Global Nuclear Fuel

A Joint Venture of GE, Toshiba, & Hitachi

Andy Lingenfelter
Manager, Engineering

Global Nuclear Fuel – Americas, LLC
Castle Hayne Road, Wilmington, NC 28401
(910)675-5954 Fax: (910)675-6614

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U.S. Nuclear Regulatory Commission
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Subject: Comments on Draft Safety Evaluation For Global Nuclear Fuel (GNF) Topical Report (TR) NEDE 33214P, "Densification Testing" (TAC NO. MC8679)

The NRC in Reference 1 requested GNF comments on the subject draft SE. Enclosure 1 provides a marked-up copy of the draft SE with revisions on showing the proposed changes. Enclosure 2 provides a summary table of the proposed changes that includes the suggested changes and discussion of the basis for the change.

We find no information in the SE that is GNF proprietary pursuant to the 10CFR2.390 criteria.

If you have any questions about the information provided here, please contact me at (910) 675-5954 or Mark Dubecky at (910) 675-6680.

Sincerely,

Andrew A. Lingenfelter
Manager, Engineering

Global Nuclear Fuel – Americas, LLC

Project No. 712

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References

1. Letter S. L. Rosenberg to A. Lingenfelter, Subject: Draft Safety Evaluation For Global Nuclear Fuel (GNF) Topical Report (TR) NEDE 33214P, "Densification Testing" (TAC NO. MC8679), July 14, 2006.

Enclosures

1. Revisions On Markup of Draft SE
2. Summary Table for Proposed Changes

cc: MA Dubecky, GNF/Wilmington
RE Brown, GE/Wilmington
JF Harrison, GE/Wilmington
JF Klapproth, GE/Wilmington
GB Stramback, GE/San Jose
MC Honcharik, USNRC
eDRF Section 0000-0057-8972

ENCLOSURE 1 – REVISIONS ON MARKUP

FLN-2006-025

COMMENTS ON DRAFT SAFETY EVALUATION FOR GLOBAL NUCLEAR FUEL (GNF) TOPICAL REPORT (TR) NEDE 33214P

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 **testing of pellet** densification ~~sampling method~~. The routine **testing of pellet** 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 **testing of pellet** densification ~~sampling method (frequency)~~ 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 ~~has been~~ **addressed for fuel** fabrication. The safety analyses of in-reactor densification include the effects on linear heat generation rate due to the shortening fuel column **and creation of axial gaps**, 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~~**operation**. The RG 1.126 requires that the thermal sintering tests, also called re-sintering tests, be performed at 1700 °C 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~~ **sampling program** to systematically re-sinter a **statistically** 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 variation in the~~ous~~ **measured** ~~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 **high** 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 **and** $(U,Gd)O_2$ 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 continues to use a pore former to produce a high-density fuel matrix with stable pores that are resistant to densification.**

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~~**the historical density requirements of the fuel**

pellets produced by GNF. GNF manufactures pellets with a high density and therefore the pellets have little propensity for further densification. 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., **highly** 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 **for densification** pellets, and the continued quality control checks the production pellet density, GNF contended that ~~the~~ routine densification testing was redundant and was no longer needed to assure acceptable in-reactor densification performance. Thus, GNF proposed to eliminate ~~the~~ routine densification testing 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

ENCLOSURE 2 – SUMMARY TABLE OF COMMENTS

FLN-2006-025

COMMENTS ON DRAFT SAFETY EVALUATION FOR GLOBAL NUCLEAR FUEL (GNF) TOPICAL REPORT (TR) NEDE 33214P

GNF requests that the following two changes be made to the technical content of the Draft SE TAC NO. MC8679.

Section	Paragraph	Change	Justification
3.1	4	From: "Figure 1 in TR NEDE-33214P illustrates this process." To: "Figure 1 in TR NEDE-33214P illustrates the historical density requirements of the fuel pellets produced by GNF. GNF manufactures pellets with a high density and therefore the pellets have little propensity for further densification."	Figure 1 in TR NEDE-33214P does not show a process. It shows the historical pellet density requirements that have been used in the design and manufacture of fuel at GNF.
4.0	1	From: 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. To: 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.	GNF requests that the second condition in the draft SE be removed. The process defined in Section 7.2 of NEDE-33214P for assessing material and process changes is applicable and adequate for assessing a material change such as a change to the pellet density. GNF has committed in NEDE-33214P to evaluate any changes (to materials or manufacturing processes) that may affect densification of the fuel in the qualification process.

GNF recommends the following changes to be made to the technical content of the Draft SE TAC NO. MC8679 to improve the clarity of the text.

Section	Paragraph	Change	Justification
1.0	1	From: "...routine densification sampling method..." To: "...routine testing of pellet densification..." Change made in places in paragraph 1.	GNF has requested permission to eliminate the routine testing of pellet densification. Currently, GNF samples at a frequency that will assure that our pellets will meet the criteria set forth in RG 1.126.
1.0	2	From: "...analyzed routinely in fuel designs and fabrication." To: "...analyzed routinely in fuel designs and addressed for fuel fabrication."	The impact of fuel densification on the performance of the fuel in-reactor has been thoroughly analyzed. The fabrication process has been engineered so as to manufacture fuel pellets with a consistent, high density so as to minimize the in-reactor densification in an economical manner.
1.0	2	From: "...shortening fuel column,..." To: "...shortening fuel column and creation of axial gaps,..."	The shortening of the fuel column has little impact on the power peaking in the fuel rod. The creation of axial gaps in the fuel column stack causes changes in the moderation in-core.
1.0	3	From: "...simulate the reactor environment." To: "...simulate the reactor operation."	The operation of the reactor, e.g., flux, power, and time, have the greatest affect on fuel densification in-reactor.
1.0	4	From: "...a routine densification test to systematically re-sinter a statistically significant..." To: "...a densification sampling program to systematically re-sinter a significant..."	GNF established a sampling program to test for densification consistent with RG 1.126 to assure that the fuel would meet the NRC recommendations for pellet densification.
3.1	2	From: "...that resulted in various and large densification." To: "...that resulted in variation in the measured densification."	The fuel manufactured by GNF has consistently met the requirements set forth in RG 1.126. The adjective "large" implies that fuel manufacture by GNF has failed to meet the criteria of RG 1.126. Furthermore there has been some variation in the measured densification due to GNF's former practice of using different powders and processing. The adjective "various" implies that the densification of the fuel was not well understood.

3.1	2	From: "...uniform microstructure and densification resistance..." To: "...uniform microstructure and high densification resistance..."	The switch to DCP powder resulted in fuel with that is highly resistant to densification.
3.1	3	From: "...added to UO_2 powder..." To: "...added to UO_2 and $(U,Gd)O_2$ powder..."	Pore former is used in the manufacture of both UO_2 and $(U,Gd)O_2$ fuel to assure that the densification of the sintered pellets is consistent.
3.1	3	Add Sentence at end of paragraph: "GNF continues to use a pore former to produce a high-density fuel matrix with stable pores that are resistant to densification."	Absent the proposed addition, the paragraph may give the impression that GNF no longer uses a pore former to manufacture fuel pellets.
3.2	1	From: "...i.e., sintered and stable fuel pellets...." To: "...i.e., highly sintered and stable fuel pellets..."	The stability of the microstructure is dependent on the parameters (time and temperature) used to prepare the fuel. GNF manufactures "highly" sintered fuel, which means that we use a high temperature with a sufficient dwell time to create a stable microstructure.
3.2	2	From: "...out-of-specification pellets..." To: "...out-of-specification for densification pellets	For clarity the phrase "for densification" was added.
3.2	2	From: "...the routine densification test..." To: "...routine densification testing..." Change made in two places	For clarity the text was changed to the process rather than the method.