September 7, 2010

Mr. Jerald G. Head
Senior Vice President, Regulatory Affairs
GE Hitachi Nuclear Energy
3901 Castle Hayne Road MC A-18
Wilmington, NC 28401

SUBJECT: FINAL SAFETY EVALUATION FOR GE HITACHI NUCLEAR ENERGY LICENSING TOPICAL REPORTS NEDC-33240P, REVISION 01, "GE14E FUEL ASSEMBLY MECHANICAL DESIGN REPORT" AND NEDC-33242P, REVISION 02, "GE14 FOR ECONOMIC SIMPLIFIED BOILING WATER REACTOR FUEL ROD THERMAL-MECHANICAL DESIGN REPORT"

Dear Mr. Head:

On August 24, 2005, GE Hitachi (GEH) Nuclear Energy submitted the Economic Simplified Boiling Water Reactor (ESBWR) design certification application to the staff of the U.S. Nuclear Regulatory Commission. Subsequently, in support of the design certification, GEH submitted the license topical reports (LTRs) NEDC-33240P, Revision 01, "GE14E Fuel Assembly Mechanical Design Report" and NEDC-33242P, Revision 02, "GE14 for Economic Simplified Boiling Water Reactor Fuel Rod Thermal-Mechanical Design Report." The staff has now completed its review of NEDC-33240P, Revision 01 and NEDC-33242P, Revision 02.

The staff finds NEDC-33240P, Revision 01, "GE14E Fuel Assembly Mechanical Design Report" and NEDC-33242P, Revision 02, "GE14 for Economic Simplified Boiling Water Reactor Fuel Rod Thermal-Mechanical Design Report," acceptable for referencing for the ESBWR design certification to the extent specified and under the limitations delineated in the LTRs and in the associated safety evaluation (SE). The SE, which is enclosed, defines the basis for acceptance of the LTR.

The staff requests that GEH publish the revised version of the LTRs listed above within 1 month of receipt of this letter. The accepted version of NEDC-33240P and NEDC-33242P shall incorporate this letter and the enclosed SE and add an "-A" (designated accepted) following the report identification number.

If NRC's criteria or regulations change, so that its conclusion that the LTR is acceptable is invalidated, GEH and/or the applicant referencing the LTR will be expected to revise and resubmit its respective documentation, or submit justification for continued applicability of the LTR without revision of the respective documentation.

Document transmitted herewith contains sensitive unclassified information. When separated from the enclosures, this document is "DECONTROLLED."

Pursuant to 10 CFR 2.390, we have determined that the enclosed SE contains proprietary information. We will delay placing the non-proprietary version of this document 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 only. If you believe that any additional information in Enclosure 1 is proprietary, please identify such information line by line and define the basis pursuant to the criteria of 10 CFR 2.390.

The Advisory Committee on Reactor Safeguards (ACRS) subcommittee, having reviewed the subject LTR and supporting documentation, agreed with the staff's recommendation for approval following the May 18, 2010, ACRS subcommittee meeting.

Sincerely,

/RA Frank Akstulewicz for:/

David B. Matthews, Director
Division of New Reactor Licensing
Office of New Reactors

Docket No. 52-010

Enclosure:
1. Safety Evaluation (Non-Proprietary)
2. Safety Evaluation (Proprietary)

cc: See next page (w/o enclosure)

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ADAMS ACCESSION NO. - ML101740389-Package NRO-002

OFFICE	BWR:PM	BC:SRSB	BWR:LPM	BWR:BC	OGC/NLO	DNRL:D
NAME	BBavol	JDonoghue	ACubbage	MTonacci	RChazell	DMatthews
DATE	06/28/10	08/23/10	09/02/10	09/07/10	08/16/10	09/07/10

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SUBJECT: FINAL SAFETY EVALUATION REPORT FOR GE HITACHI NUCLEAR ENERGY LICENSING TOPICAL REPORTS NEDC-33240P, REVISION 01, "GE14E FUEL ASSEMBLY MECHANICAL DESIGN REPORT" AND NEDC-33242P, REVISION 02, "GE14 FOR ECONOMIC SIMPLIFIED BOILING WATER REACTOR FUEL ROD THERMAL-MECHANICAL DESIGN REPORT" DATED SEPTEMBER 7, 2010

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SAFETY EVALUATION BY THE OFFICE OF NEW REACTORS
NEDC-33240P, REVISION 01, "GE14E FUEL ASSEMBLY MECHANICAL DESIGN REPORT"
AND
NEDC-33242P, REVISION 02, "GE14 FOR ESBWR FUEL ROD THERMAL-MECHANICAL DESIGN REPORT"
GLOBAL NUCLEAR FUEL

1.0 INTRODUCTION

By letters dated February 3, 2009 (Reference 1), and June 10, 2009 (Reference 2), General Electric Hitachi (GEH), asked the U.S. Nuclear Regulatory Commission (NRC) to review and approve NEDC-33240P, Revision 01, "GE14E Fuel Assembly Mechanical Design Report," and NEDC-33242P, Revision 02, "GE14 for ESBWR Fuel Rod Thermal-Mechanical Design Report." These licensing topical reports, provided by Global Nuclear Fuel (GNF) to GEH, describe the GE14E fuel assembly and fuel rod design, including mechanical specifications and performance aspects, which will serve as the initial fuel design for the Economic Simplified Boiling-Water Reactor (ESBWR). The applicant provided supplemental information in response to staff requests for additional information (RAIs) in letters dated August 23, 2006 (Reference 3), January 21, 2007 (Reference 4), January 26, 2007 (Reference 5), January 4, 2008 (Reference 6), April 18, 2008 (Reference 7), May 9, 2008 (Reference 8), October 8, 2008 (Reference 9), October 24, 2008 (Reference 10), November 12, 2008 (Reference 11), March 30, 2009 (Reference 12), August 13, 2009 (Reference 13), and August 17, 2009 (Reference 14).

NEDC-33240P, Revision 01, and NEDC-33242P, Revision 02, supersede earlier revisions of these licensing topical reports, which did not receive NRC approval.

2.0 REGULATORY EVALUATION

Regulatory guidance for the review of fuel rod cladding materials and fuel system designs appears in Section 4.2, "Fuel System Design," of NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants: LWR Edition," issued March 2007 (hereafter referred to as the SRP). The SRP also provides guidance for adhering to General Design Criterion (GDC) 10, "Reactor Design"; GDC 27, "Combined Reactivity Control Systems Capability"; and GDC 35, "Emergency Core Cooling," in Appendix A, "General Design Criteria for Nuclear Power Plants," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities." In accordance with SRP Section 4.2, the objectives of the fuel system safety review are to provide assurance of the following:

- 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.

Enclosure 1

- The number of fuel rod failures is not underestimated for postulated accidents.
- Coolability is always maintained.

Using currently approved fuel design requirements and mechanical design methodology, GEH provided the GE14E fuel assembly and fuel rod thermal-mechanical design analyses in NEDC-33240P and NEDC-33242P, respectively. The staff is reviewing these licensing topical reports to ensure that the fuel design criteria and mechanical design methodology remain valid and that the GE14E design adequately addresses the regulatory requirements identified in SRP Section 4.2.

3.0 TECHNICAL EVALUATION

In its review of NEDC-33240P and NEDC-33242P, the staff did the following:

- Verified that the fuel assembly components and fuel rod design criteria are consistent with the regulatory criteria identified in SRP Section 4.2.
- Verified that the fuel mechanical design methodology is capable of accurately or conservatively evaluating each component with respect to its applicable design criteria.
- Verified that the reference GE14E fuel assembly design satisfies the regulatory requirements.
- Verified that the reference GE14E fuel assembly design satisfies all Tier 1, Tier 2, and Tier 2* design requirements specified in the ESBWR design certification document (DCD).
- Verified that the GEH experience database supports the requested operating limits.

In addition to reviewing the material presented in NEDC-33240P, NEDC-33242P, and responses to staff RAIs, the staff conducted two separate audits at the GE-Wilmington offices and performed independent calculations. The staff's audit reports (Reference 15) document the scope of these audits which included reviewing GEH's finite element analysis (FEA) models and methods as well as the GE14E fuel assembly component structural evaluations.

3.1 GE14E Fuel Assembly Design

Section 2 of NEDC-33240P provides a detailed description of the GE14E fuel rod and fuel assembly design, illustrated in Figures 2-1 through 2-9. It is important to note that the GE14E design pertains solely to the ESBWR design; hence, it does not include design variances that would address the differences among the reactors in the boiling-water reactor (BWR) fleet.

In its response to RAI 4.8-1 (Reference 3), regarding the debris resistance of GE14E, GEH provided further details about the debris filter lower tieplate and its effectiveness relative to earlier assembly designs. Based on the applicant's response, RAI 4.8-1 was resolved.

Section 2.2 of NEDC-33240P states, “GE14E fuel assemblies are fabricated in accordance with materials and processing specifications and assembly processes specifications current at the time of fabrication.” Appendix B includes similar statements. Changes in component design, materials, or processing specifications may alter the in-reactor behavior of the fuel assembly. GEH currently does not have an approved fuel design change process (similar to GESTAR II) applicable to the ESBWR design. As such, modifications to the fuel assembly design may invalidate the staff's approval of the GE14E fuel design.

In its response to RAI 4.8-2 (Reference 3), regarding GEH’s quality control procedures, GEH provided details of the process and process control steps taken to ensure that mechanical properties are not inadvertently altered. Based on the applicant’s response, RAI 4.8-2 was resolved.

Process changes must be limited to those that do not impact the physical or mechanical properties of the assembly components or fuel rods. As defined in the Conditions and Limitations (Section 5.0 of this safety evaluation), the staff’s approval of GE14E is limited to the detailed description, without deviation, provided in Section 2 of NEDC-33240P. Changes to assembly component design or materials are not permitted without prior staff approval.

3.1.1 Dimensional Compatibility

Section 3.1 of NEDC-33240P describes design analyses performed to ensure that the GE14E fuel assembly remains mechanically compatible with reactor core components, including the top guide, fuel supports, and control blades. In addition, fuel rod and assembly design allowances must address dimensional changes and differential growth throughout the operating lifetime (e.g., irradiation growth and creep). These design requirements, which ensure mechanical compatibility and sufficient design allowances, are consistent with SRP Section 4.2 and therefore are acceptable for application to GE14E.

Relative to earlier GE designs, design allowances for GE14E have increased to accommodate differential growth among assembly components. Figures 3-1 through 3-10 (Reference 1) illustrate design allowances between assembly components and measured growth data from previous poolside measurement campaigns. In its response to RAI 4.8-5 (Reference 3), regarding the applicability of prior measurements and the assumed linearity of the data, GEH stated that the materials and fabrication processes for the fuel rods, water rods, and channels measurements are consistent with those for GE14. Based upon similarities in component design, materials, and processing specifications, the staff accepts the applicability of these growth measurements to the GE14E design. Based on the applicant’s response, RAI 4.8-5 was resolved.

GEH provided mechanical design analyses supporting the following design requirements related to differential growth among assembly components:

- Fuel rod upper end plug engagement into the upper tieplate must accommodate differential fuel rod (and tie rod) growth.

- The distance between the top of the fuel rod and the upper tieplate (expansion spring) must accommodate differential fuel rod (and tie rod) growth.

- Water rod upper end plug engagement into the upper tieplate must accommodate differential growth between tie rods and water rods.

- Water rod lower end plug engagement into the lower tieplate must accommodate differential growth between tie rods and water rods.

- Fuel channel overlap with the finger springs must accommodate differential growth between the tie rods and the fuel channel.

In its response to RAI 4.8-3 (Reference 3), regarding part-length fuel rod upper plug engagement with grid spacers and differential growth between part-length fuel rods and water rods, GEH provided a calculation demonstrating sufficient engagement for the part-length fuel rods. Based on the applicant's response, RAI 4.8-3 was resolved.

In its response to RAI 4.8-4 (Reference 3), regarding channel spring engagement and differential assembly growth, GEH provided a calculation demonstrating sufficient channel fastener spring overlap. Based on the applicant's response, RAI 4.8-4 was resolved.

Based upon the staff's review of Section 3.1 and in response to RAIs, the staff finds that the GE14E design satisfies design and regulatory criteria related to dimensional compatibility.

3.1.2 Assembly Component Structural Evaluation

Section 3.3 of NEDC-33240P describes the design criteria for the assembly component structural evaluation. Specifically, for structural components, the combined effective stress may not exceed the material tensile strength. Further, if the combined stresses exceed the material yield strength, then the applicant must justify why the resulting distortion is not significant to component performance and that cyclic loading will not cause fatigue failure. In addition to stress, design criteria include limits on fatigue not exceeding material capability and vibration not resulting in fretting wear. These design criteria are consistent with past GEH fuel designs.

Section 3.4 of NEDC-33240P describes the assembly component structural evaluations given below.

<u>Upper Tieplate</u>

The maximum loading on the upper tieplate occurs during fuel handling when the grapple that is attached to the upper tieplate handle lifts the fuel assembly. The structural evaluation included both finite element analysis (FEA) using the ANSYS code and mechanical testing. ANSYS is an industry-standard FEA code widely applied both within and outside of the nuclear industry. FEA calculations identified that the limiting stress slightly exceeded the yield strength of the material. Staff experienced with ANSYS and FEA conducted an onsite audit of the GEH engineering calculations supporting the upper tieplate structural evaluation. [[ ]] The staff reviewed the engineering calculations and supporting tests and found them to be acceptable.

Lower Tieplate

The maximum loading on the lower tieplate occurs during fuel handling when the fuel assembly is seated into the core or into fuel storage racks. The structural evaluation, based upon FEA using the ANSYS code, demonstrated that the maximum loads remained below the material yield strength. The staff conducted an onsite audit of the GEH engineering calculations supporting the lower tieplate structural evaluation and found these calculations acceptable.

Based upon an audit of the structural evaluation which demonstrated that the maximum loads remain below the material yield strength, the staff finds the GE14E lower tieplate design acceptable.

Fuel Rod End Plug

The maximum loading on the fuel rod end plugs occurs during fuel handling. Using conservative assumptions (e.g., less than the full complement of tie rods carrying the weight of the assembly), design calculations demonstrate that loads remain below the material yield strength. Based upon review of the design calculations within Section 3.4 of NEDC-33240P which demonstrate that the maximum loads remain below the material yield strength, the staff finds the GE14E fuel rod end plug design acceptable.

Plenum Spring

The plenum spring is designed to (1) resist an acceleration load during transportation and (2) exert a preload on the pellet column. The only safety function that the plenum spring serves is to ensure that the pellet stack remains undisturbed during transportation. The GEH calculations show that the plenum spring design is capable of performing this function up to the design loads. Based upon review of the design calculations within Section 3.4 of NEDC-33240P which demonstrate that the plenum spring design is capable of satisfying transportation design requirements, the staff finds the GE14E plenum spring design acceptable.

Expansion Spring

The expansion spring is designed to exert a downward force on the fuel rods while allowing for axial growth. The design calculations demonstrate that loads remain below the material tensile strength. Based upon review of the design calculations within Section 3.4 of NEDC-33240P which demonstrate that the maximum loads remain below the material tensile strength, the staff finds the GE14E fuel rod expansion spring design acceptable.

Water Rod

The water rod design is evaluated to accommodate a differential wall pressure and the effects of spacer lift forces from flow or differential component growth.

The GEH calculations show significant design margin for this structure. The staff has reviewed these calculations and finds them acceptable. During an audit at the GE-Wilmington offices (Reference 15), the staff identified a more limiting design requirement for the water rod involving handling loads during fuel movement. Upon review of the supporting GEH engineering calculations, the staff identified that the combined loading calculations did not consider the water holes (present at the top and bottom of the water rod). GEH postulated that conservative analytical assumptions offset any stress concentration associated with the water holes. The staff still had concerns and in RAI 4.2-33 requested that GEH perform more detailed calculations. In response to RAI 4.2-33 (Reference 12), GEH provided more detailed FEA of the GE14E water rod (including specific modeling of the water holes) which demonstrate that the water rod will not buckle under handling loads. Based upon the results of the more recent FEA calculations, the staff finds the GE14E water rod design acceptable. Based on the applicant's response, RAI 4.2-33 was resolved.

Spacer

The grid spacer designs (including part-length fuel rod configurations) were mechanically tested to measure lateral load before distortion. GEH relied upon testing and analyses previously completed for the GE14 design. In its response to RAI 4.8-8 (Reference 3), regarding seismic and dynamic loads, GEH stated that the GE14 fuel assemblies for BWR/4-6 have been demonstrated to be acceptable for the following peak seismic and dynamic accelerations: [[ ]] in the horizontal direction and [[ ]] in the vertical direction and would bound the shorter GE14E design. ESBWR standard plant seismic analysis shows peak safe shutdown earthquake (SSE) accelerations of [[ ]] in the horizontal direction and [[ ]] in the vertical direction. These accelerations are less than the demonstrated capability of the GE14 fuel. The shorter ESBWR fuel assembly length results in additional margin to the seismic and dynamic load criteria for GE14E fuel. It is concluded that GE14E fuel assemblies, including spacers, are qualified for the seismic and dynamic loads defined by the ESBWR standard plant seismic analysis. Based on the applicant's response, RAI 4.8-8 was resolved.

Consistent with past practice, testing was performed on unirradiated fuel assembly components to simulate beginning-of-life conditions (i.e., before irradiation hardening). In its response to RAI 4.8-6 (Reference 8), on the use of unirradiated material conditions, GEH discussed the potential embrittlement of spacer grids as a result of hydrogen uptake. Testing on spacers precharged with hydrogen was completed to simulate the effects of in-reactor corrosion. These tests confirm that the spacers maintain fracture resistance up to very high hydrogen levels. While these impact tests were completed to evaluate handling loads, they provide evidence of end-of-life performance during postulated accidents. Based on the applicant's response, RAI 4.8-6 was resolved.

Channel

In addition to its inclusion in the LOCA and seismic lateral load testing, the channel is designed to withstand steady-state and transient differential pressure. The structural evaluation, based upon FEA using the ANSYS code, demonstrated that the maximum loads remained below the material yield strength. The staff conducted an onsite audit of the GEH engineering calculations supporting the channel structural evaluation and found these calculations acceptable. Based upon an audit of the structural evaluation which demonstrated that the maximum loads remain below the material yield strength, the staff finds the GE14E channel design acceptable.

3.1.3 Assembly Design Evaluation

Flow-Induced Vibration

Section 3.4.1.10 of NEDC-33240P describes flow-induced vibration (FIV) testing performed on the GE14 assembly design. Based on a comparison of these results to earlier testing, GEH concludes that assembly differences do not have a significant effect on FIV performance. The staff was not entirely convinced by this qualitative argument and had concerns regarding which aspects of GE14E (e.g., spacer elevations) necessitate FIV testing. In its response to RAI 4.8-7 (Reference 3), regarding FIV, GEH stated that FIV testing will be performed on GE14E before fuel loading. While the staff strongly endorses validation by testing, the specifics of the proposed FIV testing raised concerns.

During an audit at the GE-Wilmington offices (Reference 15), the staff reviewed several internal GE documents comparing the response to RAI 4.8-7 to past detailed FIV test programs on different legacy fuel bundle designs. Review of these FIV test reports revealed sensitivities in measured acceleration and displacement that challenge the limited FIV testing proposed for GE14E.

The older FIV tests were broader in scope—investigating a range of temperatures, flow rates, and steam quality on Root Mean Squared (RMS) acceleration and displacement. Steam quality refers to the proportion of saturated steam in a saturated water/steam mixture. A steam quality of 0 indicates 100% water while a steam quality of 1 indicates 100% steam. Notable observations from the staff's audit include the following (see Figure 3-1):

- [[ ]]
- [[ ]]
- [[ ]]
- [[ ]]

[[

]]

Figure 3-1 RMS Acceleration versus Steam Quality

After several iterations (as documented in GEH's response to RAI 4.8-7, Supplements 1 and 2 (Refs. 3 and 8), the staff agreed to the required FIV testing for GE14E. GEH's response to

RAI 4.8-7, Supplement 3 (Reference 11), documents the basis of the proposed FIV testing and acceptance criteria. As requested by the staff, GEH also discussed past FIV test results in its response to RAI 4.8-7.

Based on the proven in-reactor performance of GE14 and the lower flow rate of the ESBWR, the staff found the limited-scope FIV testing (outlined in the response to RAI 4.8-7, Supplement 3) for GE14E to be acceptable, with conservative penalties on the acceptance criteria to account for known sensitivities to temperature and quality. However, the staff did not accept this limited-scope FIV test program to justify more substantial fuel design changes and/or new fuel design features that may influence the sensitivity of RMS acceleration to rod location, flow rate, temperature, and steam quality.

The last sentence of the proposed FIV acceptance criteria stated, “Any GE14E locations that exceed the adjusted peak GE14 value at the respective elevation will be dispositioned individually.” This acceptance criterion was too broad and was not in compliance with the level of specificity expected within DCD Tier 1 inspections, tests, analyses, and acceptance criteria (ITAAC). GEH retracted this statement in its response to RAI 4.8-7, Supplement 4 (Reference 15) and GEH proposed a revision to section 3.3.3 of NEDC-33240P to specify testing requirements for GE14E to satisfy the ESBWR FIV ITAAC. The staff finds the proposed acceptance criteria to be acceptable for inclusion in the approved version of the LTR. Based on the applicant’s response, RAI 4.8-7 was resolved.

Seismic/Dynamic Loading

Section 3.4.1.11 of NEDC-33240P (Reference 1) describes the structural capability of the GE14E assembly and assembly components to withstand seismic/dynamic loading. GEH relied upon testing and analyses previously completed for the GE14 design. As described in section 3.1.2 of this report under the heading “Spacer” it was concluded in the response to RAI 4.8-8 that GE14E fuel assemblies are qualified for the seismic and dynamic loads defined by the ESBWR standard plant seismic analysis. Therefore, based on the applicant’s response, RAI 4.8-8 was resolved.

With respect to assembly lift, GEH has incorporated acceptance criteria in DCD Tier 1, Table 2.1.1-3 stating the initial fuel to be loaded into the core will be able to withstand fuel lift and seismic and dynamic loads under normal operation and design basis conditions.

Channel Bow and Control Blade Insertion

Section 4 of NEDC-33240P (Reference 1) describes the fuel assembly channel and compatibility with the control blades. Figure 4-4 of NEDC-33240P provides dimensions, including gaps between fuel channels and control blades. Compared with current designs, the ESBWR N-lattice design includes a larger gap at both the corner and midwall relative to the C-lattice and S-lattice plants. Operating experience has shown that control blade friction occurs only at the C- and S-lattice plants. D-lattice plants (which have a larger gap than the N-lattice design) have experienced minimal issues with control blade friction.

In its response to RAI 4.8-9 (Reference 3), regarding channel bow and control blade insertion, GEH discussed margin to control blade interference relative to the current fleet. In addition to physical differences, the ESBWR control rod drive system would actively detect any control blade hangup resulting from channel-to-blade friction. The same fuel management and operating guidelines used to minimize control blade interference in the current fleet will be applied to the ESBWR. The ESBWR will maintain the same technical specification surveillance requirements and actions as the current fleet.

Based upon the improved design margins of the ESBWR N-lattice (relative to the C- and S-lattice), along with fuel management guidance and surveillance, the staff finds that GEH has adequately addressed control blade interference. Based on the applicant's response, RAI 4.8-9 was resolved.

3.2 GE14E Fuel Rod Design Evaluation

Section 2 of NEDC-33242P (Reference 2) describes in detail the GE14E fuel rod and fuel pellet design. Section 3 of NEDC-33242P identifies the design criteria used to evaluate the adequacy of the GE14E fuel rod design. The fuel rod thermal-mechanical design criteria are consistent with past GE designs (e.g., GE14).

In its response to RAI 4.8-10 (Reference 3), regarding deviations from approved methodology, GEH stated that the methodology, including the treatment of model uncertainties and manufacturing tolerances, is identical to that used to confirm compliance of the GE14 design with GESTAR for BWR/3-6 and the advanced BWR. Based on the applicant's response, RAI 4.8-10 was resolved.

In its response to RAI 4.8-11 (Reference 3), regarding the continued applicability of approved methods to ESBWR conditions, GEH demonstrated that the currently approved methods are within the qualification database for the GE14E fuel rod design and ESBWR operating conditions. Based on the applicant's response, RAI 4.8-11 was resolved.

Fuel Rod Internal Pressure

The design criterion for rod internal pressure, as defined in Section 3.1 of NEDC-33242P, is that the outward creep rate of the cladding will not exceed the fuel pellet irradiation swelling rate. This design requirement for no cladding liftoff is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E.

In addition to reviewing Sections 3 and 4 of NEDC-33242P, the NRC staff completed independent calculations using the fuel rod thermal-mechanical performance code FRAPCON-3. In support of the staff's calculations, GEH provided fuel specifications, manufacturing tolerances, and limiting axial and nodal power histories. FRAPCON-3 is a best estimate fuel rod performance code that is calibrated against a wide range of applicable empirical data. In order to obtain design calculations with the best estimate FRAPCON-3 code, manufacturing tolerances were deterministically modeled and rod power penalties were employed in lieu of modeling uncertainties (e.g., cladding creep, cladding strain, fuel swelling). Based upon engineering judgment, a 10-percent rod power penalty conservatively bounds the modeling uncertainties related to fission gas release. With respect to cladding creep prediction uncertainties, the cladding creep model in FRAPCON-3 (based upon Zry-4) was conservative for modeling GE14E's Zry-2 cladding.

The NRC staff performed FRAPCON-3 sensitivity studies to determine the worst set of initial conditions (e.g., pellet diameter, stack height) to minimize plenum volume, maximize fission gas release, and maximize rod internal pressure. Following these sensitivity studies, the staff performed several FRAPCON-3 calculations to evaluate the GE14E fuel rod design with respect to rod internal pressure and void volume. Table 3.2-1 lists the results of these calculations.

Table 3.2-1 FRAPCON-3 Calculations—Rod Internal Pressure

Case	Description	FRAPCON-3 Calculated Results	
		Fission Gas Release (%)	Rod Internal Pressure (psia)
1	UO_2—Worst case inputs along TMOL rod power curve	[[ ]]	[[ ]]
2	UO_2—Worst case inputs along TMOL+10% rod power curve	[[ ]]	[[ ]]
3	UO_2—Worst case inputs along TMOL+10% with extended knee (at [[ ]] GWd/MTU)	[[ ]]	[[ ]]
4	UO_2—Worst case inputs along TMOL+10% with extended knee (at [[ ]] GWd/MTU), power history more aggressive to achieve licensed burnup in shorter duration (i.e., extended power uprate fuel usage)	[[ ]]	[[ ]]
5	UO_2—Worst case inputs along TMOL with three AOO excursions (1 hour +25% power) at 10, 15, and 59 GWd/MTU exposure	[[ ]]	[[ ]]
6	$UGdO_2$—Worst case inputs along TMOL+10% with extended knee	[[ ]]	[[ ]]
7	UO_2 PLR—Worst case inputs along TMOL+10% with extended knee	[[ ]]	[[ ]]

The internal pressures calculated with FRAPCON-3 remain below the critical pressure that would cause an outward creep of the cladding. Best estimate critical pressure is approximately 3,000 pounds-force per square inch absolute (psia). However, large modeling uncertainties associated with cladding creep and fuel swelling rate conservatively set an upper tolerance critical pressure at 2,050 psia (1,000 psia over system pressure). The maximum calculated rod internal pressure (Case 3, uranium dioxide (UO_2)) remains below this conservative estimate of critical pressure. Furthermore, none of the FRAPCON-3 cases predict a widening of the fuel-to-cladding gap—indicative of cladding liftoff. The UO_2 Part Length Rod (PLR) (Case 7) is less limiting because of a greater plenum volume, relative to the UO_2 rod. The $UGdO_2$ rod (Case 6) is less limiting because of a greater plenum volume and a more benign power curve, relative to the UO_2 rod.

While performing these calculations, the staff identified a discrepancy between the fission gas release calculated by GSTR-M and FRAPCON-3. Upon further investigation, including benchmarking identical best estimate cases, the staff determined that the GSTR-M [[

]] In response to a staff request, GEH completed an evaluation (Reference 5) in accordance with the provisions of 10 CFR Part 21, "Reporting of Defects and Noncompliance," of a potential nonconservatism in the GE thermal-mechanical methodology, GSTR-M. GEH concluded that the error in GSTR-M was not reportable.

After reviewing the GEH evaluation (Reference 5), the staff continued to have concerns related to fission gas release and rod internal pressure calculated with GSTR-M and proposed a penalty to maintain a conservative cladding liftoff analysis. In an attempt to identify compensating conservatism within the fuel performance methodology and negate the application of a proposed critical pressure penalty, GEH issued a supplement to the 10 CFR Part 21 Notification (Reference 6). Upon further review, the staff maintained its concerns with respect to the GSTR-M cladding liftoff analysis and concluded that a [[ ]] penalty on critical pressure was required (Reference 16).

Although the staff's independent calculations show that the GE14E fuel design satisfies the rod internal pressure design criterion, the accuracy of future reload analyses with GSTR-M may be in question, especially with more aggressive rod power histories than those cited in NEDC-33242P and used in staff calculations. For example, the [[ ]] penalty on critical pressure was based on a maximum linear heat generation rate of [[ ]] kilowatts per foot. A higher rod power may necessitate a larger penalty. The required penalty on critical pressure relates to the use of GSTR-M in the cladding liftoff analysis. Migration to an NRC-approved, up-to-date fuel rod thermal-mechanical code (e.g., PRIME) may eliminate the need for such a penalty.

To resolve staff concerns regarding the use of GSTR-M for fuel rod design analysis, the staff asked GEH to provide the final ESBWR Cycle 1 thermal-mechanical operating limits for all Cycle 1 fuel rod designs. In its response to RAI 4.8-17 (Reference 15), GEH provided the final thermal-mechanical operating limits and power suppression factors for ESBWR Cycle 1. GEH's supporting rod internal pressure design calculations included the [[ ]] of critical pressure.

Based upon GEH's design calculations, including the [[ ]], provided in response to RAI 4.8-17 as confirmed by the independent calculations, the staff finds the GE14E fuel rod design acceptable for the rod power histories specified in Tables 1 and 2 of GEH's response to RAI 4.8-17 (Reference 15). Section 5 of this safety evaluation cites a limitation on GE14E rod power history. Based on the applicant's response, RAI 4.8-17 was resolved.

The NRC staff originally generated RAIs 4.8-15 and 4.8-16 to address the GSTR-M issues. The GEH 10 CFR Part 21 evaluation and staff assessments supersede the information in the responses to these RAIs. Hence, GEH responses to RAIs 4.8-15 and 4.8-16 (Reference 3) were not a factor in the staff's approval.

Fuel Pellet Temperature/Thermal Overpower Limit

Table 3-1 of NEDC-33242P specifies the design criteria, stating "The maximum fuel center temperature (Tcenter) shall remain below the fuel melting point (Tmelt)." However, Section 3.2 of NEDC-33242P states the following:

> To achieve this objective, the fuel rod is evaluated to ensure that fuel melting during normal steady-state operation and core wide anticipated operational occurrences is not expected to occur. This fuel temperature limit is specified to ensure that sudden shifting of molten fuel in the interior of fuel rods, and subsequent potential cladding damage, can be positively precluded.

During review of the ESBWR DCD Tier 2* fuel design criteria, the staff was concerned with allowing fuel melting during any AOO—moderate or infrequent classification, local or core wide—and identified this as an open item within the ESBWR DCD safety evaluation report with open items (Reference 17). GEH subsequently revised the ESBWR DCD to reflect a more restrictive requirement precluding fuel centerline melting during any AOO. Avoidance of fuel melting during AOOs is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E.

In addition to reviewing Sections 3 and 4 of NEDC-33242P, the NRC staff completed independent calculations using the fuel rod thermal-mechanical performance code FRAPCON-3. As was done for the rod internal pressure cases, manufacturing tolerances were deterministically modeled and rod power penalties were employed in lieu of modeling uncertainties.

The staff performed FRAPCON-3 sensitivity studies to determine the worst set of initial conditions (e.g., pellet diameter, cladding oxide thickness) to maximize fuel temperature. Following this sensitivity study, the staff performed several FRAPCON-3 calculations to evaluate the GE14E fuel rod design in combination with proposed thermal overpower (TOP) limits at preventing centerline fuel melt. Table 3.2-2 lists the results of these calculations.

Table 3.2-2 FRAPCON-3 Calculations—Fuel Temperature

Case	Description	FRAPCON-3 Calculated Results	
		Fuel Temp. (°F) before Spike	Fuel Temp. (°F) at Spike
1	UO_2—Worst case inputs along TMOL with [[ ]] TOP at knee	[[ ]]	[[ ]]
2	UO_2—Worst case inputs along TMOL+10% with [[ ]] TOP at knee	[[ ]]	[[ ]]
3	UO_2—Worst case inputs along TMOL+10% with [[ ]] TOP at extended knee	[[ ]]	[[ ]]
4	$UGdO_2$—Worst case inputs along TMOL with [[ ]] TOP at knee	[[ ]]	[[ ]]
5	$UGdO_2$—Worst case inputs along TMOL+10% with [[ ]] TOP at knee	[[ ]]	[[ ]]
6	$UGdO_2$—Worst case inputs along TMOL+10% with [[ ]] TOP at extended knee	[[ ]]	[[ ]]

The fuel temperatures calculated with FRAPCON-3 remain below incipient centerline melting conditions. Fuel melting temperature is defined as follows:

UO_2 Tmelt = 5,080 degrees F—58 degrees F per 10 GWd/MTU
$(U,Gd)O_2$ Tmelt = 5,080 degrees F—58 degrees F to 60 degrees F per 10 GWd/MTU (based on 8 percent Gd)

The FRAPCON-3 calculations included a 10-percent increase in rod power (above Thermal Mechanical Operating Limits (TMOL)) to cover modeling uncertainties and an extended knee to cover more aggressive fuel management. The fuel temperatures calculated with FRAPCON-3 remained below melting temperatures for UO_2 fuel rods with a [[ ]]-percent TOP and $UGdO_2$ fuel rods with a [[ ]]-percent TOP. The $UGdO_2$ rod (Case 6; [[ ]] degrees F) is more limiting because of reduced thermal conductivity of gadolinia fuel pellets, relative to UO_2 pellets (Case 3; [[ ]] degrees F).

Based upon the material presented in NEDC-33242P and the staff's independent calculations, the staff finds that the GE14E fuel rod design and prescribed TOP limits ([[ ]]-percent UO_2, [[ ]]-percent $UGdO_2$) satisfy the fuel temperature design criteria.

<u>Cladding Strain/Mechanical Overpower Limit</u>

The design criterion for fuel cladding strain (high-rate strain during AOOs), as defined in Section 3.3 of NEDC-33242P, is that cladding permanent deformation (plastic plus creep) remain below 1.0 percent. While SRP Section 4.2 defines an allowable total cladding strain limit of 1.0 percent permanent (plastic plus creep), the fuel vendor is responsible for (1) defining the total strain capability of its fuel rod design/cladding alloy, (2) providing evidence supporting this strain capability, and (3) demonstrating that this design criterion is not exceeded during AOOs.

Mechanical testing under prototypical loading on irradiated cladding specimens provides acceptable evidence of a cladding alloy's strain capability. While irradiation damage under normal operation promotes an increase in yield strength (and lower ductility), the formation of zirconium hydrides within the cladding (resulting from the absorption of hydrogen during cladding corrosion) limits the strain capability of the fuel rod cladding. As a result of this relationship, fuel vendors need to specify a design limit on cladding hydrogen content corresponding to the extent of the empirical database supporting the cladding strain specified and acceptable fuel design limit (SAFDL) per 10 CFR 50 Appendix A, GDC-10.

During its review of the ESBWR DCD Tier 2* fuel design criteria, the staff raised issues with the lack of any corrosion limits and the empirical database supporting the cladding strain design limit. The staff identified these as open items in the ESBWR DCD safety evaluation with open items (Reference 17). After several iterations (RAI 4.2-2 and 4.2-4, Refs. 3, 4, 9, and 11), GEH proposed the following cladding strain design limit and cladding hydrogen design limit, along with supporting empirical database:

- cladding strain limit = [[ ]]
- cladding strain limit = [[ ]]
- cladding hydrogen limit = [[ ]]

The applicant explained the basis of these design limits and the breakpoint in cladding strain in its response to RAIs 4.2-2 S03 and 4.2-4 S02 (Reference 8). Although the applicant used various information provided in response to RAIs 4.2-2 and 4.2-4 and during ESBWR audits collectively to justify these design limits, only the above specified strain and hydrogen limits are NRC reviewed and approved.

In addition to the material presented in NEDC-33242P, in response to the RAIs, and in presentations during audits, the staff has access to proprietary mechanical test data on similar BWR Zry-2 cladding (see RAI 4, Reference 18) that reinforce the GE14E cladding strain design limit. Based upon the above review, the staff finds the GE14E cladding strain limits and hydrogen limit acceptable.

In addition to reviewing Sections 3 and 4 of NEDC-33242P, the NRC staff completed independent calculations using the fuel rod thermal-mechanical performance code FRAPCON-3. As was done for the rod internal pressure cases, manufacturing tolerances were deterministically modeled and rod power penalties were employed in lieu of modeling uncertainties (e.g., fuel swelling).

The staff performed FRAPCON-3 sensitivity studies to determine the worst set of initial conditions (e.g., pellet diameter, cladding thickness) to maximize cladding strain. Following this sensitivity study, the staff performed several FRAPCON-3 calculations to evaluate the GE14E fuel rod design in combination with proposed mechanical overpower (MOP) limits to ensure that cladding strains were maintained below empirically based limits. The basis for GEH's specified acceptable fuel design limit (SAFDL) on cladding strain is discussed further below. Table 3.2-3 lists the results of these calculations.

Table 3.2-3 FRAPCON-3 Calculations—Fuel Cladding Strain

Case	Description	FRAPCON-3 Calculated Results	
		Plastic Strain (%)	Total Strain (%)
1	UO_2—Worst case inputs along TMOL with [[ ]] MOP at knee	[[ ]]	[[ ]]
2	UO_2—Worst case inputs along TMOL with [[ ]] MOP at knee	[[ ]]	[[ ]]
3	UO_2—Worst case inputs along TMOL+10% with [[ ]] MOP at knee	[[ ]]	[[ ]]
4	UO_2—Worst case inputs along TMOL+10% with [[ ]] MOP at extended knee	[[ ]]	[[ ]]
5	$UGdO_2$—Worst case inputs along TMOL with [[ ]] MOP at knee	[[ ]]	[[ ]]
6	$UGdO_2$—Worst case inputs along TMOL with [[ ]] MOP at knee	[[ ]]	[[ ]]

The fuel cladding strain calculated with FRAPCON-3 remained below 1.0 percent total, as well as below the GEH empirically based, hydrogen-dependent strain SAFDL. Since the calculated strain remained below the more limiting 1.0-percent total strain, separate cases at varying levels of hydrogen (based on burnup and corresponding to hydrogen-based strain SAFDLs) were not necessary. Cases investigated the impact of a power penalty (to account for fuel swelling modeling uncertainty) applied to the initial power and then separately applied to the power excursion.

Based upon the material presented in NEDC-33242P and the staff's independent calculations, the staff finds that the GE14E fuel rod design and prescribed MOP limits ([[ ]]-percent UO_2,[[ ]]-percent $UGdO_2$) satisfy the fuel cladding strain design criteria.

SAFDLs on fuel rod cladding strain and fuel centerline melting are employed to preclude fuel rod cladding failure because of pellet/cladding mechanical interaction during rapid overpower AOOs. However, as described in SRP Section 4.2, these design limits may not provide sufficient protection to preclude fuel cladding failure because of pellet/cladding interaction stress-corrosion cracking (PCI/SCC) under certain sustained cladding loading conditions. In its response to RAI 4.8-12 (Reference 3), regarding the PCI/SCC resistance of GE14E fuel, GEH provided results from past and recent ramp test programs that are applicable to GE14E's barrier design. This information shows that margin exists between current operating limits and an empirically based lower failure threshold such that PCI/SCC failures would not occur during power maneuvering. Furthermore, GE's barrier cladding design has been proven to reduce PCI/SCC susceptibility during both power maneuvering and AOO-type scenarios. As a result, PCI/SCC fuel cladding failure is unlikely during any AOO scenario that involves a sustained power excursion and does not already predict fuel rod failure from violating other SAFDLs (e.g., Minimum Critical Power Ratio (MCPR), cladding strain, centerline melt). Hence, there is reasonable assurance that fuel cladding failure would not be underestimated. Based on the applicant's response, RAI 4.8-12 was resolved.

Cladding Oxidation and Corrosion Product Buildup

As described in Section 5.3 of NEDC-33242P, the fuel rod thermal-mechanical design evaluations include the effects of cladding oxidation and corrosion product buildup (e.g., crud) on the fuel rod surface. The statistical treatment of crud buildup and oxidation within the design analyses is consistent with current fuel designs (e.g., GE14). This approach is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E.

In addition to explicitly accounting for the effects of cladding oxidation and crud, the staff requires that fuel vendors establish a design limitation on cladding oxidation. This upper bound on cladding oxidation defines (1) the limit of oxidation included in the design analyses and (2) the limit of oxidation under which cladding oxide spallation and hydride blisters have not been observed. Currently approved fuel performance models rely on uniform mechanical properties along the axial and circumferential directions of the fuel rod cladding. Localized cladding defects (e.g., spallation, hydride blisters) may significantly impact fuel rod stress and strain calculations and ultimately the ability to accurately predict cladding failure.

Earlier versions of NEDC-33242P did not define a cladding oxidation limit that satisfied the staff position. During its review of the ESBWR DCD Tier 2* fuel design criteria, the staff raised issues with the lack of any corrosion limits. The staff identified this as an open item in the ESBWR DCD safety evaluation with open items (Reference 17). In concert with its discussions of hydrogen and cladding strain (responses to RAIs 4.2-2 and 4.2-4; Refs. 3, 4, 9, and 11), GEH proposed a cladding oxidation limit of [[ ]] along with the supporting empirical database.

GEH detailed the basis of the cladding oxide design limit in its response to RAIs 4.2-2 S03 and 4.2-4 S02 (Reference 8). For pressurized-water reactor fuel designs, cladding oxide limits have been selected to minimize the possibility of spallation (in order to ensure uniform mechanical properties). Attachment A of (Reference 8) describes the difficulty with implementing a similar approach for BWRs. In its response, GEH provides hot cell examinations on medium- and high-burnup fuel rods from Duane Arnold and Limerick Unit 1 that show no evidence of hydride localization at spalled locations. Figure A-3 of Reference 8 provides pool-side cladding liftoff measurements, and Figure A-4 gives confirmatory hot cell metallography. Based upon the information provided in NEDC-33242P and in response to RAIs, the staff finds the proposed cladding corrosion design limit of [[ ]] acceptable for GE14E. Based on the applicant's responses, RAIs 4.2-2 and 4.2-4 were resolved.

GE14E fuel cladding corrosion shall be limited such that cladding oxidation thickness remains less than [[ ]] and cladding hydrogen content remains less than [[ ]]. In Reference 8 Figure A-5, GEH proposed an "action level" on measured lift-off beyond the design limit of [[ ]]. This proposed "action level" is not approved.

Cladding Hydrogen Content

Hydrogen trapped within the fuel rod as a result of manufacturing may be absorbed by the cladding. The design criterion for fuel pellet hydrogen content is intended to prevent fuel rod failure because of localized, internal hydriding. GEH relies on the manufacturing process and controls to restrict hydrogenous contaminants from all sources during the manufacturing process. This design requirement is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E criterion.

In addition to internal hydrogen sources, a design limitation on absorbed hydrogen in the fuel rod cladding from all possible sources has been established as discussed above.

Cladding Creep Collapse

The design criterion for cladding structural instability is that fuel cladding creep collapse will not occur. This design requirement is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E criterion.

The finite element methods assume a maximum initial ovality, maximum delta-pressure (e.g., minimum fill gas pressure and no fission gas release), and no support provided by fuel pellets. In addition, the maximum overpressure AOO is applied at end-of-life conditions. Because of an identical fuel rod design, the current GE14 creep collapse analysis bounds the GE14E fuel rod design.

Based upon the material presented in NEDC-33242P, the staff finds that the GE14E fuel rod design satisfies the fuel cladding creep collapse criterion.

Fuel Rod Stresses and Strain

The design criterion is that effective cladding stresses and strain will not result in fuel rod failure. This design requirement is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E criterion.

The methods employed to calculate effective stress and strain are consistent with the currently approved methods used for GE14. Relying on GE14 analyses, GEH stated that the large design margins present in GE14 are applicable to GE14E.

In its response to RAI 4.8-14 (Reference 3), regarding the modeling of the barrier liner, GEH noted that certain fuel rod thermal-mechanical analyses explicitly address the impact of the liner on heat transfer and cladding strength. Other applications conservatively neglect the zirconium barrier.

Based upon the material presented in NEDC-33242P, the staff finds that the GE14E fuel rod design satisfies the fuel cladding stress and strain criterion. Based on the applicant's response, RAI 4.8-14 was resolved.

Cladding Fatigue Analysis

The design criterion is that fatigue life usage will not exceed the material fatigue capability resulting in fuel rod failure. This design requirement is consistent with SRP Section 4.2 and therefore acceptable for application to GE14E criterion.

Section 4.2.3 of NEDC-33242P describes the cladding fatigue analysis methodology. The conservative power cycles listed in Table 4-3 of NEDC-33242P as well as the statistical methodology are consistent with current fuel designs. In its response to RAI 4.8-13

(Reference 3), regarding Zircaloy fatigue data, GEH provided the empirical database used to justify the upper and lower 95/95 fatigue curves. The RAI response further justifies the conservatism of the fatigue analysis relative to the SRP guidelines.

Based upon the material presented in NEDC-33242P and the RAI response, the staff finds that the GE14E fuel rod design satisfies the fuel cladding fatigue criterion. Based on the applicant's response, RAI 4.8-13 was resolved.

3.3 Operating Experience

Historically, the staff has relied on lead test assembly programs to generate in-reactor operating experience for new assembly design features or materials in order to validate performance and model predictions. Since no ESBWR designs have been built and the current fleet is incompatible with the 10-foot tall GE14E design, lead test assemblies are not possible. However, since the GE14E assembly component designs and materials are consistent with currently operating designs, insight into the anticipated in-reactor performance of GE14E is achievable.

Section 6 of NEDC-33242P provides information related to GEH's extensive fuel operating experience. GE14E shares the same fuel rod and spacer designs and materials as the GE14 design, with the exception of rod length and spacer pitch. No systematic failures have been reported on the nearly 1.4 million GE14 fuel rods manufactured. This operating experience provides reasonable assurance that normal operational failure modes such as cladding collapse, grid-to-rod fretting, cladding liftoff, cladding stress and strain, excessive corrosion, and cladding fatigue are unlikely for GE14E. In addition, the continued as-anticipated performance of GE14 and ongoing surveillance programs has validated model predictions (e.g., growth, creep, corrosion).

The fuel design limits, operating rod power limits, and projected rod burnups for GE14E are identical to those for GE14. Based upon the information presented in NEDC-33240P and NEDC-33242P, the staff finds the operating experience database supporting the GE14E fuel assembly design review of sufficient breadth to cover the range of burnup and operating conditions under consideration.

4.0 CONCLUSION

Based upon its review of NEDC-33240P and NEDC-33242P, the staff finds the application of GEH's fuel thermal-mechanical design criteria and methodology acceptable for GE14E. Furthermore, the staff finds the GE14E fuel assembly and fuel rod design acceptable for use in the ESBWR. Licensees referencing this topical report will need to comply with the conditions listed in Section 5.0. Furthermore, licensees will need to ensure that the GE14E fuel design criteria are consistent with the final ESBWR Tier 2* fuel design criteria in DCD Section 4.2 and Appendix 4B.

Since the GE14E fuel design meets the criteria and methodology defined in Section 2, the staff has concluded that the GE14E fuel design is acceptable.

5.0 CONDITIONS AND LIMITATIONS

Licensees referencing NEDC-33240P and NEDC-33242P must ensure compliance with the following six conditions and limitations:

1) Following the fuel assembly and fuel rod mechanical design methodology described in NEDC-33240P and NEDC-33242P, the licensee must ensure that all of the design criteria are satisfied for each refueling cycle.

2) The GE14E fuel assembly design is restricted to the design specifications provided in Section 2 of NEDC-33240P and the fuel rod cladding material processing specifications provided in Appendix B to NEDC-33240P. Changes in component design, materials, or processing specifications may alter the in-reactor behavior of the fuel assembly and invalidate the staff's approval.

3) The GE14E fuel assembly design is approved up to a peak pellet exposure of [[ ]] and a maximum operating time of [[ ]].

4) GE14E fuel cladding corrosion shall be limited such that cladding oxidation thickness remains less than [[ ]] and cladding hydrogen content remains less than [[ ]].

5) As described in Section 3.1.3, GE14E must complete the required FIV testing and satisfy the acceptance criteria (e.g., measured GE14E RMS acceleration below adjusted, measured GE14 RMS acceleration at every location) before loading into an ESBWR.

6) GE14E rod power history (peak linear heat generation rate versus peak pellet exposure) must remain at or below the thermal-mechanical operating limits and power suppression factors provided in Tables 1 and 2 of Reference 13.

6.0 REFERENCES

1. GNF Letter MFN 09-095, "NEDC-33240P, Licensing Topical Report, GE14E Fuel Assembly Mechanical Design Report, Revision 1, January 2009," February 3, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession Nos. ML090700714, ML090700717).

2. GNF Letter MFN 09-377, "Submittal of NEDC-33242P Revision 2 and NEDO-33242 Revision 2, 'GE14 for ESBWR Fuel Rod Thermal-Mechanical Design Report,'" June 10, 2009 (ADAMS Accession Nos. ML091630213, ML091630214, ML091630215).

3. GNF Letter MFN 06-297, "Response to Portion of NRC Request for Additional Information Letter No. 53 Related to ESBWR Design Certification Application—DCD Chapter 4 and GNF Topical Reports—RAI Numbers 4.2-2 through 4.2-7, 4.3-3, 4.3-4, 4.4-2, 4.4-5, 4.4-6, 4.4-15 through 4.4-17, 4.4-19, 4.4-24, 4.4-27, 4.4-31 through 4.4-34, 4.4-36, through 4.4-38, 4.4-42 through 4.4-50, 4.4-52 through 4.4-56, 4.8-1 through 4.8-16," August 23, 2006 (ADAMS Accession Nos. ML062480252, ML062480254, ML062480255). MFN 06-297, Supplement 9, RAI 4.8-8, April 19, 2010 (ADAMS Accession No. TBD)

4. GNF Letter MFN 07-040, Jason S. Post (GE) to Document Control Desk (NRC), “Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GSTRM,” January 21, 2007 (ADAMS Accession No. ML072290245).

5. GNF Letter MFN 06-297, Supplement 3, “Response to Portion of NRC Request for Additional Information Letter No. 53 Related to ESBWR Design Certification Application—DCD Chapter 4 and GNF Topical Reports—RAI Numbers 4.2-2S01, 4.2-4S01 and 4.8-16S01—Supplement,” January 26, 2007 (ADAMS Accession Nos. ML070380118, ML070380120).

6. GNF Letter MFN 07-040, Supplement 1, Dale E. Porter (GEH) to Document Control Desk (NRC), “Part 21 Notification: Adequacy of GE Thermal-Mechanical Methodology, GESTR-M—Supplement 1,” January 4, 2008 (ADAMS Accession Nos. ML080100670, ML080100672).

7. GNF Letter MFN 08-391, “Response to Portion of NRC Request for Additional Information Letter No. 110—Related to ESBWR Design Certification Application—RAI Number 4.8-7 Supplement 2,” April 18, 2008 (ADAMS Accession Nos. ML081130488, ML081130490).

8. GEH Letter MFN 08-347, “Response to Portion of NRC Request for Additional Information Letter No. 110—Related to ESBWR Design Certification Application—RAI Numbers 4.2-2 Supplement 3, 4.2-4 Supplement 2 and 4.8.6 Supplement 1,” May 9, 2008 (ADAMS Accession Nos. ML081350380, ML081350381).

9. GNF Letter MFN 08-757, “Response to Portion of NRC Request for Additional Information Letter No. 243—Related to ESBWR Design Certification Application—RAI Numbers 4.2-24 Supplement 1,4.2-26 Supplement 1,4.2-31,” October 8, 2008 (ADAMS Accession Nos. ML082880090, ML082880089).

10. GNF Letter MFN 08-789, “Response to Portion of NRC Request for Additional Information Letter No. 229—Related To Design Control Document (DCD) Revision 5—RAI Number 4.2-2 Supplement 4,” October 24, 2008 (ADAMS Accession No. ML083020523).

11. GEH Letter MFN 08-867, “Response to Portion of NRC Request for Additional Information Letter No. 231—Related to ESBWR Design Certification Application—RAI Number 14.3-398 and NRC Request for Additional Information Letter No. 229 Related to ESBWR Design Certification Application RAI Number 4.8-7S03,” November 12, 2008 (ADAMS Accession Nos. ML083190139, ML083190140).

12. GEH Letter MFN 08-946, Revision 1, “Revised Response to Portion of NRC Request for Additional Information Letter No. 243—Related To Design Control Document (DCD) Revision 5—RAI Number 4.2-33,” March 30, 2009 (ADAMS Accession Nos. ML090910653, ML090910654).

13. GEH Letter MFN 09-542, "Response to Portion of NRC Request for Additional Information Letter No. 350 Related to ESBWR Design Certification Application—Reactor—RAI Number 4.8-17," August 13, 2009 (ADAMS Accession No. ML092300406).

14. GEH Letter MFN 08-867 Supplement 1, "Response to Portion of NRC Request for Additional Information Letter No. 350 Related to ESBWR Design Certification Application—Reactor—RAI Number 4.8-7 S04," August 17, 2009 (ADAMS Accession Nos. ML092310271, ML092310272).

15. NRC Memorandum, "Audit Report and Summary (2007 & 2008) for Global Nuclear Fuels Control Blade and Fuel Assembly Design," December 22, 2008 (ADAMS Accession No. ML083230072).

16. NRC Memorandum, "Re-Assessment of GEH GSTR-M Part 21 Notification," February 24, 2009 (ADAMS Accession No. ML090510434).

17. NRC Memorandum, "Safety Evaluation with Open Items Report Input for the ESBWR Design Certification Section 4.2, Fuel System Design," March 29, 2007 (ADAMS Accession No. ML070920337).

18. WCAP-15942-NP-A, "Fuel Assembly Mechanical Design Methodology for Boiling Water Reactors Supplement 1 to CENP-287," March 2006 (ADAMS Accession Nos. ML061110272, ML061110247, ML061110351)