ENCLOSURE 2

MFN 16-061

NEDO-33798 Supplement 1, “NSF Channel Annual Experience Summary Report”

Non-Proprietary Information - Class I (Public)

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Global Nuclear Fuel

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Non-Proprietary Information – Class I (Public)

NSF Channel Annual Experience Summary Report

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REVISION SUMMARY

Revision	Section(s) Modified	Revision Description
0	--	2016 Initial Release

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SUMMARY

This report provides a summary of the ongoing experience with Global Nuclear Fuel's (GNF's) NSF channels as required by the Nuclear Regulatory Commission's (NRC's) conditions and limitations that are stipulated as a condition for the licensing of NSF channel material in reload quantities. Poolside inspections of 18 NSF channels from three different Boiling Water Reactors (BWRs) have been completed between March 2015 and September 2016. New measurements of growth, creep bulge, total channel distortion, and inferred shadow corrosion-induced bow add to the experience base and continue to demonstrate the expected behavior for NSF channels. All conditions and limitations of the NSF Topical Report (TR) Safety Evaluation (SE) that require annual reporting are met by this report.

ACRONYMS

Acronym	Explanation
BWR	Boiling Water Reactor
ECBE	Effective Control Blade Exposure
EOC	End-of-Cycle
GNF	Global Nuclear Fuel
GNF-A	Global Nuclear Fuel - Americas
LTR	Licensing Topical Report
LUC	Lead Use Channel
NRC	Nuclear Regulatory Commission
NSF	Zr-Sn-Nb-Fe Alloy
PWR	Pressurized Water Reactor
R-factor	Weighted rod power local peaking for critical power calculations
SE	Safety Evaluation
SIMCHAD	Simplified Channel Dimensional
TR	Topical Report
US	United States

1.0 INTRODUCTION

Global Nuclear Fuel (GNF) proposed the use of its NSF[1] channel material as a material solution that could mitigate channel to control blade interference that emerged in the early 2000s as an operational concern. The benefit of NSF arises from its resistance to both fluence gradient-induced bow and shadow corrosion-induced bow. GNF loaded NSF Lead Use Channels (LUCs) in several United States (US) Boiling Water Reactor (BWR) plants starting in 2002 to gain experience with the material. An expanded LUC program that allowed up to 8% LUCs was approved by the Nuclear Regulatory Commission (NRC) in 2013 ((MFN 12-074 Supplement 2-A, Reference 1).

Approval of the 8% LUC program included Condition and Limitation 3 to visually inspect and measure the length[2] of [[ ]] of the LUCs during each outage, and upon discharge to visually inspect and measure the length of [[ ]] of the LUCs and to measure the distortion (bow and bulge) of [[ ]] of the LUCs. The NRC approved the batch application of NSF channels in September 2015 (MFN 15-076, Reference 2). The expanded NSF LUC program monitoring and inspection plan, detailed in Section 3.2 of the MFN 12-074 Safety Evaluation (SE) report, must be completed as a requirement of the batch application approval. In addition, the batch approval requires the submittal of an annual NSF experience report to the NRC to ensure continued in-reactor performance and applicability of NSF models.

1.1 PURPOSE

The purpose of this report is to provide an annual NSF experience report to satisfy NRC requirements set forth in the SE report as a condition for the licensing of GNF's NSF channel material in reload quantities as specified in MFN 15-076 (Reference 2).

1.2 SCOPE

The scope of this NSF annual experience report provides a summary of the specific items that are required to be reported as set forth in the SE in Condition and Limitation 4 (Reference 2). These required items are the following:

a. Plot of NSF channel irradiation database, expressed as Effective Control Blade Exposure (ECBE) versus exposure.
b. Plot of measured channel growth versus fast neutron fluence data, along with NSF growth model predictions.
c. Plot of measured channel bulge versus exposure data.
d. Plot of measured channel bulge data versus NSF channel bulge model predictions.

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[1] NSF derives its name from the alloying elements used in a new channel material developed by GNF; Zr-Nb-Sn-Fe. This alloy is comparable to Zircaloy-2 (Zr-Sn-Fe-Cr-Ni) and Zircaloy-4 (Zr-Sn-Fe-Cr). It was developed based on applications in Pressurized Water Reactor (PWR) (Zirlo) and Russian (Zr-Nb) fuel components.

[2] Length measurements are used to determine the channel growth.

e. Plot of measured channel distortion (total) versus exposure data, segregating low and high ECBE data.

f. Plot of inferred shadow bow versus ECBE data, along with NSF shadow bow model predictions.

SE Condition and Limitation 5 (alterations to distortion models), 6 (elimination of channel-control blade interference counter measures), and 7 (changes in R-factor uncertainty) specified in Reference 2 require reporting when changes have been made. Because no changes were made in this annual reporting cycle, they are not included herein.

2.0 NSF CHANNEL INSPECTIONS AND PERFORMANCEINSPECTIONS

One post-irradiation poolside examination of NSF channels included in the 8% expanded LUC program was completed in March 2016 following their first irradiation cycle. None of those 8% LUC channels were discharged, and therefore, the inspection requirements were to perform visual inspection and length measurements on [[ ]] of the [[ ]] channel NSF LUC batch size. Visual inspection and length measurement data for NSF channels in the 2% LUC classification was also obtained from an inspection in March 2015 and an inspection in March 2016. In addition, Simplified Channel Dimensional (SIMCHAD) measurements were included in the March 2015 inspection.

The three plants included in the 2015 and 2016 inspections are summarized in Table 2-1, and details of the inspected channels are summarized in Table 2-2, which include a range of exposure and ECBE conditions. Currently, the irradiated NSF SIMCHAD and length measurement database encompasses the burnups and ECBEs shown in Figure 2-1 (Condition and Limitation 4.a). The database is bounded with [[ ]] channel exposure and [[ ]] ECBE.

2.2 PERFORMANCE

The measured growth, creep bulge, total distortion, and inferred shadow corrosion bow for NSF channels are summarized in the following sections. Comparisons are made to Zircaloy-2 in some cases to show the broader context in which the data exist.

2.2.1 NSF Channel Growth

Consistent with Condition and Limitation 4.b, new NSF channel growth measurements are shown in Figure 2-2 as a percentage change from the nominal original length. New growth measurements are also compared to prior measurements in Figure 2-2. The data shows that NSF growth is trending with fluence above and below the current model line and does not indicate that NSF's distortion model requires modification. At high fluence, the population of NSF channels continues to [[ ]] channels that start to exhibit signs of breakaway growth initiation between [[ ]] fast fluence.

2.2.2 NSF Channel Creep Bulge

Consistent with Condition and Limitation 4.c, the measured channel creep bulge as a function of exposure is shown in Figure 2-3 for 100T NSF channels and in Figure 2-4 for 120T NSF channels. Data are plotted for the [[ ]] inch elevations. Only 120T channels were inspected between March 2015 and September 2016. NSF creep bulge at these elevations is [[ ]]. Maximum bulge is approximately [[ ]], with most bulges being less than [[ ]]. Consistent with Condition and Limitation 4.d, the measured bulges compared to predicted values are shown in Figures 2-5 and 2-6 for 100T and 120T NSF channels, respectively. The model tends to predict bulge well for the available data, with some over prediction mostly at [[ ]] inches. Bulge uncertainty is currently set at [[ ]] and covers much of the variation in the data, thus no changes to the NSF bulge model are warranted.

2.2.3 NSF Channel Total Distortion

Consistent with Condition and Limitation 4.e, the measured total distortion as a function of exposure for NSF channels is shown in Figure 2-7. NSF's total distortion is [[ ]] about the zero-distortion axis between [[ ]]. Maximum distortion for NSF channels with ECBE [[ ]] compared to NSF channels with ECBE [[ ]]. NSF total distortion is [[ ]] compared to that of Zircaloy-2 channels.

2.2.4 NSF Channel Inferred Shadow Corrosion Bow

Consistent with Condition and Limitation 4.f, the inferred shadow corrosion bow data from channels in S-Lattice and C-Lattice plants are plotted versus ECBE in Figure 2-8 for exposures greater than [[ ]]. A comparison between the current S120T/C100T NSF model and inferred shadow bow data is also provided in Figure 2-8. There is good agreement between the model and data and therefore no modifications to the NSF shadow corrosion bow model are warranted.

NSF D-Lattice data is also shown in Figure 2-8; however, there are only [[ ]]. As with [[ ]], the D-Lattice and S-Lattice/C-Lattice NSF models are [[ ]]. The NSF D-Lattice model is [[ ]] D-Lattice model, and the NSF D-Lattice and S-Lattice/C-Lattice models are [[ ]] over most of the ECBE range due to the [[ ]]. Near the [[ ]] ECBE saturation point, the S-Lattice/C-Lattice and D-Lattice NSF models diverge about [[ ]] but are much closer to each other at [[ ]]. The [[ ]] channels in the NSF D-Lattice population are bounded by either the [[ ]], and with such [[ ]]

Table 2-1 NSF 2015-2016 Channel Inspections (Plants and Classifications)

Plant	Plant Type	Number of Channels in Program	Use Classification	Operating History	Inspection Date and Cycle
[[					
					]]

Table 2-2 Summary of NSF Channels Inspected in 2015-2016

Plant	ID	Inspection Date and Cycle	Inspection Scope	Bundle Exposure (GWd/MTU)	ECBE (inch-days)	Fuel Design
[[	14P222	[[	Visual, Growth, SIMCHAD	[[		GE14
	14P221		Visual, Growth, SIMCHAD			GE14
	14P224		Visual, SIMCHAD			GE14
	14P223		Visual, SIMCHAD			GE14
	14P200		Visual, SIMCHAD			GE14
	14P197		Visual, SIMCHAD			GE14
	14P198		Visual, SIMCHAD			GE14
	14P199		Visual, SIMCHAD			GE14
	JLS362		Visual, Growth, SIMCHAD			GE14
	JLS365		Visual, Growth, SIMCHAD			GE14
	JYU105		Visual, Growth			GNF2
	JYU102		Visual, Growth			GNF2
	JYU107		Visual, Growth			GNF2
	JLC214		Visual, Growth			GE14
	GER322		Visual, Growth[1]			GNF2
	GER157		Visual, Growth[1]			GNF2
	GER160		Visual, Growth[1]			GNF2
]]	GER176	]]	Visual, Growth[1]		]]	GNF2

Notes:

1. The growth data field inspection report is not finalized and therefore the [[ ]] length data are not included in this report.

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Figure 2-1 Range of Exposure and ECBE for Irradiated NSF Channel Distortion and Length Measurement Database

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Figure 2-2 GNF Channel Growth Data and NSF Irradiation Growth Data

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Figure 2-3 Measured Creep Bulge versus Exposure for NSF 100T Channels

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Figure 2-4 Measured Creep Bulge versus Exposure for NSF 120T Channels

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Figure 2-5 Measured Creep Bulge versus Predicted Creep Bulge for NSF 100T Channels

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Figure 2-6 Measured Creep Bulge versus Predicted Creep Bulge for NSF 120T Channels

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Figure 2-7 Measured Total Channel Distortion versus Exposure for NSF and Zircaloy-2 Channels

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Figure 2-8 Plot of Inferred Shadow Bow versus ECBE for NSF and Zircaloy-2 Channels
([[ ]] Exposure Except as Noted)

3.0 REFERENCES

1. Letter, Andrew A. Lingenfelter (GNF) to Document Control Desk (NRC), "Accepted Version of Enhanced Lead Use Channel (LUC) Program for NSF Fuel Bundle Channels," MFN 12-074 Supplement 2-A, April 15, 2013.

2. Letter, Brian R. Moore (GNF) to Document Control Desk (NRC), "Approved Version of NEDE-33798P Revision 0, 'Application of NSF to GNF Fuel Channel Designs'," MFN 15-076: September 30, 2015.