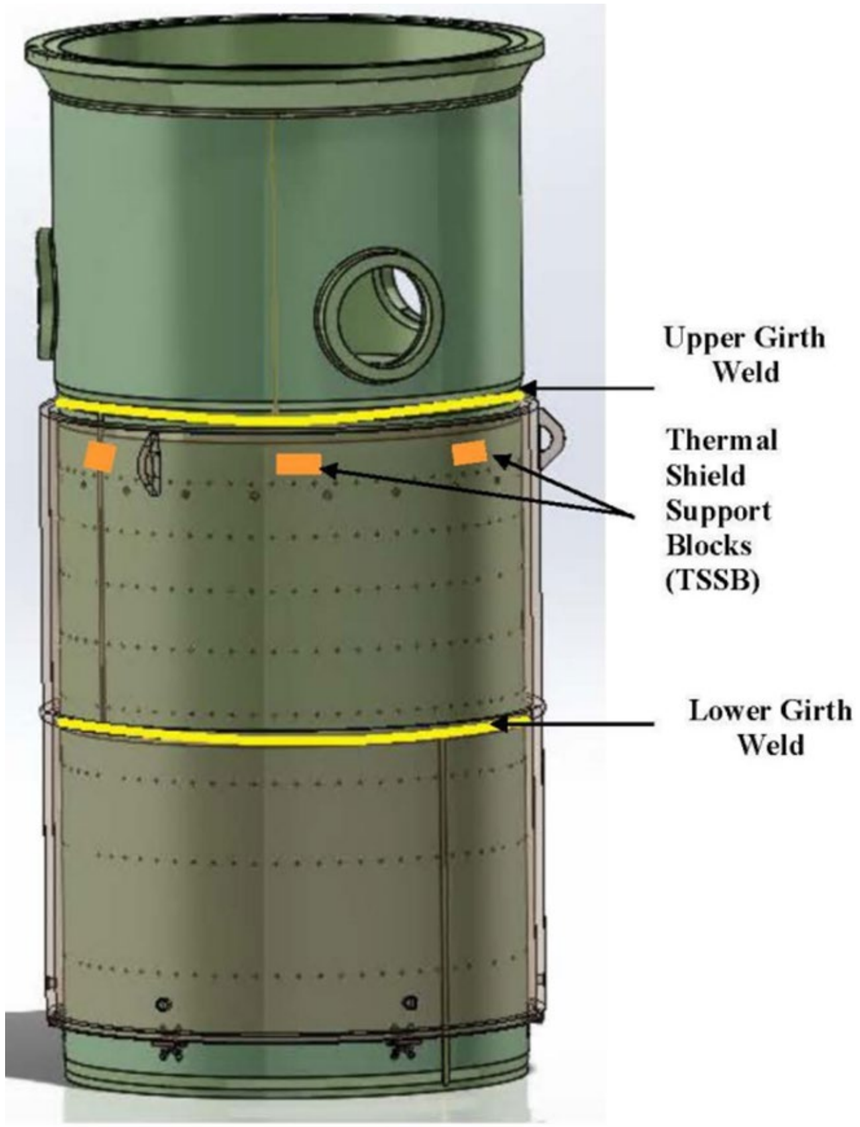
Background: OE

- 2-Loop Combustion Engineering (CE) PWR
  - In operation for 42 years at time of inspection (2018)
  - Thermal shield was removed in the 1980's due to excessive vibration and core barrel cracking near thermal shield supports identified/repaired at that time.
- Visual Inspections (EVT-1) revealed the following:
  - Core Support Barrel (CSB) Middle Girth Weld: One vertical indication 1.3" long, perpendicular to the weld.
  - Indications at two CSB thermal shield pads adjacent to repair areas.
- Expanded scope visual exam (EVT-1) included all 3 axial welds on core support barrel
  - Middle Cylinder Axial Weld: 45 total visual indications near axial weld; Maximum length 1.88".
  - CSB visual indications were observed in the CSB middle cylinder material adjacent to, or near, welds mostly the axial weld.



Background: OE

- 3-Loop Westinghouse PWR
- An indication was detected during a general visual VT-3 ASME Section XI B-N-3 exam of the CB in fall 2022:
  - Linear indication at the upper girth weld (UGW) identified on the CB inner diameter (ID) surface
  - Indication was circumferential and approximately 12” in length
- Extent of condition VT-1/EVT-1 was performed at the UGW:
  - 100% coverage of the UGW ID and outer diameter (OD) surfaces
  - Identified four additional indications on the ID and no relevant indications on the OD
- UT was performed on all five indications:
  - The five indications ranged from 1.1” to 17.76” in length and 37% to 92% in through-wall depth



Background: MRP-227

- The UGW cracking OE observed in Fall of 2022 has several aspects that indicate the need to enhance the current MRP-227 examination requirements:
  - Cracking that could not be dispositioned by analysis alone was observed in the UGW
  - The UGW is designated as an Expansion component in MRP-227 Revision 1-A rather than as a Primary component
  - This cracking would have been missed if a one-sided surface inspection (as permitted by MRP-227) had been conducted from the other surface
- From review of 2012 10-year ISI video there is evidence that at least one of the cracks was present prior to the end of the plant's original 40-year operating license. The crack length and generally accepted crack growth rates would also suggest that the other cracks were also likely present at that time but could not be identified visually.

Industry Core Barrel Focus Group

- A joint CB focus group was set up to coordinate industry activities related to:
  - Understanding technical issues associated with recent CB cracking
  - Coordinating an agreed upon industry approach to resolving issues
  - The goal is generic applicability and overarching recommendations
- Membership includes PWROG, EPRI, NSSS Vendors, and utility personnel

Interim Guidance

MRP 2023-005

(Issued May 19, 2023)

- NEI 03-08 “Needed”
- Westinghouse and CE Plants
- Effective May 1, 2024
- Next Planned CB Removal coinciding with MRP-227 Exam
- Promotes UGW to Primary
- 2-sided EVT-1 or EC, or 1-sided UT of UFW, UGW, and UAW

MRP 2023-005 Rev. 1

(Issued March 15, 2024)

- NEI 03-08 “Needed”
- Westinghouse and CE Plants
- Effective May 1, 2024
- Next Planned CB Removal coinciding with MRP-227 Exam
- Identifies inaccessibility of UGW on some CE plants

MRP 2024-020

(Issued October 29, 2024)

- NEI 03-08 “Needed”
- B&W Plants
- Effective November 1, 2024
- Part A next planned CSA removal / Part B one of next two planned refueling outages.
- Adds several Core Barrel Cylinder and Core Support Shield Cylinder welds as primary and expansion.

2024 NRC Tech. Exchange Mtg.

MRP 2024-004

(Issued February 15, 2024)

- NEI 03-08 “Needed”
- Westinghouse Plants
- One of next two planned refueling outages after June 1, 2024
- Supplemental guidance to require inspection of ID side of UGW and UFW for plants in PEO who have not performed previously

MRP 2024-008

(Issued July 16, 2024)

- NEI 03-08 “Needed”
- Westinghouse and CE Plants
- Effective January 1, 2026
- Next Planned CB Removal coinciding with MRP-227 CB Weld Exams
- Requires UT of CB welds only accessible from one side

Interim Guidance – MRP 2024-008 (WEC/CE)

- Issued on July 16, 2024
- Applicable to Westinghouse and Combustion Engineering (CE) designs
- NEI 03-08 “Needed” guidance to be implemented at the next planned core barrel removal coinciding with MRP-227 examinations of CB Welds
- Effective as of January 1, 2026
- Noteworthy changes in MRP 2024-008 include:
  - Core barrel or CSB welds that are only accessible from one surface must be inspected volumetrically (UT)
  - Primary Components:
    - Westinghouse-design plants: LGW
    - CE-designed plants with welded core shrouds assembled from two vertical sections: UGW and MGW
    - CE-designed plants with welded core shrouds assembled from full-height shroud plates: upper MGW and lower MGW
  - Expansion Components:
    - Westinghouse-design plants: MAW, LAW, and LFW.
    - CE-designed plants with welded core shrouds assembled from two vertical sections: MAW, LAW, and LGW/LFW.
    - CE-designed plants with welded core shrouds assembled from full-height shroud plates: upper MAW, lower MAW, LAW, and LGW/LFW.

Interim Guidance – MRP 2024-020 (B&W)(1/3)

- Issued on October 29, 2024.
- Applicable to operational B&W plants.
- This guidance supersedes guidance in MRP 2021-005.
- NEI 03-08 “Needed” guidance, implementation requirements:
  - Part A to be implemented at the next planned core support assembly removal starting after November 1, 2024.
  - Part B to be implemented in one of the next two (2) planned refueling outages starting after November 1, 2024.

Interim Guidance – MRP 2024-020 (B&W)(2/3)

- Guidance:
  - Part A:
    - Core Barrel Cylinder Components:
      - Adds the Top Flange Circ. Weld region ID and OD (EVT-1/VT-1, UT, or EC) and the Top and Bottom Cylinder Center Circ. Weld region (UT) as primary components.
      - Adds the Bottom Flange Circ. Weld region as an expansion component. Method and coverage to be submitted to NRC for approval.
      - Adds associated examination acceptance criteria.
    - Core Support Shield Cylinder Components:
      - Adds the Bottom Flange Circ. Weld region ID and OD (EVT-1/VT-1, UT, or EC) and Top Flange Circ. Weld region ID and OD (EVT-1, UT, or EC) as primary components.
      - Adds associated examination acceptance criteria. No expansion links are identified.

Interim Guidance – MRP 2024-020 (B&W)(3/3)

- Guidance (cont.):
  - Part B:
    - This one-time requirement requires and accelerates portions of the Part A requirements that can be performed via EVT-1/VT-1 without an otherwise unplanned core support assembly removal.
      - Core Support Shield Top Flange Weld – ID Surface
      - Core Support Shield Bottom Flange Weld – ID Surface
      - Core Barrel Cylinder Top Flange Weld – ID Surface
    - This addresses operating experience: providing valuable near-term data from the B&W design fleet, while minimizing burden to the utilities.
    - Implementing Part A Guidance during this same timeframe addresses Part B Guidance.

Follow-up on Site-Specific Work at 3-Loop Plant with OE

- Completed Re-inspection (UT) of unmitigated UGW indications during Fall 2024 outage.
  - Essentially no change in length or depth within the accuracies of the technique.
  - The measured lengths of Indications 4 and 5 were different than previous reported in 2022, however this was attributed to improvements in measurement technique rather than to growth.
- Completed EVT-1 on the ID of the UAW (Item W3.2) in accordance with MRP-227, Rev 1-A (See Table 5-3, Item W3b).
  - No relevant indications identified
  - The rest of the expansion items in MRP 2023-005 R1 will be addressed in the following outage
- Completed EVT-1 of ID of UGW including accessible surfaces of open crack arrest holes
  - No growth of indications 1-5 and no new indications identified
- Open crack arrest holes and unmitigated indications (#2 and #5) justified to be acceptable through planned 80-year plant life.
- Core samples removed entirety of indication #3 and right side of indication #4.
  - Sample sent for metallurgical exams (in process)
  - Core sample holes mitigate indications #3 and #4, these locations were plugged to address bypass flow.

Industry Completed Work

- PWROG - Development of Fault Tree for Potential Causes of Cracking
- PWROG - Investigation of the Effect of Manufacturing Process on the Potential for Flaws Adjacent to the Core Barrel Outlet Nozzles
- PWROG - Utilization of Neutron Noise Data to Monitor for Active Core Barrel Cracking and Separation
- PWROG - Investigation and Exploration of Core Barrel Repair Options
- PWROG - Investigation of the Effect of Manufacturing Process (fit-up stress) and Flow-Induced Vibration on the Potential for Flaws Adjacent to the Core Barrel Outlet Nozzles

- EPRI - Investigation of Weld Residual Stress and Presence of Outlet Nozzle in Vicinity of the UGW
- EPRI - Issuance of interim guidance, MRP 2023-005 and R1 for Westinghouse and CE Plants
- EPRI - Issuance of Supplemental guidance, MRP 2024-004 for Westinghouse Plants
- EPRI - Issuance of interim guidance, MRP 2024-008 for Westinghouse and CE Plants
- EPRI - Issuance of interim guidance, MRP 2024-020 for B&W Plants
- EPRI - Study of thermal stress distribution around the circumference of the Core Barrel ID
- EPRI - Investigations of the possibility of thermal fatigue crack growth in UGW

Industry Ongoing Work

- PWROG - PWR Core Barrel Lower Girth Weld (LGW) Failure Operability Feasibility Assessment
- PWROG - B&W Core Barrel Circumferential Weld Failure Operability Feasibility Assessment
- PWROG - Evaluation of and Basis for Methodology Changes to Improve Flow-induced Vibration (FIV) Fatigue Crack Growth (FCG) Criteria for CE and W Core Barrel Evaluations

- PWROG / EPRI - Development of a Standard Set of Welded Inspection Specimen Designs for UT Technique Development and Demonstration Purposes
- PWROG / EPRI - Development of guidance/method for determination of defect rates to consider in inaccessible regions
- PWROG / EPRI - Harvesting, Transport, and Laboratory Testing of Core Barrel Samples

- WRTC and ORNL - Research for the feasibility of welding irradiated stainless steel which could support future Core Barrel repair options
- EPRI - Development of a UT inspection protocol for CB weld inspections
- EPRI - Continued collaboration with PWROG on irradiated SS weld and base metal fracture toughness guidance

Possible Future Industry Work

- PWROG – Fault Tree for Core Barrel Cracking – for B&W Plants
- EPRI – Fabrication of standard sets of UT inspection mockups for remaining CB welds

Conclusions Based on Current State of Knowledge

- At this time, nothing has been discovered that would allow the FG to conclude that this issue is unique to the 3-loop plant with OE in fall 2022.
- All PWR core barrels made with 304 SS (standard grade) prior to the mid-1980's are likely to have some HAZ sensitization due to the standard materials and core barrel construction welding practices typical of that period of component construction.
- There may be weld-to-weld differences in stresses believed to be controlling SCC (WRS, thermal stresses, and fabrication stresses). These are being discussed for further exploration to gain additional insight on relative susceptibility.
- The FG maintains its position that the updated guidance properly addresses inspecting the core barrel weld locations which are both the most susceptible to SCC and present a high potential consequence of degradation.

Questions?