SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ENHANCED LEAD USE CHANNEL PROGRAM FOR NSF CHANNELS

GLOBAL NUCLEAR FUEL - AMERICAS

1.0 INTRODUCTION

The objective of the topical report (TR) process is, in part, to add value by improving the efficiency of other licensing and inspection processes, for example, the process for reviewing license amendment requests from commercial operating reactor licensees. The purpose of the U.S. Nuclear Regulatory Commission (NRC) TR program is to minimize industry and NRC time and effort by providing for a streamlined review and approval of a safety-related subject with subsequent referencing in licensing actions, rather than repeated reviews of the same subject.

A TR is a stand-alone report containing technical information about a nuclear power plant safety topic, which meets the criteria of a TR. A TR improves the efficiency of the licensing process by allowing the NRC staff to review a proposed methodology, design, operational requirements, or other safety-related subjects that will be used by multiple licensees, following approval, by referencing the approved TR. The TR provides the technical basis for a licensing action or operational guidance.

By letter dated September 25, 2012 (Reference 1), as supplemented by a letter dated January 25, 2013 (Reference 2), Global Nuclear Fuel (GNF) requested review and approval of an expanded lead use channel (LUC) program for their developmental zirconium alloy NSF. The NRC is treating this letter submittal as a TR. NSF derives its name from its primary alloying elements: niobium (Nb), tin (Sn), and iron (Fe). The expanded LUC program would allow greater numbers of channels to be exposed to varying in-reactor operating strategies, nuclear conditions, and water chemistry, in order to gain experience and gather data for batch application. Once approved, the enhanced NSF LUC program will be incorporated into NEDE-24011-P, entitled “General Electric Standard Application for Reactor Fuel (GESTAR II).”

The NRC staff found that, in general, the submittal meets the objectives of a TR and reinforces previously established NRC regulations and guidelines as noted within this safety evaluation (SE). The NRC has evaluated this submittal against the criteria of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, and has determined that it does not represent a backfit to a licensee. Specifically, NRC staff technical positions outlined in this SE are consistent with the aforementioned regulations and established staff positions.

ENCLOSURE 2

2.0 REGULATORY EVALUATION

Regulatory guidance for the review of fuel system materials and designs and adherence to General Design Criteria (GDC) -10, GDC-27, and GDC-35 is provided in NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants" (SRP), Section 4.2, "Fuel System Design" (Reference 3). In accordance with SRP Section 4.2, the objectives of the fuel system safety review are to provide assurance that:

- the fuel system is not damaged as a result of normal operation and anticipated operational occurrences (AOOs),
- fuel system damage is never so severe as to prevent control rod insertion when it is required,
- the number of fuel rod failures is not underestimated for postulated accidents, and
- coolability is always maintained.

The main focus of the limited SRP guidance with respect to boiling water reactor (BWR) fuel bundle channels is control blade interference and insertability. SRP Section 4.2.II.1.A.v states:

> Control blade/rod, channel, and guide tube bow as a result of (1) differential irradiation growth (from fluence gradients), (2) shadow corrosion (hydrogen uptake results in swelling), and (3) stress relaxation, which can impact control blade/rod insertability from interference problems between these components. For BWRs, the effects of shadow corrosion should be considered for new control blade or channel designs, dimensions (e.g., the distance between control blade and channel is important), or materials. The effects of channel bulge should also be considered for interference problems for BWRs. Design changes can alter the pressure drop across the channel wall, thus necessitating an evaluation of such changes. Channel material changes can also impact the differential growth, stress relaxation, and the amount of bulge and therefore must be evaluated. If interference is determined to be possible, tests are needed to demonstrate control blade/rod insertability consistent with assumptions in safety analyses. Additional in-reactor surveillance (e.g., insertion times) may also be necessary for new designs, dimensions, and materials to demonstrate satisfactory performance.

With respect to ensuring control blade insertability under externally applied loads (i.e., Safe Shutdown Earthquake and loss of coolant accident (LOCA)), SRP 4.2 Appendix A Section IV states:

> For a BWR, several conditions must be met to demonstrate control blade insertability (1) combined loads on the channel box must remain below the allowable value defined above for components other than grids (otherwise, additional analysis is needed to show that the deformation is not severe enough to prevent control blade insertion) and (2) vertical liftoff forces must not unseat the lower tieplate from the fuel support piece such that the resulting loss of lateral fuel bundle positioning could interfere with control blade insertion.

Standard Technical Specifications include the following allowance for lead test assemblies (LTAs), which would apply to LUCs:

> Fuel assemblies shall be limited to those fuel designs that have been analyzed with NRC staff approved codes and methods and have been shown by tests or analyses to comply with all safety design bases. A limited number of lead test assemblies that have not completed representative testing may be placed in nonlimiting core regions.

Provisions within GESTAR II limit the number of lead use elements to approximately 2% of the core. Hence, the “limited number” within the Standard Technical Specifications allowance would be 2% of the core. GNF’s NSF LUC program proposes to expand the limited number allowance from 2% to 8% based upon operating experience with the NSF channels.

The term “nonlimiting core regions” was included to build in safety margin (relative to the legacy fuel) for unproven design features. In practice, compliance to this provision has meant that LTA fuel rods operated at no more than 95% of the peak fuel rod in the core. It’s not clear that this provision applies to LUCs. With respect to the safety function of fuel assembly channels, a limiting core location would be in a control cell location since these channels would be more susceptible to shadow corrosion-enhanced bow. However, avoiding control cell locations would undermine the intent of the program, which is to gain in-reactor experience and gather data on channel bow. Based on the NSF LUC program’s objectives, the staff finds the unrestricted placement of NSF LUC channels within the core (including control cell locations) acceptable.

3.0 TECHNICAL EVALUATION

The main safety functions of the BWR fuel channel are to (1) establish the pathway through which the control blade moves (i.e., maintain ability to insert control blades), and (2) provide structural stiffness to the fuel bundle during lateral loading applied during design basis events, such as an earthquake.

Recent operating experience has shown that channel distortion and associated control blade interference continues to be a major issue in the U.S. BWR commercial fleet. GNF has been studying and testing distortion-resistant channel alloys to address this operating experience. The developmental NSF zirconium alloy has shown promising results. The purpose of any lead use program is to gain in-reactor experience and gather data necessary for NRC approval of batch application for the new design feature or material. According to current provisions of GESTAR II, the total quantity of test assemblies is limited to less than 2% of the core. The expanded NSF LUC program would allow greater numbers of channels to be exposed to varying in-reactor operating strategies, nuclear conditions, and water chemistry. Specifically, GNF has requested that the NSF LUC limit be increased to 8% of the core exclusive of other lead assembly programs.

The staff's review of the expanded NSF LUC program will be to ensure that the introduction of the proposed limited number of NSF channels will not result in an unreasonable level of risk to public health and safety.

3.1 NSF Channel Design Evaluation

It's important to note that GNF has not requested approval of the NSF channels, but instead approval of an expanded LUC program. Almost by definition, any LUC is not approved since the required in-reactor experience and data has not yet been acquired. However, knowledge of the LUC design and materials is important in order to assess risk.

3.1.1 Design Specifications and Requirements

As-fabricated channel performance is dictated by its design and material properties. NSF channels will be manufactured with a new zirconium alloy which is outside of the ASTM specifications for Zircaloy-2 and Zircaloy-4. Differences in material properties may necessitate changes in physical dimensions. Currently, several different approved fuel channel designs are utilized in the U.S. BWR commercial fleet. For example, GNF2 fuel bundle design includes a thick corner / thin wall channel design comprised of Zircaloy-2 or Zircaloy-4 (See Reference 4). In response to a request for information regarding NSF channel designs (Request for Additional Information (RAI) #2, Reference 2), GNF stated that all design specifications remain unchanged from currently approved channels.

Given identical design specifications, only differences in material properties between the existing alloys, Zircaloy-2 (ASTM nominal Zr-1.5%Sn-0.15%Fe-0.1%Cr-0.05%Ni) and Zircaloy-4 (ASTM nominal Zr-1.5%Sn-0.2%Fe-0.1%Cr), and the developmental NSF (Zr-Ni-Sn-Fe) alloy will impact as-fabricated channel performance. In response to an RAI regarding NSF material properties (RAI #1, Reference 2), GNF provided a comparison of relevant elastic, thermal, mechanical, and nuclear properties. A majority of the NSF's material properties are equivalent to Zircaloy. Where differences exist, these differences have been factored into channel design evaluations. GNF concludes that NSF channels will satisfy all design requirements. GNF's design evaluation of NSF channels was informed by limited in-reactor experience and irradiated data. See Section 3.1.2.

3.1.2 Operating Experience

Enclosure 1 of Reference 1 describes GNF's operating experience with NSF channels beginning in 2002. To date, a total of [ ] NSF LUCs have been irradiated in commercial BWRs including C-, D-, and S-Lattice core configurations. Figure 1 of Enclosure 1 provides measured irradiation growth of NSF channels compared against the existing Zircaloy-2 database as a function of neutron fluence. Figure 2 of Enclosure 1 provides measured fluence gradient-induced bow for NSF and Zircaloy-2 channels as a function of exposure. [

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Figure 3 of Enclosure 1 (Reference 1) provides inferred shadow corrosion-induced bow of NSF channels compared against the existing Zircaloy-2 database as a function of effective control blade exposure (ECBE). [.]

Figure 4 of Enclosure 1 (Reference 1) provides measured irradiation assisted creep bulge of NSF channels compared with the existing Zircaloy-2 database. [.]

Figures 5 and 6 of Enclosure 1 (Reference 1) provide pool-side photos of irradiated NSF channels compared with Zircaloy-2 and Zircaloy-4 channels. [.]

3.2 NSF Channel Surveillance Program

The expanded NSF LUC program (Enclosure 1, Reference 1) includes a monitoring plan that is designed to provide a reasonable level of assurance against unanticipated channel distortion. The monitoring plan dictates specific requirements on the number of NSF LUCs that must be included in scram-time testing or settle time testing within each normal Technical Specification testing interval. In response to an RAI regarding abnormal cell friction indications (RAI #3, Reference 2), GNF stated that in the event of friction observations in cells containing NSF channels, the plant will immediately go into established augmented surveillance procedures. Furthermore, if friction indications at any plant suggest an unexpected systemic condition with NSF lead use channels, then all plants participating in the LUC program will enter the augmented surveillance procedures.

The expanded NSF LUC program (Enclosure 1, Reference 1) includes a post-irradiation inspection plan that is designed to gather data during subsequent reload cycles to identify negative trends and confirm expected performance. The inspection plan dictates specific requirements on the number and type of inspections to be performed on NSF LUCs.

The expanded NSF LUC program (Enclosure 1, Reference 1) also states that GNF will summarize the progress and results from each NSF LUC program to the NRC annually.

4.0 CONCLUSION

In their proposal, GNF requested an expansion of the existing LUC program for their developmental zirconium alloy NSF. The expanded LUC program would allow greater numbers of NSF channels to be exposed to varying in-reactor operating strategies, nuclear conditions, and water chemistry, in order to gain experience and gather data for batch application. The focus of the staff's review was to ensure that the introduction of the proposed, limited number of NSF channels would not result in an unreasonable level of risk to public health and safety. Based upon (1) existing operating experience and data that shows improved resistance to channel bow, (2) design evaluations that account for differences in material properties and satisfy design requirements, and (3) the prescribed monitoring and inspection plan, the staff finds the expanded NSF LUC program acceptable.

As described in Enclosure 1 of Reference 1, GNF intends to incorporate the expanded NSF LUC program into GESTAR II. The staff finds this acceptable.

Licensees referencing the expanded NSF LUC program will need to comply with the conditions and limitations listed in Section 5.

With regard to the expanded NSF LUC program, the staff has concluded, based on the considerations discussed above, that: (1) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, (2) such activities will be conducted in compliance with the commission's regulations, and (3) issuance of this safety evaluation will not be inimical to the common defense and security or to the health and safety of the public.

5.0 CONDITIONS AND LIMITATIONS

Licensees referencing the expanded NSF LUC program must ensure compliance with the following conditions and limitations:

1) NSF lead use channels are restricted to currently approved channel design specifications with NSF alloy compositions that meet current GNF specifications, which target the nominal composition listed in Enclosure 1 of Reference 1.

2) NSF lead use channels may be used in quantities up to 8% of the total number of channels in the core. This limit is exclusive of other lead assembly programs.

3) The NSF LUC program monitoring and inspection plan, detailed in Section 3.2, must be fulfilled.

4) As further in-reactor experience and measurements are collected, GNF will continue to demonstrate that NSF LUCs satisfy design requirements.

6.0 REFERENCES

1. GNF Letter MFN 12-074, "Enhanced Lead Use Channel (LUC) Program for NSF Fuel Bundle Channels," September 25, 2012, Agencywide Documents Access and Management System (ADAMS) Accession No. ML12270A245.

2. GNF Letter MFN 12-074, Supplement 1, "Supplemental Information for Enhanced Lead Use Channel (LUC) Program for NSF Fuel Bundle Channels," January 25, 2013, ADAMS Accession No. ML130280676.

3. NUREG-0800, “Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants” (SRP), Section 4.2, “Fuel System Design,” Revision 3, March 2007, ADAMS Accession No. ML070740002.

4. GNF Letter MFN 11-194, “GNF2 Advantage Generic Compliance with NEDE-24011-P-A (GESTAR II),” NEDC-33270P, Revision 4, October 6, 2010, ADAMS Accession No. ML100740145.

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