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

December 11, 1997

NRC INFORMATION NOTICE 97-85: EFFECTS OF CRUD BUILDUP AND BORON DEPOSITION ON POWER DISTRIBUTION AND SHUTDOWN MARGIN

Addressees

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

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to alert addressees to a potentially significant problem pertaining to anomalous behavior of the core axial power distribution and erosion of shutdown margin (SDM) attributed to crud buildup on the nuclear fuel and subsequent boron deposition in the crud layer. It is expected that recipients will review the information for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Background

The Callaway Plant is a PWR with a Westinghouse nuclear steam supply system, owned and operated by Union Electric Company (UE). The core contains 193 fuel assemblies and is currently in its ninth cycle of operation. The plant is licensed to operate at 3565 MWt.

Beginning with operating cycle 4, UE observed unexpected behavior in the power distribution at the plant. This anomaly was characterized by a gradual unexpected power shift toward the bottom of the core and was first detected at a core average burnup of approximately 7000 Megawatt-Days per Metric Ton of Uranium (MWD/MTU) in cycle 4. The power shift continued until burnup effects became dominant and caused power to shift back to the top of the core near the end of the cycle. In addition to the anomalous power distribution, deviations were observed in the estimated critical position (ECP) of the control rods. Although ECPs for plant restarts that occurred early in each cycle agreed well with measured critical positions, this agreement disappeared for restarts that occurred later in core life. During cycles 4 and 5, ECP deviations increased to over 0.5 percent $\Delta k/k$.

After analyzing relevant data, performing scoping calculations, and reviewing industry experience, UE and Westinghouse concluded that the power distribution anomaly was most likely caused by the formation of crud and deposition of lithium borate initiated by subcooled nucleate boiling. The ECP deviations were another effect of this anomaly.

Incore detector indications of flux depressions between fuel grids in high power fuel assemblies, as well as visual examinations showing crud deposits on fuel pins, supported these conclusions.

Discussion

Axial offset (AO) is a measure of the difference between power in the upper and lower portions of the core. This difference must remain within limits established in the technical specifications to ensure that both SDM and clad local peaking factors are not exceeded. Exceeding these limits could result in the reactor fuel exceeding 10 CFR 50.46 limits on fuel clad temperature (2200 °F). If the reactor approaches these limits, compensatory measures, including a power reduction, must be taken to maintain the reactor within its operational limits.

On the basis of investigations by UE and Westinghouse, the cause of the axial offset anomaly (AOA) at Callaway is most likely crud buildup on fuel assemblies in the upper portion of the reactor core. This crud buildup is especially pronounced in high-power assemblies. High core power results in increased subcooled nucleate boiling in the upper core, which, in turn, causes greater crud accumulation on the fuel assemblies. Lithium borate is absorbed and concentrated in the crud layer, reducing the fission rate in the upper portion of the core. The visual indications of crud buildup and flux depression between the grid straps support these conclusions. As a result of the reduced fissioning in the upper core, the power distribution shifts toward the bottom of the core. This resulting power shift causes a reduction in SDM and an increase in local peaking factors. Near the end of cycle, excess burnup in the bottom of the core and reduced boron and lithium concentrations in the reactor coolant system cause the power distribution to shift back toward the upper portion of the core, partially restoring the burnup distribution.

A number of Westinghouse plants have experienced AOAs ranging from -3 percent to -15 percent. These plants include Callaway, Catawba 1, Comanche Peak 2, Millstone 3, Seabrook, Vogtle 1 and 2, and Wolf Creek.

The -15 percent AO at Callaway is the largest to date. In response to the anomaly and continued erosion of SDM, the licensee for Callaway reduced reactor power to 95 percent on July 15, 1997, and to 70 percent in mid-August 1997. On September 6, 1997, with the unit at 70 percent power and with AO at approximately 0 percent, the licensee, in consultation with Westinghouse, reduced reactor power to 30 percent in the hope of releasing the lithium borate from the crud, thereby creating a more positive AO when power was returned to 70 percent. Similar results had been seen in a previous cycle following a downpower event at Callaway. The results of this maneuver were not as predicted. After 24 hours at 30 percent power, only 25 percent of the lithium borate had been released from the crud. When power was increased to 70 percent, approximately 70 percent of the lithium borate that had been released during the

power reduction was reabsorbed into the crud. The AO at the conclusion of the maneuver was larger than before (the AO trended several percentage points negative after the maneuver). Westinghouse and the licensee surmised that the cause of the worsening AO was the release of depleted boron during the power reduction, followed by absorption of fresh boron into the crud during the return to 70 percent power.

Currently SDM is decreasing at the rate of 3-4 percent-millirho (pcm) per day. As SDM has decreased (the technical specification limit is 1300 pcm), UE has taken several actions to restore it. These actions include reducing operational flexibility by modifying the rod insertion limits and relaxing the rod worth uncertainties in the SDM calculations (based on an approved Westinghouse topical report).

By reducing power and introducing operational restrictions, the licensee has continued to operate Callaway within the limits of the safety analysis for the plant. UE and Westinghouse are continuing their investigation into this phenomenon.

This information notice requires no specific action or written response. However, recipients are reminded that they are required by 10 CFR 50.65 to take industry-wide operating experience (including information presented in NRC information notices) into consideration, where practical, when setting goals and performing periodic evaluations. If you have any questions about the information in this notice, please contact one of the technical contacts listed below or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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97-84	Rupture in Extraction Steam Piping as a Result of Flow-Accelerated Corrosion	12/11/97	All holders of OLs for nuclear power reactors except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel
95-49, Sup. 1	Seismic Adequacy of Thermo-Lag Panels	12/10/97	All holders of OLs for nuclear power reactors
97-83	Recent Events Involving Reactor Coolant System Inventory Control During Shutdown	12/05/97	All holders of OLs for pressurized-water reactors, except those licensees who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel
97-82	Inadvertent Control Room Halon Actuation Due to a Camera Flash	11/28/97	All holders of OLs for nuclear power reactors
97-81	Deficiencies in Failure Modes and Effects Analyses for Instrumentation and Control Systems	11/24/97	All holders of OLs for nuclear power reactors except those who have ceased operations and have certified that fuel has been permanently removed from the vessel
97-80	Licensee Technical Specifications Interpretations	11/21/97	All holders of OLs for nuclear power reactors

OL = Operating License
CP = Construction Permit

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