August 3, 2007

Andrew A. Lingenfelter, Manager
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Global Nuclear Fuel- Americas, LLC
P.O. Box 780, M/C F12
Wilmington, NC 28402

SUBJECT: FINAL SAFETY EVALUATION FOR GLOBAL NUCLEAR FUEL (GNF) TOPICAL REPORT (TR) NEDC-32851P, REVISION 2 ,"GEXL14 CORRELATION FOR GE14 FUEL" (TAC NO. MD5486)

Dear Mr. Lingenfelter:

By letter dated September 25, 2001, GNF submitted TR NEDC-32851P, Revision 2, "GEXL14 Correlation for GE14 Fuel," to the U.S. Nuclear Regulatory Commission (NRC) staff. The NRC staff closed the review in a letter dated July 11, 2003, while GNF conducted additional testing. By letter dated April 13, 2007, GNF submitted Supplement 1 to TR NEDC-32851P, Revision 2, "GEXL14 Correlation for GE14 Fuel," which provided the additional data. By letter dated May 30, 2007, an NRC draft safety evaluation (SE) regarding our approval of TR NEDC-32851P, Revision 2, was provided for your review and comments. By letter dated June 25, 2007, GNF commented on the draft SE. The NRC staff's disposition of GNF comments on the draft SE are discussed in Attachment 2 to the final SE enclosed with this letter.

The NRC staff has found that TR NEDC-32851P, Revision 2, is acceptable for referencing in licensing applications for General Electric fueled boiling water reactors to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that GNF publish accepted proprietary and non-proprietary versions of this TR within three months of receipt of this letter. The accepted versions shall incorporate this letter and the enclosed final SE after the title page. Also, they must contain historical review information, including NRC requests for additional information and your responses. The accepted versions shall include an "-A" (designating accepted) following the TR identification symbol.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, GNF and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

/RA/

Ho K. Nieh, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 712

Enclosures: 1. Non-proprietary Final SE
2. Proprietary Final SE

cc w/encl 1 only: See next page

August 3, 2007

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*No major changes to SE input. NRR-043

OFFICE	PSPB/PM	PSPB/PM	PSPB/LA	SNPB/BC*	PSPB/BC	DPR/DD
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DATE	07/19/07	7/31/07	7/31/07	5/3/07	8/1/07	8/3/07

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FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT NEDC-32851P, REVISION 2

"GEXL14 CORRELATION FOR GE14 FUEL"

GLOBAL NUCLEAR FUEL

PROJECT NO. 712

1.0 INTRODUCTION AND BACKGROUND

By letter dated September 25, 2001 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML012760506), Reference 1, Global Nuclear Fuel - Americas, LLC, hereafter referred to as GNF, submitted a request to the U. S. Nuclear Regulatory Commission (NRC) to review topical report (TR) NEDC-32851P, Revision 2, "GEXL14 Correlation for GE14 Fuel." This revision includes changes to the correlation statistics for the GNF 10x10 fuel design based entirely on experimental data and additional testing of the GE14 fuel. The review of TR NEDC-32851P, Revision 2, was closed by the NRC staff in letter dated July 11, 2003, while GNF conducted additional testing to obtain critical power data for GE14 top peaked axial power shape. Supplement 1 to TR NEDC-32851P, Revision 2, was provided by letter dated April 13, 2007 (ADAMS Accession No. ML071080327) and proprietary enclosure (ADAMS Accession No. ML071080333), Reference 2, which includes the additional test data.

The TR presents the GEXL14 correlation development for determination of the minimum critical power ratio (MCPR) during normal operation and postulated transient events for the General Electric Corporation (GE) boiling water reactor (BWR). The GEXL14 correlation is a critical quality and boiling length correlation used to predict the occurrence of boiling transition in BWR fuel designs. The test data used to support the development of the correlation include full-scale simulations of 7x7, 8x8, 9x9, and 10x10 fuel assemblies that were obtained at the GE ATLAS test facility in San Jose, California. The database supporting the basic GEXL correlation includes over 20,000 full-scale boiling transition data points and encompasses all of the fuel assembly designs and operating regions for BWRs. Testing has been performed in the ATLAS facility to demonstrate that the GEXL correlation can be used to predict the onset of boiling transition during postulated transient conditions that are analyzed in the safety analysis process.

The specific GEXL14 correlation developed for use in the core design and safety analysis process is intended to accurately predict the expected critical power performance of the fuel assembly design. In the core design process, the GEXL14 correlation is used to determine the expected thermal margin for the operating cycle. In the safety analysis process, the GEXL14 correlation is used in the determination of the change in critical power transients and in the determination of an acceptable MCPR safety limit. Based on the supporting test database, the TR concludes that the safety related conditions have been satisfied with respect to the development of an acceptable critical power correlation.

Revision 1 of TR NEDC-32851P, which describes the GEXL14 critical power correlation for GE14 fuel, was transmitted to the NRC by letter dated August 8, 2000. The lead plant application for GE14 fuel was the Duane Arnold Energy Center (DAEC) Extended Power Uprate (EPU). The DAEC Technical Specification Change Request for EPU, Reference 4, referred to TR NEDC-32851P, Revision 1, for critical power determination for the new fuel. As part of the DAEC EPU review, the NRC staff evaluated Revision 1 of the TR, including the experimental database used for the development of the GEXL14 critical power ratio (CPR) correlation for the GE14 (10x10) fuel lattice design. Several issues were identified by the NRC staff. The summary of the NRC staff's findings and GNF's corrective actions to resolve the issues are discussed below.

During the week of March 26, 2001, four members of the NRC staff visited the GNF engineering and manufacturing facility in Wilmington, North Carolina. The purpose of the visit was to perform an onsite review of the safety analyses and system and component performance evaluations used to support the proposed EPU. The areas covered by the review included:

1. Fuel performance of the 10x10 GE14 fuel lattice design used for DAEC, including available post-irradiation examination data;

2. Review of the GEXL14 correlation database for GE14 fuel;

3. Verification that the experimental database range covered DAEC's expected operating ranges or state points (i.e., pressures, mass fluxes, inlet subcooling) for all three axial profiles (cosine, inlet-peaked, and outlet-peaked); and

4. Review of the GE14 fuel design compliance with the NRC-approved methodology.

During the audit, the NRC staff evaluated the thermal-hydraulic compatibility of the DAEC resident fuel types in the low-flow/high power conditions with off-normal void distribution.

A formal Request for Additional Information letter summarizing the audit issues was issued in June 2001. Attachment 1 provides a summary of the chronology of events related to the TR review. Attachment 2 provides the resolution by NRC to the comments submitted by GNF on June 25, 2007.

2.0 REGULATORY EVALUATION

The regulation at Title 10 of the *Code of Federal Regulations* (10 CFR), Section 50.34, "Contents of applications; technical information," requires that Safety Analysis Reports be submitted that analyze the design and performance of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents. As part of the core reload design process, licensees (or vendors) perform reload safety evaluations to ensure that their safety analyses remain bounding for the design cycle. To confirm that the analyses remain bounding, licensees confirm that key inputs to the safety

analyses, such as the CPR are conservative with respect to the current design cycle. If key safety analysis parameters are not bounded, a re-analysis or re-evaluation of the affected transients or accidents is performed to ensure that the applicable acceptance criteria are satisfied.

The NRC staff review was based on the evaluation of the technical merit and compliance with any applicable regulations associated with reviews of TRs.

General Design Criterion (GDC)-10, “Reactor design,” of Appendix A to 10 CFR Part 50 is intended to ensure that reactor cores are designed with appropriate margin such that specified acceptable fuel design limits are not exceeded during normal operation or anticipated operational occurrences (AOOs).

To ensure compliance with GDC-10, the NRC staff confirms that the thermal and hydraulic design of the core and the reactor coolant system have been accomplished using acceptable analytical methods, is equivalent to or is a justified extrapolation from proven designs, provides acceptable margins of safety from conditions which would lead to fuel damage during normal reactor operation and AOOs, and is not susceptible to thermal-hydraulic instability.

Reference 5, NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Section 4.4, "Thermal and Hydraulic Design," describes the normal review of thermal and hydraulic design and requires that additional independent audit analyses be performed for new CPR correlations.

3.0 TECHNICAL EVALUATION

The GE critical quality - boiling length critical power correlation (GEXL) was developed to accurately predict the onset of boiling transition in BWR fuel assemblies during both steady-state and reactor transient conditions. The use of the GEXL correlation is necessary for determining the MCPR operating limits resulting from transient analysis, the MCPR safety limit analysis, and the core operating performance and design. The GEXL correlation is an integral part of the transient analysis methodology used by GNF. It is used to confirm the adequacy of the MCPR operating limit, and it can be used to determine the time of onset of boiling transition in the analysis of other events.

The GEXL correlation has been used in the safety analysis process for GE fueled BWRs since 1974. The GEXL correlation is based on the relationship of critical quality with boiling length. It expresses bundle average critical quality as a function of boiling length, thermal diameter, system pressure, lattice geometry, local rod peaking pattern (R-factor), mass flux, and annular flow length.

During the DAEC EPU audit, the NRC staff reviewed GE’s experimental database used to develop the GEXL14 CPR correlation for the GE14 (10x10) fuel lattice design. The EPU onsite audit findings and the resolutions to identified open items are discussed below:

(1) The NRC staff found that in its CPR correlation methodology, GNF was using the COBRAG computer code (with the GEXL correlation built in) to generate data instead of using experimental data obtained from their critical heat flux test facility in San Jose, California. The use of artificial data instead of raw data affects the validity of the statistical results obtained from this methodology. The statistical results are important because they are used in the calculation of the safety limit MCPR (SLMCPR) for all BWRs that use GE14 fuel. The correlation uncertainty associated with the data points affects the uncertainty of the safety limit calculations, as well as the degree of conservatism that is used to establish the reactor operating limits.

The NRC staff is aware of the difficulty in predicting critical power phenomena in the upper portion of the core because of the active multiple phase transitions and the part-length rods present in GE14 fuels. The COBRAG code has never been reviewed by the NRC staff for this purpose. Consequently, GNF agreed to remove the COBRAG-generated data from the development of the GEXL correlation for the GE14 fuel design.

(2) The NRC staff was concerned that GNF had not conducted sufficient testing of the new GE14 fuel to adequately evaluate the GEXL14 correlation. The NRC staff discovered that the experimental data collected to develop and validate the GEXL14 correlation did not include inlet and outlet power shapes. GNF pointed out to the NRC staff that there are similarities between the GE11 (9x9) fuel lattice design and the GE14 (10x10) fuel lattice designs, namely the presence of part-length rods. However, the NRC staff believes that there are also significant differences, such as the locations of the part-length rods relative to the water holes in the GE14 fuel design. To resolve the issue, GNF proposed to obtain additional critical heat flux (CHF) data to validate the GEXL14 correlation. In the interim, GNF proposed a self imposed “additional correlation uncertainty” while they obtained the additional data.

3.1 Supplemental Data and Power Shape Sensitivity Comparison

Subsequent to the NRC staff’s finding during the DAEC EPU audit, GNF obtained (inlet/bottom peaked) data from its ATLAS facility. GNF also obtained (outlet/top peaked) data from Stern Laboratory in Ontario, Canada. This additional data was used to validate the GE14 correlation uncertainty and CHF behavior for inlet and outlet peaked power profiles.

The ATLAS facility critical power data used to develop the GEXL14 correlation contained bottom peaked and cosine axial power shape data, but no top peaked axial power shape data. Additional critical power data have subsequently been collected from the Stern Laboratory test facility. A total of [ ] critical power data points were collected to verify the axial power shape sensitivity. These data points were not used in the development of the GEXL14 correlation, but were used to validate the capability of the GEXL14 correlation to predict the trend with axial power shape. The GEXL14 correlation coefficients were not adjusted in this process, only the additive constants were determined for the rod-to-rod peakings used in the Stern Laboratory tests.

The statistics for the validation of the GEXL14 correlation against the Stern Laboratory data is given in the Table 4-10 of TR NEDC-32851P, Supplement 1. Analysis of the ATLAS facility and Stern Laboratory data show that the numbers compare very well to the GEXL14 correlation statistics for the ATLAS facility data used to develop the correlation, as shown in Table 1 below. The correlation statistics for the ATLAS facility data had a mean ratio of calculated to measured critical power (ECPR) of [ ] and a standard deviation of [ ] percent. The General Electric Thermal Analysis Basis method was used to account for the absence of inlet/outlet peaked experimental data resulting in an increase in the licensing basis uncertainty to [ ] percent. It is seen from the close agreement between these data that the GEXL14 correlation predicts the trend with axial power shape very well.

The interim additional correlation uncertainty was calculated using a conservative estimate of the outlet peaked standard deviation. A correlation uncertainty of [ ] percent has been used for outlet peaked power shapes in all GEXL14 applications. This has resulted in as much as a [ ] percent increase in the SLMCPR for operating plants with GE14 fuel. When additional data was obtained and the correlation statistics were determined, the correlation upskew and downskew CPR uncertainties were found to be within the original correlation total uncertainty. Therefore, the original correlation uncertainty of [ ] percent can be reinstated.

Using the actual calculated standard deviation and considering the data in Table 1, the overall uncertainty is calculated to be [ ] percent. This is within the original licensing basis uncertainty of [ ] percent.

Table 1. GEXL14 Statistics versus Experimental Data

	Bottom Peaked Axial Power Shape (Stern)	Top Peaked Axial Power Shape (Stern)	Cosine Power Shape (ATLAS)
Number of Data Points	[ ]	[ ]	[ ]
Mean ECPR, μ	[ ]	[ ]	[ ]
Standard Deviation	[ ]	[ ]	[ ]

Table 1 demonstrates that these uncertainties are within the original licensing basis correlation uncertainty of [ ] percent for various axial power shapes.

Figure 4-1 of TR NEDC-32851P, Supplement 1, compares the power shape sensitivity between inlet/outlet peak power shapes and cosine for GE14 (GEXL14), GE12 (GEXL10), GE11 (GEXL07), and GE13 (GEXL09). The latter two are correlations for 9x9 bundles for which ATLAS facility tests for all three power shapes were performed. The comparison shows that the outlet peak relative performance for GEXL14 is very consistent with the outlet peak relative performance for previous 9X9 fuel. This shows that additional spacers at varying locations within the bundle do not introduce any new sensitivities into the axial power shape effects. The agreement of the GEXL14 correlation predictions with the Stern Laboratory data for inlet and

outlet peaked axial power shapes confirms this observation and demonstrates that the GEXL correlation accurately predicts the sensitivity with axial power shape.

3.2 High R-factor

The data collected in the ATLAS facility and the standard critical power database from the Stern Laboratory tests had R-factors up to [ ]. This R-factor range had previously been judged to be sufficient to cover fully controlled bundles. [

], MFN-05-095, J. S. Post to NRC, "Part 21 Notification Completion, Critical Power Determination for GE14 and GE12 with Zircaloy Spacers", September 20, 2005 (Reference 6), and FLN-2005-034, A. A. Lingenfelter to NRC, "Recent Experimental Thermal Hydraulics and GNF2 Licensing Meeting, October 26-27, 2005", December 15, 2005 (Reference 7), [

] However, GNF conducted an additional test at the Stern Laboratory simulating a fully controlled bundle and having a very high R-factor of 1.26. Comparison of the ECPR results from the Stern Laboratory test with those of the GEXL14 correlation prediction of an ECPR of [ ] and a standard deviation of [ ] demonstrates that the extension of the upper R-factor application range to 1.25 is justified.

The pressure range was also adjusted. The previous ATLAS facility testing covered the pressure range from 800 to 1300 psia. The Stern Laboratory testing extended this range from 700 to 1400 psia.

The GEXL14 correlation for GE14 fuel is valid over the range stated in Table 2 below.

Table 2. GEXL14 Applicability Range

Pressure	4.8 to 9.7 MPa (700 to 1400 psia)
Mass Flux	*136 to 2448 kg/sec-m^2 (0.1 x 10^6 to 1.8 x 10^6 lb/hr-ft^2)
Inlet Subcooling	0 to 233 kJ/kg (0 to 100 Btu/lb)
R-factor	*0.9 - 1.25

*exception in R-factor and Mass flux plane, the parameters should also satisfy:
(1.2-R)/0.05 $\geq$ (G-1.5)/0.3 for 1.15 < R < 1.20
(1.25-R)/0.05 $\geq$ (G-1.3)/0.2 for 1.20 < R < 1.25

The upper mass flux range for R < 1.15 is 2448 kg/sec-m^2

4.0 CONCLUSION

The GEXL14 correlation has been validated against ATLAS facility data for cosine and inlet peaked axial power shapes and against Stern Laboratory data for inlet and outlet peaked axial power shapes. These comparisons show that the axial power shape sensitivity is well predicted by the GEXL correlation. The power shape sensitivity has been shown to be very similar for the different 9X9 and 10x10 fuel product lines.

The TR NEDC-32851P was reviewed as part of the DAEC EPU submittal. The technical issues which were discovered during the DAEC EPU review were resolved in the EPU audit and supplemental documentation (Reference 8). On the basis of these prior reviews and the NRC staff review of Supplement 1 to TR NEDC-32851P, Revision 2, the NRC staff considers the methodology described in TR NEDC-32851P, Revision 2, acceptable. GNF satisfactorily responded to the issues with timely and appropriate corrective actions, explanations, and additional test data. Therefore, on the basis of the above review and justification, the NRC staff concludes that the proposed GEXL14 critical power correlation is acceptable.

5.0 REFERENCES

1. G. A. Watford to NRC, “GEXL14 Correlation for GE14 Fuel, NEDC-32851P Revision 2 and GEXL10 Correlation for GE12 Fuel with Inconel Spacers, NEDC-32464P Revision 2," September 25, 2001 (ADAMS Accession No. ML012760506).

2. A. A. Lingenfelter to NRC, “Supplement 1 to GEXL14 Correlation for GE14 Fuel, NEDC-32851P, Revision 2, September 2001,” April 13, 2007 (ADAMS Accession No. ML071080327) and proprietary enclosure (ADAMS Accession No. ML071080333).

3. NEDE-24011-P-A-14, General Electric Standard Application for Reactor Fuel (GESTAR II), June 2000 (ADAMS Accession No. ML011230173).

4. Nuclear Management Company to the NRC, "Duane Arnold Energy Center, Docket No. 331, Op. License No. DPR-49, Technical Specification Change Request (TSCR-042): ‘Extended Power Uprate,’" November 16, 2000, and attachments (ADAMS Accession No. ML003771301).

5. NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," April 1996.

6. J. S. Post to NRC, “Part 21 Notification Completion, Critical Power Determination for GE14 and GE12 Fuel with Zircaloy Spacers,” September 20, 2005 (ADAMS Accession No. ML052690084).

7. A. A. Lingenfelter to NRC, “Recent Experimental Thermal Hydraulics and GNF2 Licensing Meeting, October 26-27, 2005,” December 15, 2005 (ADAMS Accession No. ML060050548).

8. Duane Arnold Energy Center, NRC Staff Safety Evaluation for Amendment No. 243, Extended Power Uprate, November 6, 2001 (ADAMS Accession No. ML013050342).

Attachments: 1. Chronology of Events
2. Summary of Comments and Resolution

Principle Contributors: J. Gilmer
A. Attard

Date: August 3, 2007

CHRONOLOGY OF EVENTS FOR APPROVAL OF GEXL14

CORRELATION TOPICAL REPORT (TR) NEDC-32851P

Date	Description
September 1999	Revision 1 of TR NEDC-32851P issued.
March 26, 2001	Duane Arnold Energy Center (DAEC) extended power uprate (EPU) audit conducted at Global Nuclear Fuel (GNF) (identified requests for additional information (RAIs) related to review of TR NEDC 32851P, Revision 1).
March 27, 2001	GNF letter and attached responses to RAIs regarding GE14 review.
June 2001	Presentation to the U.S. Nuclear Regulatory Commission (NRC) staff on axial power shape sensitivity (echoed GNF's position provided in responses to Revision 1 in March 2001).
September 2001	GNF submitted TR NEDC-32851P, Revision 2, to the NRC staff for review.
November 2001	Safety Evaluation for DAEC EPU accepted by NRC.
February 2002	NRC staff meeting with GNF to discuss TR NEDC-32851P, Revision 2: corrective actions, commitment to proposed testing program, preventative actions, and double hump considerations.
April 2002	GNF letter describing proposed interim evaluation process.
May 2003	GNF letter committing to additional testing. Letter referenced the February 2002 testing commitment and suggested that there was no need for NRC review because GNF would be compliant with GESTAR II when the additional data was acquired.
July 2003	NRC letter rejecting GNF position that correlation issues are addressed by GESTAR, Amendment 22, requiring no staff review when the additional data is acquired.
January/February 2005	GNF conducts additional tests at Stern Laboratory to obtain additional data for the GEXL14 correlation.
March 2005	Final SE on GESTAR II, Amendment 27.
October 2005	GNF presentation to the NRC staff on testing results to resolve test data deficiency for the GE14 fuel.
April 2007	GNF letter provided Supplement 1 to NEDC-32851P, Revision 2.

ATTACHMENT 1

SUMMARY OF COMMENTS AND RESOLUTION

Location	Comment	Resolution
Table 2	The units on the mass flux are shown as 106 lb/hr-ft2 but should be 10^6 lb/hr-ft2 . This may be a Wordperfect-MS Word conversion problem.	Accepted.
Chronology of Events Table September 1999	Based on our records TR NEDC-32851, Revision 1, was not submitted for review. The date on Revision 1 is September 1999.	Accepted.
Chronology of Events Table February 2002	The commitment to perform additional testing was made at this meeting (FLN_2002_004 dated February 12, 2002).	Accepted.
Chronology of Events Table May 2003	This letter referenced the February 2002 commitment and suggested that there was no need for an NRC review because GNF would be compliant with GESTAR II when the additional data was acquired.	Accepted.
Chronology of Events Table July 2003	NRC letter rejecting GNF position that correlation issues are addressed by GESTAR II, Amendment 22, without review when the additional data was complete.	Accepted.
Chronology of Events Table March 2005	The GESTAR II, Amendment 27, does not include information or relationships to the GEXL14 correlation.	Accepted.