



Global Expertise • One Voice

Baffle Former Bolt Overview of Industry Experience

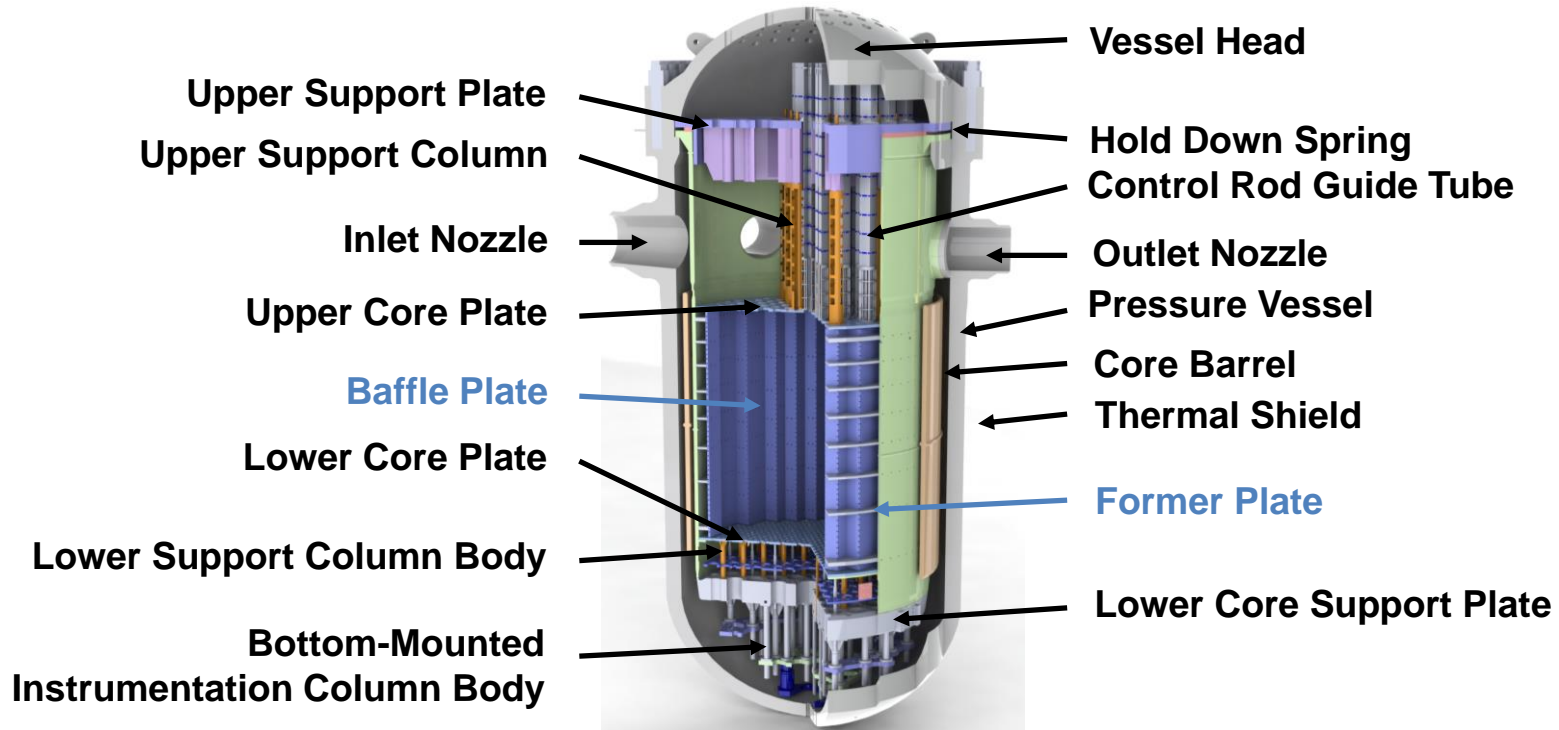
Heather Malikowski (Exelon), Chair

Bryan Wilson (Westinghouse)

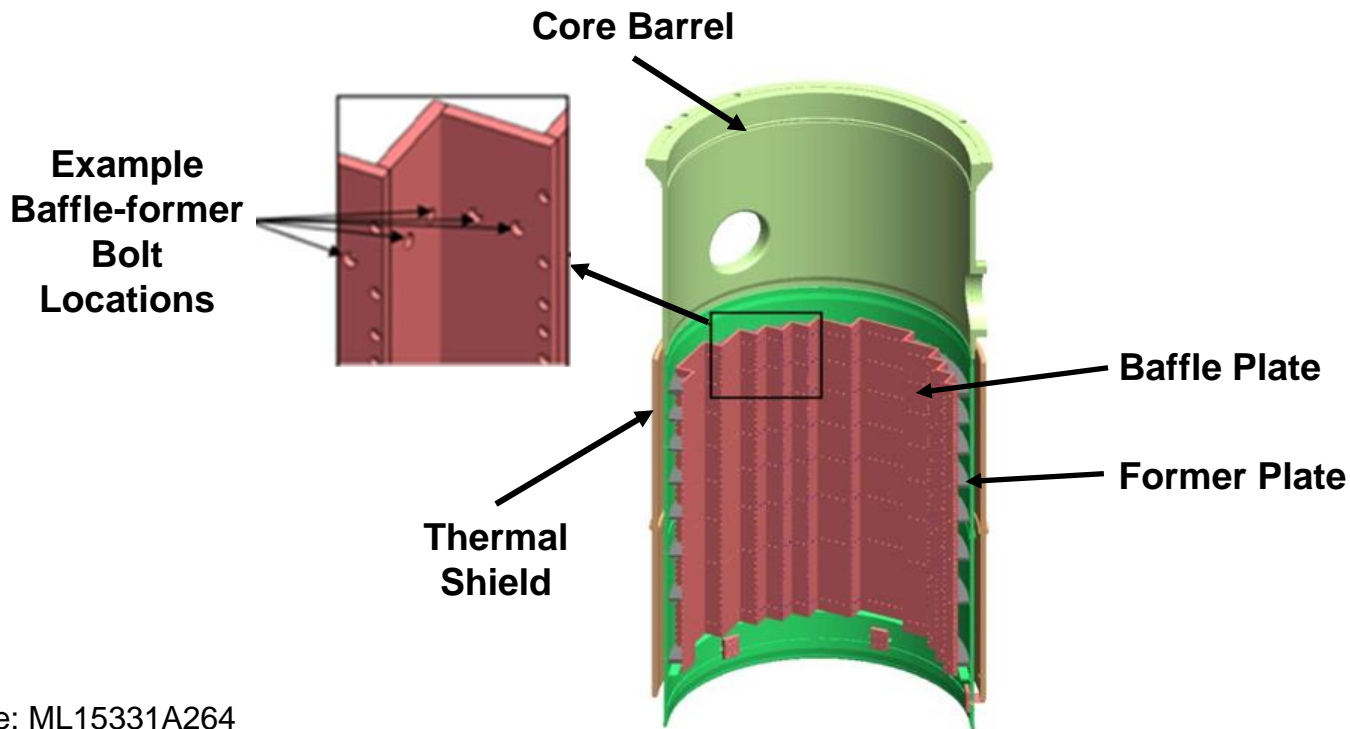
PWROG Materials Committee

July 19, 2016

Westinghouse NSSS Internals

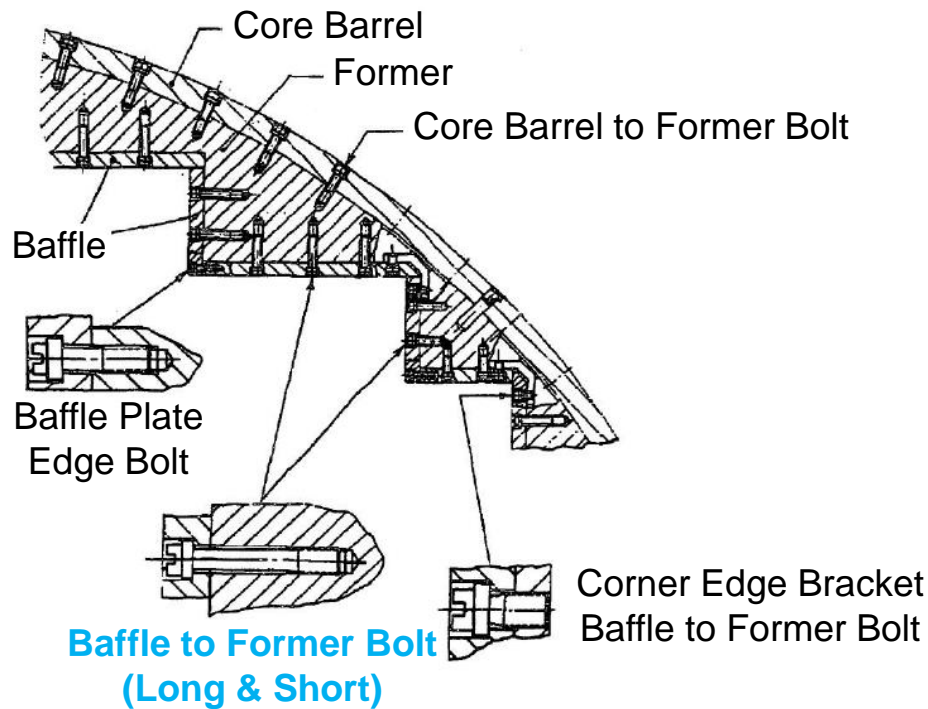


Baffle-Former Assembly



Source: ML15331A264

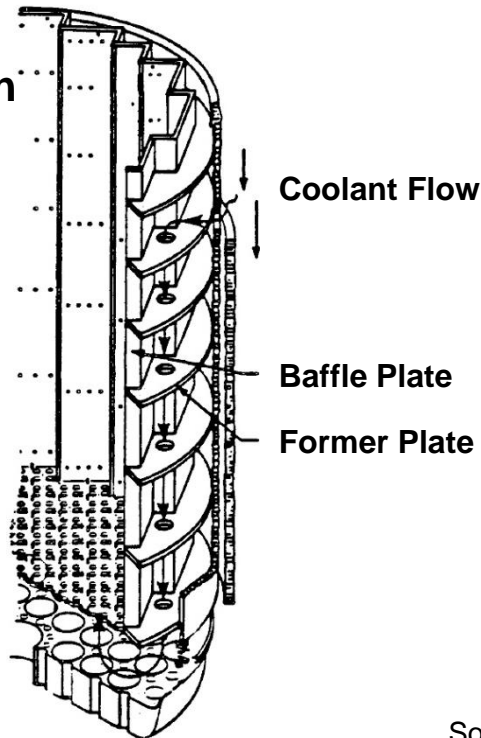
Baffle-Former Assembly Details



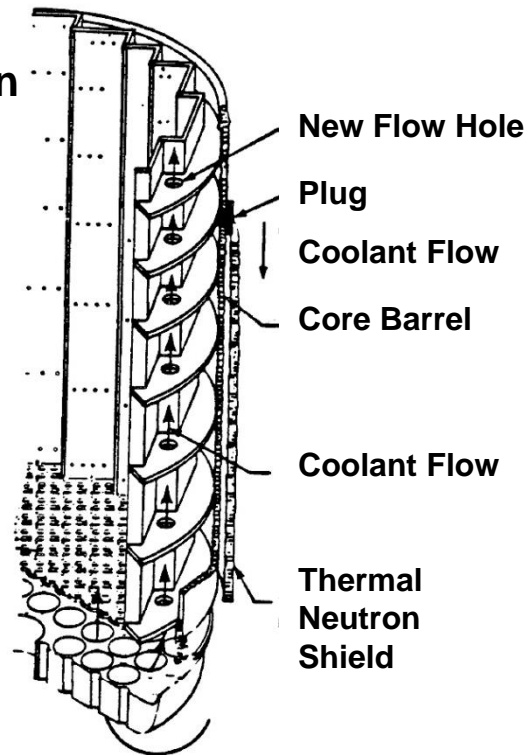
Source: ML15331A179

Coolant Flow Configurations

Downflow Configuration



Upflow Configuration



Source: ML073190376

Timeline

Operating Experience

First UT baffle-former bolts (BFB) inspections in French PWR CP0 units and first cracks found



First degraded baffle-former bolts found in U.S.



DC Cook finds degraded bolts by visual inspection



Ginna performs first MRP-227 inspections



Indian Point 2, Salem 1 find degraded bolts (visual+UT)



WCAP-13266: BFB Program for the Westinghouse Owners Group - Plant Categorization

NRC Information Notice 98-11 on BFBs

MRP publishes assessment of French BFB OE (MRP-03)

MRP publishes Reactor Internals Inspection Guidelines (MRP-227)

NRC reviews & approves MRP-227

Westinghouse Technical Bulletin TB-12-5, related to the DC Cook OE

Guidance

Note: UT deployed as it became available and qualified for the various sites

EDF Experience 1989-Present

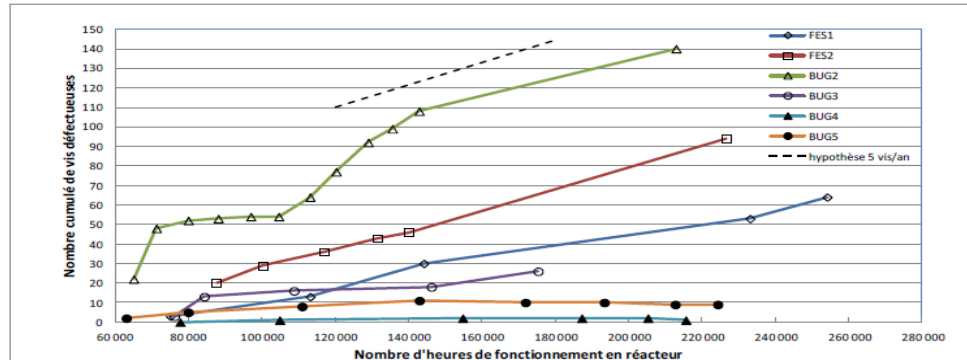
- Baffle bolt failures reported 1989 – Present
 - Limited to CP0 design
 - 3-loop (converted to upflow)
 - Significant plant-to-plant variability
 - CPY design (<5 indications over life of plant)



Overall BFB Timeline – CP0 Units

- X-axis: number of operating hours
- Y-axis: cumulative number of bolts found 'failed'/unconclusive'
- ----- : evolution trend, assuming 5 failed bolts per year

BUG2-FES2-FES1-BUG3: 4/6 CP0 units are 'affected'
BUG5-BUG4: 2/6 CP0 units are 'unaffected'



EDF Response

- Safety Case
 - LOCA Loads
 - Acceptable loads on remaining bolts
 - Acceptable loads on fuel assembly grids
 - Minimal number of “healthy bolts” ~30% with limits on distribution
- Periodic bolt replacement
 - Failed original bolts
 - Periodic replacements included previously replaced bolts
 - Sufficient number of “healthy bolts” to push next inspection to 10 years (based on projection model)

Joint Owners Baffle Bolt Program (15-22 EFPY)

- Sponsored Inspections of four plants
 - Point Beach Unit 2: 2-loop, Upflow (converted) , Type 347SS
 - 8% UT Indications
 - Partial replacement program
 - Farley Unit 1: 3-loop, Upflow (converted), Type 316SS
 - No UT Indications
 - Proactive replacement of minimum pattern
 - Ginna: 2-loop, Downflow, Type 347SS
 - 9% UT Indications (Of these, 14 were sent for metallurgical examination. Results showed no indications of cracking, so this 9% likely contains a number of false calls)
 - Partial replacement program
 - Farley Unit 2: 3-loop, Converted Upflow (downflow at time of inspection), Type 316SS
 - No UT Indications
 - Proactive replacement of minimum pattern

WEC MRP-227 Baffle-Former Bolt Inspections (25-35 EFPY)

- Point Beach Unit 1: 2-Loop, Upflow (converted), Type 347SS
 - 1st Inspection: No UT Indications
- Point Beach Unit 2: 2-Loop, Upflow (converted), Type 347SS
 - 2nd Inspection: 2% Additional UT Indications
- Ginna: 2-Loop, Downflow, Type 347SS
 - 2nd Inspection (partial inspection of 123 original bolts and 56 replacement bolts):
1 Additional UT Indications (Partial Replacement – 25 bolts)
- Prairie Island Unit 1: 2-Loop, Downflow, Type 347SS
 - 1st Inspection: 6% UT Indications
- Prairie Island Unit 2: 2-Loop, Downflow, Type 347SS
 - 1st Inspection: 10% UT Indications

WEC MRP-227 Baffle-Former Bolt Inspections (25-35 EFPY)

- Surry Unit 1: 3-Loop, Downflow, Type 347SS
 - 1st Inspection: <1% UT Indications
- Surry Unit 2: 3-Loop, Downflow, Type 347SS
 - 1st Inspection: <1% UT Indications
- Robinson: 3-Loop, Downflow, Type 347SS
 - 1st Inspection: <1% UT Indications
- Turkey Point Unit 3: 3-Loop, Downflow, Type 347SS
 - 1st Inspection: No UT Indications in 305 of 1088 bolts inspected
- Indian Point Unit 2: 4-Loop, Downflow, Type 347SS
 - Inspection results addressed in detail on a later slide

International Plants

- Doel 1: 2-Loop Downflow, Type 316SS
 - 1st Inspection: 2% UT Indications
- Doel 2: 2-Loop Downflow, Type 316SS
 - 1st Inspection: <1% UT Indications
- Krsko: 2-Loop, Downflow (prior to inspection), Type 316SS
 - 1st Inspection: <1% UT Indications
- Tihange 1: 3-Loop, Upflow (converted), Type 316SS
 - 960 of 1088 bolts inspected in each of the following inspections
 - 1st Inspection: 4% UT Indications
 - 2nd Inspection: 3% UT Indications
 - 3rd Inspection: No confirmed UT Indications (5 bolts either not inspectable or not interpretable)

B&W-Designed RV Internals Baffle-to-Former Bolt Examinations (19-32 EFPY) [1 of 2]

- Four baffle-to-former bolt (BFB) UT examinations completed at B&W-designed units to date
 - Oconee Unit 1
 - No relevant UT indications
 - Four BFBs uninspectable due to large welds on locking bars
 - Oconee Unit 2
 - No relevant UT indications
 - One BFB uninspectable due to UT probe not seating properly
 - Oconee Unit 3
 - One BFB identified with crack-like indications
 - One BFB uninspectable due to UT probe not seating properly
 - Crystal River Unit 3
 - No relevant UT indications
 - UT performed due to visual indication from baffle-to-baffle bolts

B&W-Designed RV Internals Baffle-to-Former Bolt Examinations (19-32 EFPY) [2 of 2]

- All BFBs Type 304 solution annealed stainless steel
- B&W design is an upflow configuration
- One BFB out of 3,450 BFBs UT examined identified with crack-like indications
- VT examination of all 3,456 BFBs identified no relevant indications

Observations from Broader OE

- With the exception of the OE at Cook Unit 2, Indian Point Unit 2, and Salem Unit 1 (discussed later in the presentation), the following observations can be made:
 - Bolts with UT indications tend to be randomly distributed
 - Distributions are consistent with expectations of IASCC failures
 - Quantity and distribution of bolts with indications bounded by historical generic safety assessment (WCAP-15328)
 - Industry response to replacement of bolts with indications has been positive

Experience with Clustered Bolt Failures

- DC Cook Unit 2 (2010 / 22 EFPY) (4-Loop Downflow Configuration)
 - Fuel failure in peripheral assembly attributed to wear against broken bolt head
 - Bolt heads and lock bars found on lower core plate
 - Visual inspections revealed 18 degraded bolts on single plate
 - Additional bolts removed from plate with visual indications to define extent of localized degradation (approx. 40 bolts in single patch)
 - Additional test bolts removed from symmetrical locations to evaluate potential for degradation on other plates (all of these test bolts were found to be intact)
 - No UT inspections performed in 2010 (at that time UT was not qualified or optimized for the Cook 2 bolt design)
 - Degraded and test bolts replaced
 - Westinghouse issued Technical Bulletin TB-12-5
 - 100% Visual inspection conducted in 2012 with no additional indications

Experience with Clustered Bolt Failures

- Indian Point Unit 2 (2016 / 31 EFPY) (4-Loop Downflow Configuration)
 - Degraded bolts and lock bars noted in visual exams performed prior to MRP-227 100% UT exams that were planned to occur during this outage
 - Markings on periphery of neighboring fuel assembly identified (no fuel failure).
 - Inspections identified 227 with visual degradation or UT indications
 - Includes 14 that were not inspectable
 - UT indications were clustered
 - Spanned various quadrants
 - Multiple groups of 10+ adjacent failures
 - At least one cluster of 50+ adjacent failures
 - Observed failure pattern exceeds WCAP-17096 acceptance criteria
 - Site-specific response:
 - Performed Acceptable Bolting Pattern Analysis (ABPA)
 - Performed Replacement Bolting Pattern Analysis
 - Performed engineering evaluations supporting Unit 3 Extent of Condition Evaluation
 - Performed engineering evaluations supporting Unit 2 Assessment of Potential Safety Impacts
 - Performed baffle-former bolt removal and replacement
 - Quarantined select bolts for potential future testing

Experience with Clustered Bolt Failures

- Salem Unit 1 (2016 / 28 EFPY) (4-Loop Downflow Configuration)
 - Conduct visual exams every other refueling outage in response to DC Cook Unit 2 OE and TB-12-5; MRP-227 exams were not planned until 2017
 - Degraded bolts and lock bars noted in visual exams followed by performance of UT exams
 - Loose or protruding bolt heads resulted in fuel fretting and a leaker at one fuel assembly
 - Inspections identified 182 with visual degradation or UT indications
 - Includes 18 that were not inspectable
 - UT indications were clustered
 - Concentrated to a few adjacent octants
 - Multiple groups of 10+ adjacent failures
 - At least one cluster of 50+ adjacent failures
 - Observed failure pattern exceeds WCAP-17096 acceptance criteria
 - Site-specific response:
 - Performed Acceptable Bolting Pattern Analysis (ABPA)
 - Performed Replacement Bolting Pattern Analysis
 - Performed engineering evaluations supporting Unit 1 Justification for Past Operation
 - Performed engineering evaluations supporting Unit 2 Extent of Condition Evaluation
 - Performed baffle-former bolt removal and replacement
 - Quarantined select bolts for potential future testing

Conclusions from Recent OE

- These three plants share a common plant design configuration (4-loop downflow) and bolt design
- Bolts with visual or UT indications tend to be clustered
- Distributions seem to indicate the presence of a mechanism causing adjacent bolts to become more susceptible to failure
- Most likely cause is redistribution of a sustained stress resulting in increased IASCC susceptibility
- Quantity and distribution of bolts with indications warranted the creation of an industry focus group and the issuing of Westinghouse NSAL-16-1 and AREVA CSB 16-02



Global Expertise • One Voice
www.pwrog.com