Salem Plant Events 2016

SCS Power Plant Simulator Conference

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Salem and Hope Creek Nuclear Generating Stations
PSEG Nuclear – Salem and Hope Creek

Second largest site in country (for now)
- Approximately 3,575 MWe
- Enough electricity for ~3 million homes

Each unit licensed for 60 years (license renewal completed)
- Salem Unit 1 (PWR, 1180* MW) – 20 Year extension Started in Aug 2016
- Salem Unit 2 (PWR, 1175* MW) – 20 Year extension Starts in April 2020
- Hope Creek (BWR, 1219* MW) – 20 Year extension Starts in April 2026

Salem Units experienced long unplanned outages in 2016
- Salem Unit 1 Baffle Bolt Replacement
- Salem Unit 2 Main Power Transformer Anomaly

*Mean Annual Net Rating
Salem Unit 1R24 Refueling Outage Scheduled for 25 Days

Every other outage Visual Inspection of Reactor Internals performed

Visual inspection showed Reactor Core Former Baffle Bolts degradation

- Identified 18 (out of 832) baffle bolts with missing or protruding bolt heads
- ALL missing bolt heads recovered

Ultrasonic testing was originally planned for a later outage

- Originally planned in 2019 for NRC license renewal aging management program commitment (MRP 227)

Based on Visual results decision was made to perform Ultrasonic testing and repair during this the 2016 outage
What the heck are Baffle Bolts?

There are structures located within Westinghouse reactor vessels that support and orient the reactor fuel assemblies and direct coolant flow through the core. The core baffle, one of these internal structures, is a set of vertical plates surrounding the outer rim of the reactor's fuel assemblies. The baffle provides lateral restraint to the core and directs coolant flow through the core. The vertical baffle plates are bolted to the edges of horizontal former plates, which are bolted to the inside surface of the core barrel. There are typically eight levels of former plates located at various elevations within the core barrel. The baffle-former bolts secure the baffle plates to the former plates. To cool the baffle structure, some water flowing through the reactor vessel is directed between the core barrel and the baffle plates in either a downward direction ("down-flow"), or an upward direction ("up-flow"). "Down-flow" plants place more stress on baffle-former bolts, which contributes to susceptibility of the bolts to degradation. Plants with the modified "up-flow" direction have shown little baffle-former bolt cracking as compared to the "down-flow" designs. Newer PWRs use the "up-flow" configuration and several older units have converted to the "up-flow" configuration.

Operating experience indicates that the baffle-former bolts are more susceptible to degradation in older Westinghouse four-loop reactors that have a "down-flow" configuration and have baffle-former bolts made of Type 347 stainless steel. There are seven U.S. reactors that match these characteristics: Indian Point Units 2 and 3, Salem Units 1 and 2, D.C. Cook Units 1 and 2, and Diablo Canyon Unit 1 (Diablo Canyon Unit 2 has a different configuration than Unit 1).
Baffle and Former Assembly
Baffle Plate and Former Plate

Note: UT deployed as it became available and qualified for the various sites
Baffle and Former Assembly
Salem’s baffle bolts are 5/8 inch in diameter and about 2 inches long.

Once bolted in place, a lock bar is welded across the bolt head to secure the bolt.

Structural integrity or foreign material (FME) potential issues.

**What is a baffle bolt?**
Timeline

**Operating Experience**
- First UT baffle-former bolts (BFB) inspections in French PWR CP0 units and first indications 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)

**Guidance**
- 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 12-05, related to the DC Cook OE

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

Specialized Tool needed for Ultrasonic Inspection, Removal and Replacement of Baffle Bolts

Surprise, turns out that there are only two in the World
  - One from Areva
  - One from Westinghouse

Westinghouse selected since did not require Barrel pull
  - Surprise – Westinghouse Tool was being used at another Plant
  - Had to wait for tool as other plant completed their repairs
Highly specialized repair equipment and technicians
Baffle Bolt Tooling Head
Results

Planned 25 Day outage became 170 Day outage (4/6/16 – 7/30/16)
Significant delay waiting for tool to become available

189 Bolts were replaced
- 11 baffle bolts visually identified as severed at the bolt to shank area
- 19 baffle bolts visually identified as protruding from counter bore
- 135 unsatisfactory ultra-sonic (UT) test
- 16 baffle bolts unable to UT assumed bad
- 9 baffle bolts with visually cracked lock bar welds
- Refueling preps began

As of 6/28/16 there was light at the end of the tunnel!
Mean While Back at Unit 2......
The Reactor Tripped from 100%
Multiple Generator Trips

On 6/28/2016 in the middle of the Unit 1 Outage Salem Unit 2 tripped from 100 pct on Generator Protection leaving 2 of 3 Units down during Summer Run.

No smoking gun found for Unit 2 trip

- Some signs of water intrusion and arcing found on Iso-Phase bus
- Seal ups performed and additional test monitoring installed and Unit restarted

7/4/16 at 82 Pct Power monitoring equipment detected pre-trip

( momentary 7 to 10ms ground fault spike not wide enough to trigger trip relay )

- Power reduced to < P9 and Turbine Manually Tripped
- Additional testing found some issues but no smoking gun
- Some repairs made and Unit restated

7/10/16 at 40 Pct Power monitoring equipment detected pre-trip

- Power reduced and Turbine Manually Tripped
Industry experts called in to help could not determine a root cause for the Generator Protection ground fault. Additional acoustic monitoring equipment was installed and the Unit returned to service.

7/24/16 at 100 Pct Power monitoring equipment detected pre-trip

- Power reduced to < P9, minutes after getting to P9 the Generator Tripped.
- Examination of acoustic monitoring pointed to 2A Main Power Transformer (MPT) as the potential source of the grounds.
- The 2A MPT was oil drained for internal inspection.
- A neutral wire on a metering CT within the MPT had broken and was hanging free (next slide)
Neutral Wire on a metering CT had broken hanging free

MPT A interior view (normally full of oil)

Broken Dangling wire swaying in oil can momentarily come in contact with copper 25 KV Bars
Cause of spurious trips was broken dangling metering CT neutral wire

- The failed wire could sway due to oil flow/movement and had the opportunity to touch the copper bars below it, our 25KV system.
- This was the cause of our grounds and turbine trips
- Although internal to Alpha transformer the transformer bars go to both the alpha and bravo buses. That is why we also saw a ground on the alpha phase and the bravo phase as well.
- Acoustic Monitoring was key to isolating the issue to the MPT. MPT’s are new from last outage to not initially suspected.
- Vendor ABB had installed over 1000 transformers similar to ours, they have never seen this type of failure before
- MPT repaired and refilled and Unit 2 returned to Service on 8/7/16
- On 8/30/16 Unit 2 tripped from 100 pct on an unrelated issue with RCP short caused by water intrusion
- On 9/9/16 Unit 2 returned to service. Has been up since.
Salem Units 2016 Reactor Power
Conclusion

Plan for the Worst Case

Do not assume NEW Plant Equipment is without flaws

*Top Management in place at the start of the year “retired” at the end of the year*

Questions?