Updated Baffle-Former-Bolting (BFB) Inspection Results in the United States

MRP-227-A Inspections

Kyle J. Amberge, Principal Technical Leader
EPRI-Materials Reliability Program

NRC-Industry Materials Technology Exchange Meeting
May 2019

Baffle Former Bolt Inspection Requirements

- BFB degradation initially identified in late 1980s in France
  - Volumetric UT inspections are most appropriate technique for identifying cracking due to irradiation assisted stress corrosion cracking (IASCC) and fatigue
- MRP-227-A requires 100% baseline UT at 25-35 EFPY
  - Visual inspections of BFBs are not mentioned in MRP-227-A
  - UT reinspection period is every 10-years if no degradation is found
- Based on operating experience in 2016, EPRI issued interim guidance to PWRs
  - MRP-2016-021, dated 7/25/2016 for Tier 1 plants
  - MRP-2017-009, dated 3/15/2017 for all plants
    - Plant-specific re-inspection interval may be limited to $\leq$ 6-years based on
    - Allowance for plant-specific engineering evaluation based on plant actions taken
- NRC performed assessment of EPRI's interim guidance (ML17310A861)
  - Plant-specific evaluations of re-inspection periods are to be provided to NRC
  - Guidance included in updated version of MRP-227 Revision 1-A (ML19081A001)

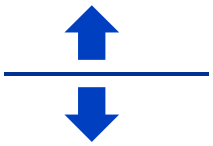
Summary of BFB OE from 2016-2017

- Highest risk US plants share a common plant design configuration
  - 4-loop Westinghouse-design PWR with downflow baffle assembly
  - 347SA BFB bolt material installed at original construction
  - Shortest BFB bolt design with smallest head-to-shank transition radius
  - Characteristics in Westinghouse TB-12-5 from 2010 event at Tier 1 PWR unit
- Initial BFB failures initiate due to IASCC, then “unzippering” as clusters grow
- Bolts with visual/UT indications in downflow plants tend to be “clustered”
  - Summarized in NSAL-16-1 Revision 1, dated 8/1/2016
- Plants categorized into Tiers based on risk and design
  - Tier 1: 4-loop Down-Flow plants, highest risk
  - Tier 2: 2-loop and 3-loop Down-Flow plants, still high risk
  - Tier 3: original Down-Flow plants, converted to Up-Flow, lower risk
  - Tier 4: original Up-Flow plants, lowest risk, but not immune to IASCC
- Several Tier 1 US PWRs installed replacement BFBs after UT inspections

Summary of 2016-2019 Baffle Former Bolt NDE Results

Plant Type	Tier	Outage	Visual Indications	UT Indications (UT Untestable)	BFBs Replaced	BFBs Removed in 2 Pieces
4-Loop downflow	1	10/2010	18	No UT performed	52	42
4-Loop downflow	1	3/2016	31	182 (14)	278	107
4-Loop downflow	1	4/2016	18	139 (25)	189	141
3-loop downflow ^	3	9/2016	0	3 (7) ^	0	0
4-Loop downflow	1	11/2016	4	170 (9)	201	55*
4-Loop downflow	1	3/2017	0	257 (3)	270	37
4-Loop downflow	1	4/2017	0	9 (0)	129 proactive	0
4-Loop downflow	1	5/2017	0	1 (0)	61 proactive	0
4-Loop downflow	1	9/2017	0	48 (4)	212	11
3-Loop downflow	2	10/2017	0	2 (34)	0	0
4-Loop downflow ^	1, now 3’	3/2018	0	3 (1)	210 proactive^	0
4-Loop downflow	1	4/2018	0	13 (0)	0	0
4-Loop downflow	1	4/2018	0	7 (6)	0	0
3-Loop downflow	2	10/2018	0	1 (1)	0	0
4-Loop downflow	1	11/2018	0	3 (2)	0	0
3-Loop downflow	2	3/2019	0	13 (6)	0	0
4-Loop downflow	1	3/2019	0	13 (0)	0	0
4-Loop downflow ^	1, now 3’	3/2019	0	13 (0)	188 proactive^	1
4-Loop downflow	1	4/2019	31	194 (3)	Planning 272+	*Work on-going*

Previously Reported Info.



New Info.

^*also, several units were converted to “upflow”* (now Tier 3)

BFB UT inspection in Spring 2018: 4-Loop Tier 1 unit

- Second UT examination for Tier 1A plant (Type 347 BFBs)
  - Previously replaced 201 BFBs in fall 2016
- No visual degradation identified prior to planned 100% UT exams
- Inspections identified 3 BFB with UT indications (1 untestable)
  - No clustering
- Observed indications met WCAP-17096-NP-A acceptance criteria
  - Site-specific response was NOT needed
  - No replacements were required

- Utility proactively replaced 210 BFBs and converted to upflow
  - Utility has replaced a total of 411 BFB in past two outages 11/2016 and 4/2018
  - Unit is now considered at Tier 3' unit (operated 42 years as Downflow)

BFB UT inspection in Fall 2018: 3-Loop Tier 2 unit

- First UT examination for Tier 2B plant
- No visual degradation identified prior to planned 100% UT exams
- Inspections identified 1 BFB with UT indication (plus 1 untestable)
- No clustering
- Observed indications met WCAP-17096-NP-A acceptance criteria
  - Site-specific response was NOT needed
- No replacements were required

BFB UT inspection in Fall 2018: 4-Loop Tier 1 unit

- First UT examination for Tier 1B plant (Type 316 BFBs)
- No visual degradation identified prior to planned 100% UT exams
- Inspections identified 3 BFB with UT indication (plus 2 untestable)
  - No clustering
- Observed indications met WCAP-17096-NP-A acceptance criteria
  - Site-specific response was NOT needed
  - No replacements were required

BFB UT inspection in Spring 2019: 4-Loop Tier 1 unit

- Second UT examination for Tier 1A plant (Type 347 BFBs)
  - Previously replaced 270 BFBs in spring 2016
- No visual degradation identified prior to planned 100% UT exams
- Inspections identified 13 BFB with UT indications (no untestable)
  - No clustering
- Observed indications met WCAP-17096-NP-A acceptance criteria
  - Site-specific response was NOT needed
  - No replacements were required

BFB UT inspection in Spring 2019: 4-Loop Tier 1 unit

- Second UT examination for Tier 1A plant (Type 347 BFBs)
  - Previously replaced 212 BFBs in spring 2017
- No visual degradation identified prior to planned 100% UT exams
- Inspections identified 13 BFB with UT indications (no untestable)
  - No clustering
- Observed indications met WCAP-17096-NP-A acceptance criteria
  - Site-specific response was NOT needed
  - No replacements were required

- Utility proactively replaced 188 BFBs and converted to upflow
  - Utility has replaced a total of 400 BFB in past two outages 11/2017 and 4/2019
  - Unit is now considered at Tier 3' unit (operated 42 years as Downflow)

BFB UT inspection in Spring 2019: 4-Loop Tier 1 unit

- Second UT examination for Tier 1A plant (Type 347 BFBs)
  - First UT examination was performed in spring 2016 due to finding visible BFB degradation
  - Utility replaced 189 BFBs in 5/2016 based on clustered failures adjacent to 'west' baffle wall
  - Engineering analysis performed to identify next UT inspection; UT was planned for fall 2020
- Visual inspections in 4/2019 identified significant degradation of BFBs
  - 31 BFBs were found to be broken and/or protruding
- Utility immediately performed 100% UT inspections in 4/2019
- UT inspections identified 194 BFBs with UT indications (plus 3 untestable)
  - One replacement Type 316 BFB identified with UT indication (found in interior of large cluster)
- Significant clustering of degraded bolts, mostly adjacent to 'east' baffle wall
  - Opposite baffle wall from observations made in spring 2016
- Observed indications did NOT meet WCAP-17096-NP-A acceptance criteria
  - Site-specific response was required; utility plans to replace ~272 BFBs – work ongoing now
  - Combined with prior replacements (189) in 5/2016, total replacement quantity of ~460 BFBs
- Utility may also consider other potential future actions for fall 2020

Utility Actions Related to Spring 2019 BFB Inspections

- PWR Utility owner is planning formal root cause evaluation
- Findings of BFB degradation in spring 2019 are not unexpected
  - Amount and severity of degradation after only 3 years is unexpected
- Utility was already planning to re-UT inspect BFBs in fall 2020
  - Plan included potential replacements as identified by NDE in fall 2020
  - Utility accelerated UT and replacements based on spring 2019 findings
- Utility will evaluate other potential causes
  - Utility will also assess engineering activities performed in 2016-2017 that may have precluded these most recent inspection findings

Industry Actions Related to BFBs

- Industry utility members are considering potential technical actions related to BFB inspection results and OE in spring 2019 outages
- Ultrasonic inspections of BFBs are finding the degradation that was predicted
  - MRP-191 risk ranking and MRP-227-A guidance identified that BFB failures could happen within time-span relevant to operating life of PWRs
- Mechanism of BFB degradation is fairly well understood by industry since 1990s (NRC IN 98-11)
  - Initiation of cracking due to IASCC from high bolt stresses and neutron fluence
  - Progression of random failures to clustering is something that is a new observation in past several years
  - Many compounding factors combine to confound causal analyses
  - Downflow configuration clearly drives high bolt stresses and aggravates failure clustering
  - EDF utility noted that clustering has never been observed in the EDF PWR units
  - Likely due to conversion of all of the EDF PWR units to upflow in 1990s-2000s
  - EDF performed UT inspections every outage and replaced BFBs in the 7 high-susceptibility units
- Inspection guidance related to UT re-inspection periods requires use of plant-specific evaluations
  - Generically applicable solutions to establishing re-inspection periods are not available
- Plant-specific prediction tools for BFB failures based on time-based models may need to be fine-tuned based on clustering progression and any new OE would inform any adjustments

Together...Shaping the Future of Electricity