UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

June 18, 2012

The Honorable Gregory B. Jaczko
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: GRAND GULF NUCLEAR STATION, UNIT 1, EXTENDED POWER UPRATE LICENSE AMENDMENT REQUEST

Dear Chairman Jaczko:

During the 595th meeting of the Advisory Committee on Reactor Safeguards, June 6-8, 2012, we completed our review of the extended power uprate (EPU) license amendment request for Grand Gulf Nuclear Station, Unit 1, (GGNS) [1] and the associated NRC staff's draft final safety evaluation.[2] Our Subcommittee on Power Uprates also reviewed this matter on May 24, 2012. During these reviews, we had the benefit of discussions with representatives of the NRC staff and Entergy Operations, Inc. (Entergy or the licensee). We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATION

1. The Entergy Operations, Inc. application for the GGNS EPU should be approved subject to the conditions imposed in the staff's draft final safety evaluation.

2. The license condition for monitoring during power ascension testing provides reasonable assurance that unanticipated vibration modes induced in the steam dryer will be detected and addressed.

3. The license condition to perform periodic surveillance of the neutron absorbing material in the fuel storage racks provides adequate assurance of subcriticality of the spent fuel until the staff completes its review of the licensee's criticality analysis.

BACKGROUND

GGNS is a boiling water reactor (BWR) plant of the BWR/6 design with a Mark III containment. The current licensed thermal power (CLTP) is approximately 1.7% higher than the originally licensed thermal power (OLTP) of 3,833 megawatts-thermal (MWt) due to measurement uncertainty recapture. Entergy applied for an EPU of approximately 13.1% from the CLTP of 3,898 MWt. This will result in a total uprate of 15% from OLTP to 4,408 MWt. The licensee plans to implement this increase in power during 2012.

DISCUSSION

The approach to achieving a constant pressure power uprate (CPPU) for GGNS consists of: (1) an increase in the core thermal power to create increased steam flow with a more uniform core power distribution; (2) a corresponding increase in the feedwater system flow; (3) no increase in maximum core flow; and 4) reactor operation primarily along the maximum extended load line limit analysis (MELLLA) rod/flow lines. EPU operation does not require increasing the maximum normal operating reactor vessel dome pressure because the plant, due to modifications to non-safety power generation equipment, has sufficient pressure control and turbine flow capabilities to control the inlet pressure conditions at the turbine.

The higher steam flow necessary for the GGNS EPU will be achieved by retaining the existing MELLLA power/flow map and increasing core flow (and power) along the MELLLA upper boundary line. The current MELLLA power/flow map was approved in the GGNS License Amendment No. 156, dated October 10, 2002. [3] Additional energy requirements for a CPPU are met by an increase in the bundle enrichment, an increase in the reload fuel batch size, and/or changes in fuel loading pattern to maintain the desired plant operating cycle length.

The licensee completed major plant modifications to support operation at EPU conditions as described in the license amendment request.

The power ascension program will be conducted in accordance with an approved test plan that identifies specific conditions for ascension after each power increment. This program stems from a license condition imposed by the staff in its review of the GGNS EPU application. Entergy anticipates that the power ascension process will be completed within approximately eight weeks.

The GGNS EPU application follows the guidelines in the NRC-approved General Electric (GE) licensing topical reports for CPPUs of BWRs, including the Power Uprate Safety Analysis Report (PUSAR), the ELTR1, and the ELTR2. [4-6] The staff's evaluation of the application follows the methodology prescribed in the review standard (RS-001) for extended power uprates. [7]

The EPU core will initially contain both GE14 and GNF2 fuel assemblies. The required changes in the core design are implemented in a fashion that limits the impact on fuel safety parameters, which include the minimum critical power ratio (MCPR), the linear heat generation rate (LHGR), and the maximum average planar linear heat generation rate (MAPLHGR). The licensee stated in the PUSAR that the maximum LHGR operating limit is determined by the fuel rod thermal mechanical design and is not affected by the EPU. Hence, all key core parameters for the GGNS EPU will be within the current experience base.

The interim methods licensing topical report NEDC-33173P, "Applicability of GE Methods to Expanded Operating Domains," [8] documents the applicability of GE neutronic and thermal-hydraulic methods for BWR EPU and MELLLA applications. The safety evaluation report for NEDC-33173P-A Revision 1 [9] imposes 24 limitations and conditions for application of these methods to expanded operating domains. In a letter dated December 28, 2010, regarding the

topical report NEDC-33173P [10], the staff concluded that extension of the approval of interim methods for GNF2 fuel is acceptable. Of the 24 limitations and conditions imposed when these methods are applied to EPU conditions, 13 are applicable to GGNS. In its review, the staff determined that the GGNS EPU application complies with all applicable conditions and limitations.

Accident Analyses

The licensee performed loss-of-coolant accident (LOCA) analyses for GGNS at EPU conditions using NRC-approved methods. [11] Independent audit calculations for the large break Appendix K design basis accident yielded peak cladding temperatures (PCTs) of less than 1690 °F. Because PCTs were well below the 2200 °F limit, the staff determined that TRACE audit calculations for the limiting large and small break LOCAs were unnecessary to confirm adequacy of the licensee's EPU LOCA analyses. [12-13]

The PRIME T-M methodology, which includes an empirical equation that explicitly models thermal conductivity degradation (TCD), was approved by the staff in a safety evaluation dated January 22, 2010. [14] The GNF2 fuel system design evaluation for the GGNS EPU application was performed using PRIME T-M. [15] FRAPCON audit calculations performed by the staff in its review of the GNF2 compliance report yielded similar values to those predicted by PRIME T-M. In addition, there were large margins between acceptance criteria and peak values predicted by downstream safety analyses affected by TCD. Hence, the staff concluded that TCD is acceptably addressed for the GGNS EPU.

The licensee performed analyses of GGNS containment response following a design-basis LOCA and an Appendix R scenario at EPU conditions. The analyses were performed using NRC-accepted methods [4], and results indicate that all containment parameters remain well within design limits. Entergy is not requesting containment accident pressure credit to assure adequate net positive suction head for emergency core cooling system pumps. The staff reviewed the licensee's assessment of the containment temperature and pressure transients and concluded that the licensee has adequately accounted for the increase of mass and energy resulting from the proposed EPU. The bulk suppression pool temperature increases from 186°F to 200°F (approximately 10°F less than the design limit of 210°F). Evaluations show that existing piping and pipe support analyses remain valid and are able to accommodate the increases in suppression pool temperature. The staff further concluded that containment systems will continue to provide sufficient pressure and temperature mitigation capability to ensure that containment integrity is maintained and that the proposed EPU is acceptable with respect to primary containment functional design.

Licensee calculations for plant-specific anticipated transients without scram (ATWS) at EPU conditions also indicate that plant parameters remain below design limits. Based on its review, the staff concluded that GGNS meets the ATWS acceptance criteria specified in 10 CFR 50.62 [16] and that the level of protection at EPU conditions does not differ significantly from that at CLTP levels.

The higher decay heat levels at EPU conditions will reduce the times available for operator response. The licensee has made changes in the GGNS normal and emergency operating procedures (EOPs) to accommodate the higher decay heat levels. The licensee indicated that EOP flow charts were reviewed and validated (using plant simulators), and identified changes have been implemented.

Spent Fuel Pool (SFP) Storage

The SFP storage racks at GGNS contain Boraflex as a permanently installed neutron absorber. The Boraflex begins to break down after achieving a threshold gamma radiation dose. The criticality analysis in NEDC-33621P [17] divides the SFP into two regions. Region 1 takes credit for Boraflex. This requires accurate or bounding predictions of the amount and location of Boraflex degradation. Region 2 does not take credit for Boraflex, but requires certain storage locations to remain empty to maintain subcriticality requirements.

For region 1, the staff has not completed its review of the algorithms that the licensee is using to predict and model Boraflex degradation in the criticality analysis. For region 2, the staff considers misloading events to be credible for fuel handling activities in the SFP. During our review, the licensee indicated that they will be updating their submittal to include an analysis of a misloading event.

These items will not be resolved in time to meet the EPU schedule. Therefore, Entergy has proposed a license condition, which is more limiting than that contained in NEDC-33621P. The licensee will perform periodic surveillances of the Boraflex neutron absorbing material using Boron-10 Areal Density Gage for Evaluating Racks (BADGER) testing. The first test campaign will be completed by December 31, 2012. The staff has agreed to this license condition, which will remain in effect until the criticality analysis is approved and will not extend beyond the end of the current fuel loading (Cycle 19). We concur that this license condition provides adequate assurance of subcriticality of the spent fuel until the staff completes its review of the licensee's criticality analysis submittal.

Risk Evaluation

The GGNS EPU application was not submitted as a risk-informed license application. Nevertheless, the licensee has submitted assessments of risk associated with operation at EPU conditions. The staff considered this risk information in its decision-making process to determine if special circumstances exist that could potentially rebut the presumption of adequate protection justified by the compliance of GGNS EPU operation with deterministic requirements and regulations. The staff has concluded that the proposed GGNS EPU will not create any special circumstances.

Power Range Neutron Monitoring System and Stability

Under EPU conditions, GGNS will use the Option III long-term stability solution. [18-19] Approval of the new Power Range Neutron Monitoring System (PRNMS) required for Option III was granted in March 2012. [20] Option III is a detect-and-suppress solution, which combines closely spaced Local Power Range Monitor (LPRM) detectors into “cells” to effectively detect any mode of reactor instability.

Material Degradation

The licensee evaluated the effects of EPU conditions on relevant materials degradation mechanisms including intergranular stress corrosion cracking (IGSCC), irradiation assisted stress corrosion cracking (IASCC), flow-accelerated corrosion (FAC), fatigue, radiation embrittlement, and flow-induced vibration (FIV).

IGSCC and IASCC

The increased fast neutron flux within the core will significantly increase the potential for IASCC and IGSCC. The higher flux will increase the rate of radiation hardening and radiation induced segregation in austenitic stainless steels within the reactor vessel and increase their susceptibility to IASCC. The increased rate of radiolysis of the coolant could also increase steady state and transient concentrations of oxidizing species and increase the aggressiveness of the coolant. Unless mitigation practices are adjusted to account for these effects, the potential for IASCC of austenitic stainless steel core internals and IGSCC of weldments in austenitic stainless steel reactor coolant piping will increase.

The licensee has applied both hydrogen water chemistry and noble metal chemical additions to reduce the electrochemical potential and reduce susceptibility to IASCC and IGSCC. To compensate for the potential increases in susceptibility at EPU conditions, the licensee will continue to follow the BWR Vessel and Internals Project (BWRVIP) recommendations and Electric Power Research Institute (EPRI) Water Chemistry Guidelines to assure effectiveness of its water chemistry program and continue to monitor and control the hydrogen to oxygen molar ratio in the coolant. In addition, the licensee will follow BWRVIP inspection recommendations [21,22, and 23] for components identified as potentially susceptible, such as the top guide, the shroud, and the core plate. The staff concluded that the effects of EPU conditions on the potential for IASCC and IGSCC will be adequately managed.

FAC

EPU conditions require higher steam and feedwater flowrates that may lead to an increase in FAC for some components. The program includes predictive analyses using the EPRI CHECWORKS™ model and periodic inspections. At EPU conditions, the licensee asserts and the staff agrees, that the GGNS FAC program is consistent with industry guidelines and should provide reasonable assurance that unacceptably high FAC rates will be detected before components reach unsafe conditions.

Fatigue

The licensee performed plant-specific fatigue evaluations for reactor pressure vessel components, supports, and reactor coolant pressure boundary and balance-of-plant piping that will experience an increase in pressure, temperature, and/or flowrate due to the proposed EPU and that have an OLTP 40-year cumulative usage factor (CUF) greater than 0.5. The staff found the licensee's evaluation methodology acceptable. Results indicate that all evaluated components meet the American Society of Mechanical Engineers (ASME) Code fatigue CUF allowable value of 1.0 for the 40-year plant life.

Radiation Embrittlement

After reviewing the licensee's evaluation of the changes in neutron fluence due to the proposed EPU, the staff concluded that the industry integrated surveillance program remains bounding for the GGNS reactor pressure vessel and that the material surveillance programs will continue to meet regulatory requirements. The licensee has evaluated the effect of the increased fluence due to EPU conditions on the GGNS reactor pressure vessel. The Charpy upper shelf energy (USE) for the limiting beltline material is projected to remain well above the minimum requirement in the ASME code. The staff has reviewed the licensee's evaluation of the effects of the proposed EPU and concluded that the USE values will continue to be acceptable and that the proposed pressure-temperature limits will continue to meet regulatory requirements.

FIV

The proposed EPU could also increase FIV in certain components, which could lead to high cycle fatigue failure. EPU operating experience has revealed that the steam dryer is the most likely component to be affected. Although the steam dryer does not perform a safety function, it must retain its structural integrity to avoid generating loose parts. The steam flow velocity at GGNS will be higher than that at Susquehanna but lower than those at Quad Cities Unit 2, Nine Mile Point Unit 2, and Hope Creek.

The licensee has replaced the original GGNS steam dryer in preparation for EPU operation. The replacement steam dryer design is based on the design of the curved hood six-bank replacement dryer used in Susquehanna Unit 1. The replacement dryer includes several structural enhancements to increase its resistance to high-cycle fatigue. These enhancements include the use of thicker plate material for dryer components, moving welds away from high stress locations, the use of more robust weld types, and re-design of components focused on stress minimization.

For the replacement dryer stress analysis, the licensee estimated the FIV loads acting on the steam dryer under CLTP conditions using the Plant Based Load Evaluation (PBLE) methodology developed by General Electric Hitachi Nuclear Energy and GGNS plant-specific main steam line (MSL) strain gage data. [24,25] The estimated loads take into account the several safety relief valve (SRV) acoustic resonances excited near CLTP. These loads are applied to a structural finite element model of the dryer to determine the peak stress intensities at CLTP. The licensee then projects the FIV loads at CLTP to EPU conditions and determines frequency based scaling factors. These scaling factors account for the SRV acoustic resonances that may take place during power ascension from CLTP to EPU. The scaling factors along with other bias errors and uncertainties are applied to estimate the peak stress intensities under EPU conditions. Based on these calculations, the licensee concluded that the peak stress intensity in the replacement steam dryer at EPU conditions satisfy the ASME design criterion with adequate margin.

Based on its review and audits, the staff concluded that the GGNS steam dryer stress analysis demonstrated that the peak stress intensity due to FIV at EPU conditions is less than half the ASME code fatigue stress limit and that steam dryer stress intensities are acceptable for normal, upset, emergency, and faulted load combinations.

The licensee has instrumented the replacement dryer with pressure transducers, accelerometers, and strain gages. Analysis of CLTP data from these instruments will provide a GGNS-specific benchmark of the PBLE dryer stress analysis methodology. Prior to EPU power ascension, the benchmark will be used to verify that the GGNS replacement dryer operates with dynamic stress levels less than those allowed by ASME Code limits.

The licensee will implement a slow and deliberate program for power ascension, with defined hold points. The program provides a careful approach to the EPU power level to ensure satisfactory equipment performance. It includes monitoring and analysis to trend the steam dryer performance and a long-term inspection program to verify performance of the steam dryer and piping system. Specifically, the licensee will monitor dryer strains and accelerations, along with MSL strain gage signals (related to MSL internal acoustic pressure waves) and transmit relevant data and evaluations to the NRC staff during the power ascension process.
This license condition for monitoring during power ascension testing provides reasonable assurance that unanticipated vibration modes induced in the steam dryer will be detected and addressed.

SUMMARY

We agree with the staff's reasonable assurance determination that the health and safety of the public will not be endangered by the licensee's operation at the proposed EPU power level and that such activities will be conducted in compliance with the Commission's regulations. The Entergy application for the GGNS EPU should be approved subject to the license conditions imposed in the staff's draft final safety evaluation. We commend the licensee on the quality of this application and the staff for its thorough review.

Sincerely,

/RA/

J. Sam Armijo
Chairman

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Letter to The Honorable Gregory B. Jaczko, NRC Chairman, from J. Sam Armijo, ACRS Chairman dated June 18, 2012

SUBJECT: GRAND GULF NUCLEAR STATION, UNIT 1, EXTENDED POWER UPRATE LICENSE AMENDMENT REQUEST

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