ENCLOSURE 2

MFN 12-074

Enhanced LUC Program for NSF Channels

Non-Proprietary Information – Class I (Public)

IMPORTANT NOTICE

This is a non-proprietary version of Enclosure 1, which has the proprietary information removed. Portions of the document that have been removed are indicated by white space with an open and closed bracket as shown here [[ ]].

Enhanced Lead Use Channel (LUC) Program for NSF Fuel Bundle Channels

Objectives

Increasing the number of NSF channels that may be inserted using the traditional LUC process, which allows utilities to insert non-licensed materials using a 10 CFR 50.59 evaluation. This will expand GNF's experience base with statistically significant quantities in varied environments while decreasing cell friction concerns in the reactors implementing the enhanced LUC program.

This stepwise / measured approach to increasing the quantities of NSF channels in operating BWRs provides a bridge to inserting reload quantities, which are ultimately necessary for a bow-resistant channel to provide the greatest safety benefit.

Material Description

GNF fuel channels will be manufactured with a channel-bow-resistant material known as NSF. The term NSF reflects the presence of niobium (Nb), tin (Sn) and iron (Fe) as the primary alloying metals combined with zirconium in the following weight percentages: 1% niobium; 1% tin; and 0.35% iron. Similar zirconium alloys containing niobium are commonly used in PWRs and Russian plants for cladding, spacer grids and guide tubes, but have not been commercially used in BWRs.

Experience Base of NSF Channels

GNF's experience with NSF channel began in 2002 when four LUCs were inserted in Limerick Unit 1 Cycle 10 (a C-Lattice plant). Based on evidence of low irradiation growth of Zr-Nb-Sn-Fe alloys, NSF was considered an improved channel material that would be resistant to fluence gradient-induced bow that occurs at bundle locations near the periphery. Between 2003 and 2005, GNF determined a new channel bow mechanism called shadow corrosion-induced bow that could also occur when fresh fuel assemblies were controlled early in life. Shadow corrosion-induced bow was found to be related to increased hydrogen on channel sides that exhibited shadow corrosion. In 2005 and 2006, GNF inserted four NSF LUCs into Perry Cycle 11 and three NSF LUCs into Clinton Cycle 11; [[ ]] Both Perry and Clinton are S-Lattice plants that have the smallest gap between the blade and the channel and thus the greatest susceptibility to shadow corrosion. In 2007, GNF inserted four additional NSF LUCs into Hatch Unit 2 Cycle 20 (a D-Lattice plant with the largest gap between the blade and the channel).

[[ ]] were discharged. Coupons were cut from one channel and sent to a hot cell for post-irradiation examination. [[

]] In addition, four additional NSF LUCs were inserted into Hatch Unit 2 prior to Cycle 22. [[

]] NSF channels operating in three different plants (one S-Lattice, one C-Lattice and one D-Lattice).

The operational experience in this LUC phase supports the conclusions that [[

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Fluence Gradient-Induced Bow Performance

The irradiation growth of the NSF channels was determined by measuring channel length during the outages. These measurements are plotted in Figure 1 and compared to Zircaloy-2 channel length data and other growth data for Zircaloy-2 and NSF. [[

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The corresponding fluence gradient-induced bow of NSF channels is plotted in Figure 2 and compared to Zircaloy-2 channels. In this plot, positive bow is toward the control blade and negative bow is away from the control blade. [[

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Shadow Corrosion-Induced Bow Performance

Shadow corrosion-induced bow is inferred from the measured bow by subtracting out the predicted fluence bow. This inferred shadow bow is then correlated to a metric that quantifies the amount of early life control a specific bundle experiences. This metric is called the Effective Control Blade Exposure (ECBE) and is a weighted average of insertion length and insertion time giving it units of inch-days. The available data on the inferred shadow bow of NSF is plotted in Figure 3 and compared to the Zircaloy-2 database. [[

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Creep Bulge

The creep bulge is calculated from poolside measurements of channel deflection. The available data on the creep bulge of NSF is compared to the Zircaloy-2 database in Figure 4. The observations indicate [[
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Corrosion Performance

The corrosion performance requirement for channels relates to metal thinning as this is accounted for in the mechanical design. Overall, the [[

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The visual observations of channels under normal corrosion conditions [[
]] Examples of typical surface conditions of NSF [[ ]] are provided in Figure 5. The measured oxide thickness of NSF after [[
]] For comparison, the measured oxide thickness of Zircaloy-2 channels after [[
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Measurements on Zircaloy-4 channels after [[
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Oxide thicknesses of [[

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<u>Proposed LUC Program</u>

GNF has operated LUCs to [[
]] These test programs were performed in accordance with the provisions of GESTAR II which limit the total quantity of test assemblies to less than 2% of the core. Thus, GNFs LUC programs have typically included [[
]] and therefore can provide an operational benefit to the plant.

To take advantage of the proven performance of NSF channels prior to licensing, GNF proposes the LUC limit be increased to 8% exclusive of other lead assembly programs. This proposal is prudent because of the proven ability of NSF to operate as expected both from current BWR LUC experience as well as previous PWR and Russian experience. In other words, other lead use programs would not be impacted by this proposed increase in Lead Use material and continue to be allowed up to the 2% limit of GESTAR II. For example, the 8% NSF LUC limit would allow insertion of ~60 LUCs for a 764 bundle core.

Sixty (60) channels is considered a sufficient number of assemblies to allow utilities to use these channels in various core configurations (control cells, center cells, outer cells) so that diverse channel distortion drivers (fluence gradient, shadow corrosion, channel bulge) can be experienced and quantified. The amount of data obtained from similar quantities in several plants would be sufficient to support re-evaluation of current channel distortion operational challenges and provide an expanded basis to assess the cell friction of future core reloads.

Safety Analysis

The channel component includes general design functions and safety related design functions. The general design functions include:

1 The channel forms the flow path shell for fuel bundle coolant flow.

2 The channel provides surfaces for control rod guidance in the reactor core.

3 The channel provides structural stiffness to the fuel bundle during lateral loadings applied from fuel rods through the fuel spacers.

4 The channel forms the coolant flow leakage path at the channel/lower tie plate interface.

5 The channel transmits fuel assembly seismic loadings to the top guide and fuel support of the core internal structure.

The safety functions of the fuel channels include:

1 The four channels in a cell establish the pathway through which the control blade moves. The lateral stiffness of the channel prevents channel buckling and ensures that the pathway remains available during design basis events, such as an earthquake. Excessive bulge and bow of channels may affect the movement of rods and the scram time. Therefore, the fuel channels impact the capability to shut down the reactor and maintain it in a safe shutdown condition.

2 The channel provides a barrier to allow parallel coolant flow paths and provides a heat sink which cools the outer row of fuel rods during a LOCA event.

3 The channel provides a barrier to fuel rod failure propagation from one fuel assembly to others by maintaining separation of fuel rods and by restricting the movement of debris that may be associated with the initial failure. Therefore, the fuel channel may help to mitigate the consequences of certain severe accidents.

The NSF alloy has demonstrated improved bow characteristics in smaller quantity lead use programs, as noted above in the experience section. Hence, the operational experience in these lead use programs supports the conclusions that NSF is [[

]] Further, the previous LUC programs provide a degree of confidence that there will be no unanticipated issues in the behavior and performance as compared to Zircaloy.

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The safety basis for the proposed 8% LUC quantity is [[

]] a lead use quantity that would allow utilities to use these channels in various core configurations, increasing operational diversity and providing an expanded basis for channel performance quantification while progressing to full reload applications of NSF.

Monitoring Plan

GNF proposes that each plant with an expanded NSF LUC program where the number of NSF channels is greater than 2% will comply with a monitoring plan sufficient to protect the core against unanticipated channel distortion. Control rod cells with NSF channels will be evaluated as part of the normal scram-time testing population. The plant technical specifications (TS) require scram-time testing of 10% of the control rods every 120 days (nominally). During operation beyond the first cycle, at least [[ ]] of the NSF LUC program channels must be scram-time tested or settle tested within each normal TS testing interval. If cells with NSF channels are selected in the conduct of normal TS testing, then they would be counted as part of the [[ ]] requirement for NSF LUC testing. If the TS testing does not include at least [[ ]] of the NSF LUC program channels, additional scram testing or settle testing would be required until the prerequisite quantities have been reached. As the testing progresses through the operating cycle, the deliberate selection of specific control rod drive cells containing NSF channels is acceptable to maximize coverage and ensure inclusion of cells suspected to have increased friction. The settle testing may be performed while operating, during scheduled power reduction or while shutdown.

Post-Irradiation Inspection Plan

During fuel outages, a subset [[ ]] of the expanded NSF LUC program channels will be inspected visually to evaluate corrosion performance and to measure the length change. After discharge a subset [[ ]] of the expanded NSF LUC program channels will be [[ ]] In addition after discharge, [[ ]] of the NSF LUC channels to confirm that [[ ]]

Reporting Results

GNF will summarize the progress and results from each of the NSF LUC programs to the NRC annually.

Incorporation Into GESTAR II

When approved by the US NRC, the enhanced NSF LUC program will be incorporated by reference into Section 1.2.1 General Criteria, Subsection B. The following paragraph and references will be added.

> GNF proposed in Reference 1-14 an enhanced lead use program for the use of channels made of the niobium-tin-iron (NSF) zirconium alloy. The US NRC has reviewed and approved the program by Reference 1-15. This program allows NSF Lead Use Channels (LUC) to be used in quantities up to 8% of the total number of channels in the core. The NSF LUC limit of 8% is exclusive of other lead assembly programs. In other words, other lead use programs are not affected and continue to be allowed up to the ~2% limit of GESTAR II.

References

1-14 Letter from A.A Lingenfelter (GNF) to Document Control Desk (US NRC), Subject: Enhanced Lead Use Channel (LUC) Program for NSF Fuel Bundle Channels, September 25, 2012, MFN 12-074.

1-15 NRC Safety Evaluation for Reference 1-14.

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Figure 1 Irradiation growth response of Zircaloy-2 and NSF under both BWR and BOR60 reactor conditions. The fluence from BOR60 has been corrected to correspond to BWR conditions.

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Figure 2 The measured bow of Zircaloy-2 and NSF channels as a function of exposure.

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Figure 3 The inferred shadow corrosion-induced bow of Zircaloy-2 and NSF channels plotted as a function of ECBE.

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Figure 4 Creep bulge data for NSF channel compared to the Zircaloy-2 database.

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Figure 5 NSF channel surfaces for normal corrosion conditions.

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Figure 6 NSF cycle channel surfaces following shadow corrosion conditions.