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

August 11, 2011

Mr. R.W. Borchardt
Executive Director for Operations
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: TOPICAL REPORT NEDC-33173P, SUPPLEMENT 2, PART 1, 2 AND 3, "ANALYSIS OF GAMMA SCAN DATA AND REMOVAL OF SAFETY LIMIT MINIMUM CRITICAL POWER RATIO (SLMCPR) MARGIN"

Dear Mr. Borchardt:

During the 585th meeting of the Advisory Committee on Reactor Safeguards, July 13-15, 2011, we reviewed the staff's evaluation of General Electric Hitachi Nuclear Energy (GEH) Licensing Topical Report NEDC-33173P-A, Supplement 2, Parts 1, 2 and 3, "Analysis of Gamma Scan Data and Removal of Safety Limit Minimum Critical Power Ratio (SLMCPR) Margin." Our Power Uprates Subcommittee also reviewed this matter during a meeting on June 7, 2011. During these meetings we had the benefit of discussions with representatives of the NRC staff and GEH. We also had the benefit of the documents referenced.

CONCLUSION AND RECOMMENDATION

1. We concur with the staff's conclusion that the 0.02 additional margin on the SLMCPR imposed for extended power uprates (EPU) may be removed.

2. We recommend that the 0.03 additional margin on SLMCPR imposed for operation in Maximum Extended Load Line Limit Analysis Plus (MELLLA+) conditions be reduced to 0.02.

BACKGROUND

In a letter report dated June 22, 2007, we concurred with the staff in accepting the application of the methods, documented in GEH Licensing Topical Report NEDC-33173P-A, "Applicability of GE Methods to Extended Operating Domains," to EPU and MELLLA+ operating domains, subject to the limitations imposed. MELLLA+ expands the operating domain of a BWR power-flow map so that the upper boundary is 120 percent of the originally licensed thermal power (OLTP) for core flow down to 80 percent of the rated value. For core flow between 80 percent and 55 percent, power must be correspondingly decreased from 120 percent to approximately

100 percent of the OLTP. This expanded domain increases operating flexibility at EPU conditions by allowing reactivity control at maximum power by adjusting the flow instead of relying wholly on adjusting rod positions. Because of uncertainties in predictions of bundle and pin power, an added margin of 0.02 was required for the SLMCPR for EPU conditions. For operation in the MELLLA+ expanded domain, a margin of 0.03 was added to the SLMCPR in part to account for the larger uncertainties introduced by the higher power to flow ratios which n turn give rise to higher void fractions and harder neutron spectra in the upper part of the core. GEH has assessed, in NEDC-33173P-A Supplement 2, the predictions made by its methods against new gamma scan data on bundle powers taken under EPU conditions and pin powers about 4 percent above OLTP to reduce the uncertainties and additional SLMCPR margins. Whether the added margins should be reduced or removed is the subject of this letter report.

DISCUSSION

To reduce the margins added to the SLMCPR, predictions obtained using GEH methods must compare sufficiently well with data at EPU and MELLLA+ conditions. To this end, in NEDC-33173P-A, Supplement 2, Parts 1 and 3, GEH presents Cofrentes (a 12 percent uprated BWR/6) bundle gamma scan data of fuel operated under conditions representative of EPU. The scans measure the axial power profile in each of the four bundles surrounding transverse incore probes (TIPs) at various core locations. The core was highly heterogeneous and contained several different fuel designs. The gamma scan data were compared with predictions obtained using GEH methods to determine the bundle power uncertainty components of the SLMCPR. GEH also presented Fitzpatrick GE14 fuel pin gamma scan data. Fitzpatrick is a BWR/4 that implemented a 4.1 percent power uprate. These measured data were compared against predicted pin power peaking, and the root mean square (RMS) uncertainties were determined.

Because the comparisons with the Cofrentes data indicate that the uncertainties in predictions are lower than the 'historical' RMS values, GEH has proposed, and the staff has accepted, that the bundle power uncertainty component does not require an additional margin for EPU. Furthermore, the Fitzpatrick pin power gamma scan data for EPU conditions were predicted by GEH methods with less than 'historical' uncertainty. The staff has accepted GEH's proposal that the SLMCPR margin added to account for pin power uncertainties above the historical RMS values be removed.

Whether the uncertainties can best be characterized by RMS values remains an open question. The example distribution of differences between the measured and predicted values, presented by GEH, has skew, and an Anderson-Darling test for normality was inconclusive. It is not clear that the uncertainties can be characterized by RMS values when they may not be normally distributed, and then summed to derive the overall uncertainty for comparison with the historical values. Indeed, the RMS data at EPU conditions are insufficient to allow definitive conclusions to be drawn about the uncertainty distributions in the prediction of pin and bundle powers. Nonetheless, for EPU conditions, the comparisons between the new data and predictions by GEH methods appear to indicate that the errors lie within the scatter of the historical values, leading us to concur with the staff's position that the 0.02 additional margin on SLMCPR for EPU may be removed.

For MELLLA+, there are fewer data available for comparison in regions of the expanded domain of operations that might determine the SLMCPR, for example for core average conditions close to120 percent OLTP and 80 percent rated flow conditions. Nonetheless, a partial reduction in the additional SLMCPR margin for MELLLA+ operation can be justified based on the Cofrentes data, in which the EPU operational conditions in a flow window did provide limited data in the MELLLA+ expanded domain. The staff proposed a reduction of the added SLMCPR margin for MELLLA+ operation from 0.03 to 0.01. The remaining 0.01 additional margin is meant to account for uncertainties that might arise from bundle and pin-power predictions when the SLMCPR has to be determined at higher power-to-flow ratios than those for EPU conditions.

We recommend instead that a 0.02 SLMCPR margin be retained for MELLLA+ applications as opposed to the 0.03 currently required for the reasons now discussed.

First, the existing data, including those recently obtained from Cofrentes and Fitzpatrick lie in the range of average core power-to-flow ratios spanning from [redacted] MWt/Mlbm/hr. Application to uncertainty assessments for MELLLA+ operation would require extrapolation of these data up to 50 MWt/Mlbm/hr. Some of the data for individual channels may cover local power-to-flow ratios that are in the range of MELLLA+. However, for MELLLA+ operation the whole core will experience high power to flow ratios at low flow conditions, in comparison to a few maximum power bundles experiencing high power-to-flow ratios at various points in the cycle.

Second, BWR core average void fraction has historically been about 40 percent, and the GEH reactor physics methods were developed and initially validated for these conditions. With operation in the expanded MELLLA+ domain, the core would operate with core average void fraction increasing from about 40 percent to almost 70 percent and with maximum bundle void fractions as high as 90 percent. The neutron spectrum at these conditions becomes epithermal, and the principal physics approximations and the validation base for the diffusion-theory-based code TGBLA6 and the nodal code PANAC11, which are at the heart of the GE methods considered here, become less applicable and the uncertainties in the code predictions are expected to increase. Examination of NEDC-33173P Supplement 2, Part 1, Figures 4-11, and 4-12 shows the trending of PANAC11 versus Cofrentes gamma scan data as a function of axial height. At the top of the core where the void fraction increases there is a noticeable bias and increase in scatter in the comparisons. In addition, GEH calculates the lattice physics data at [redacted] percent void conditions and then extrapolates the data to model the higher void conditions at the upper part of the fuel bundles. It might be possible to adjust such methods to provide adequate predictions for a few high exit void channels dispersed in a plethora of lower void channels.

Third, the operation of the core at combined high power and low flow MELLLA+ conditions will introduce overall spectral conditions, particularly in the upper regions of the core, which will impact not only the accuracy of the pin power distribution but also the accuracy of the core depletion predictions. The high void content and heterogeneity of the fuel lattice in these upper regions will reduce the validity of methods such as those based on neutron diffusion theory and will magnify the limitations in the treatment of such physics phenomena as resonance self-shielding which are important for the accurate prediction of the core depletion at high void conditions.

MELLLA+ operation will include cases where most channels contain flows of high exit void fraction. The application of GEH methods for these conditions needs to be validated. The increased SLMCPR margin of 0.02 is needed until this is accomplished.

Sincerely,

/RA/

Said Abdel-Khalik
Chairman

References:

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2. TR NEDC-33173P, Revision 2, "Applicability of GE Methods to Expanded Operating Domains," 08/2009 (ML092300242)

3. TR NEDC-33173P, Supplement 2, Part 1, "Applicability of GE Methods to Expanded Operating Domains – Power Distribution Validation for Cofrentes Cycle 13," 08/2009 (ML092300242)

4. TR NEDC-33173P, Supplement 2, Part 2, "Applicability of GE Methods to Expanded Operating Domains – Pin-by-Pin Gamma Scan at FitzPatrick October 2006," 08/2009 (ML092300242)

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6. Letter from GEH to NRC, MFN 10-355, "Response to Request for Additional Information Re: GE-Hitachi Nuclear Energy Americas Topical Report NEDC-33173P, Revision 2 and Supplement 2, Parts 1-3 - Analysis of Gamma Scan Data and Removal of Safety Limit Critical Power Ratio Margin (TAC No. ME1891)," 12/17/2010 (ML103640071)

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9. Letter from GE to NRC, MFN 05-029, “Responses to RAIs – Methods Interim Process (TAC No. MC5780),” 04/08/2005 (ML051050022)

10. TR NEDC-33006P-A, Revision 3, “General Electric Boiling Water Reactor Maximum Extended Load Line Limit Analysis Plus,” 06/2009 (ML091800530)

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12. TR NEDC-32601P-A, “Methodology and Uncertainties for Safety Limit MCPR Evaluations,” 08/31/1999 (ML003740145)

13. TR NEDC-32694P-A, “Power Distribution Uncertainties for Safety Limit MCPR Evaluations,” 08/31/1999 (ML003740151)

9. Letter from GE to NRC, MFN 05-029, “Responses to RAIs – Methods Interim Process (TAC No. MC5780),” 04/08/2005 (ML051050022)

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12. TR NEDC-32601P-A, “Methodology and Uncertainties for Safety Limit MCPR Evaluations,” 08/31/1999 (ML003740145)

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Letter to Mr. R. W. Borchardt, EDO, NRC, from Said Abdel-Khalik, Chairman, ACRS, dated August 11, 2011

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