May 26, 2016

MEMORANDUM TO: Michael R. Johnson
Deputy Executive Director for Reactor
and Preparedness Programs
Office of the Executive Director for Operations

FROM: Jeremy S. Bowen ***/RA/***
Executive Technical Assistant
Office of the Executive Director for Operations

SUBJECT: COMMUNICATIONS INFORMATION ON DEGRADED BAFFLE-FORMER BOLTS

As requested, enclosed is a communication tool (public website “Spotlight”) detailing the current status of the degraded baffle-former bolts issue.

The material included in the communication tool is based on the current understanding of the information available to the U.S. Nuclear Regulatory Commission staff.

Enclosure:
As stated

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BAFFLE-FORMER BOLTS

SUMMARY

Baffle-former bolts help hold together a structure inside the reactor vessel of Westinghouse four-loop pressurized water reactors (PWRs). Two of these reactors recently identified a large number of degraded baffle-former bolts during their 2016 spring refueling outage inspections. Indian Point, Unit 2 and Salem, Unit 1 found and reported these degraded bolt conditions in event notifications: EN 51829 and EN 51902.

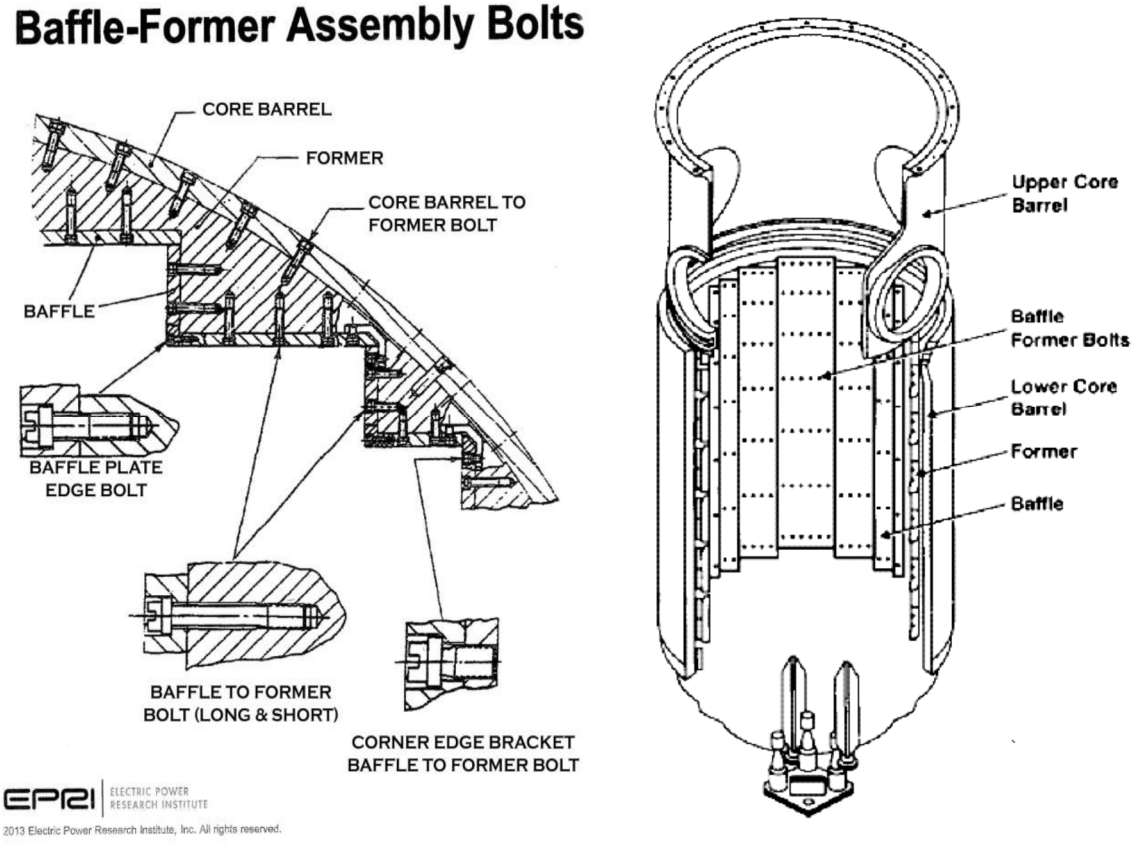
These plants identified more degraded bolts than prior operating experience would suggest. That experience indicates that larger numbers of degraded bolts could appear in older Westinghouse four-loop plants that have a "down-flow" reactor internals configuration and use baffle bolts made of Type 347 stainless steel. There are seven U.S. units with these conditions: 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).

The NRC's initial assessment determined that degraded baffle-former bolts do not warrant the immediate shutdown of any plant. The issue falls short of presenting a significant safety concern, and these recent events posed no threat to the public or the environment.

BACKGROUND

Structures located within Westinghouse reactor vessels 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 that 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"). Newer PWRs use the "up-flow" design, and several older units have converted to "up-flow" to minimize a condition where high velocity water can pass through gaps in the core baffle joints and hit nearby fuel assemblies. "Down-flow" plants place more stress on baffle-former bolts. Plants with the modified "up-flow" direction have shown little baffle bolt cracking as compared to the unconverted "down-flow" designs.

Figures below: *Baffle-former assembly bolts (left). This shows the three styles of baffle plate bolts: edge bolts, baffle-former bolts, and corner edge bolts. Baffle-former bolts are the bolts that have experienced the recent issues at Indian Point-2 and Salem-1. A typical core barrel baffle arrangement is shown (right).*



Typical baffle-former bolts are stainless steel (Type 347, Type 316, or Type 304), approximately 5/8" diameter, and typically 1.5 - 2" long. Plants that have replaced baffle-former bolts have done so per a Westinghouse-approved design using bolts with less susceptible material properties (i.e., Type 316 stainless steel vs. Type 347 stainless steel) and an improved head geometry to reduce stress concentrations. Most baffle-former bolt designs secure the bolt heads with a welded locking tab (see photo below, right). These lock tabs normally retain the bolt heads should they become detached. However, if the failed bolts protrude, the tabs, weld materials, and bolt heads could crack and detach, generating foreign material in the reactor coolant system.

Baffle bolts (left); typical baffle bolt lock tab (right)

SAFETY/RISK IMPLICATIONS

Baffle-former bolt degradation was first noted back in the late 1980's in foreign plants, and has been periodically reported at U.S. plants. The U.S. Nuclear Regulatory Commission (NRC) issued an information notice in 1998 describing the foreign events (Information Notice No. 98-11: Cracking of Reactor Vessel Internal Baffle-Former Bolts in Foreign Plants).

Baffle-former bolts' location subjects them to significant mechanical stress and high levels of neutrons coming from the core for many years. These conditions lead to irradiation-assisted stress corrosion cracking of these bolts. Management of this cracking is the subject of an NRC-approved Electric Power Research Institute (EPRI) Materials Reliability Program (MRP) topical report: MRP-227-A, "Materials Reliability Program: Pressurized Water Reactor Internals Inspection and Evaluation Guidelines" " (Agencywide Documents Access Management System Accession No.: ML120170453).

Baffle-former bolt issues during normal plant operations include broken parts and lock tabs becoming foreign material in the reactor coolant system. This could potentially lead to fuel leaks and/or localized fuel failure issues. The additional stresses of a loss of coolant accident (LOCA) or seismic event could displace baffle plates if significant numbers of bolts are damaged or missing. LOCA stresses are more likely to cause this damage; and during the worst case scenario of a large LOCA, the potential exists for a baffle plate to detach or deform. Such an event would likely only affect the fuel assemblies next to the baffle plates and would not meet the definition of "core damage." A detached or deformed plate is unlikely to block reactor coolant flow, or to challenge the ability to safely shut down the reactor since most plants don't have control rods located in fuel assemblies near the edge of the core. Many factors reduce the "worst case" scenario, including the fact that most bolts that fail ultrasonic testing (UT) are only partially cracked and can still bear some load. Baffle edge bolts remain intact, providing significant restraint against plate detachment; this factor is not normally credited in minimum bolting analyses.

Impact for other reactor designs

All but two Combustion Engineering designed PWRs employ a welded, rather than bolted, baffle assembly (or "core shroud"). No issues have been observed in the two units with bolted core shrouds that use Type 316 stainless steel bolts. Babcock & Wilcox designed PWRs generally use Type 304 stainless steel baffle-former bolting and also have not exhibited any significant issues.

General Electric boiling water reactors are unaffected by this issue because they use a different design involving a welded core shroud assembly.

Although Diablo Canyon, Unit 2 is a Westinghouse four-loop PWR, it was previously converted to the "up-flow" configuration and has Type 316 stainless steel bolting. A 100% visual inspection of the Diablo Canyon, Unit 2 baffle-former bolts was performed by the licensee during its May 2016 refueling outage and no problems were identified.

RECENT ISSUES

Indian Point, Unit 2 – During its 2016 spring refueling outage, while performing inspections adhering to the standards of MRP-227-A, the licensee discovered baffle-former bolt degradation issues. During this review it was determined that 227 of 832 baffle-former bolts inspected at the plant were potentially degraded (had UT indication of cracking, visual defects such as a missing bolt head or cracked locking tab weld, or were inaccessible for UT). This issue was reported under Event Notification (EN) EN 51829 "BAFFLE BOLT INDICATIONS IDENTIFIED DURING INSERVICE INSPECTION" on March 29, 2016. The licensee (Entergy) is in the process of analyzing the root cause and has replaced these degraded bolts. An additional 51 bolts were also replaced to provide further margin for baffle plate structural integrity and allow for testing of bolts that are considered to be non-degraded. Entergy and the NRC are also assessing any implications for Indian Point, Unit 3 (the currently running unit). Entergy has reported that Indian Point, Unit 3 is believed to be less susceptible to the baffle-former bolt degradation condition for several reasons – less operational time, resulting in less irradiation of the bolt material; fewer thermal cycles (less cumulative fatigue on the Unit 3 baffle-former bolts); and slightly lower differential pressure across the baffle plates. The NRC is actively inspecting the licensee's evaluations. An NRC Blog posting titled: "An Outage Twist: Degraded bolts at New York Nuclear Plant Warrant Attention", was issued on the NRC public blog gateway on April 27, 2016.

Salem, Unit 1 – During its refueling outage in spring 2016, the licensee (Public Service Enterprise Group (PSEG)) performed reactor vessel visual inspections and discovered degraded baffle-former bolts. Numerous bolts with cracking or indications were noted based on visual examinations and subsequent UT inspections. PSEG reported this condition on May 3, 2016, under EN 51902 "ANOMALIES IDENTIFIED DURING VISUAL INSPECTION OF REACTOR VESSEL INTERNALS."

RESPONSE AND NEXT STEPS

The NRC examined the degraded baffle-former bolts issue for potential reduction in safety margin using NRC guidance LIC-504, "Integrated Risk-Informed Decision-Making Process for Emergent Issues." The LIC-504 process guides the decision on whether immediate regulatory action, such as ordering a plant to shutdown, is required. This initial assessment is based on an overall risk assessment of the issue. In this case, the NRC examined whether the core damage frequency rose unacceptably as a result of degraded baffle-former bolts such that a plant shutdown would be warranted. The initial assessment determined that this situation does not warrant the immediate shutdown of any plant.

Westinghouse performed a “bolt pattern analysis” for Indian Point, Unit 2 and is in the process of completing one for Salem, Unit 1 to determine the minimum allowable number of baffle-former bolts required and which degraded bolts require replacement before restart of these units. In general, both licensees are replacing all bolts with an indication of degradation and any bolts that were unable to be ultrasonically tested. The NRC staff will assess and review the Westinghouse analysis and both licensees’ root cause information, including the results of metallurgical analysis, in order to develop an appropriate longer term regulatory response. In addition to inspecting the repairs and analyses of the two units where degradation was observed, the NRC staff is inspecting the licensee’s evaluation supporting continued operation of the other units at those sites.

For other plants with similar designs (Diablo Canyon, Unit 1 and D. C. Cook, Unit 1 & 2), the licensees are expected to enter this relevant operating experience into their corrective action programs. Part of that process is to assess the issue for impact on the operability of the affected units. The NRC’s resident inspectors will ensure the licensees have taken these actions and will evaluate each licensee’s operability determination.

On May 16, 2016, EPRI’s Materials Reliability Program convened a special task group meeting to evaluate results from the Indian Point and Salem sites and assess the generic implications for the current industry inspection and evaluation guidelines. NRC staff will meet with EPRI/MRP staff to discuss whether changes to any MRP inspection guidance for baffle-former bolts is necessary.

The NRC is likely to issue a generic communication on the issue once more root-cause information becomes available. Currently, the agency position is there is no immediate safety concern, and that these events posed no significant threat to the public or to the environment. The NRC will ensure the condition is suitably understood and addressed and that appropriate regulatory actions are taken.