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Nuclear

RS-05-061

May 12, 2005

U. S. Nuclear Regulatory Commission
ATTN: Document Control Desk
Washington, DC 20555-0001

Dresden Nuclear Power Station, Units 2 and 3
Renewed 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
Renewed Facility Operating License Nos. DPR-29 and DPR-30
NRC Docket Nos. 50-254 and 50-265

Subject: Request for Additional Information for Review of Quad Cities Replacement Steam Dryer

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

(4) Letter from Danny Bost (Exelon Generation Company, LLC) to U. S. NRC, "Commitments and Plans Related to Extended Power Uprate Operation," dated March 31, 2005

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.

A001

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. EGC provided preliminary analytical results to the NRC in public meetings held between September 2004, and January 2005, and submitted updated evaluations for justifying continued operation of the DNPS units at extended power uprated (EPU) conditions, including a quantitative assessment of dryer loading, in Reference 4.

On February 8, 2005, the NRC requested additional information (RAI) related to review of the Quad Cities replacement steam dryers, including the methods used to quantify steam dryer loads in the dryer design analysis. As part of an ongoing effort to address EPU-related issues, support continued operation of the DNPS units at EPU power levels, and to support returning the QCNPS units to continuous EPU operations, EGC and its contractors have recently completed documenting finalized results that quantify the steam dryer loading, as well as provide detailed analysis results of the replacement steam dryers. The attachments to this letter provides information related to the completed analyses and responses to the NRC's RAI dated February 8, 2005.

RAI Question 3(d) and its response are considered proprietary to Continuum Dynamics, Incorporated (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," paragraph (a)(4), and 10 CFR 9.17, "Agency records exempt from public disclosure," paragraph (a)(4). Attachment 2 provides a non-proprietary version of RAI question 3(d) and EGC's response.

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

Respectfully,

Patrick R. Simpson

Patrick R. Simpson
Manager – Licensing

Attachments:
1. Affidavit and Quad Cities Units 1 and 2, Individual RAI Responses for the Dryer Replacement Project, Revision 5, May 3, 2005
2. Non-Proprietary Version of RAI Question 3(d) and Response

ATTACHMENT 1

Affidavit and Quad Cities Units 1 and 2, Individual RAI Responses for the Dryer Replacement Project, Revision 5, May 3, 2005

Continuum Dynamics, Inc.
(609) 538-0444 (609) 538-0464 fax 34 Lexington Avenue Ewing, NJ 08618-2302

AFFIDAVIT

Re: Response to Question 3D from "Request for Additional Information for Review of Quad Cities Replacement Steam Dryer" dated February 8, 2005

I, Alan J. Bilanin, being duly sworn, depose and state as follows:

1. I hold the position of President and Senior Associate of Continuum Dynamics, Inc. (hereinafter referred to as C.D.I.), and I am authorized to make the request for withholding from Public Record the Information contained in the documents described in Paragraph 2. This Affidavit is submitted to the Nuclear Regulatory Commission (NRC) pursuant to 10 CFR 2.390(a)(4) based on the fact that the attached information consists of trade secret(s) of C.D.I. and that the NRC will receive the information from C.D.I. under privilege and in confidence.

2. The Information sought to be withheld, as transmitted to EXELON by email on April 29, 2005 and is the response to Question 3D of the above referenced RAI's and was prepared by Continuum Dynamics, Inc.

3. The Information summarizes:

   (a) a process or method, including supporting data and analysis, where prevention of its use by C.D.I.'s competitors without license from C.D.I. constitutes a competitive advantage over other companies;
   (b) Information which, if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality, or licensing of a similar product;
   (c) Information which discloses patentable subject matter for which it may be desirable to obtain patent protection.

   The information sought to be withheld is considered to be proprietary for the reasons set forth in paragraphs 3(a), 3(b) and 3(c) above.

4. The Information has been held in confidence by C.D.I., its owner. The Information has consistently been held in confidence by C.D.I. and no public disclosure has been made and it is not available to the public. All disclosures to third parties, which have been limited, have been made pursuant to the terms and conditions contained in C.D.I.'s Nondisclosure Secrecy Agreement which must be fully executed prior to disclosure.

5. The Information is a type customarily held in confidence by C.D.I. and there is a rational basis therefore. The Information is a type, which C.D.I. considers trade secret and is held in confidence by C.D.I. because it constitutes a source of competitive advantage in the competition and performance of such work in the industry. Public disclosure of the Information is likely to cause substantial harm to C.D.I.'s competitive position and foreclose or reduce the availability of profit-making opportunities.

I declare under penalty of perjury that the foregoing affidavit and the matters stated therein are true and correct to be the best of my knowledge, information and belief.

Executed on this 11 day of May 2005.

Alan J. Bilanin
Continuum Dynamics, Inc.

Subscribed and sworn before me this day: May 11, 2005

Barbara A. Agans, Notary Public

BARBARA A. AGANS
NOTARY PUBLIC OF NEW JERSEY
MY COMM. EXPIRES MAY 6, 2007

Quad Cities Units 1 and 2,

Individual RAI Responses for the Dryer Replacement Project

Revision 5

May 3, 2005

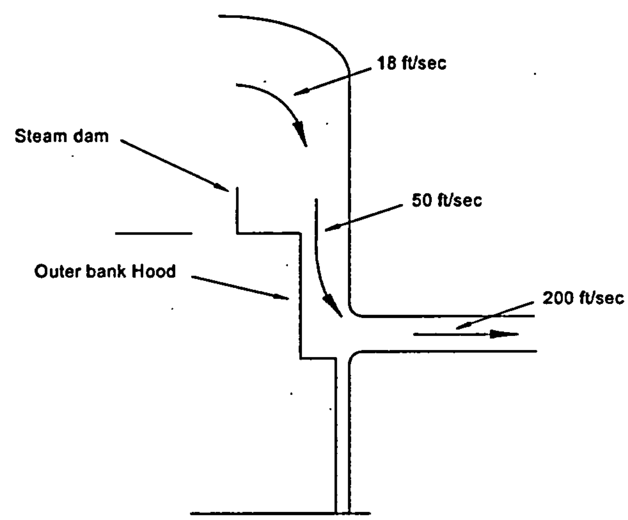
RAI #1 (a)

The licensee is requested to provide the following information regarding its assumptions for steam dryer loads:

(a) the basis for its assumption that acoustic loading as predicted by the acoustic circuit analysis is the principal load applied to the steam dryer,

Response

Following completion of the extended power uprates (EPU), the steam dryers at Quad Cities, Units 1 (QC1) and 2 (QC2), experienced structural damage during subsequent operation. Finite element analysis (FEA) performed by General Electric (GE) indicated that the most heavily loaded areas of the steam dryer were the outer bank hoods opposite the main steam line (MSL) inlets. The FEA determined that a differential pressure of 1 to 4 pounds per square inch differential (psid) was needed to create the damage observed on the steam dryers



Estimation of steam velocities in QC at EPU Conditions

The sketch above estimates the mean steam velocities over the steam dam (dryer outlet), at the dryer outer bank hood in front of the MSL entrances, and in the MSL at EPU conditions. These velocities are 18 feet per second (ft/sec), 50 ft/sec, and 200 ft/sec, respectively. Given that strong turbulence has velocity fluctuations on the order of 10% of the mean velocity, pressure fluctuations p' resulting from shed eddies or turbulence are determined as follows:

$$p' = q' = \rho U u' \sim .1\rho U^2$$

where

q' - fluctuation in dynamic pressure
ρ - mean density (2.24 lbm/ft^3 reactor conditions)
U - mean velocity
u' - fluctuation in mean velocity

Corresponding pressure fluctuations were calculated using the velocities stated above. The results are shown in the table below.

Location	U (ft/sec)	q' (psi)	u' (ft/sec) (assumed)
Steam Dome	18	0.02	1.8
Outer Bank Hood	50	0.12	5.0
MSL	200	1.9	20.0

The fluctuating pressures due to eddy shedding or turbulence on the outer bank hood cannot account for the damage observed, even if these fluctuations were increased five-fold.

If it is postulated that pressures on the dryer outer bank hood are acoustic, then the pressure fluctuations scale as:

$$p' \cong \rho u' a$$

where a is the acoustic speed of steam (1600 ft/sec at reactor pressure). Pressure fluctuations of 4 psid correspond to velocity fluctuations of $u' \sim 5$ ft/sec, which is exactly the magnitude of velocity fluctuation that is anticipated from eddy shedding/turbulence on the outer bank hood (strong turbulence).

The discussion above demonstrates that eddy shedding and turbulence provide the dominant source of the acoustic oscillations, and it is the steam dome and MSLs that store the energy in acoustic waves. This is the basis for the assumption that acoustic loading, as predicted by the acoustic circuit analysis, is the principal load applied to the steam dryer. This assumption was also supported by the scale model testing that is described in Section 3 of GE Report NEDC-33192.

Reference

1. NEDC-33192, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005

RAI #1(b)

The licensee is requested to provide the following information regarding its assumptions for steam dryer loads:

(b) the basis for the inclusion or exclusion of other potential flow-induced loads (such as those incurred due to turbulent or bistable flow, fluid-structure interaction, or acoustic-structure interaction), and their consideration in the steam dryer analysis, and

Response

As stated in the response to RAI 1(a), the primary loads applied to the steam dryer are generated from acoustic oscillation. In a technical report titled, "A Note On Fluid-Structure Interaction," dated March 24, 2005, Dr. Fred Moody provides a mathematical model concerning fluid-structure interaction. The mathematical model developed by Dr. Moody resulted in a load reduction to the dryer when fluid-structural interaction was postulated. Therefore, the new dryer design load definition, excluding fluid-structural interaction, was demonstrated to be conservative. Furthermore, the turbulent loads are bounded (see the response RAI 1(a)) and are on the order of tenths of a psi. Therefore, they are insignificant when compared to the acoustic loads. This conclusion was also supported by the SMT described in Section 3 of GE Report NEDC-33192. This forms the basis for exclusion of other potential flow-induced loads.

References

1. Dr. F. Moody, "A Note On Quad Cities Steam Dryer Fluid-Structure Interaction," dated March 24, 2005
2. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005

RAI #1(c)

The licensee is requested to provide the following information regarding its assumptions for steam dryer loads:

(c) validation of the analysis assumptions for the steam dryer loads and excitation sources.

Response

Validation of the acoustic circuit model (ACM) was confirmed through two sets of scale model testing. The first set of tests collected SMT data from the QC1 reactor vessel and MSL piping. Data collected from the scale model was used to validate the portion of the ACM for the reactor steam dome. The results of this test are described in Exelon Report AM-2004-006, "CDI Benchmark Results of GE Scale Model Test Facility," dated December 1, 2004.

The entire ACM, including the reactor vessel, steam dryer, and main steam piping, was validated during a second round of scale model testing. The results of this benchmark effort were presented to the NRC technical staff during a public meeting held in the Exelon Corporate office on April 25 – 27, 2005. The second round of benchmark testing demonstrated that the ACM provides reasonable predictions of dryer pressure loads.

Finally, ACM loads were used in FEA and compared against calculated loads attributed to the damage seen on the QC1 and QC2 steam dryers. Although performed after damage occurred, the resulting analysis could have predicted the actual damage experienced. This demonstrates that the loads are of the appropriate magnitude.

References

1. Exelon Report AM-2004-006, "CDI Benchmark Results of GE Scale Model Test Facility," dated December 1, 2004
2. Exelon presentation slides provided to the NRC staff during April 25 through 27, 2005 Public Meeting held in Exelon Corporate office in Warrenville, IL

RAI #2(a)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers:

(a) description of SMT apparatus and setup;

Response

A description of the SMT apparatus and setup is contained in Section 4 of GE Report NEDC-33192P.

Reference

1. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005

RAI #2(b)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers:

(b) description of testing conducted and its results in identifying the significant loads on the steam dryer and their sources;

Response

A description of the testing conducted and results is contained in Section 6 of GE Report NEDC-33192P.

Reference

1. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing" dated April 2005

RAI #2(c)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers:

(c) description of testing conducted or planned to determine the resonance flow rate at the safety relief valve and to evaluate the pressure change with flow velocity to compare with the computational fluid dynamics (CFD) results, and plans for resolution of the remaining open items;

Response

A description of the SMT performed on the safety relief valves is contained in Section 6.3.3.3 of GE Report NEDC-33192P. CFD analysis was not performed to determine the flow characteristics of the safety valves. However, a CFD analysis was performed to evaluate the steam flow characteristics in the steam dome of the vessel for both the original and replacement steam dryers. CFD analysis of the full scale dryer and sub-scale model dryer demonstrate that the flow lines are similar, supporting the use of SMT data for dryer load development.

References

1. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005
2. NEDC-33191P-R1, "Computational Fluid Dynamics Flow Visualization of Quad Cities Sub-scale Original Dryer Model as a Function of Reynolds Number," Revision 1, dated April 2005

RAI # 2(d)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers:

(d) evaluation of SMT results for assessing the integrity of the steam dryer, including the potential for changes in peak loading based on plant operating points;

Response

The pressure loading on the steam dryer during normal operation is related to the steam flow in the reactor and the MSLs. The plant operating point (as defined by the core power level, core flow, and feedwater temperature) affects the pressure loading on the dryer only to the extent that the reactor heat balance condition at that operating point affects the amount of steam generation. The limiting operating condition for steam generation is full reactor thermal power at normal feedwater temperature. Under these conditions, the core flow does not affect the steam generation. Other operating conditions, such as reduced feedwater temperature or single loop operation, result in reduced steam flow generation and, therefore, are less limiting with respect to the pressure loading on the dryer. The Scale Model Tests (SMT) for assessing the integrity of the steam dryer were performed at a system flow rate corresponding to the steam flow rate at full EPU operating conditions.

As shown in Section 6.5 of GE Report NEDC-33192P, the SMT loads are conservative when compared with the available plant data. In addition, a conservative factor of approximately 1.25 has been applied to the pressure scaling relationship discussed in the report for use when developing the fluctuating pressure load definition inputs for the steam dryer structural integrity assessments. Therefore, the load definition developed using the SMT is expected to bound the peak loading at all operating points for normal plant operation.

Reference

1. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005

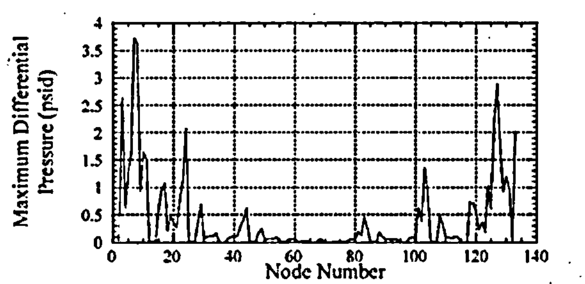
RAI # 2(e)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers:

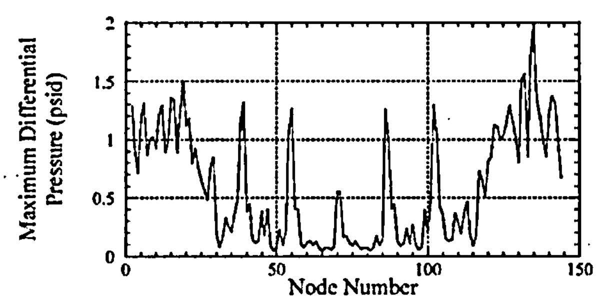
(e) comparison of SMT test data to acoustic circuit analytical results and CFD predictions, and resolution of differences (including maximum pressure points and locations); and

Response

Exelon has used both QC1 SMT results and QC2 in-plant loads with acoustic circuit modeling to develop the two new dryer load cases. CFD analysis was not used for load definition. For the two design load cases that are used for the new dryer analyses, there are differences in the frequency and amplitudes of the responses as shown below. There are a number of known reasons for the differences. First, inputs used to develop the load cases are from two different plants. Second, the new steam dryer was analytically inserted into the Helmholtz solver and the direct measurement for the SMT, as opposed to using instrument lines and direct measurement with a strain gauge for the in-plant data. To be sure that the new dryer design is structurally viable, the design analyses used both load cases. In addition, both load cases included plus 10% and minus 10% frequency shifts, giving six finite element evaluations.



New Dryer QC2 In-plant Peak Load at EPU Scaled Flow



New Dryer QC1 SMT Peak Load at EPU Scaled Flow

References

1. CDI Technical Note 05-03, "Quad Cities Unit 2 New Dryer Vulnerability Loads," Revision 1, dated April 2005
2. CDI Technical Note 05-04, "Quad Cities Unit 2 New Dryer SMT Loads," Revision 5, dated April 2005

RAI # 2(f)

The licensee is requested to provide the following information regarding its scale model test (SMT) program for the Quad Cities steam dryers

(f) plans to validate SMT results with Quad Cities Unit 1 replacement steam dryer pressure and strain data.

Response

Data from the pressure transducers on the steam dryer will be used as the benchmark for the QC1 scale model data. An initial assessment will be made using the six pressure transducers identified in the startup test plan. If significant discrepancies are identified between the plant and model data from these sensors, then an action plan will be developed to investigate the cause of the discrepancies and modify the model accordingly. If the data from the initial six pressure transducers matches well with the model data, the data from remaining pressure transducers will be compared to model data at equivalent locations. This comparison will be documented.

References

1. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005
2. TIC-1224, "Quad Cities Unit 2 Power Ascension Test Procedure for the Reactor Vessel Steam Dryer Replacement," Revision 0, May 2005

RAI # 3(a)

The licensee is requested to provide the following regarding its ACM used in predicting loads on the steam dryer:

(a) description of the acoustic circuit model;

Response

The theoretical development of the acoustic circuit analysis is documented in previously submitted CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," dated January 2005. The acoustic circuit analysis uses either six or eight measurements of pressure along the four MSLs to predict the differential pressure time histories at specified locations on the steam dryer. In addition to measured plant data, the analysis requires geometry of the steam dome, dryer, and MSLs to the positions where pressure data are obtained. Further, the model requires input of the thermodynamic conditions in the reactor to determine acoustic speed, steam flow velocity, etc. The model is not predictive in that data must be provided, but it provides a method by which in-plant data is used to estimate reactor component loads.

References

1. CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," dated January 2005
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," dated January 2005

RAI # 3(b)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(b) user's manual and theoretical analysis for the acoustic circuit analysis code (containing all steps in the procedure, including how matrices are manipulated to infer the amplitudes and phasing of assumed sources throughout the steam lines and steam dome, and how steam dryer loads are computed from those sources) that confirm that the code has been benchmarked, with an example problem including a description of the problem, input data, and output results;

Response

No formal user's manual exists for the ACM since the code is proprietary and property of CDI. The formulation of the algorithm and coding is documented in CDI Report DRF-CDI-174, "Acoustic Circuit and Helmholtz Analyses and Models." This report was made available for review and inspection during the April 25 - 27, 2005, meeting between Exelon and the NRC. Exelon's benchmarking of the code was submitted to the NRC in a letter from Patrick R. Simpson (Exelon Generation Company) to U.S. NRC, "Request for Addition Information Regarding Exelon Justification Submitted May 12, 2004, for Continued Operation of Dresden Units 2 and 3", dated February 9, 2005. Additional benchmarking of acoustic circuit analysis against SMT data was provided to the NRC during a public meeting held at the Exelon Corporate office on April 25 - 27, 2005.

References

1. CDI Technical Note 05-04, "Quad Cities Unit 2 New Dryer SMT Loads," Revision 5, dated April 2005
2. CDI Report DRF-CDI-174, "Acoustic Circuit and Helmholtz Analyses and Models"
3. Exelon Report No AM-2004-006, "CDI Benchmark Results of GE Scale Model Test Facility"

RAI #3(c)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(c) definition and identification of the acoustic (vibration) sources and locations and their mathematical representations;

Response

The identification of the acoustic sources and locations, along with their mathematical representations, are documented in CDI Report No. 04-09P. In addition, a detailed discussion of the acoustic circuit methodology was held in the public meeting conducted in the Exelon Corporate office on April 25 - 27, 2005.

References

1. CDI Report No. 04-09P, "Methodology to Determine Unsteady Pressure Loading on Components in Reactor Steam Domes," dated January 2005
2. CDI Technical Note 05-04, "Quad Cities Unit 2 New Dryer SMT Loads," Revision 5, dated April 2005

RAI #3(e)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(e) validation of the capability and sensitivity of the MSL strain gauges and their setup for inferring changes in internal pressures in the MSLs;

Response

Two sets of strain gauges composed of two strain gauges each will be installed 180 degrees apart in the circumferential direction (Figure 1) and configured in opposite arms of the Wheatstone bridge. Four strain gauges would be installed around the circumference of the pipe, oriented in the hoop direction. Each strain gauge should be set approximately 90° apart. One set (channel) of strain gauges will consist of strain gauges A and B and the other set (channel) will consist of strain gauges C and D. Each set, a separate channel, will provide approximately the same strain time history with the radial motion in phase, time, and frequency. The ovaling mode, when compared between the two channels, will be out of phase (180 degrees). This distinction can be analyzed during the data reduction phase of the testing by using two channel analysis and evaluating the cross spectrum in magnitude and phase, or by bandpass filtering around suspected ovaling mode frequencies. In addition, by adding the two channels, the ovaling mode should cancel and the radial motion should add (double) in amplitude.

The strain gauge is capacitive discharge welded to the pipe; consequently, it is theoretically sensitive to infinitesimally small strain. The QC2 data acquisition system (DAS) includes a 24-bit analog to digital (A/D) converter coupled with a strain gauge signal conditioner that produces a strain sensitivity of 0.01 Volts per micro-strain (V/με). This combination provides a strain resolution of 0.000012με on a ±1 Volt input range. Strain gauge circuitry will be calibrated using a shunt calibration technique commonly used with the Wheatstone bridge. Measurement system uncertainty has been determined to be ±3.03%. The conversion from strain to internal pressure requires implementation of hoop equations to relate the measured strain to internal pipe pressure. The application of these equations provides a relationship between strain and pressure of 3.98psi/με with an overall uncertainty of 6.3%, which includes the uncertainty in the pipe characteristics and measurement system.

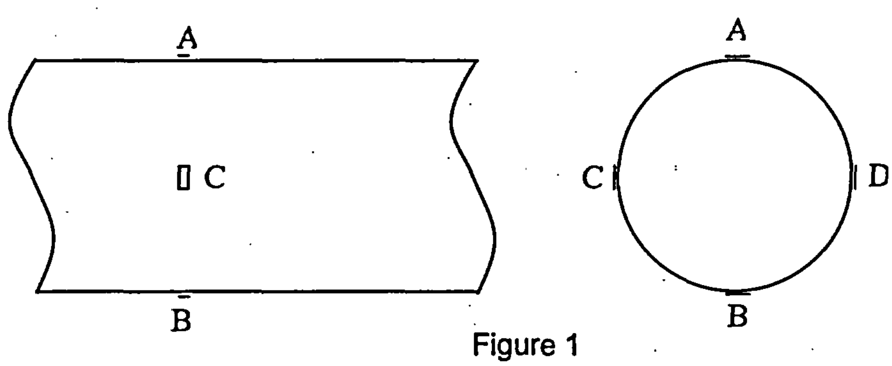


Figure 1

Reference

1. Structural Integrity Associates, Inc. (SIA) Report EXLN-17Q-302, "Quad Cities Strain Gage Uncertainty Evaluation," Revision 0, dated April 25, 2005

RAI #3(f)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(f) validation of the capability of the acoustic circuit model to adequately predict the steam dryer loads; and

Response

Exelon performed a benchmark with SMT data in conjunction with acoustic circuit analysis. This benchmark is documented in Exelon Report AM-04-006, which was submitted to the NRC in Reference 3 below.

Additionally, ACM loads were used in FEA and compared against calculated loads attributed to the damage experienced on the QC1 and QC2 steam dryers. Although performed after damage had occurred, the resulting analysis could have predicted the actual damage experienced. This demonstrates that the loads have adequate conservatism.

References

1. Exelon Report AM-04-006, "CDI Benchmark Results of GE Scale Model Test Facility," dated December 1, 2004
2. GE Report GENE-0000-0039 3540-01P, "Exelon Steam Dryer Dynamic Time History Analyses: Original, 2003 Repair and 2004 Repair Dryer Configuration Using Loads from Scale Model Test Results and Plant Measurements," Revision 0, dated April 2005
3. Letter from Patrick R. Simpson (Exelon Generation Company) to U.S. NRC, "Request for Addition Information Regarding Exelon Justification Submitted May 12, 2004, for Continued Operation of Dresden Units 2 and 3", dated February 9, 2005

RAI #3(g)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(g) access to the acoustic circuit model computer code for NRC staff reviewers and contractors to perform example computations and sensitivity evaluations.

Response

The acoustic circuit analysis resides on CDI's internal computers. Initiation of new calculations that change dimensions of components or thermodynamic properties in the steam dome involve days of computations to obtain acoustic fields in a fully 3-dimensional unsteady computation. The design record file was made available to the NRC during a public meeting held on April 27, 2005.

Reference

1. CDI Report DRF-CDI-174, "Acoustic Circuit and Helmholtz Analyses and Models"

RAI #4(a)

The licensee is requested to provide the following information regarding its finite element model (FEM) analysis of the steam dryer:

(a) description of the FEM analysis and methodology;

Response

The evaluation of the dryer response to the applied acoustic pressure transient loads was formulated using a direct integration approach. The pressure loads were applied as equivalent nodal forces at all dryer surfaces subjected to the pressure differentials normal to the surface. The dryer support ring was constrained to the ground at four support lug locations. The dryer FEM included the complete dryer geometry above the support ring, as well as the dryer skirt, with water below the support ring. Derived response consisted of deflections, strains, stresses, and reactions at all locations on the FEM dryer surfaces. The stress results were evaluated based on stress intensities, selecting the maximum elemental stress intensity as a representative characteristic of every major structural component (e.g., inner/outer hoods, support ring, cross beams, and vane bank plates). Details of the analysis are provided in GE Report GE-NE-0000-0034-3781P, "Quad Cities Units 1 and 2 Replacement Steam Dryer Analysis Stress, Dynamics, and Fatigue Analysis for EPU Conditions," Revision 0, dated April 2005.

References

1. GE-NE-0000-0034-3781P, "Quad Cities Unit 2 Replacement Steam Dryer Analysis Stress, Dynamic, and Fatigue Analyses for EPU Conditions," Revision 0, dated April 2005
2. Mahadeo Patel and Sam Ranganath, "Fatigue Analysis of the Quad Cities Replacement Dryer," XGEN Report 2005-1, Rev. 2, April 2005, XGEN engineering, San Jose, CA

RAI #4(b)

The licensee is requested to provide the following information regarding its finite element model (FEM) analysis of the steam dryer:

(b) justification for FEM assumptions, including damping and super-element modeling;

Response

The dryer geometry can be well represented using 3-dimensional thin shell finite elements because all major dryer component dimensions comply with the requirements of the thin shell theory. Wherever the thin shell geometry representation was deemed insufficient, 3-dimensional solid sub-modeling was employed to more accurately describe the structural geometry. The shell finite element mesh varied from 2x2 inch element size on the outer vane banks to 3x3 inches towards the inner dryer surfaces, based on the fact that the applied loads were much lower near the middle and center dryer banks causing lower stress gradients, thereby a coarsened mesh size. The skirt mesh size is approximately 2 inches across the whole skirt geometry. This level of resolution allows for a very accurate stress evaluation at any point on the dryer geometry.

The 3-dimensional solid sub-modeling allows evaluating stress more accurately at the locations where the shell model accuracy was considered less adequate. The dryer material properties were assumed as linear isotropic temperature-dependent. The dryer response was assumed to be small strain, small deflection/rotation with no contact interface between the dryer components. As such, the dryer geometry and its stiffness matrix were not updated in the course of the direct integration procedure, allowing for more efficient analysis execution. The evaluation of results showed that all the basic assumptions proved valid as the derived deflections/strains were well within the established linear small deflection theory limits.

To maintain a high level of modeling detail within feasible computational parameters (e.g., model size and analysis duration), the model employed a number of super elements representing the vane bank internal structure and the tie bar supports. The inclusion of the super elements is usually effective where there is a need to model a complex component that connects to the rest of the structure at relatively few points. The vane banks fit this requirement due to their internal complexity and detail saturation, and because they connect to the rest of the dryer at only 28 points each.

Since representing vane bank super elements by connecting points only may not have properly reflected the dynamic properties of the vane banks, multiple internal master degrees of freedom (MDOFs) were retained in the overall dryer model. A subsequent sensitivity study proved that the number of the retained MDOFs was sufficient to accurately describe the internal dynamic properties of the vane banks.

The tie bar supports have complex solid geometry that cannot be represented by shell elements or adequately simulated by beam elements. They can, however, be easily modeled as 3-dimensional solids and included in the model as super elements attached to the tie bars and vane tops at relatively few points, thus attaining a high level of accuracy without computational penalty. The high fundamental frequency of an individual tie bar support did not warrant the inclusion of any internal tie bar support nodes in the overall dryer FEM.

Damping values are based on the alpha/beta mass and stiffness approach using 1%, with the following exceptions. Based on the added fluid damping, a value of 2% is used for the skirt; 4% damping is used for the vane bank inserts where they are hung and subjected to friction and impact losses (i.e., greater losses than would be expected for a bolted structure). Further detailed discussion on the basis for the 1% and 2% damping values are found in GE Report DRF GE-NE-0000-0032-1827, "Quad Cities Replacement Steam Dryer Damping Values for Hood and Skirt, Flow Induced Dynamics Analysis," Revision 0, dated April 2005.

References

1. eDRF 0000-0034-1855,"Damping Value for Steam Dryer Structural Dynamic Analysis," dated November 5, 2004
2. GE-NE-0000-0034-3781P, "Quad Cities Unit 1 and 2 Replacement Steam Dryer Analysis Stress, Dynamic, and Fatigue Analyses for EPU Conditions," Revision 0, dated April 2005
3. GE Report DRF GE-NE-0000-0039-8548, "Quad Cities Replacement Steam Dryer Damping Values for Hood and Skirt, Flow Induced Dynamics Analysis," Revision 0, April 2005

RAI #4(c)

The licensee is requested to provide the following information regarding its finite element model (FEM) analysis of the steam dryer:

(c) validation of the adequacy of derived acoustic loads on the steam dryer from examination of FEM analyses for the original, modified and replacement Quad Cities steam dryers under pre-EPU and EPU operation, including modeling of forcing functions;

Response

The GE FEM was independently benchmarked using a FEM model created by XGEN. A description of the XGEN FEM model and validation results are described below.

The loading on the steam dryer was determined by acoustic circuit analysis. The acoustic circuit analysis provides pressure time history of the dryer components. The pressure time history from the acoustic circuit analysis was applied directly to the different components of the dryer model and the stress results of the time history analysis were evaluated. The time history approach preserves the phase relationship between the loading on different dryer components. The peak stresses from the FEA were compared with the fatigue endurance limit to determine whether cracking would be predicted. If the analysis predicts no cracking (i.e., peak stresses under the endurance limit) for pre-EPU operation, but predicts the cracking experienced at locations on subsequent repairs (e.g., the June 2003 repair) under EPU conditions, a reasonable case can be made that the loading on the dryer is understood and is consistent with field experience.

The following cases were selected for detailed analysis:

- Analysis of the original "as-installed" dryer for pre-EPU operation: the loading was the acoustic circuit pressures for pre-EPU conditions. The dryer FEM included solid elements at critical locations.
- Analysis of the June 2003 repair under EPU conditions: specifically, the location of the repair gusset attachment to the front plate was of interest since cracking was discovered after about six months of EPU operation. Validation of the analysis – acoustic circuit analysis and time history analysis – requires that cracking be predicted in the repair gusset attachment area.

A 1% damping value was assumed in the pre-EPU and June 2003 repair configuration EPU assessments. This is a reasonable value considering that there will be some local yielding in discontinuity regions. The 1% value is typically used for vibrations of structural components. The focus is to explain field behavior using realistic damping values.

The FEM model and the analysis methodology were specifically intended for the QC2 dryer. The results are also applicable to QC1 since the structural model of the original dryer and the subsequent modification was generally the same for both units. Thus, the overall conclusions of the validity of FEM analysis and methodology are applicable for both QC units.

The XGEN model predicts no cracking (i.e., peak stresses under the endurance limit) for pre-EPU operation, but predicts the cracking experienced at locations on subsequent repairs (e.g., the June 2003 repair) under EPU conditions. Therefore, a reasonable case can be made that the loading on the dryer is understood and is consistent with field experience. The fatigue

analysis performed by XGEN on the QC2 dryer describes the results of the time history analysis based on the fine grid acoustic circuit analysis for QC2.
Key conclusions from the study are as follows.

- Use of the fine grid pressure input for pre-EPU conditions with the solid element model of the original dryer configuration predicted stresses close to or below the fatigue threshold. Thus, cracking is not predicted for pre-EPU conditions. This is consistent with field observations indicating no significant cracking issues under pre-EPU conditions.

- Use of the fine grid pressure input for EPU conditions with the solid element model of the June 2003 repair showed high stresses in excess of the fatigue threshold near the top attachment of the repair gussets to the front plate. This is consistent with field observations of extensive cracking in the June 2003 dryer repair configuration.

The prediction of no cracking under pre-EPU operation, the prediction of cracking as experienced on the June 2003 repair configuration, and the consistency of the predictions with field data suggests that the predictive model – both the pressure time history and the dynamic time history analysis – is reasonable and can be used for evaluating steam dryer components. Considering the statistical nature of high cycle fatigue and the expected data scatter, the consistency of the high stress location with the region of observed cracking is encouraging. This conclusion is supported by GE Report GE-NE-0000-0039-3540-01P, Exelon Steam Dryer Dynamic Time History Analyses: Original, 2003 Repair and 2004 Repair Dryer Configuration Using Loads from Scale Model Test Results and Plant Measurements," Revision 0, dated April 2005.

References

1. Mahadeo Patel and Sam Ranganath, "Fatigue Analysis of the Quad Cities Replacement Dryer," XGEN Report 2005-1, Revision 2, dated April 2005, XGEN engineering, San Jose, CA
2. GE Report GENE-0000-0039-3540-01P, "Exelon Steam Dryer Dynamic Time History Analyses: Original, 2003 Repair and 2004 Repair Dryer Configuration Using Loads from Scale Model Test Results and Plant Measurements," Revision 0, dated April 2005
3. GE-NE-0000-0034-3781P, "Quad Cities Unit 1 and 2 Replacement Steam Dryer Analysis Stress, Dynamic, and Fatigue Analyses for EPU Conditions," Revision 0, dated April 2005

RAI # 4(d)

The licensee is requested to provide the following information regarding its finite element model (FEM) analysis of the steam dryer:

(d) comparison of FEM results for Quad Cities and Dresden steam dryers, and determination of any adjustments necessary to previous steam dryer analysis results described in Exelon letter dated December 10, 2004; and

Response

Results of steam dryer analyses that were submitted to the NRC in a letter dated December 10, 2004, are superseded by the following GE reports.

1. GENE-0000-0038-6481-01, Revision 0, Class III, March 2005, "Exelon Steam Dryer Dynamic Time History Analyses: Dresden Unit 2 2004 Repair and Dresden Unit 3 2003 and 2004 Repair Dryer Configurations Using Loads from Plant Measurements," (submitted to the NRC in a letter dated March 31, 2005)
2. GENE-0000-0039-3540-01P, Revision 0, Class III, April 2005, "Exelon Steam Dryer Dynamic Time History Analyses: Original, 2003 Repair and 2004 Repair Configurations Using Loads from Scale Model Test Results and Plant Measurements"

FEM was employed in analyzing the dryer to compute the responses to the dynamic pressure loads. The pressure loads are determined from acoustic analysis using plant pressure measurements. It should be mentioned that the acoustic pressure prediction between the application to QC2 and Dresden Unit 2 (D2) evolved and hence the D2 pressure prediction process was less challenging.

Table 1 below contains the maximum stress intensities reached at different times for the various components due to the QC2 and D2 loads on the 2004 repair model. Although the pressure contours show that the magnitudes of the pressure field of the QC2 pressure load is considerably higher than that of D2, the maximum induced stress intensities between the plants is similar, as demonstrated in Table 1.

The maximum pressures occurred on the outer hood 90° side for the D2 and QC2 pressure loads. These maximum pressures occur at different times for the nodes considered. Except for amplitudes, the pressure profiles are similar. The D2 maximum pressure of approximately 0.2 psi is significantly less than the QC2 maximum pressure of approximately 1.5 psi. The typical frequency spectra for the two plants show a similar trend between the pressure loads. The most significant pressure load occurs in the lower frequency range, namely around 24 Hz for the D2 spectrum, while the QC2 load spectrum shows significantly greater loads at higher frequencies. It should also be noted that the QC2 load amplitude at 24 Hz is approximately the same as the D2 amplitude at 24 Hz.

A significant difference in the pressure loading between D2 and QC2 is that at the time of the maximum cover plate and gusset response, the maximum pressure is on the cover plate in the case of D2, as opposed to being on the outer hood in the case of QC2. Although this argument is not conclusive, the observation could explain why the maximum response is comparable under significantly different pressure loading.

Table 1. Maximum Stress Intensity Reached by QC2 and D2 Components

Component	Max Stress Intensity (psi)	
	QC2	D2
Outer Hood	2483	1985
Inner Hood	1244	1558
Top Hood	4124	3479
Cover Plate	2808	3456
Gusset	4065	5063

In conclusion, no adjustment to the FEM used to determine the results presented in the December 10, 2005, letter is required. The applied loads have been modified for use as input to the time history FEA. The loading has been modified since the issuance of the December 10, 2005, letter due to improvements in the methods used to determine loads.

References

1. GENE-0000-0038-6481-01, "Exelon Steam Dryer Dynamic Time History Analyses: Dresden Unit 2 2004 Repair and Dresden Unit 3 2003 and 2004 Repair Dryer Configurations Using Loads from Plant Measurements," Revision 0, Class III, dated March 2005
2. GENE-0000-0039-3540-01P, "Exelon Steam Dryer Dynamic Time History Analyses: Original, 2003 Repair and 2004 Repair Configurations Using Loads from Scale Model Test Results and Plant Measurements," Revision 0, Class III, dated April 2005

RAI # 4(e)

The licensee is requested to provide the following information regarding its finite element model (FEM) analysis of the steam dryer:

(e) access to the FEM computer code (ANSYS) for NRC staff reviewers and contractors to perform example computations and sensitivity evaluations.

Response

The FEM computer code was made available to the NRC during a public meeting held in the Exelon Corporate office on April 25 – 27, 2005. During the three-day public meeting, NRC reviewers were allowed access to the ANSYS computer model developed by GE, and were provided technical design information concerning the steam dryer design.

Reference

1. GE-NE-0000-0034-3781P, "Quad Cities Unit 1 and 2 Replacement Steam Dryer Analysis Stress, Dynamic, and Fatigue Analyses for EPU Conditions," Revision 0, dated April 2005

RAI # 5(a)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(a) finalized steam dryer design including materials, dimensions, and fabrication methods;

Response

The replacement steam dryer uses modules of dryer vanes that are enclosed in a housing to make up the steam dryer assembly. The modules or subassemblies of dryer vanes, called dryer units, are arranged in six parallel rows called banks. The dryer banks are attached to an upper support ring, which is supported by four steam dryer support brackets that are welded attachments to the reactor pressure vessel (RPV). The steam dryer assembly does not physically connect to the shroud head and steam separator assembly and it has no direct connection with the core support or shroud. A cylindrical skirt attaches to the upper support ring and projects downward forming a water seal around the array of steam separators. Normal operating water level is approximately mid-height on the dryer skirt. During refueling, the steam dryer is supported from the floor of the equipment pool by the lower support ring, which is located at the bottom edge of the skirt. The steam dryer is installed and removed from the RPV by the reactor building crane. A steam separator and dryer lifting device, which attaches to four steam dryer lifting rod eyes, is used for lifting the dryer. Guide rods in the RPV are used to aid dryer installation and removal. Upper and lower guides on the dryer assembly are used to interface with the guide rods. The replacement steam dryer assembly is shown in Figure 1.

Wet steam flows upward from the steam separators into an inlet header, horizontally through the dryer vanes and the outlet side perforated plates, vertically in the outlet header, and into the RPV dome. Steam then exits the RPV)through steam outlet nozzles. Moisture (liquid) is separated from the steam by the vane surface and the hooks attached to the vanes. The captured moisture flows downward under the force of gravity to a collection trough that carries the liquid flow to drain vertical drain channels. The liquid flows by gravity through the vertical drain channels to the lower end of the skirt where the flow exits below normal water level. The active height of the original dryer vanes was 48 inches. In the replacement steam dryer, the active vane height is increased to 72 inches. Table 1 provides a comparison between major configuration parameters of the replacement and original steam dryer.

Current industry practice was applied to the materials and fabrication of the replacement steam dryer. The dryer was constructed from wrought 300 series stainless steel and Grade CF3 stainless steel castings. Except for the dryer vane material, the maximum carbon content of the wrought stainless steel was limited to 0.02%. Maximum harness of wrought 300 series stainless steel was limited to Rockwell B92. Susceptibility to stress corrosion cracking was avoided by careful control of the solution heat treatment, sensitization testing, and testing for intergranular attack (IGA). Therefore, with the exception of the dryer vane material, the new replacement steam dryer material and fabrication is consistent with Boiling Water Reactor Vessel Internals Project (BWRVIP)-84, "Guidelines for Selection and Use of Materials for Repairs."

Table 1: Comparison of Major Steam Dryer Configuration Parameters

Steam Dryer Configuration Parameter	**Original Dryer**	**Replacement Dryer**
Number of Banks	6	6
Active height (flow area) for vane modules	48 inches	72 inches
Approximate Weight	35 tons	50 tons
OD of upper support ring	247 inches	247 inches
Approximate over all height	195 inches	200 inches
Length of skirt	102 inches	102 inches
Skirt thickness	¼ inch	3/8 inch
Cover plate thickness	¼ inch	1 inch
Hood thickness	½ inch	1 inch outer banks, ½ inch inner banks
Upper support ring cross section	3 x 7 inches solid	6 x 8 square tube with ½ inch wall thickness

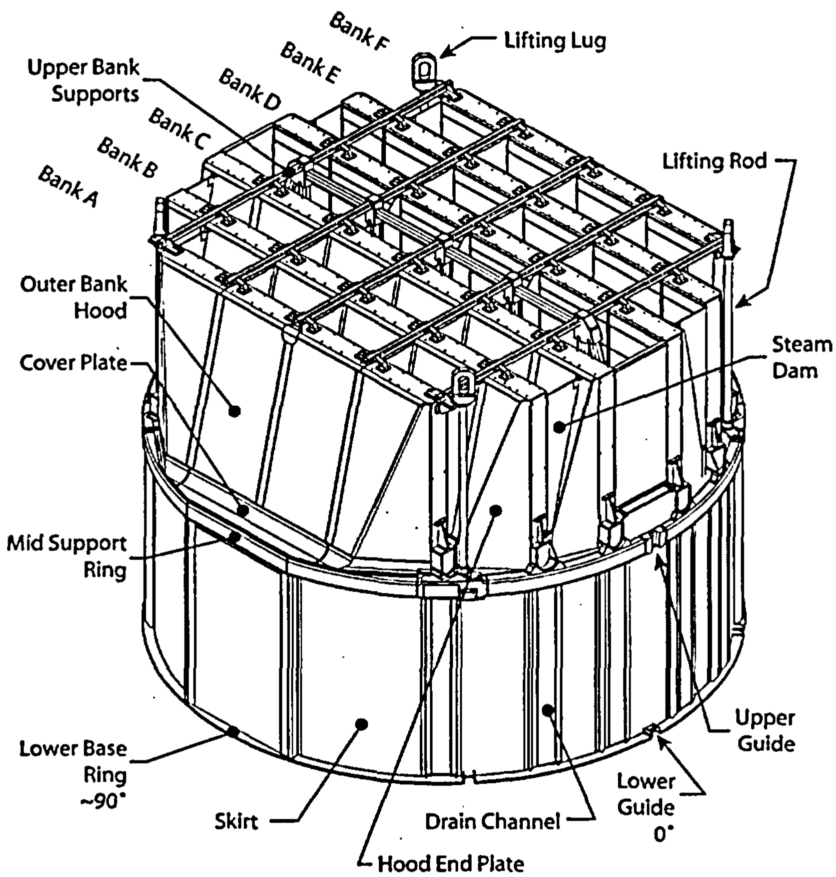


Figure 1: Replacement Steam Dryer

References

1. GE Specification 26A6274, "Steam Dryer Fabrication," Revision 6, dated August 2, 2004
2. GE Specification 26A6273, "Replacement Steam Dryer Materials Requirements," Revision 4, dated July 14, 2004
3. GE Specification 26A6266, "Steam Dryer," Revision 3, dated April 24, 2005
4. GE Specification 26A6266AB, "Steam Dryer Design Specification Data Sheet," Revision 2, dated April 24, 2005

RAI # 5(b)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(b) description of steam dryer instrumentation, including sensor types, characteristics, locations, and qualification, and wiring and mast layout and integrity;

Response

The QC2 replacement dryer instrumentation includes six (6) accelerometers (Vibro-Meter CA 901 series), twenty-seven (27) pressure transducers (Vibro-Meter CP-104 and CP-211 series), and nine (9) strain gauges (Kyowa KHC 10-120 series). The purpose of the instrumentation is to measure the dynamic loading on the dryer under operating conditions. GE specification 26A6395, "Dryer Vibration Instrumentation," shows the MSL sensor placement, contains a list of all dryer instruments and their locations (Figures 1 through 4), and the purpose and function of each instrument (Section 5.3). Characteristics and qualification of the instruments are described in GE Report GE-NE-0000-0037-1951-01, "Dryer Vibration Instrumentation Uncertainty." The structural design evaluation of the instrumentation mast is contained in GE Report GENE-0000-0034-6964-01, "Structural Design Evaluation of Quad Cities New Dryer Instrumentation Mast." The mast layout and wiring is shown in Figures B4-2, B4-3, B4-5, and B4-6 of GE Specification 26A6487-P, "Steam Dryer Vibration Instrument Installation."

References

1. GE Specification 26A6493, "Steam Dryer Vibration Instrumentation," Revision 3, dated April 22, 2005
2. GE Specification 26A6499, "Data Acquisition System Installation and Test Procedure," Revision 2, dated April 22, 2005
3. GE Specification 26A6366, "FIV Sensors, Signal Conditioner & Data Acquisition System," Revision 2, dated April 22, 2005
4. GE Specification 26A6380, "Steam Dryer Hammer Test Specification," Revision 2, dated April 22, 2005
5. GE Specification 26A6388, "Steam Dryer Vibration Measurement," Revision 3, dated April 20, 2005
6. GE Specification 26A6485, "Charge Converter, Junction Box and Signal Conditioning," Revision 2, dated April 22, 2005
7. GE Specification 26A6484, "Sensors in the String Assembly Before and After Sensor Installation," Revision 2, dated April 22, 2005
8. GE Specification 26A6487, "Steam Dryer Vibration Instrument Installation," Revision 3, dated April 22, 2005
9. GE Specification 26A6473, "Steam Dryer Replacement Weld Map," Revision 0, dated April 11, 2005
10. GENE-0000-0034-6964-0R2-P, "Structural Design Evaluation of Quad Cities New Dryer Instrumentation Mast," Revision 2, dated April 2005
11. GE Specification 26A6395, "Dryer Vibration Instrumentation," Revision 1, dated April 22, 2005
12. GE Specification 26A6492, "Steam Dryer Vibration Instrument Installation Procedure," Revision 2, dated April 22, 2005
13. GE-NE-0000-0037-1951-01, "Dryer Vibration Instrumentation Uncertainty," Revision 0, dated April 2005

RAI # 5(c)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

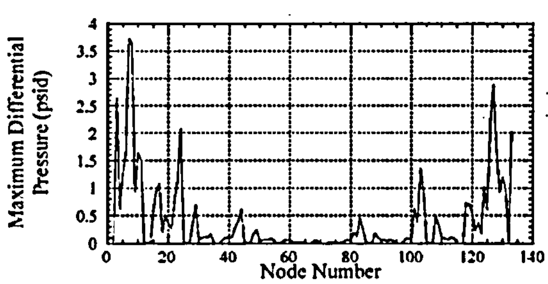
(c) comparison of the CFD and acoustic circuit analysis loads on the steam dryer;

Response

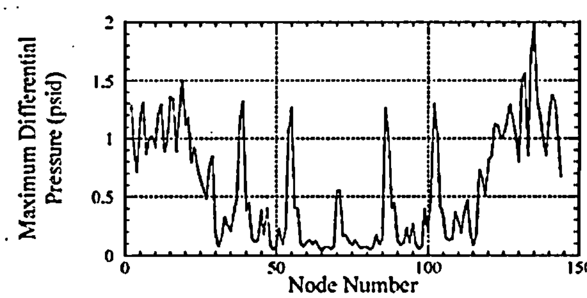
CFD analysis was not used to define loads on the QC replacement steam dryers. Rather, Exelon developed two separate dryer load cases using data collected from two independent sources. One source of data was the 1/17th sub-scale model testing of the QC1 reactor vessel and main steam piping. The second source of data was instrumentation installed on the QC2 reactor vessel and main steam piping during a plant startup.

The frequency and amplitudes of the response for the two design load cases are shown below. There are a number of known reasons for the differences. First, inputs used to develop the load cases are from two different reactor vessels and main steam piping configurations. Second, the new steam dryer was analytically inserted into the Helmholtz solver and the direct measurement for the SMT, as opposed to using instrument lines and direct measurement with a strain gauge for the in-plant data.

To ensure that the new dryer design was structurally viable, the design analysis used both load cases. In addition, both load cases included plus 10% and minus 10% frequency shifts, giving six finite element evaluations. The new dryer was then designed using the maximum stress intensity factors from all of the six finite element evaluations performed.



New Dryer QC2 In-plant Peak Load at EPU Scaled Flow



New Dryer QC1 SMT Peak Load at EPU Scaled Flow

References

1. CDI Technical Note No. 05-03, "Quad Cities Unit 2 New Dryer Vulnerability Loads," Revision 1, dated April 2005
2. CDI Technical Note No. 05-04, "Quad Cities Unit 2 New Dryer SMT Loads," Revision 5, dated April 2005

RAI # 5(d)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(d) steam dryer analysis demonstrating acceptable performance during plant operation, up to and including EPU conditions, with forcing functions, modeling, and stresses at critical locations;

Response

The structural analysis of the new steam dryer is contained in GE Report GE-NE-0000-0034-3781. This report summarizes the dynamic, stress, and fatigue analyses that demonstrate the QC replacement stream dryers are structurally adequate for EPU conditions.

References

1. GE-NE-0000-0034-3781P, "Quad Cities Unit 1 and 2 Replacement Steam Dryer Analysis Stress, Dynamic and Fatigue Analyses for EPU Conditions"
2. NEDC-33192P, "Engineering Report for Quad Cities Unit 1 Scale Model Testing," dated April 2005
3. XGEN Report 2005-1, "Fatigue Analysis of the Quad Cities Replacement Dryer," Revision 2, dated April 2005

RAI # 5(e)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(e) evaluation of the impact of steam dryer instrumentation on fluid flow in the steam dome, and steam dryer dynamic characteristics (e.g., damping);

Response

The QC2 replacement dryer contains instrumentation designed to measure the dynamic pressures on the steam dryer hood to help define the dynamic loads on the dryer structure. Ideally, it is best to install pressure sensors mounted flush on the surface for the dryer. However, this is highly invasive and undesirable. For this reason, a sensor cover plate was designed to install the pressure sensor with minimum perturbation to the flow with minimum error for dynamic pressure measurements. To determine the effects that cover plates would have on the dynamic pressure measurements, a CFD study was performed. In addition to the CFD analysis, wind tunnel testing was also performed. The results of this study are contained in GE Report GE-NE-0000-0038-2076-01-P, "Summary of the Effects of the Sensor Cover Plates on Dynamic Pressure Measurements," Revision 0, dated April 2005. The study and testing concluded that the dryer external flow field is not significantly affected as a result of the presence of the cover plates.

Reference

1. GE-NE-0000-0038-2076-01, "Summary of the Effects of the Sensor Cover Plates on Dynamic Pressure Measurements," Revision 0, dated April 2005

RAI # 5(f)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(f) evaluation of potential loose parts from steam dryer, instrumentation, wiring, and mast, and their consequences; and

Response

An evaluation was performed to determine the potential of loose parts from the steam dryer, instrumentation, wiring, and mast. The evaluation concluded that safe reactor operation would not be compromised with the presence of the potential lost part(s) in the reactor vessel. The evaluation is contained in GE Report GE-NE-0000-0035-4745P-R2, "Potential Lost Parts Analysis for Quad Cities Generating Station Unit 2 Installed Dryer Instrumentation," Revision 2, dated April 2005.

Reference

1. GE-NE-0000-0035-4745P-R2, "Potential Lost Parts Analysis for Quad Cities Generating Station Unit 2 Installed Dryer Instrumentation," Revision 2, dated April 2005

RAI # 5(g)

The licensee is requested to provide the following information regarding the replacement steam dryers for Quad Cities Units 1 and 2:

(g) access to the CFD computer code for the replacement steam dryer for NRC staff reviewers and contractors to perform example computations and sensitivity evaluations.

Response

CFD analysis was not used to develop load definition for the steam dryer. Load definitions were developed using SMT data, in conjunction with in-plant start up data. However, GE performed a CFD analysis to validate the steam flow path within the reactor steam dome through the MSL nozzles.

References

None

RAI #6

The licensee is requested to describe a startup plan that will provide confidence in the integrity of the Quad Cities replacement steam dryers during startup and operation at EPU conditions. The plan is expected to include hold points during power ascension, data and parameters to be measured, acceptance criteria that will initiate proactive measures to address inadequate steam dryer performance prior to failure (e.g., evaluation of plant and dryer data, potential loose parts effects, and dryer inspection results), and decision criteria for allowing continued plant operation or commencing plant shutdown. For example, the plan is expected to provide for the performance of blind predictions of the loading of the Quad Cities replacement steam dryer by the acoustic circuit model based on MSL strain gauge data at pre-EPU baseline conditions and at specific hold points as part of the power ascension to EPU operation.

Response

The objective of the start-up test plan is to provide steps that are necessary to perform the Start-up Test Program to EPU conditions, with the instrumented replacement steam dryer in place. The incremental power increase methodology ensures a carefully monitored approach to the targeted higher power level. First and foremost in the performance of the start-up plan is the safety of the reactor and nuclear plant. A Startup Test Procedure has been written specifically with this objective in mind, and provides the necessary criteria, instruction, oversight, and precautions to successfully execute the Replacement Reactor Vessel Steam Dryer Power Ascension Test Program.

A copy of the power ascension map is provided below. Reactor power will be raised to the pre-EPU power level of 2511 megawatts thermal (MWt) over a 3.5-day period. Data will be taken at 33 test conditions (TCs) up to 2511 MWt. A hold period of approximately 24 hours is planned at TC 33 while:

1. An evaluation of the data taken up to that point is performed,

2. A presentation of the results of the evaluation is made to the Plant Operations Review Committee (PORC), and

3. Approval is given by PORC and the Site Vice President to proceed with power ascension.

Power will then be raised over a 29-hour period to 2957 MWth, or 930 MW electric (MWe) if full EPU thermal power is not achievable. During this power increase, data will be taken at an additional eight TCs (TC 34 through TC 41). For power levels both above and below EPU, there will be four primary methods to obtain data at each TC.

1. A temporary DAS supplied by GE will gather data on the 42 sensors on the dryer and the 56 strain gauges installed on MSL piping in the drywell, main steam isolation valve (MSIV) room, and feedwater heater bay.

2. High-speed data recorders will capture data from:
   - Three reactor steam dome pressure sensors
   - Four pressure measurements at the MSL flow venturis
   - Four main turbine control valve positions
   - 33 accelerometers on MSL components in the drywell

3. System equipment parameters will be obtained by computer points and by Operator round inputs. This data will be comprised of approximately 1000 data points.

4. Data will be manually gathered using handheld instruments for local vibration levels on small bore piping on the feedwater system and local area temperatures. This data will be taken at only two of the TCs, namely the pre-EPU rated power level and the maximum EPU power level.

There are three levels of acceptance criteria documented in the Startup Test Procedure:

1. Plant Equipment Acceptance Limits: Normal alarm points or established equipment operating limitations based upon historical performance data.

2. Level 2 Criteria: This will not necessarily result in altering plant operation or test plan, but will result in initiating an Issue Report (IR) to enter the station's Corrective Action Program.

3. Level 1 Criteria: Actions include the initiation of an IR and seeking immediate resolution. Power will be held at a known safe level, based on prior, testing until the condition is resolved. The test portion will be repeated to verify Level 1 can be satisfied. The test procedure will document actions taken to resolve the condition. (Examples: dryer strain gauges and moisture carryover criteria)

Exelon and GE have developed acceptance criteria for dryer measurements (i.e., Go/No-Go criteria) that will provide an immediate decision on whether the loading on the dryer is acceptable. In addition, strain gauges and accelerometer results will be trended during power ascension based on direct readings and Fast Fourier Transform (FFT) analysis. Attachment 1 contains details of the dryer acceptance criteria. In summary, the current plan for the acceptance criteria includes four acceptance criteria for the dryer, plus a criterion for the minimum number of operable front hood strain gauges:

A. Criterion "A" will be reached when the dryer strain gauges indicate that the peak dryer stress levels have reached American Society of Mechanical Engineers (ASME) Fatigue Curve "B" (16,500 psi). If this criterion is exceeded, power will be reduced to a level below this criterion. A detailed load mesh will be generated by acoustic circuit analysis and a FEA will be performed. If the FEA results are acceptable, new acceptance criteria will be generated based on plant data. If FEA results are not acceptable, this power level will not be exceeded. This criterion will be considered a Level 1 criterion.

B. Criterion "B" provides an alert indication that strain gauge results are high. The FEA will determine the peak stress locations of the dryer and application of appropriate weld quality and stress concentration factors. A Design Flow Induced Vibration Criterion of 10,800 pounds force per square inch (psi) will be applied for outside dryer components, and 13,600 psi will be applied for inside dryer components. This criterion will be a Level 2 criterion and, if exceeded, will result in an IR being written to enter the Corrective Action Program, and be communicated per the start-up test procedure.

C. Criterion "C" will be checked only when EPU power levels have been reached and the dryer strain gauges have reached 50% of the Criterion A levels. Criterion C will entail a comparison of the dryer pressure gauge data to load case time history pressure inputs to the dryer design. Six pressure gauges on the steam dryer will have criteria developed. These criteria will be used to compare the two load case frequencies and amplitudes against actual plant pressure data. A FFT will be applied to the locations of the six pressure gauges for both load cases. The resulting frequency and amplitude plots will be used to compare against actual plant data. The acceptance criteria will be that the measured pressure loading must be within ±20% for frequency, and no more than +30% for amplitude, when compared to the load cases. This criterion will not be employed until EPU power levels are reached and 50% of the Criterion "A" has been exceeded. If Criterion C is exceeded, power will be reduced to the last acceptable power level. A detailed acoustic circuit and FEA will then be performed. This criterion will be considered a Level 1 criterion.

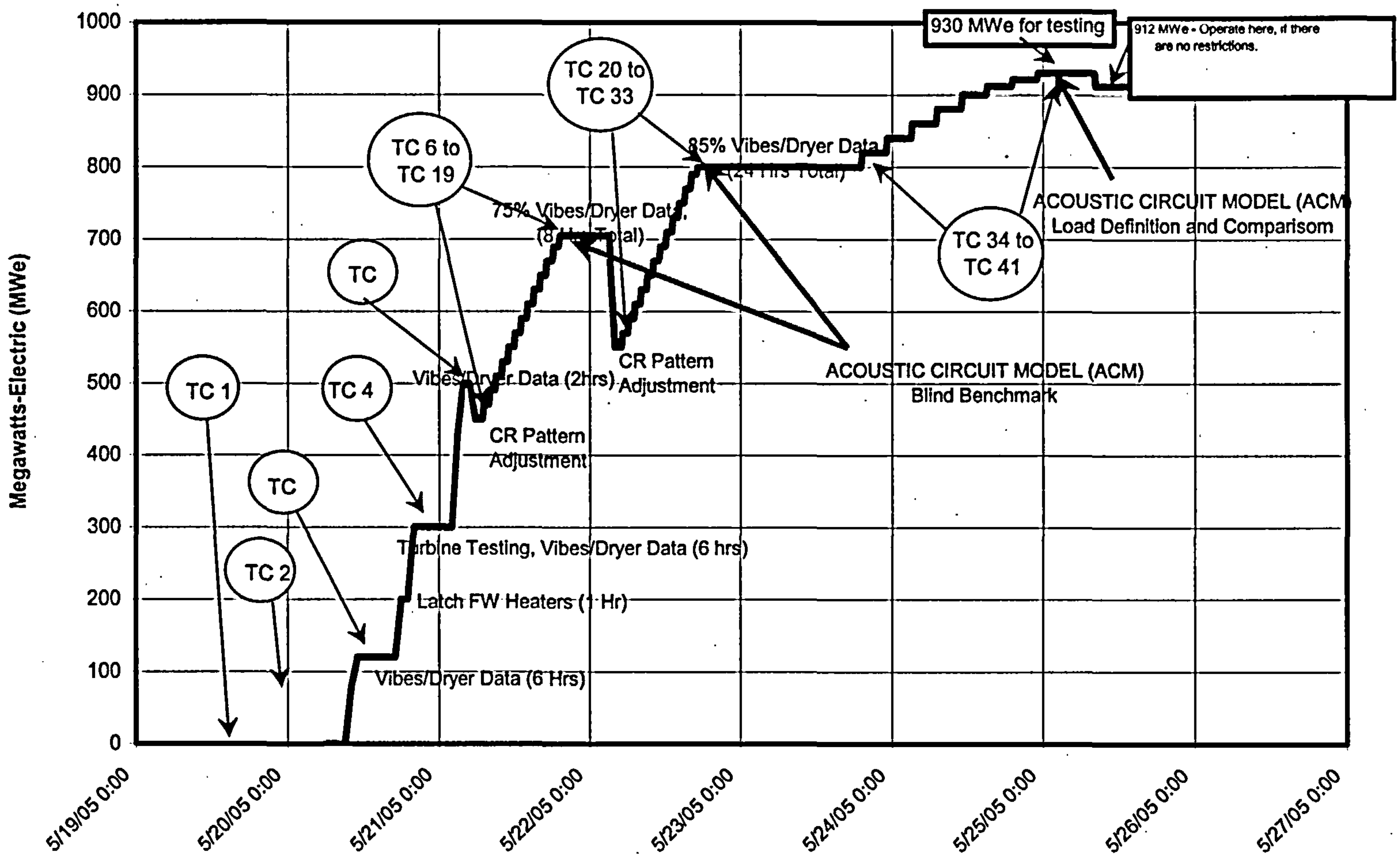
D. Criterion "D" provides a backup to the strain gauge criteria in the unexpected loss of the critical number of strain gauges with accelerometer criteria. The structural response (stress and acceleration) time histories are calculated at every element using a finite element model (FEM) and a given input forcing function. These stress time histories are then scanned to determine the maximum calculated stress over all elements for the time period of the forcing function. A normalizing factor, equal to the maximum Level Criteria (i.e., 16,500 psi for Level "A") divided by the calculated maximum stress, is then determined. The calculated maximum acceleration value at the accelerometer location over the entire time period of the forcing function is then multiplied by the normalizing factor to arrive at the accelerometer acceptance criteria.

E. Minimum Number of Operable Front Hood Strain Gauges: at least two of three strain gauges. If a condition where less than two strain gauges on the front hood were to occur, a detailed acoustic circuit (after benchmarking) would produce a refined load mesh that would be analyzed in the FEM and compared against the design flow induced stress criteria for each power level.

References

1. Startup Test Plan Summary, Revision 0, dated April 2005
2. GE-NE-0000-0032-1827, DRF Section 0000-0036-2077, Quad Cities Replacement Steam Dryer Instrumentation Acceptance Criteria, dated April 2005.
3. TIC-1224, Quad Cities Unit 2 Power Ascension Test Procedure for the Reactor Vessel Steam Dryer Replacement, Revision 0, May 2005

QC2 May 2005 PLANNED OUTAGE STARTUP POWER ASCENSION



ATTACHMENT 2

Non-Proprietary Version of RAI Question 3(d) and Response

RAI #3(d)

The licensee is requested to provide the following regarding its acoustic circuit model used in predicting loads on the steam dryer:

(d) [[CDI Proprietary Information]]

Response

[[CDI Proprietary Information]]

References

1. CDI Technical Note No. 05-03, "Quad Cities Unit 2 New Dryer Vulnerability Loads," Revision 1, dated April 2005
2. CDI Technical Note No. 05-04, "Quad Cities Unit 2 New Dryer SMT Loads," Revision 5, dated April 2005