July 14, 2006

Andrew Lingenfelter, Manager
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SUBJECT: DRAFT SAFETY EVALUATION FOR GLOBAL NUCLEAR FUEL (GNF) TOPICAL REPORT (TR) NEDE-33214P, "DENSIFICATION TESTING" (TAC NO. MC8679)

Dear Mr. Lingenfelter:

By letter dated October 3, 2005, GNF submitted TR NEDE-33214P, “Densification Testing” to the U.S. Nuclear Regulatory Commission (NRC) staff for review. Enclosed for GNF’s review and comment is a copy of the NRC staff's draft safety evaluation (SE) for the TR.

Pursuant to Section 2.390 of Title 10 of the *Code of Federal Regulations* (10 CFR), we have determined that the enclosed draft SE does not contain proprietary information. However, we will delay placing the draft SE in the public document room for a period of 10 working days from the date of this letter to provide you with the opportunity to comment on the proprietary aspects. If you believe that any information in the enclosure is proprietary, please identify such information line-by-line and define the basis pursuant to the criteria of 10 CFR 2.390. After 10 working days, the draft SE will be made publicly available, and an additional 10 working days are provided to you to comment on any factual errors or clarity concerns contained in the draft SE. The final SE will be issued after making any necessary changes and will be made publicly available. The NRC staff's disposition of your comments on the draft SE will be discussed in the final SE.

To facilitate the NRC staff's review of your comments, please provide a marked-up copy of the draft SE showing proposed changes and provide a summary table of the proposed changes. If you have any questions, please contact Michelle Honcharik at 301-415-1774.

Sincerely,

/RA by WReckley for/

Stacey L. Rosenberg, Chief
Special Projects Branch
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Office of Nuclear Reactor Regulation

Project No. 712

Enclosure: Draft SE

cc w/encl: See next page

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ADAMS ACCESSION NO.: ML061870056 *No major changes to SE input. NRR-043

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DRAFT SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT NEDE-33214P

"DENSIFICATION TESTING"

GLOBAL NUCLEAR FUEL

PROJECT NO. 712

1.0 INTRODUCTION AND BACKGROUND

In letter dated October 3, 2005, Global Nuclear Fuel (GNF) submitted to the U. S. Nuclear Regulatory Commission (NRC) Topical Report (TR) NEDE-33214P, "Densification Testing," (Reference 1) for review and approval. TR NEDE-33214P describes the intent to eliminate a routine densification sampling method. The routine densification sampling method is described in the NRC Regulatory Guide (RG) 1.126, "An Acceptable Model and Related Statistical Methods for the Analysis of Fuel Densification" (Reference 2). TR NEDE-33214P intends to demonstrate that the elimination of the routine densification sampling method will not adversely affect the in-reactor densification performance and the fuel pellets continue to meet licensing requirements of RG 1.126.

Since the discovery of in-reactor densification of oxide nuclear fuel pellets, the impact of the densification on safety has been analyzed routinely in fuel designs and fabrication. The safety analyses of in-reactor densification include the effects on linear heat generation rate due to the shortening fuel column, fuel stored energy due to the increasing fuel cladding gap, and flattening of the cladding due to the formation of axial gaps along the fuel column. The NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 4.2 "Fuel System Design," (Reference 3) states that if axial gaps in the fuel column occur due to densification, the cladding has the potential of collapsing into a gap and collapsed cladding is assumed to fail. This phenomenon is called creep collapse.

The in-reactor densification is a function of the temperature, irradiation history, porosity, and material characteristics including initial density. The extent of the in-reactor densification is found to be closely correlated to the out-of-reactor densification tests or thermal sintering tests. A thermal sintering test subjects fuel pellets in a heated furnace to a constant elevated temperature for an extended period of time to simulate the reactor environments. The RG 1.126 requires that the thermal sintering tests, also called re-sintering tests, be performed at 1700 EC for 24 hours to ensure a density change that bounds most in-reactor density changes for a wide range of fuel types.

Consistent with the RG 1.126 requirements, GNF established a routine densification test to systematically re-sinter a significant portion of production fuel pellets to obtain the densification performance data. The GNF fuel density requirements for fuel designs and fabrication specify the maximum densification allowed for an individual pellet. The GNF fuel density history showed a trend of increasing fuel density and decreasing amount of densification.

2.0 REGULATORY EVALUATION

The fuel system consists of arrays of fuel rods including fuel pellets and tubular cladding, spacer grids, end plates, and reactivity control rods. The objectives of the fuel system safety review are to provide assurance that: (1) the fuel system is not damaged as a result of normal operation and anticipated operational occurrences, (2) fuel system damage is never so severe as to prevent control rod insertion when it is required, (3) the number of fuel rod failures is not underestimated for postulated accidents, and (4) coolability is always maintained. The NRC staff acceptance criteria are based on the criteria in Reference 3. These criteria include three parts: (1) design bases that describe specified acceptable fuel design limits (SAFDLs) as depicted in General Design Criterion 10 to Appendix A of Part 50 of Title 10 of the *Code of Federal Regulations*, (2) design evaluation that demonstrates that the design bases are met, and (3) testing, inspection, and surveillance plans that show that there are adequate monitoring and surveillance of irradiated fuel. The design bases include: (1) fuel system damage, (2) fuel rod failure, and (3) fuel coolability. Densification is identified as a failure mechanism that leads to creep collapse of the cladding.

3.0 TECHNICAL EVALUATION

3.1 Current Approach in Fuel Production

During fuel manufacture, there is a process called sintering that subjects all production fuel pellets to a heated furnace for certain period of time. Although the sintering temperature is close to re-sintering tests, the time involved in the sintering process usually is shorter than the re-sintering tests. The sintering process results in stable and consistent microstructure pellets, which result in less in-reactor densification. Thus, the sintering process is a very important stage during fuel fabrication. The density sampling of the sintered pellets during fuel fabrication is performed to assure that the products meet the density requirements.

In the past, GNF used several processes to produce UO_2 powder including the ammonium diuranate (ADU) and wet chemical recovery processes. These processes tended to have uneven powder particles that resulted in various and large densification. Recently, GNF made several fundamental changes to improve UO_2 powder and pellet manufacture. GNF established a single UO_2 powder production process, the dry conversion process (DCP), which produced even and consistent powder particles. The DCP resulted in stable fuel pellets with highly uniform microstructure and densification resistance, i.e., very limited densification.

Following the discovery of in-reactor densification and implementation of routine out-of-reactor densification (or re-sintering) testing, GNF found that it was necessary to increase the sintering temperature and time to adequately assure the pellet dimensional stability. In addition, GNF added a volatile pore former during the fuel fabrication. The pore former is an organic material which is added to UO_2 powder at the blending stage for fuel density control. During the sintering process, the pore former will escape as a gas and create large stable pores in pellets to reach the desired final density. The results show that the pore former improved the pellet consistency and reduced fuel density uncertainties.

GNF has established quality control procedures to assure that the density of all pellets is within the specification requirements. Various documents control the density of natural UO_2, UO_2, and

Gd_2O_3-UO_2 fuel pellets. Out-of-specification pellets will prompt corrective actions. Figure 1 in TR NEDE-33214P illustrates this process. Thus, the frequent tests and multiple cross checking provide a high level of confidence that out-of-specification pellets will be excluded in the early stages.

Based on the current approach and improved procedures, the NRC staff concludes that GNF has adequately demonstrated that the fuel fabrication has produced consistently stable pellets with low densification and meets all the density requirements.

3.2 Elimination of Routine Densification Test

The current GNF fuel fabrication showed a strong correlation between sintered pellets and in-reactor densification performance, i.e., sintered and stable fuel pellets had less densification in reactors. GNF will continue the current density sampling of the sintered pellets during fuel fabrication to assure that the products meet the density requirements. Furthermore, GNF will implement additional qualification processes for any change in materials or processes that could have the potential to impact the densification performance. The additional qualification processes will verify the changes and will not result in altering the densification performance and, thus, meet the RG 1.126 requirements.

Since the current approach in the fuel fabrication produces stable and almost no out-of-specification pellets, and the continued quality control checks the production pellet density, GNF contended that the routine densification test was redundant and was no longer needed to assure acceptable in-reactor densification performance. Thus, GNF proposed to eliminate the routine densification test from the fuel fabrication process.

The NRC staff reviewed the GNF proposed approach. Based on the fuel fabrication history and satisfactory in-reactor densification performance, the NRC staff concludes that the routine densification test can be removed from the fuel fabrication process and may be supplemented with additional qualification processes for meeting the RG 1.126 requirements provided that GNF continues the established monitoring program to assure that the pellet density requirements are met using a qualified measurement technique on 100 percent of pellet lots.

4.0 CONDITIONS AND LIMITATIONS

Based on the review, the NRC staff requires that GNF continue the established monitoring program to assure that the pellet density requirements are met using a qualified measurement technique on 100 percent of pellet lots. Figure 1 in TR NEDE-33214P depicts the fuel density requirements that will prompt corrective actions for out-of-specification pellets. Any changes in the limits of Figure 1 in TR NEDE-33214P will require a prior approval by the NRC staff.

5.0 CONCLUSION

The NRC staff has reviewed the GNF submittal of the proposed elimination of routine densification test. Based on the evaluation, the NRC staff approves the proposed elimination of routine densification test in TR NEDE-33214P with the conditions and limits as described in Section 4.0 of this SE.

6.0 REFERENCES

1. NEDE-33214P, "Densification Testing," September 2005 (ADAMS Package Accession No. ML052850035).

2. Regulatory Guide 1.126, Revision 1, "An Acceptable Model and Related Statistical Methods for the Analysis of Fuel Densification," March 1978 (ADAMS Accession No. ML003739385).

3. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 4.2 "Fuel System Design."

Principle Contributor: S. Wu

Date: July 14, 2006