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

August 3, 1998

NRC INFORMATION NOTICE 98-29: PREDICTED INCREASE IN FUEL ROD CLADDING OXIDATION

Addressees:

All holders of operating licenses for nuclear power reactors, except those licensees 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 addressees of recent Westinghouse experience with one of its reactor fuel designs which has exhibited higher than expected rates of oxidation of zircalloy cladding at high burnups . It is expected that recipients will review the information for applicability to their facilities and consider action as appropriate, to avoid similar problems. The material and discussion contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances:

On October 28, 1997, Westinghouse notified NRC that modification of its fuel cladding corrosion model in its fuel rod design code, PAD, to reflect new data on Zircaloy-4 oxidation at high burnup may create compliance issues for its Integral Fuel Burnable Absorber (IFBA) fuel with Zircaloy-4 cladding. The modified code may predict higher fuel temperatures and internal pressures at high burnup conditions. This, in turn, may lead to code results that do not meet the Westinghouse criterion prohibiting gap reopening and that do not meet the loss-of-coolant accident (LOCA) criterion in 10 CFR 50.46(b)(2).

The Westinghouse criterion prohibiting gap reopening was approved by the NRC staff for steady-state operation when internal pressure in the rod exceeds reactor coolant system pressure. The staff approved this criterion in lieu of a criterion requiring that the internal pressure of the fuel rod not exceed reactor coolant system pressure. Both criteria have the same purpose, which is to not allow separation between the fuel pellet and the cladding late in life; this limits temperature difference between fuel and clad and therefore minimizes maximum fuel temperature.

The acceptance criterion in 10 CFR 50.46(b)(2) requires that the calculated maximum total oxidation of the cladding not exceed 0.17 times the total thickness of the cladding before oxidation. Total oxidation includes both pre-accident oxidation and oxidation occurring during a LOCA. If this total oxidation limit were to be exceeded during an accident, the cladding could become embrittled. The cladding could then fracture and fragment during the reflood period and lose structural integrity. This in turn could compromise the structural soundness and coolable geometry of the core and ultimately the ability to keep the core cooled.

Historically, the focus of compliance with 10 CFR 50.46 has been on 10 CFR 50.46(b)(1), "Peak Cladding Temperature," which usually is most limiting at the beginning of fuel life. Because the oxidation rate is known to be dependent on temperature, total oxidation was also deemed most severe at the beginning of life (BOL). The contribution of preaccident oxidation to the calculated total oxidation had not previously been thought to be significant, but as measured cladding oxidation thickness in the later stages of assembly service life increased faster than had been predicted, it became so.

On November 6, 1997, the NRC staff, Westinghouse, and the Westinghouse Owners Group (WOG) met in a public meeting to discuss this matter. At that meeting, the WOG stated that it would provide a list of affected plants, the projected dates when each might become vulnerable to potential non-compliance, and details of its plans to address the issue. The WOG also stated that each affected plant would take appropriate individual actions in terms of reporting pursuant to 10 CFR 50.46(a)(3)ii before the plant reached its projected date of vulnerability.

Westinghouse stated that it planned to perform more detailed assessments for individual plants and to make timely recommendations to each licensee for compensatory actions with regard to the compliance issue. In the longer term, Westinghouse will correct its model in PAD to better account for recent higher burnup oxidation data and will begin using the revised model by August 1998.

The NRC staff found that this approach was adequate to address in the near term the specific problems reported by Westinghouse and that plants with Westinghouse IFBA fuel could continue to operate in compliance with 10 CFR 50.46. The staff noted that the burnup related phenomena, which could result in noncompliance with the oxidation requirements of 10 CFR 50.46, may not be limited to Westinghouse IFBA fuel but might affect any Zircaloy fuel used in high burnup applications. The staff also notes that the oxidation-related phenomena discussed in this information notice may affect licensees' compliance with the reporting requirements of 10 CFR 50.46(a)(3), as well as the performance criteria of 10 CFR 50.46(b).

Discussion:

Westinghouse employs the NRC-approved PAD computer code to evaluate fuel performance. In 1996, Westinghouse found that two cladding-related models in PAD were nonconservative in analyses of fuels at high burnup. It has recently been shown that the effects of these non-conservatisms in the models could lead to nonconservative calculation of post-LOCA cladding oxidation. These analyses are used to show compliance with 10 CFR 50.46 (b), criterion (2).

The first deficient model deals with fuel rod gap pressure. For the last several years, Westinghouse plants have used high-duty fuel rods, with IFBA and Zircaloy-4 cladding in their core designs. The IFBA rods have a boron coating on the UO2 pellet surface. Westinghouse discovered that for higher burn up IFBA fuel, the rod internal pressure buildup attributed to helium released from IFBA was higher than the buildup previously modeled by the PAD code. Westinghouse revised the PAD model to account for increased helium release from IFBA rods and the increased rod pressure buildup resulting from this helium release.

The second deficient model is the Zircaloy-4 cladding oxidation calculation in the PAD code. Westinghouse corrected the corrosion model for Zircaloy-4 cladding material to address the accelerated levels of corrosion actually being measured for high burnup fuel rods. The measured corrosion levels were higher than had been calculated using the previous oxidation model. Using the corrected corrosion model, Westinghouse interpreted the PAD results to indicate that the degraded thermal conductivity of the cladding due to the higher oxidation levels produced an increase in fuel cladding temperatures and consequent higher clad creep rates. These higher creep rates could, in turn, lead to gap reopening, which would be contrary to a Westinghouse design criterion. In addition, Westinghouse concluded that with potential gap re-opening, degraded thermal conductivity of the fuel pellets due to high burnup further elevated the local fuel temperature.

The accompanying higher stored energy level and the high pre-LOCA oxidation level could, as early as the second half of the second duty cycle, make this higher burnup fuel more limiting with respect to the LOCA criterion of 10 CFR 50.46(b)(2) than the analysis of record for BOL fuel. Westinghouse further indicated that the gap reopening is a concern not only for IFBA rods, but also for gadolinia rods which contain gadolinia powder mixed homogeneously with UO2 pellets. The gadolinia degrades the thermal conductivity of the fuel pellets, resulting in a higher operating temperature of the fuel.

Westinghouse stated that exceeding the criterion prohibiting gap reopening did not directly lead to clad failures. However, fuel rods with gap reopening could be more vulnerable to swelling and rupture during LOCAs and could challenge the 17 percent oxidation limit. Therefore, high burnup or high duty-fuel rods with a tendency toward gap reopening would be more vulnerable under LOCA conditions. Licensees and fuel vendors with other types of Zircaloy clad fuels may wish to consider the relevance of this information to the oxidation models in use for their specific fuels in light of this new experience, which suggests that oxidation levels at high burnup may be more severe than previously expected.

This information notice requires no specific action or written response. 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.

Original signed by D.B. Matthews FOR

Jack W. Roe, Acting Director
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Information Notice No.	Subject	Date of Issuance	Issued to
98-28	Development of Systematic Sample Plan for Operator Licensing Examinations	8/3/98	All holders of operating licenses for nuclear power plants
98-27	Steam Generator Tube End Cracking	7/24/98	All holders of operating licenses for pressurized-water reactors except those who have permanently ceased operation and have certified that fuel has been permanently removed for the reactor vessel
96-48, Sup. 1	Motor-Operated Valve Performance Issues	7/24/98	All holders of operating licenses for nuclear power reactors except those who have permanently ceased operation and have certified that fuel has been permanently removed from the reactor vessel.
98-26	Settlement Monitoring and Inspection of Plant Structures affected by Degradation of Porous Concrete Subfoundations	7/24/98	All holders of operating licenses for nuclear power reactors; all of or applicants for licenses to operate Independent Spent Fuel Storage Installations; and designers and fabricators of Independent Spent Fuel Storage Installations.

OL = Operating License
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