

February 16, 2006

LICENSEE: Exelon Generation Company, LLC

FACILITY: Quad Cities Nuclear Power Station

SUBJECT: SUMMARY OF PUBLIC MEETING ON NOVEMBER 8 AND 9, 2005, WITH EXELON GENERATION COMPANY, LLC ON OPEN ISSUES REGARDING EVALUATION OF STEAM DRYER PERFORMANCE AT QUAD CITIES, UNITS 1 AND 2 (TAC NOS. MC4397 and MC4398)

On November 8 and 9, 2005, the Nuclear Regulatory Commission (NRC) staff held a public meeting with Exelon Generation Company, LLC (Exelon, the licensee) to discuss the remaining open issues regarding the licensee's evaluation of data collected during the restart of Quad Cities, Units 1 and 2 with power ascension up to extended power uprate (EPU) conditions to support their long-term EPU operation. NRC staff from the Office of Nuclear Reactor Regulation (NRR) and Region III, and NRC contractors from Argonne National Laboratory (including a consultant from Pennsylvania State University by telephone) participated in the public meeting with the licensee and its supporting organizations. A list of attendees is provided in the Agencywide Documents Access and Management System (ADAMS) (Accession No. ML053250389).

At a public meeting on August 29 to September 1, 2005, the licensee had presented its evaluation of data collected at Quad Cities, Units 1 and 2 during power ascension to demonstrate the structural capability of their steam dryers under EPU conditions. At the conclusion of the August 29 to September 1 meeting, the NRC staff identified 12 open items related to licensee's steam dryer analysis. The licensee agreed to address those open items to resolve the issue of steam dryer performance for Quad Cities and Dresden. The NRC staff provided a summary of the August 29-September 1 meeting in a memorandum dated October 3, 2005 (ADAMS Accession No. ML052550592).

On September 23, 2005, Exelon submitted an updated commitment letter in support of the continued operation of Quad Cities, Units 1 and 2 at EPU conditions. In its letter, Exelon discussed the evaluation of data collected from the instrumented steam dryer at Quad Cities, Unit 2, and the comparison of the main steam line (MSL) strain gage data obtained at Quad Cities, Units 1 and 2. From this evaluation, Exelon provided confidence in the structural adequacy of the new steam dryers in Quad Cities, Units 1 and 2 while the open items with the steam dryer load definition and stress analyses identified during the public meeting with the NRC staff on August 29 to September 1, 2005, are resolved. On October 17 and 28, 2005, Exelon provided its response to the first 10 open items from the August 29 to September 1 meeting.

During the November 8-9 meeting, the licensee discussed the actions taken, and planned, to address the open items regarding the EPU restart for Quad Cities, Units 1 and 2 from the August 29 to September 1 meeting. The presentation slides provided by Exelon are available in

ADAMS (Accession No. ML060460381). The open items and their status based on the November 8-9 meeting are summarized below:

1. Why does the acoustic circuit model (ACM) underpredict pressures at specific locations on the Quad Cities, Unit 2 steam dryer, and what impact does this underprediction have on the uncertainty of the stress analysis?

With respect to Open Item 1, the licensee discussed its development of uncertainty (random and bias) terms for its steam dryer analysis, including MSL strain gage uncertainty (5.03%), pressure instrument uncertainty (2.9%), pressure instrument phenomenological bias (-3 to -8%), ACM low frequency bias (3% peak-to-peak and 0.4% RMS), and ACM methodology bias (7.8% RMS, -0.5% peak-to-peak, and 13.1% RMS for the 135-160 Hz range). The licensee considered that the -0.5% bias uncertainty based on the peak-to-peak data was appropriate for its "modified 930 MWe" version of the ACM. The licensee combined these uncertainties to calculate a total uncertainty of 6.3% for its steam dryer analysis. The NRC staff noted that the ACM overpredicted the loading for some portions of the Quad Cities, Unit 2 steam dryer (such as the skirt region) and underpredicted the loading for other portions of the steam dryer (such as the middle portion of the outer hood slanted plate). The licensee considered the loads obtained from the skirt pressure measurement locations close to the hood to be indicative of loads on the bottom of the steam dryer hood. The staff also noted that the ACM underpredicted the measured pressure load in some portions of the frequency range of primary interest (150 to 170 Hz). As a result, the staff raised a question as to the impact of the uncertainty for the ACM methodology resulting in the actual stress being higher than calculated by the ACM on the dryer hood in the frequency range of interest. The staff believed that this question could be addressed by calculating an ACM uncertainty considering the loads acting on the hood region only (sensors P1-P12) for RMS, peak-to-peak, and pressures between frequencies of 135 and 160 Hz. The licensee indicated that it would consider using the more conservative ACM bias uncertainty (discussed in Exelon AM-2005-012) associated with loads at frequencies between 135 and 160 Hz. Upon combining the ACM uncertainty with other uncertainties in the stress analyses, the margins to the stress limits could be determined for the steam dryer components and evaluated for appropriate action. The licensee stated that it would address this question regarding ACM uncertainty with regard to the available stress margin for the steam dryer components at Quad Cities.

2. If the uncertainty of the individual aspects of the stress analysis (such as the ACM) will not be determined, combined, and applied, what is the end-to-end uncertainty of the entire stress analysis for the steam dryers in Quad Cities, Units 1 and 2?

With respect to Open Item 2, the licensee discussed its consideration of the strain gage readings on the Quad Cities, Unit 2 steam dryer to strain calculated by the licensee's stress analysis. The licensee determined that the Quad Cities, Unit 2 steam dryer experienced less strain than calculated by the stress analysis based on three strain gages installed on the dryer. The staff requested the results of the comparison for each of the Quad Cities, Unit 2 steam dryer strain gages. The staff considers that the licensee's comparison of measured strain to calculated strain will be helpful to provide confidence in the capability of the Quad Cities, Unit 2 steam dryer to withstand the applied pressure loads.

However, differences in responsiveness to applied loads might make this determination not applicable to other steam dryers. Therefore, the individual uncertainty terms for the stress analysis needs to be determined when evaluating the structural capability of other steam dryers. The licensee indicated that it would provide information available for the other strain gages installed on the Quad Cities, Unit 2 steam dryer.

3. With the modifications to the ACM to best match the Quad Cities, Unit 2 steam dryer pressure data at 930 MWe, what is the confidence in the application of the ACM to Quad Cities, Unit 1 and Dresden, Units 2 and 3?

With respect to Open Item 3, the licensee presented its comparison of measured pressure data to pressure loads calculated by the ACM at 790, 912, and 930 MWe for Quad Cities, Unit 2. The comparison suggested that the ACM calculates higher loads at lower power levels at Quad Cities, Unit 2. The licensee noted that a comparison of the ACM calculations to measured pressure loads across the Quad Cities, Unit 2 steam dryer indicates that the assumed acoustic damping in the steam dome area was too high and the assumed acoustic damping in the skirt region of the steam dryer was too low. The licensee was not aware whether these damping assumptions in the ACM would be corrected. The staff questioned the lack of comparison of frequency peaks for the ACM calculations and actual pressure data. Since the ACM bias uncertainty is frequency dependent, the dynamic behavior of the dryer needs to be evaluated to determine appropriate uncertainties over the specific dryer regions in the frequency ranges of interest. The licensee stated that it would address this question on the frequency dependence of the ACM uncertainty.

4. Is it sufficient to use a +/-10% time step on the frequency spectrum in the stress analysis without considering significant peaks within that range?

With respect to Open Item 4, the licensee discussed its evaluation of small spectra increments within the $\pm 10\%$ frequency band in the stress analysis. The licensee found only small increases in stress intensity for various dryer components for the frequency increments within the $\pm 10\%$ frequency band. The licensee calculated the minimum design margin to be 14% on the trough brace gusset for the Quad Cities, Unit 1 steam dryer and to be 17% on the skirt for the Quad Cities, Unit 2 steam dryer. The licensee plans to provide a written description of its evaluation of the $\pm 10\%$ frequency band. The staff suggested that this evaluation be conducted for 2% and 1% of critical damping. The staff noted that division of the 140 to 170 Hz frequency band into smaller segments showed increases in stress of some dryer components above the values determined at nominal conditions and $\pm 10\%$ frequency intervals. Therefore, the uncertainty of the stress for those dryer components needs to be addressed, along with other analysis uncertainties, as part of the evaluation of adequate stress margin.

5. How significant is the omission of low frequency pressure loads on the steam dryer by the ACM?

With respect to Open Item 5, the licensee presented its evaluation of the omission of low frequency loads by the ACM through filtering low frequency loads (less than 20 Hz) from the measured pressure data obtained by the four sensors on the Quad Cities, Unit 2 steam dryer nearest the MSL nozzles. The licensee determined that the omission of low frequency loads resulted in a small negative bias (about 3%) in the pressure loads calculated by the ACM on the steam dryer. Further, the licensee reported that the skirt is the only component in the Quad Cities, Unit 2 steam dryer with modal frequencies less than 20 Hz, and that the strain measured in the skirt is an order of magnitude lower than the strain calculated by the finite element model. The licensee acknowledged that this evaluation only applies to the replacement steam dryers for Quad Cities, Units 1 and 2. In response to an NRC staff question, the licensee evaluated five other points to determine that the low frequency loads represented only a small percentage (less than 3% in all but one parameter comparison) of the total pressure load. When this evaluation is documented, the NRC staff will consider the licensee to have satisfied this open item regarding the omission of low frequency loads by the ACM when calculating the pressure loads on the steam dryer. The 3% bias in the calculated pressure loads from the omission of low frequency loads by the ACM needs to be considered in assessing the impact of uncertainties in the stress analysis on the confidence in the structural integrity of the steam dryer.

6. Are the differences in the resonance response of the Quad Cities, Units 1 and 2 steam dryers during the hammer tests significant?

With respect to Open Item 6, the licensee presented a comparison of the hammer tests for the Quad Cities, Units 1 and 2 steam dryers. The staff pointed to an apparent higher response of the Quad Cities, Unit 1 steam dryer in the 150 to 170 Hz frequency range. In particular, the staff noted the responsiveness of the 270E hood of the Quad Cities, Unit 1 steam dryer. The staff indicated the importance of identifying significant frequency bands, including supporting the frequency differences between the hammer test and plant conditions. In that the licensee considers it not reliable to extrapolate the hammer test results showing low structural damping (<1% of critical damping) to reactor operating conditions, the staff believed it important to evaluate the sensitivity of the steam dryer stresses to structural damping so that the effect of damping on structural integrity of the steam dryer can be determined. The resulting uncertainties need to be considered along with other uncertainties in evaluating the stress margin for steam dryer components. The licensee stated that it would address these staff questions.

7. Is the methodology used to extrapolate the loads to 2957 MWt appropriate based on the Quad Cities, Unit 2 steam dryer data?

With respect to Open Item 7, the licensee presented its evaluation of sensor data from the Quad Cities, Unit 2 steam dryer to develop scaling factors based on power law exponents to extrapolate the steam dryer loading from 2885 MWt (maximum achieved thermal power) to 2957 MWt (maximum licensed thermal

power). From its evaluation of the sensor data as the power level neared the maximum achieved MWt conditions, the licensee calculated increased scaling factors for the upper dryer and skirt to extrapolate the stress from 2885 to 2957 MWt. Following the licensee's presentation, the staff pointed to the rapid rise in strain obtained from strain gage S-7 on the Quad Cities, Unit 2 steam dryer. The staff also raised questions regarding the significant increase in data from the pressure and strain sensors in the frequency range of 150 to 170 Hz near the maximum thermal power. The licensee stated that it would address these staff questions regarding extrapolation of steam dryer loading.

8. Does a comparison of the MSL strain gage data for Quad Cities, Units 1 and 2 support interim EPU operation for Quad Cities, Unit 1 until the stress analysis uncertainty issue is resolved?

With respect to Open Item 8, the licensee discussed its comparison of MSL strain gage data from Quad Cities Units 1 and 2. The licensee considered the pressure loading suggested by the MSL strain gage data from the two reactor units to be comparable. The staff concluded that the MSL strain gage comparison could not fully demonstrate that similar pressure loading is being applied to the Quad Cities, Units 1 and 2 steam dryers. The staff considered that the strain measurement data does not support a conclusion that differences in the performance of the steam dryers in Quad Cities, Units 1 and 2 are only due to loss of single MSL strain gages in Quad Cities, Unit 1. The licensee stated that it would address this question with its consultant.

9. Are the criteria used for strain gages S-5, S-7, and S-9 (outer hood locations) during the recent EPU restart of Quad Cities, Unit 2 met with the most recent stress analysis?

With respect to Open Item 9, the licensee presented its evaluation of data from strain gages S-5, S-7, and S-9 in comparison to the acceptance criteria during the Quad Cities, Unit 2 restart. The licensee found that the strain gage criteria were met using the most recent analysis. With the impact of structural damping assumptions to be addressed through Open Item 6, the NRC staff considered that Open Item 9 can be closed.

10. What is the uncertainty of the steam dryer strain gages installed in Quad Cities, Unit 2, and how does it impact available margin for steam dryer structural integrity?

With respect to Open Item 10, the licensee presented its evaluation of the sensitivity of the strain gages installed on the steam dryer in Quad Cities, Unit 2 for location and orientation. Based on its review of strain gages S-5, S-7, and S-9, the licensee found the calculated strain to be higher than the measured strain on the steam dryer. The NRC staff considered the licensee's evaluation to have resolved this open item for Quad Cities, Unit 2. Where applicable, the steam dryer strain gage measurement uncertainty needs to be considered in assessing the structural capability margin.

11. What are the results of the application of the lessons learned from the Quad Cities, Unit 2 steam dryer data with regard to EPU operation at Dresden, Units 2 and 3?

With respect to Open Item 11, the licensee discussed its ongoing application of the EPU lessons learned from Quad Cities to Dresden. Although a final decision has not been reached, the licensee is considering replacement of the steam dryers in Dresden, Units 2 and 3 at their next respective refueling outages (RFOs) with an improved design that would be very similar to the new Quad Cities steam dryers. The licensee is also planning to install additional strain gages on one MSL in Dresden, Unit 2 during its fall 2005 RFO to obtain additional information regarding steam dryer pressure loading. More extensive MSL instrumentation will be applied to the Dresden units when the replacement steam dryers are installed. The staff will have additional discussions regarding the Quad Cities EPU lessons learned with the licensee following the fall 2005 RFO at Dresden, Unit 2.

12. What is the source of the significant frequency peaks in the pressure loading on the steam dryers in Quad Cities, Units 1 and 2, and what impact will those peaks have on plant equipment during long-term EPU operation?

With respect to Open Item 12, the licensee responded that the Quad Cities steam dryers have been designed to accommodate the pressure loading determined to be applied during EPU operation. The licensee is working to identify the source of the frequency peaks observed in the pressure loading on the Quad Cities steam dryers. The licensee has initiated an effort to use a small-scale model steam line to evaluate the generation of frequency resonances at valve branch lines. After identifying the source of significant frequency resonances, the licensee plans to test mitigation techniques using a more extensive scale model. With the relatively small margin to the stress limits for some dryer components in the Quad Cities units, the NRC staff agreed that it is important to evaluate potential mitigation techniques for the resonance peaks. The licensee has not indicated its intention regarding documenting any planned or completed actions related to the source mitigation efforts.

In summarizing its conclusions from the November 8-9 meeting, the NRC staff stated that, based on its review of the information provided by the licensee and the discussions during the meeting, several questions remain regarding the licensee's consideration of the impact of uncertainties in the stress analysis and its assumptions on the potential to exceed the allowable stress limits in the Quad Cities steam dryers under EPU conditions. For example, the staff raised questions regarding the consideration of uncertainties associated with the calculation of pressure loads on the steam dryer by the ACM at various locations and frequency ranges; sensitivity of the stress analysis to assumptions for acoustic and structural damping; impact of resonances within the $\pm 10\%$ frequency band; extrapolation of sensor data to maximum thermal power levels in the frequency range of interest; comparison of MSL strain data from Quad Cities, Units 1 and 2; and differences in steam dryer responsiveness to pressure loads. The staff noted that the licensee's stress calculations found relatively small margins to the applied stress limits for some parts of the steam dryers in Quad Cities, Units 1 and 2. In that the questions associated with the stress analysis uncertainties involve whether the steam dryer

stress limits might be exceeded, the staff could not reach agreement with the licensee that the analysis supports long-term EPU operation for Quad Cities.

The NRC staff considers the questions regarding uncertainties in the steam dryer stress analysis to be less significant for Quad Cities, Unit 2 as a result of the pressure sensors and strain gages installed directly on the steam dryer. Further, the licensee will conduct a detailed inspection of the Quad Cities, Unit 2 steam dryer during the spring 2006 RFO. With the reliance on the ACM to determine steam dryer loads in Quad Cities, Unit 1, the staff considers the questions regarding the steam dryer analysis uncertainties to be more focused on that unit. These questions would also be applicable to the Dresden units.

The licensee will be providing additional information on the questions associated with several open items from the NRC staff review. In determining the uncertainty for each applicable term in the steam dryer stress analysis, the staff suggested during the November 8-9 meeting that the licensee evaluate the sensitivity of the uncertainty factors in question for the Quad Cities, Unit 1 steam dryer with regard to: (1) dryer components with the lowest margin and (2) dryer components considered to be the most susceptible to the generation of loose parts (such as the outer hood). The staff also requested that the licensee discuss the location, function, and potential to generate loose parts for each of these analyzed dryer components. Based on this evaluation, the licensee could assess the confidence in the structural integrity of the Quad Cities, Unit 1 steam dryer in light of the potential impact of uncertainties on the stress analysis. This information will also help the licensee to determine appropriate long-term plans for Quad Cities and Dresden.

At the end of the November 8-9 meeting, the NRC staff and licensee discussed the status of the open items from the August 29 to September 1 meeting regarding the performance of the steam dryers at Quad Cities, Units 1 and 2. The staff and licensee noted the open items that were resolved based on the information submitted by the licensee and the November 8-9 discussions. The staff and licensee also discussed the additional information that the licensee will provide to address the questions associated with the remaining open items. The licensee noted that it might request that the management meeting planned for late November be rescheduled to allow additional time to resolve the remaining questions on its steam dryer analysis.

Following the discussion of the Quad Cities steam dryers, the licensee provided an overview of the results of the inspection of the steam dryer in Dresden, Unit 2 during the fall 2005 RFO. The licensee's presentation slides on the Dresden, Unit 2 steam dryer inspection are available in ADAMS. At the time of the November 8-9 meeting, the licensee had not completed its

assessment of the planned repairs to cracks identified in the Dresden, Unit 2 steam dryer. The licensee indicated that additional information on the Dresden, Unit 2 steam dryer repairs would be provided subsequent to the November 8-9 meeting.

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