UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

August 25, 2003

NRC INFORMATION NOTICE 89-69, SUPPLEMENT 1: SHADOW CORROSION RESULTING IN FUEL CHANNEL BOWING

Addressees

All holders of operating licenses for boiling water reactors (BWRs), except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform the addressees of control blade shadow corrosion resulting in fuel channel bowing in BWR plants. The NRC anticipates that recipients will review the information for applicability to their facilities and consider taking actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice do not constitute NRC requirements; therefore, no specific action or written response is required.

Background

Fuel channel bow is elongation of one fuel channel face relative to the opposite fuel channel face. Fuel channel bow has been known to occur, and has been modeled in fuel licensing (thermal limits) analysis, and mitigated in core design. Previous occurrences of fuel channel bow have been known to arise from three sources: initial manufacturing, residual stress relaxation under irradiation, and differential irradiation growth caused by fast fluence gradients. These effects have been explicitly incorporated in fuel licensing (thermal limits) analysis.

Description of Circumstances

Recent experience has shown a new phenomenon called “shadow corrosion-induced” channel bow. Shadow corrosion of the channel outer surface can occur when a control blade is inserted next to the fuel channel. When controlled early in life, the resulting shadow corrosion can result in increased absorbed hydrogen-induced growth of the channel wall closest to the control blade, which leads to channel bowing towards the control blade late in fuel bundle life.

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There are two effects from the new phenomenon and direction of the channel bow: (1) the bow assumed in the thermal limits calculation may not represent the new data, and (2) the bow towards the control rod blade can lead to control rod-fuel channel interference. The concerns related to the control blade/channel interference are: (1) that friction causes the fuel bundles to lift, (2) that the stresses are transferred to the reactor internals and (3) that scrams are slower. GE Nuclear Energy (GENE) recommends an additional surveillance to detect this control blade/channel interference. These recommendations provide the methodology for identifying the most susceptible locations for significant shadow corrosion-induced channel bow and for measuring the settle time/scram time for control rods in the sampled area. The available experience and channel dimensional characterization shows the condition to be most significant where there is a large control blade with a small channel-to-control blade gap. These conditions contribute both to develop shadow corrosion and shadow corrosion-induced channel bow, and additionally result in a greater channel-control blade interference for a given channel bow magnitude.

GENE has completed an evaluation of the impact on thermal limit calculations and identified the following. An inaccuracy is introduced into the thermal limits calculation if the assumed bow does not represent the actual channel bow data. The impact on thermal limit calculations can be greater than 0.01 on minimum critical power ratio (MCPR), which exceeds the threshold for report ability. Absent a detailed plant-specific calculation, GENE recommends a generic interim penalty of 0.02 on the operating limit MCPR (OLMCPR) for all affected BWR/6 plants until a plant-specific calculation can be performed.

GENE has also evaluated the impact on thermal limits calculations for BWR/2-5 plants. The maximum MCPR impact on any operating cycle has been found to be 0.002. This is within the uncertainty range for this calculation and is below the threshold for a Reportable Condition. GENE indicated that long-term actions are to update the channel bow data used in the approved fuel licensing models and incorporate the effects of shadow corrosion into future reload licensing analyses.

Discussion

During shutdown for the Cycle 9 refueling outage at Limerick 1, the licensee noticed significant difficulty with control rod settling in fuel bundles of symmetric control cell locations. Review of post shutdown scram times revealed longer than expected scram times for these locations. This prompted the licensee to investigate. The preliminary investigation showed that excessive channel bowing caused the control blade interference. After reviewing the operating history, the licensee determined that the channels in these control cells had been exposed to fast flux gradients for two successive cycles that were sufficient to cause significant channel bow toward the control blade. The investigation also revealed that shadow corrosion was a contributor to the channel bow. The combined effects led to the interference condition.

A similar event occurred at the Grand Gulf Nuclear Station during their twelfth operating cycle. While inserting a control blade, the licensee noticed that the insertion was slower than expected and the blade did not settle appropriately into an even notch position. Settling problems were also noted at other symmetric control cell locations. During the refueling for Cycle 13, the licensee discovered that control rod blade position indication was temporarily lost from one of

these symmetric control cells. The licensee visually examined the bundles and control blades in these affected cells and discovered contact patterns consistent with excessive channel bow. The visual examination of the control blades revealed that their function remained intact. As at Limerick 1, the Grand Gulf cells experiencing the control blade interference were those containing third cycle bundles that had experienced significant control blade exposure early in lifetime. GENE concludes the interference condition was most likely caused by shadow corrosion-induced bow of these higher exposure channels.

The control blade settling problem was also experienced at Clinton, Perry, River Bend, and Susquehanna. The root cause investigations all identified excessive channel bow as the likely major contributor. GENE investigation of the Clinton channels confirmed the presence of excessive channel bow, and was able to associate it with early-in-life control blade exposure and differential hydride induced growth of opposite channel faces. Although no specific inspections were performed, GENE believes shadow corrosion-induced channel bow is likely involved in the other 2 plants.

On March 3, 2003, GENE issued a Part 21 notification describing the control blade shadow corrosion-induced channel bow phenomenon. On April 28, 2003, GENE provided NRC and industry interim surveillance recommendations for monitoring fuel channel bow that are in addition to the required control rod technical specification surveillances. The interim surveillance program augments the surveillance requirements in the plant technical specifications until other appropriate actions to mitigate the channel bow problem can be identified and implemented. The surveillance program is intended to provide early indication of potentially degraded control blade performance, and assure that appropriate actions are taken before the friction between the control blades and the channels becomes excessive. This program also includes the extent and frequency of the surveillance. On June 6, 2003, GENE informed the NRC staff, that the impact on thermal limits calculations for BWR/2-5 plants is less than the reportable threshold. GENE indicated that the long-term actions are to update the channel bow data used in the approved fuel licensing models and incorporate the effects of this data into future reload licensing analyses.

The following documents provide additional information regarding fuel channel bowing:

Event Notification 39634, “Part 21 Notification- Fuel Channel Bow,” dated March 4, 2003 and updated June 9, 2003

Event Notification 39806, “Interim Surveillance Program for Fuel Channel Bow Monitoring (Part 21,” dated April 29, 2003

IN 89-69, “Loss of Thermal Margin Caused by Channel Box Bow,” dated September 29, 1989

Part 21 Notification, “Fuel Channel Bow Reportable Condition & 60-Day Interim Notification,” dated March 3, 2003, (Adams ML031420086)

Part 21 Notification, Interim Surveillance Program for Fuel Channel Bow Monitoring, Rev. 0 dated April 28, 2003, (Adams ML031420342) and Rev. 1 dated April 30, 2003 (Adams ML031420335)

Part 21 Notification, "Channel Bow Thermal Limits Impact, GNF-A Thick/Thin Fuel Channels, BWR 2-5 Plants," dated June 6, 2003 (Adams ML031700267)

Letter from Exelon Nuclear to NRC, "Limerick Generating Station Unit 1 Cycle 9 Channel Bow Assessment" dated July 25,2002 (Adams ML022120417)

This information notice requires no specific action or written response. If you have any questions about the information in this notice, please contact the technical contact listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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