

RS-05-014

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U. S. Nuclear Regulatory Commission
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Dresden Nuclear Power Station, Units 2 and 3
Facility Operating License Nos. DPR-19 and DPR-25
NRC Docket Nos. 50-237 and 50-249

Quad Cities Nuclear Power Station, Units 1 and 2
Facility Operating License Nos. DPR-29 and DPR-30
NRC Docket Nos. 50-254 and 50-265

Subject: Request for Additional Information Regarding Exelon Justification Submitted May 12, 2004, for Continued EPU Operation of Dresden Units 2 and 3

- References:**
- (1) Letter from Jeffrey A. Benjamin (Exelon Generation Company, LLC) to U. S. NRC, "Commitments and Information Related to Extended Power Uprate," dated April 2, 2004
 - (2) Letter from U. S. NRC to C. M. Crane (Exelon Generation Company, LLC), "Commitments and Information Related to the Extended Power Uprate at Dresden and Quad Cities Nuclear Power Stations," dated April 20, 2004
 - (3) Letter from Keith R. Jury (Exelon Generation Company, LLC) to U. S. NRC, "Commitments and Plans Related to Extended Power Uprate Operation," dated May 12, 2004

In Reference 1, Exelon Generation Company, LLC (EGC) provided a summary basis for continued operation of Dresden Nuclear Power Station (DNPS), Units 2 and 3, at EPU conditions. In Reference 2, the NRC noted that the summary basis did not provide a quantitative technical assessment of the potential loadings and resulting stresses that could cause failure of the DNPS steam dryers or other plant components. To address this concern, EGC provided the quantitative input to the technical assessment in Attachment 1 of Reference 3.

On August 16, 2004, the NRC provided EGC with a list of comments regarding DNPS steam dryer loading information contained in References 1 and 3. In August 2004, analyses of the steam dryer loading were incomplete, and documentation of analytical results that quantified the DNPS steam dryer loading was not available. However, EGC provided preliminary analytical

results to the NRC in public meetings held between September 2004, and January 2005. EGC and its contractors have recently completed documenting finalized results that quantify the steam dryer loading. Therefore, Attachment 1 provides information related to the completed analyses and responses to the NRC's comments.

In addition, EGC is updating the quantitative input to the technical assessment of the loadings described in Attachment 1 of Reference 3. Attachment 2 contains a revised report from Continuum Dynamics, Inc. (CDI) describing evaluations of hydrodynamic loading on the DNPS Units 2 and 3 steam dryers. Attachment 3 contains a CDI report outlining a methodology for determining pressure loading on components in the reactor steam dome. This report contains information considered proprietary to CDI. Therefore, EGC requests that this information be withheld from public disclosure in accordance with 10 CFR 2.390, "Public inspections, exemptions, requests for withholding." Attachment 4 contains an affidavit and a non-proprietary version of the report in Attachment 3. Attachment 5 provides results of benchmark testing performed to validate the steam dryer loads.

Should you have any questions concerning this letter, please contact Mr. Thomas G. Roddey at (630) 657-2811.

Respectfully,



Patrick R. Simpson
Manager, Licensing

Attachments:

- (1) Comments on Exelon Justification Submitted May 12, 2004, for Continued EPU Operation of Dresden Units 2 and 3
- (2) CDI Report No. 05-01, "Revised Hydrodynamic Loads on Quad Cities Unit 2 Steam Dryer to 200 Hz, with Comparison to Dresden Unit 2 and Dresden Unit 3 Loads," Revision 0
- (3) CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," Revision 5 (Proprietary)
- (4) CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," Revision 5 (Non-Proprietary)
- (5) Exelon Report No. AM-2004-006, "CDI Benchmark Results of GE Scale Model Test Facility," dated December 1, 2004

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Dresden Nuclear Power Station
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station
Illinois Emergency Management Agency – Division of Nuclear Safety

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Comments on Exelon Justification Submitted May 12, 2004, for Continued EPU Operation of Dresden Units 2 and 3

1. *In its May 12 submittal, Exelon references its summary of the basis for continued extended power uprate (EPU) operation at the Dresden units provided in an attachment to the licensee's submittal dated April 2, 2004. Comments on the April 2 summary of the basis for continued Dresden EPU operation include:*

- (a) *Exelon does not provide a quantitative discussion of the structural integrity of the Dresden steam dryers in terms of the forcing function causing the loading on specific locations of the steam dryer or the material strength to avoid steam dryer failure.*

Response:

Exelon Generation Company, LLC (EGC) in conjunction with General Electric Company (GE) and XGEN Engineering (XGEN), developed dynamic finite element analyses that were applied to the original dryer, 2003 and 2004 dryer repair modifications, and the new dryer design. The applied loads were derived using data collected from Quad Cities Nuclear Power Station Unit 2 (Q2), Dresden Nuclear Power Station Unit 2 (D2) plant data, and Q1 scale model test data. Verified results were reviewed during a meeting between EGC and the NRC on January 25 and 26, 2005. EGC will provide the finalized results to the NRC consistent with the commitments contained in References 1 and 2.

- (b) *Exelon does not address continued functionality of reactor pressure vessel internals (other than the steam dryers), or the steam and feedwater systems or their components for operation at EPU conditions.*

Response:

EGC performed a detailed review of reactor vessel internals, main steam (MS), and feedwater (FW) systems. The results of this effort were previously presented to the NRC as part of an extent of condition review. Reports containing results of these reviews were submitted to the NRC on January 5, 2005.

- (c) *In discussing the gusset plate installation in Dresden Unit 2, Exelon calculated that the stress level was reduced by the October 2003 repair, but does not address the potential loading that might be sufficient to cause failure.*

Response:

Plant data collected from Q2 and scale model test results for Q1 were used to develop dynamic loads for acoustic circuit model analyses. The results were applied to the dynamic finite element analysis, which shows that the gusset tips will have higher stresses with the October 2003 design. The D2 dryer was modified during the Fall 2004 refueling outage to remove the higher stresses in this location.

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- (d) *Exelon states that action will be taken if an unexplained increase in moisture carryover at or above 0.10% occurs in the Dresden units, but does not address proactive measures, such as application of lessons learned from the Quad Cities units.*

Response:

The dryer monitoring plan remains in effect for both Dresden units. These plans include monitoring of key reactor and plant parameters, including moisture carryover, for indication of dryer performance degradation, along with specified actions to be taken for exceeding threshold values as outlined in the monitoring plan. The D3 steam dryer was thoroughly inspected during the Fall 2004 refueling outage. After damage was identified on the D3 dryer, the D2 steam dryer was proactively inspected during Fall 2004. Both D2 and D3 dryers were modified to improve the overall dryer stress levels during the outages.

- (e) *Exelon states that minor and inconsequential cracking might occur in the Dresden steam dryers at the gusset repair locations, but that such cracking would not be a structural concern. However, the licensee does not discuss whether such cracking could generate loose or lost parts in the reactor coolant or steam systems.*

Response:

Both Dresden units were thoroughly inspected during the Fall 2004 outages. Some damage was observed, but there was no cracking at the gusset tips and, consequently, there are no loose or lost parts concerns at this location. During the recent outages on both units a more robust repair design was installed that further limits the stress levels at the gusset tips. This design has been analyzed with plant loads derived from data collected at D2 and Q2, along with loads generated from scale model tests. The results of the stress analysis were presented to the NRC during a meeting between EGC and the NRC on January 25 and 26, 2005.

2. *In Attachment 1 to the May 12 submittal, Exelon provides reports by its contractor Continuum Dynamics, Inc. (CDI) describing the evaluation of the hydrodynamic loading on the Dresden Units 2 and 3 steam dryers. Comments on the CDI study include:*

- (a) *The relationship of the Dresden Unit 2 and 3 reports with a cover date of May 2004 should be compared to the studies referenced in the April 2 submittal by the licensee.*

Response:

Attachment 2, CDI Report No. 05-01, "Revised Hydrodynamic Loads on Q2 Steam Dryer to 200 Hertz, with Comparison to Dresden Unit 2 and Dresden Unit 3 Loads," provides the results of additional analytical work for D2, D3, and Q2. Appendix D of this report provides a comparison of hydrodynamic loads for all three units.

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- (b) *The reports do not indicate whether the applied methodology would have correctly predicted the damage identified in the Dresden Unit 2 steam dryer in October 2003, or in the Dresden Unit 3 steam dryer in December 2003.*

Response:

Loads derived from Q2 in-plant data and Q1 scale model testing were benchmarked against damage observed with the 2003 dryer repairs and the original dryer design using dynamic finite element modeling. This benchmarking shows that the high stress regions correlated well to the observed damage.

Recent plant data collected on D2 was used to evaluate the adequacy of the 2004 dryer modification, but has not been used to evaluate the original dryer. After the higher load cases for the 2004 repairs and the stress analysis for the new dryers are complete, a stress analysis of the D2 and D3 loads will be applied to the original dryer to determine whether these loads would predict the observed damage. This activity will likely occur after the Q1 in-plant data load methodology benchmark.

- (c) *The reports focus on the occurrence of low frequency loading on the steam dryers (the report states that frequencies are being limited to below 50 Hz). The reasoning for this is vague, and does not explain how this cutoff relates to the ability of the acoustic waves to propagate. The reports do not discuss the basis for eliminating potential damage that might occur as a result of higher frequency loading. For example, the reports provide Power Spectrum Density (PSD) plots of in-plant measured oscillating pressure data and the pressure circuit analysis results for a low frequency range from 0 to 50 Hz only. The licensee should provide the PSD plots at least from 0 to 230 Hz because most of the main steam accelerometer data showed the structural response at Quad Cities Unit 2 at about 160 Hz.*

Response:

Attachment 2 provides the results of additional analytical work for D2, D3, and Q2. Appendix D of this report provides a comparison of hydrodynamic loads for all three units. This additional analytical work completed analyses at higher frequencies.

- (d) *The reports describe an acoustic circuit model for determining the hydrodynamic loading on the Dresden Unit 2 and 3 steam dryers. The model in these reports should be compared to the acoustic modeling performed in GENE-000-0018-3359-P (August 2003) and used to support the determination of the root cause and extent of condition for the steam dryer failure at Quad Cities Unit 2 in June 2003. The capability of the acoustic circuit model described in the May 12 submittal to overcome the weaknesses in the evaluations intended to avoid steam dryer cracking at Quad Cities Unit 1 in November 2003 and Quad Cities Unit 2 in March 2004 should be discussed. In particular, Exelon should provide a quantitative assessment of steam dryer structural integrity regarding the resulting*

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stress in conjunction with the application of the actual measured forcing function. The structural integrity of the steam dryers at Dresden Units 2 and 3 was based on the structural analysis for Quad Cities Unit 2 where the flat pressure spectra was applied statically on the dryers. The use of flat spectra assumes the pressure in the inlet nozzle plenum to be random while acoustic loading may be sinusoidal and low in damping.

Response:

Considerable work has been completed since the May 12, 2004, submittal to the NRC. This additional analysis includes CDI Report 05-01, and stress analyses using Q2, D2 plant data, and Q1 scale model test loads. In a meeting between EGC and the NRC on January 25 and 26, 2005, EGC presented verified stress results based on dynamic finite element analysis.

- (e) *The Dresden Unit 2 report indicates that data were collected at only one power level (11.60E6 lbm/hr steam flow). The Dresden Unit 3 report indicates that data were collected at several power levels (9.86E6 to 11.63E6 lbm/hr steam flow). The evaluation of the sensitivity of the acoustic circuit model in calculating hydrodynamic loads at various power levels, including 11.95E6 lbm/hr steam flow, should be discussed. In addition, Exelon should extend the data measurement to the approved EPU level of 11.95E6 lbm/hr, where feasible.*

Response:

Additional plant data was collected at Q2 on August 11, 2004. However, the environmental conditions did not allow EGC to collect data at the highest FW flows. The increased FW flow rates did indicate that pressure oscillation loads increased. Additional plant data was also collected at D2 and D3 near the maximum FW flow limit. The results of this load comparison are provided in CDI report 05-01, Appendix D.

For Q2, it is predicted that increased flow rates will further increase the loads with the current steam path configuration. This is due to the high frequency contribution of the Safety/Relief Valve (S/RV)/Electromatic Relief Valve (ERV) standpipes, and the expected increase due to increased steam velocities.

D2 and D3 have a different SRV/ERV standpipe configuration. Recent data collected for D3 at low power levels shows that the standpipe high frequency contribution occurs at very low power levels and is essentially nonexistent at full EPU power levels.

This explains why the Dresden units have a lower slope for load versus power when compared to Q2, as shown in CDI report 05-01, Appendix D.

- (f) *The reports state that the steam line venturi data were used to drive the model to predict the average root mean square (rms) pressure measured at the turbine instrumentation. The validation of the acoustic circuit model to accurately predict hydrodynamic loading at specific locations of the steam dryer should be*

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discussed. In the pressure circuit analysis, the measured venturi data were input into the model, and the frictional damping coefficient was adjusted in the main steam lines until the average rms pressure was predicted at the turbine, consistent with the measured data at the turbine instrument lines. However, the friction coefficient is a function of the Reynold number, pipe inner surface roughness, diffusion, restriction, etc., and may vary in different portions of the steam line. Exelon should benchmark the resulting data at the steam dryer using the measured data at the venturi and the turbine. Exelon should confirm whether any codes used in the pressure circuit analysis were reviewed and approved by the staff in accordance with the requirements of 10 CFR Part 50, Appendix B. Further, Exelon should explain the determination that, at 11.60E6 lbm/hr flow rate, the peak differential pressure at the steam dryer is about 1.3 (or 1.4) psi while the peak oscillating pressure is about 8.0 psi at the venturi and 6 psi at the turbine.

Response:

EGC has benchmarked the acoustic circuit methodology against scale model test results. This benchmarking showed a good correlation between predicted acoustic circuit results and scale model test microphone data. These benchmarking results are provided in Attachment 5, and additional benchmarking is underway. Vermont Yankee is pursuing a blind benchmark with scale model testing, and EGC is planning to benchmark acoustic circuit analysis against the Q1 instrumented steam path. These load definition benchmarks will provide the verification that the NRC is requesting, even though it is not intended to meet the requirements of 10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants." EGC will provide the finalized results to the NRC consistent with the commitments contained in References 1 and 2.

Attachments 3 and 4 contain CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Dome," Revision 5. This document explains how measured MS pressure oscillations are transformed into dryer loads.

- (g) *The reports indicate that narrow spikes observed at 20 and 40 Hz in the turbine instrumentation data were eliminated from further analysis based on the determination that these spikes were the result of the electromagnetic field of the turbine generator. The basis for this determination should be discussed.*

Response:

The resultant pure tone that was exhibited from the fast Fourier transforms of the pressure oscillation signal was the initial basis for eliminating the 20 and 40 hertz signals. More recent scale model test results of Q1 do not show a similar true tone signal at 20, 40, 60, 120, or 180 hertz, providing further evidence that these frequencies are electromagnetic interference.

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- (h) *The reports indicate that the maximum predicted pressure load occurs at the 270° position across the steam dryer cover plate (Figure 7 in the Dresden Unit 2 report and Figure 20 in the Dresden Unit 3 report) when compared to low PSD values predicted by the acoustic circuit model (Figure 6 in the Dresden Unit 2 report and Figure 19 in the Dresden Unit 3 report) in the steam dome of the reactor vessel. The reports state that this indication of steam excitation above and below the steam dryer would be difficult to anticipate by steam dryer inspection and steam dome geometry. The reports also provide PSD traces for other steam dryer locations with extremely low PSD values for some locations. These results should be discussed in comparison to the steam dryer cracking identified at Dresden Unit 2 in October 2003 and at Dresden Unit 3 in December 2003, and at other high stress locations identified in square hood steam dryers.*

Response:

Loads from Q2 plant data and Q1 scale model testing were benchmarked using dynamic finite element analysis against failures observed with the 2003 dryer repairs and the original dryer. These benchmarks show that the high stress regions in the analytical models correlated well to the observed damage. These benchmarking results are provided in Attachment 4.

Recently collected data from D2 was used to evaluate the 2004 dryer modification for adequacy, but has not been used to evaluate the original dryer. After the higher load cases are completed for the 2004 repairs and the stress analysis for the new steam dryers, a stress analysis of the D2 and D3 loads will be applied to the original dryer to determine whether the observed damage would be predicted with these loads. This activity will most likely take place after the Q1 in-plant data load methodology benchmark. EGC will provide the finalized results to the NRC consistent with the commitments contained in References 1 and 2.

- (i) *The reports conclude that the steam dryer loads are largest for components located near the main steam nozzles and decrease for components near the center of the reactor vessel. The applicability of this general conclusion in predicting the potential for steam dryer failure at specific dryer locations should be discussed.*

Response:

Results of Q1 scale model testing and the acoustic circuit analyses performed using plant data collected at Dresden and Quad Cities consistently show this correlation. EGC is instrumenting the new steam dryer at Q1 with pressure transducers to further validate this conclusion.

- (j) *The Dresden Unit 2 (Unit 3) report concludes that the highest peak differential pressure found on any dryer component (270° cover plate) at 11.60E6 (11.63E6) lbm/hr steam flow was 1.3 (1.4) psid instantaneously, and 0.40 (0.38) psid rms. This conclusion should be discussed in relation to whether*

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these pressures are consistent with the steam dryer damage that occurred at Dresden Units 2 and 3 during EPU operation. In addition, it appears that the peak differential pressures for Dresden Units 2 and 3 are higher than the differential pressure of 1.0 psid used for the Quad Cities Unit 2 root cause analysis.

Response:

Loads from Q2 plant data and Q1 scale model testing were benchmarked against damage observed on the Dresden steam dryers with the 2003 repairs and the original dryer design using dynamic finite element analysis. These benchmarks have successfully shown that the high stress regions correlated well to the observed damage.

Recently collected plant data from D2 was used to evaluate the adequacy of the 2004 dryer modification, but the original dryer design has not been evaluated. After the higher load cases for the 2004 repairs and the stress analysis for the new dryers are completed, a stress analysis of the D2 and D3 loads will be applied to the original dryer to determine whether these loads would predict the observed damage. This activity will likely take place after the Q1 in-plant data load methodology benchmark.

3. **Additional Comments on Attachment 1:**

- (1) *The equations developed on pages 2 through 4 seem to be designed for the analysis of piping sections. Is there a precedent for applying these equations to large open cavities like the steam dome?*

Response:

CDI Report No. 04-09P (i.e., Attachment 3) provides the basis for the current approach. As previously stated, EGC's benchmark of the methodology against scale model test results showed very good correlation between predicted acoustic circuit analysis results and scale model test microphone data. Additional benchmarks are being conducted that will include Q1 in-plant data. The results are provided in Attachment 4, "CDI Benchmark Results of GE Scale Model Test Facility."

- (2) *On the diagram of the model shown on page 5 (Figure 1), there do not appear to be any sections corresponding to the safety relief valve piping. Are the safety relief valves considered in the model? If not, is there justification for neglecting them, in light of the fact that they were originally hypothesized to be a source for acoustic waves?*

Response:

The revised CDI Report No. 05-01 includes the S/RV piping in the model and extends the analysis to 200 hertz, which encompasses the S/RV/ERV standpipe frequencies. This report is in Attachment 3.

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- (3) *On page 8, it is stated that the loads may not be bounding for the flow rate of consideration here. Are there any thoughts on how accurately the data can be scaled to higher flow rates?*

Response:

For the steam flows at which plant data was collected, the results appear to be consistent with observed damage. These results are provided in Attachment 3, CDI Report 05-01.

Scaling plant data to higher steam flows with acoustic circuit analysis has not been demonstrated to provide an exact correlation. However, scale model testing of the Q1 steam path was used to develop loads at simulated higher plant power conditions. These results were used in evaluating the 2003 and 2004 dryer modifications, along with the new dryer design using dynamic finite element analysis.

- (4) *On page 9, the derivation of the damping coefficients is described. To summarize, there are two sets of data (1 from the turbine instruments and 1 from the venturi instruments) that are used. One set is used to 'drive' the model, and damping coefficients are adjusted until the resulting model matches with the second set of data. Is this summary correct? If so, none of the data is being used to verify the accuracy of the final model. Would it be possible to predict damping coefficients via another method, and use the second set of data to justify the accuracy of the model?*

Response:

CDI Reports No. 05-01 and No. 04-09P (i.e., Attachments 2 and 3, respectively) outline an improved methodology based on a three-dimensional Helmholtz Solver of the steam dome and the use of improved plant data collection techniques. As previously stated, EGC has performed benchmarking of the acoustic circuit load definition methodology and additional benchmarks are being completed, including the Q1 benchmark against in-plant data.

4. Additional Comments on C.D.I. Report No. 04-02, Revision 3 dated May 2004:

- (1) *On page 8, it is indicated that the pressure oscillations in main steam lines C and D are higher than those in the other 2 lines. Is this difference solely due to the HPCI branch line (C) and the RCIC branch line (D)?*

Response:

Scale model test results and plant data collection during High Pressure Coolant Injection System (HPCI) and Reactor Core Isolation Cooling System (RCIC) surveillance testing did not show a noticeable contribution that accounts for higher pressure oscillations in main steam lines (MSLs) C and D.

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- (2) *It is stated that data was removed between 19-21 hertz and 39-41 hertz, due to the belief that spikes in the data were being artificially induced by the strong electromagnetic field of the turbine. Were these spikes stationary at 20 and 40 hertz as flow rate was increased? Or were there other indications that the spikes were artificial, other than the fact that they occurred at 20 and 40 hertz?*

Response:

The resultant pure tone exhibited from the fast Fourier transforms of the pressure oscillation signal was the initial basis for eliminating the 20 and 40 hertz signal. More recent scale model test results of the Q1 plant do not show a similar true tone signal at 20, 40, 60, 120, or 180 hertz, providing further evidence that these frequencies are electromagnetic interference.

- (3) *On page 11, Table 3 indicates that two measurements were taken at 9.86×10^6 lbm/hr. The "Turbine Inlet Measured rms (psid)" for these two measurements varies by 8%. Is this variation due to measurement uncertainty, changes in the system from one test to another, not enough temporal data, etc.?*

Response:

Attachment 3 contains CDI Report No. 04-09P, which explains the methodology for transforming measured MS pressure oscillations into dryer loads.

As result of lessons learned and comments provided by the independent reviewers, EGC is also improving the method for collecting MSL pressure oscillation data by using strain gauges. However, both the plant data and scale model testing data show variations in measured rms values for similar locations on different MSLs. EGC is continuing to investigate the cause of these variations.

- (4) *On page 17, the pressure vs. time data for Figure 4-a demonstrates that there is a frequency mode on the order of 15 seconds. This low frequency mode is not captured because there is only 20 seconds of data. What is the justification for neglecting very low frequency modes?*

Response:

While it is possible to define longer time periods for load definitions, analyzing the dynamic load steps with finite element analysis for more than two seconds of time presents a technical challenge beyond current technology. EGC's vendors and independent reviewers have stated that the analyzed data is representative of the power levels at which the data has been collected.

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- (5) *On page 59, is there a known reason for the large discrepancy between rms pressure for lines C and D at 9.86×10^6 lbm/hr?*

Response:

Attachment 3 (i.e., CDI Report No. 04-09P) outlines the methodology for transforming measured MS pressure oscillations into dryer loads. EGC is also improving the method for collecting MSL pressure oscillation data by using strain gauges. This is a result of lessons learned and comments provided by independent reviewers. However, both the plant data and scale model testing data show variations in measured rms values for similar locations on different MSLs. EGC is continuing to investigate the cause of these variations.

- (6) *For many of the figures (ex. Figure 24 on page 65), there are PSD peaks up to 50 hertz. In light of this, is not reasonable to assume that much of the oscillatory power characterization is being lost due to the fact that the temporal resolution does not resolve frequencies above 50 hertz?*

Response:

The revised CDI Report No. 05-01 extends the analysis to 200 hertz. This report is provided in Attachment 2.

References

1. Letter from Danny Bost (EGC) to U. S. NRC, "Commitments and Plans Related to Extended Power Uprate Operation," dated December 10, 2004
2. Letter from Danny Bost (EGC) to U. S. NRC, "Revised Commitments and Plans Related to Extended Power Uprate Operation," dated January 31, 2005