ENCLOSURE 2

ATTACHMENT 4

"Quad Cities 1 & 2, Impact of Replacement Dryer Added Mass on Existing Plant Seismic Qualification," GE-NE-0000-0034-9378-NP, Revision 1, Non-Proprietary, dated April 2005

GE Nuclear Energy

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Quad Cities 1 & 2

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TABLE OF CONTENTS

APPENDIX A – TABLES

APPENDIX B - FIGURES

ACRONYMS AND ABBREVIATIONS

AISC	American Institute of Steel Construction
AP	Annulus Pressurization
ASME	American Society of Mechanical Engineers
BOP	Balance of Plant
BWR	Boiling Water Reactor
FIV	Flow Induced Vibration
FUF	Fatigue Usage Factor
LOCA	Loss of Coolant Accident
NI	Nuclear Island
NFI	New Fuel Introduction
NFV	New Fuel Vault
NRC	Nuclear Regulatory Commission
NSSS	Nuclear Steam Supply System
OBE	Operating Basis Earthquake
QC1RX	Quad Cities 1, Refueling Outage X
RRS	Required Response Spectra
SSE	Safe Shutdown Earthquake

1.0 INTRODUCTION

1.1 **Purpose.** This letter provides the results of the seismic evaluation conducted by GE Nuclear Energy to determine the impact the added mass of the replacement steam dryers will have on the existing overall plant seismic/dynamic qualification. The present evaluation was required because the added mass of the replacement dryer assembly was initially estimated to be between 40% and 50% of that of the existing steam dryer assembly. The weight of the existing steam dryer assemblies at Quad Cities 1 and 2 is of the order of 75,000 lbs. Consequently, in the present evaluation the added weight, of each replacement dryer assembly, was conservatively taken to be 40,000 lbs, which corresponds to a total dryer assembly weight of approximately 115,000 lbs.

However, subsequent to the analysis performed for the present evaluation, the final weight of the replacement dryer assembly, fully instrumented, was certified by the Barnhart Crane and Rigging Company to be 100,200 lbs. Consequently, significant conservatism is inherent to the present evaluation.

1.2 **Conclusion.** Based on the present evaluation, in conjunction with the theoretical qualitative evaluation completed, it is concluded that the added weight of the Quad Cities 1 & 2 replacement steam dryer assemblies will have no significant impact on the existing overall plant seismic/dynamic qualification. The work scope of the present evaluation does not include the seismic/dynamic qualification (e.g., structural integrity and fatigue design adequacy) of: (i) the replacement steam dryer assembly itself, (ii) the steam dryer RPV support lugs, and (iii) the ASME Code, Section III stress analysis of the RPV vessel wall. The conclusion does apply to: (i) all other RPV and internals components, (ii) the RPV major supports (i.e., the RPV stabilizer and the RPV skirt), (iii) all Nuclear Steam Supply System (NSSS) safety related piping and equipment, (iv) the star truss, and (v) all Balance-of-Plant (BOP) safety related piping and equipment.

1.3 **Background.** A nuclear power plant primary structure seismic/dynamic analytical model is comprised of: (i) the Nuclear Island (NI) consisting of the RPV and internals, the biological shield wall, and the pedestal, (ii) the Balance-of-Plant (BOP) consisting of the primary & secondary containment structures, the reactor building, and the mat foundation, and (iii) the elastic sub-grade. The seismic/dynamic response of a nuclear power plant primary structure is a function of its eigen or dynamic characteristics in addition to the characteristic frequency content of the actual seismic/dynamic input motion. The dynamic characteristics (natural frequencies, etc.) are, in turn, dependent on the distributed mass and stiffness characteristics of the physical geometry and the material composition of the primary structure.

The existing seismic/dynamic qualification of a nuclear power plant can be negated, even when the seismic/dynamic design input motion is held constant, if sufficient changes are made to the primary structure mass and stiffness characteristics. Consequently, whenever significant changes are made to the mass and stiffness characteristics of a nuclear power plant primary structure, an investigation must be completed to assess the impact the changes will have on the existing overall plant seismic/dynamic qualification.

To date, a number of significant changes have been made to the stiffness and mass characteristics of the Quad Cities 1 and 2 primary structures. These include: (i) New Fuel Introductions (NFIs) whenever a new nuclear fuel core design is introduced, (ii) shroud repair (shroud circumferential weld-cracks and the consequent introduction of shroud repair hardware), and (iii) replacement steam dryer added mass. In addition, a number of errors (see Section 2.0 below), have been discovered in the Quad Cities 1 & 2 primary structure analytical model since they were first generated in the late 1960's.

The chronology of the Quad Cities 1 & 2 primary structure model changes and error corrections is summarized in Section 2.0 below. The details of the model changes, errors, and corrections are described and the changes in the actual seismic/dynamic responses due to upgrades and corrections are compared and discussed.

2.0 PRIMARY STRUCTURE MODEL HISTORY

2.1 <u>1994 Regeneration.</u> The original licensing basis seismic design adequacy evaluations for the Quad Cities Nuclear Power Station, Units 1 and 2 primary structures were completed in the late nineteen sixties and early nineteen seventies. The primary structure seismic models utilized in the original evaluations are referred to as "benchmark" seismic models in this report.

The site horizontal seismic licensing design basis free field input motion is defined by: (i) 1957 San Francisco, Golden Gate Park Earthquake spectra, and (ii) the Housner spectra. The horizontal OBE peak ground acceleration is 0.12g and that for the SSE is 0.24g. The vertical peak ground accelerations are two-thirds of the corresponding horizontal OBE and SSE values.

The building structural properties for the Quad Cities 1 & 2 nuclear power plants are different in the NS & EW directions. Consequently, individual NS and EW primary structure models were needed for the structural seismic design adequacy evaluations required for the shroud repair programs initiated for each plant in 1994 and completed in 1995.

The NS and EW primary structure models were reconstituted from the corresponding primary structure benchmark models utilized in the original plant seismic design adequacy evaluations described above. The details of the reconstitution of the original benchmark primary structure analytical models are documented in Reference 4.1.

2.2 <u>1994-1995 Shroud Repair Analysis.</u> The benchmark NS and EW primary structure models, reconstituted for the Reference 4.2 Quad Cities 1 and 2 shroud repair projects, were modified to include the bounding multiple shroud weld-crack configurations and for the associated shroud repair hardware. Seven circumferential, 360°, through wall shroud weld-cracks (H1 through H7), in addition to the all-cracked and the un-cracked conditions, were postulated for evaluation. Furthermore, two sets of analyses were performed for each of these nine weld-crack cases. In the first set the shroud weld-cracks were represented as pinned connected joints and in the second set as roller connected joints in the primary structure models. The location and designation of each weld-crack is identified in Figure B2 in Appendix B of this report. In total there were 17 (only one analysis set for the un-cracked case) postulated weld-crack configurations to be evaluated.

In turn, it was required to evaluate each of the postulated 17 weld-crack configurations for: (i) two licensing design basis earthquakes (Housner and Golden Gate Park), (ii) two excitation levels (OBE and SSE), and (iii) two horizontal primary structure models (EW and NS). It then follows that, conceptionally, there are in total 136 primary structure, seismic, time history analyses associated with the Reference 4.2 shroud repair seismic design adequacy evaluation for Quad Cities 1 and 2. However, because the licensing basis structural damping is the same for both OBE and SSE the analyses need be performed for only OBE or SSE. If the analysis is performed for SSE the OBE values will be one-half of the corresponding values generated for SSE. Based on load case reduction studies, actual analyses were performed for only the bounding cases.

The shroud repair hardware consists of: (i) an upper shroud stabilizer spring, (ii) a middle shroud stabilizer spring, (iii) a lower shroud stabilizer spring, and (iv) the tie rods. The shroud stabilizer springs provide horizontal supports between the cracked shroud and the vessel wall that provide load paths for the horizontal inertia of the fuel core during seismic excitation. The vertical tie rods are connected to the shroud support plate at the lower end and the shroud flange at the upper end and constrain the rotation of the cracked shroud about any horizontal axis.

In addition to the shroud weld-cracks and the installed shroud repair hardware, the nuclear core of the benchmark models was updated to the projected Cycle 14 nuclear core configuration. The Cycle 14 nuclear core configuration differs slightly between Units 1 and 2. However, the difference was so small that one average core configuration was representative for both units. Consequently, the same NS and the same EW models were representative for both Units 1 and 2.

The Quad Cities 1 and 2 primary structure modifications associated with the 1994-1995 shroud repair resulted in changes in the benchmark model mass and stiffness characteristics. Consequently, in addition to the generation of bounding design loads for the new installed shroud repair hardware, the overall plant seismic design adequacy had to be reconfirmed for all shroud weld-crack repair configurations. The design loads, generated for the shroud repair, required to reaffirm the overall plant seismic qualifications are summarized in Table A1 in Appendix A of this report. The reaffirmation or demonstration of the overall plant seismic qualification to these 1994 shroud repair bounding loads is discussed at more length in Subsection 3.1 below. The details of that reaffirmation are documented in Reference 4.2.

2.3 <u>1995 Improved Methodology for Tie Rod & Weld-Crack Rotational Springs.</u> Difficulty was encountered in demonstrating the structural design adequacy of the shroud repair tie rods to the loads generated for the 1994 shroud repair analysis in which the shroud weld-cracks were represented as "pinned" and "roller" joints in the primary structure model. Because of the inherent conservatism in that methodology and the number of analyses required, GE completed the development of a more realistic, improved analytical methodology for representing the shroud weld-cracks and tie rod equivalent rotational stiffness in the primary structure analytical models. The details of the improved methodology, including the theoretical derivations of the weld-crack and tie rod equivalent rotational spring stiffness, are documented in Reference 4.3.

With the introduction of the improved methodology for representing the shroud weld-cracks, the two sets of analyses associated with the "pinned" and "roller" representations were replaced with one set of analyses in which each shroud weld-crack is more realistically represented as a pin connection with an equivalent rotational spring stiffness. Moreover, non-bounding shroud weld-crack configuration identified in the original "pinned" and "roller" analysis cases were eliminated when the "improved methodology" was applied. With the "improved methodology", separate primary structure time history analyses were performed for: (i) two licensing design basis earthquakes (Golden Gate Park & Housner), (ii) two horizontal primary structure Models (NS & EW), (iii) one earthquake level (either OBE or SSE), and (iv) four shroud weld-crack configurations (un-cracked, H3, H4 & all-cracked). In all, sixteen primary structure time history analyses are required and the bounding primary structure member loads extracted when the "improved methodology" is applied.

Also, during a GE internal review of the seismic analyses conducted for the Dresden 2 & 3 and Quad Cities 1 & 2 shroud repair hardware design, a discrepancy was discovered in the documentation of the original 1968 and 1970 GE seismic analyses used to reconstruct the primary structure seismic models utilized in the shroud repair projects. The review was conducted to provide answers to NRC questions pertaining to the consistency of the mass distribution in the shroud portion of the seismic model relative to corresponding masses utilized in related subsystem stress analyses. In the 1968 documentation, the mass corresponding to the top guide node was incorrectly listed as 1.73E3 slugs as opposed to the correct value of 17.33E3 slugs.

Consequently, reanalysis was required to reconfirm the seismic design adequacy of the existing shroud repair hardware design as well as other RPV and internals components (e.g., fuel, guide tubes, CRDs, etc.) and the vessel major supports (i.e., the RPV skirt and stabilizer and the star-truss) that had been confirmed for the original 1994 shroud repair loads. The reconstituted primary structure models, used for the 1994 shroud repair analysis, were modified to include the improved representation of the shroud weld-cracks and the tie rods. In addition, the top guide nodal mass was corrected and the bounding weld-crack cases reanalyzed.

The resulting, bounding loads in: (i) the RPV & internals, (ii) the shroud repair hardware, and (iii) the RPV major supports are tabulated in Table A1 of Appendix A. Note that, with the sole exception of the shear in the shroud at the shroud support plate, all loads are significantly reduced when the improved methodology and the top guide nodal mass corrections were incorporated into the primary structure seismic models. Further discussion and comparison of the member loads relative to the corresponding values obtained for the 1994-1995 shroud repair analysis is provided in Subsection 3.2 below.

2.4 <u>1996 Top Guide Mass Correction.</u> As described in Subsection 2.3 above for the introduction of the "improved Methodology", during a GE internal review of the seismic analyses conducted for the Dresden 2 & 3 and Quad Cities 1 & 2 shroud repair hardware design, a discrepancy was discovered in the documentation of the original 1968 GE seismic report which were used to reconstruct the primary structure seismic models utilized in the shroud repair projects. The review was conducted to provide answers to NRC questions pertaining to the consistency of the mass distribution in the shroud portion of the seismic model relative to corresponding masses utilized in related subsystem stress analyses. In the 1968 report, the mass corresponding to the top guide node was incorrectly listed as 1.73E3 slugs as opposed to the correct value of 17.33E3 slugs.

In addition to this top guide nodal mass correction, the "improved methodology" for representing the shroud weld-cracks was also applied in the 1996 shroud analyses.

It then follows that the shroud repair primary structure loads documented in Reference 4.3 and in the 1996 shroud analyses are based on identical modifications of the benchmark model for Quad Cities 1 and 2. Consistently, the bounding loads reported are identical, see Table A1. See Subsection 3.2 below for further discussion.

2.5 <u>**1998 Shear Area Corrections in Turbine and Reactor Buildings:**</u> During the 1998 Sargent & Lundy (S&L) reconstruction of the Quad Cities combined Reactor-Turbine Building seismic model required for the assessment of the Reactor Building steel superstructure for lifted crane loads, several discrepancies were found between the model input data presented in Reference 4.1. As discussed in Subsection 2.1 above, the seismic models given in Reference 4.1 were used by GE for the shroud repair work and were regenerated.

The balance-of-plant portions of the Reference 4.1 seismic models were reviewed. The primary discrepancy was that Turbine Building shear areas were taken as total cross-sectional areas and this error was carried over in the 1994 Reference 4.1 report. In addition to the Turbine Building shear area correction, S&L refined the calculations of the Reactor Building shear areas and the results are also included in the 1998 analyses.

The corrections to the reactor building and turbine building section properties were incorporated into the Quad Cities primary structure seismic models which also contained: (i) the shroud repair hardware, (ii) the improved representation of the shroud weld-cracks and the tie rods, (iii) the top guide nodal mass correction. The resulting corrected models, corresponding to the un-cracked, all-cracked, H3 and H4 shroud weld-crack configurations, were then subjected to the bounding Golden Gate Park SSE free-field acceleration time histories.

As for the previous analyses, the resulting primary structure critical member loads in: (i) the RPV & internals, (ii) the shroud repair hardware, and (iii) the RPV major supports are summarized in Table A1 of Appendix A to this report. The resulting loads and load comparisons are discussed in Subsection 3.2 below.

2.6 <u>**2000 Errors Resolution.**</u> An evaluation was performed in 2000 to address both the original errors and the additional errors discovered in the Quad Cities 1 and 2 primary structure seismic models. The "original errors" and the "additional errors" are described below. The Quad Cities 1 and 2 primary structure models were corrected for both the "original errors" and the "additional errors" described below and the seismic analysis rerun for the bounding shroud weld-crack configurations and load cases.

As for previous analyses, the resulting primary structure critical member loads in: (i) the RPV & internals, (ii) the shroud repair hardware, and (iii) the RPV major supports are tabulated in Table A1 of Appendix A. Note that the primary structure member loads associated with the corrections for the "original errors" plus the corrections for the "additional errors" are essentially the same as the corresponding values associated with the corrections for the "original errors" only. The resulting loads and load comparisons are discussed in Subsection 3.2 below.

Original Errors. The seismic input motion for Jet Pump evaluation was generated during the last quarter of 1999 and was based on primary structure models that had been corrected for all known (original) errors up to that point in time. As indicated above, the original primary structure seismic model errors were first introduced in late 1960s and early 1970s when GE combined the nuclear island portion of each primary structure seismic model with the Reactor Building and Turbine Building portions, Reference 4.1. The additional model errors are described below.

Additional Errors. Consequent to the 1998 discovery of the turbine building and reactor building shear area errors and during the verification of the seismic input motions required for the Quad Cities 1 & 2 Jet Pump evaluation, several (seemingly) significant, additional errors were discovered in the Quad Cities 1 & 2 primary structure seismic models employed in the evaluation.

The Quad Cities 1 and 2 primary structure is comprised of: (i) two nuclear islands, each comprised of a shield wall, a pedestal, and an RPV and internals, (ii) two reactor buildings, and (iii) two turbine buildings. The shield wall, pedestal, reactor building, and turbine building portions of the Quad Cities 1 & 2 primary structure seismic models were generated for GE by John Blume and Associates. GE developed the detailed model of the RPV and internals.

The corresponding Quad Cities 1 and 2 primary structure seismic models are mathematical, centerline, beam element models consisting of two nuclear islands, two reactor buildings, and two turbine buildings. The centerline axis about which each model is generated is defined by the intersection of two vertical planes. The first vertical plane contains (i.e., is defined by) the centroidal axes of the two nuclear islands. The second vertical plane corresponds to the East-West/Vertical plane of symmetry between Units 1 and 2. The second vertical plane is orthogonal to the first.

As discussed above, the reactor buildings and turbine buildings section properties generated by Blume and Associates were for two reactor buildings and two turbine buildings. Due to symmetry associated with the East-West direction, the primary structure East-West model can be made up of only one reactor building, one turbine building and one nuclear island. However, because there is no symmetry associated with the North-South direction, the North South model must be comprised of both reactor buildings, both turbine buildings and both nuclear islands.

GE combined only one nuclear island in both the North-South and the East-West models when generating the primary structure seismic models for Quad Cities 1 and 2. With the exception of several relatively minor errors (due to simplified RPV redundant mass, see below), the East-

West model 1, consisting of one nuclear island, one reactor building and one turbine building, was essentially correct. However, the North-South model should include two nuclear islands, not just the one presently included. Also the redundant simplified RPV mass added by Blume to the reactor building models must be removed from both models when the Blume models are integrated with the detailed GE model of the RPV and internals.

The total redundant mass of the RPV and internals, "smeared" at three nodes in the Blume model for each reactor building, was deleted from the three reactor building nodes over which the mass was distributed when GE originally combined the detailed RPV model into the composite primary structure seismic models in 1967. Note that the mass of two RPV and internals was deleted from the three reactor building nodes for the North-South primary structure seismic model and that the mass of only one RPV and internals was deleted from the East-West model.

2.7 <u>2001-1 GE14 New Fuel Introduction (NFI).</u> The 2001-1 overall seismic qualification of the Quad Cities 1 and 2 nuclear power stations subsequent to the introduction of the new GE 14 fuel core design was evaluated.

The fundamental technical requirement is the introduction of the new GE14 fuel design must not adversely effect the existing, overall plant seismic/dynamic qualification. Typically the overall plant seismic qualification is established by demonstrating the seismic structural design adequacy of the : (i) the RPV and internals components, (ii) the shroud weld-crack hardware, (iii) the vessel major supports (i.e., RPV skirt, RPV stabilizer, star truss), and (iv) all Balance of Plant (BOP) safety related structures, piping and equipment. Specifically, this includes the New Fuel Vaults (NFVs) and the Spent Fuel Storage Racks (SFSRs). From a licensing perspective, this must be demonstrated for the bounding, current plant operating configurations, which may include the "mixed core" condition as well as an all GE14 fuel core. Consequently, the evaluation also addressed the bounding "mixed fuel core" configuration as well as the all GE14 fuel core.

As indicated in Table A1, for the bounding cases analyzed, and with the two minor exceptions indicated by Note 2 in the table, all element loads associated with the introduction of the new GE14 fuel were bounded by the corresponding loads obtained in the Subsection 2.6 resolution.

2.8 <u>2001-2 Upgraded Seismic Analysis with Original Steam Dryer.</u> The 2001-2 Quad Cities 1 and 2 seismic analysis, including all up to date primary structure model corrections and upgrades, includes: **(i)** Improved methodology for representing shroud weld-crack and tie rods in primary structure model, **(ii)** Top guide nodal mass correction, **(iii)** Turbine building and reactor building corrected shear areas and section properties, **(iv)** Two nuclear islands in NS model and redundant simplified RPV mass removed from both NS and EW primary structure models, and **(v)** Nuclear fuel core design upgraded to GE 14 fuel.

Primary structure seismic time history analyses were run for all sixteen possible weld-crack configurations and load cases. The member loads in: (i) the RPV & internals, (ii) the shroud repair hardware, and (iii) the RPV major supports for the individual cases are tabulated in Tables A2 and A3 of Appendix A. The bounding loads corresponding to all sixteen cases are summarized in Table A1. See Subsection 3.2 below for further discussion of the results.

2.9 <u>2005 Upgraded Seismic Analysis with Replacement Dryer Added Mass.</u> The Quad Cities 1 and 2 corrected and upgraded primary structure seismic models, applied in the 2001-2 Upgraded Seismic Analysis discussed in Subsection 2.8 above, were modified to include the added weight of the replacement steam dryers. A concentrated mass corresponding to 40,000 lbs was added to the RPV vessel wall node at which the entire dryer assembly mass is concentrated in the primary structure models. This corresponds to a replacement dryer assembly total weight equal to approximately 115,000 lbs. The Certified weight of the actual replacement dryer assembly is 100,200 lbs. Thus the weight of the replacement dryer in the actual analyses is approximately 15% greater than that of the actual replacement dryer.

All sixteen possible, weld-crack configurations and load case, primary structure time history analyses were rerun for the upgraded replacement dryer added mass. The member loads in: (i) the RPV & internals, (ii) the shroud repair hardware, and (iii) the RPV major supports for the individual cases are tabulated in Tables A4 and A5 of Appendix A. The bounding loads corresponding to all sixteen cases are summarized in Table A1.

A theoretical assessment of the impact the replacement dryer added weight would have on the existing, overall plant seismic qualification was completed in November of 2004. That assessment was based on: (i) a replacement dryer assembly total weight of 105,000 lbs, (ii) the plant fully seismically qualified with the original dryer assembly, and (iii) added weight of the replacement dryer did not significantly change the existing eigen (dynamic) characteristics (natural frequencies) of the primary structure model. The mass of the existing dryer assembly was increased in one of the bound primary structure model configurations and the eigenanalysis rerun. It was confirmed that the changes in the bounding model, natural frequencies, due to the increased mass, were within acceptable limits. Consequently, it was concluded that the replacement dryer added mass would have no significant impact on the existing plant seismic qualification.

See Subsection 3.2 below for further discussion of the results.

3.0 PLANT SEISMIC QUALIFICATION

3.1 <u>Plant Seismic Qualification to 1994 Shroud Repair Bounding Loads.</u> The modifications associated with the shroud repair resulted in significant changes in the benchmark model mass and stiffness characteristics. Consequently, in addition to the generation of bounding design loads for the new installed shroud repair hardware, the overall plant seismic design adequacy had to be reconfirmed for the bounding loads from all primary structure model shroud repair modification configurations.

The reconfirmation of the seismic structural design adequacy of all primary structure safety related substructures, components, piping, and equipment was addressed at the conclusion of the 1994-1995 shroud repair project. In particular, the seismic structural design adequacy of: (i) the RPV and internals, (ii) the shroud repair hardware, and (iii) the RPV major supports, for the bounding seismic loads generated for the 1994 shroud repair project, Reference 4.2, was reviewed. The associated, bounding seismic loads are summarized in Table A1 of Appendix A.

Reconfirmation of the design loads and Required Response Spectra (RRS) for all BOP safety related structures, piping and equipment was also established for the 1994 shroud repair seismic analysis results. The loads and RRS for every single component were not generated and compared to the original plant design loads. However, RRS were generated at selected RPV piping nozzles and piping support locations throughout the BOP. Corresponding member loads and RRS at those same locations were regenerated using the reconstituted primary structure benchmark models, discussed in Subsections 2.1 and 2.2 above. When the corresponding RRS at locations on the vessel wall, from the two analyses, were overlaid it was one could not differentiate between the two. This demonstrates that the BOP seismic response was essentially unchanged by the implementation of the shroud repair.

Therefore, overall plant seismic qualification was established to the 1994 shroud repair seismic loads. It then follows that overall plant seismic qualification for any significant plant modifications made after the 1994 shroud repair can be demonstrated by simply comparing member end loads and RRS from the new analysis to the corresponding quantities from the 1994 shroud repair project. Additional discussion on the plant overall seismic qualification for current seismic loads is provided in Subsections 3.4 below.

Except for the RPV major supports, adequate seismic design margins existed for all primary structure safety related systems and components. This included the RPV & internals components and the shroud repair hardware. Note that the loads calculated in the shroud repair hardware were utilized as design loads in the actual design of the hardware.

Specifically the RPV major supports, which provide direct support for the vessel, consist of: (i) the RPV skirt and the (ii) the RPV stabilizer, and those which provide indirect support, (iii) the star truss. The seismic structural design adequacy of these components to the 1994 shroud repair loads, Reference 4.2, is addressed in Reference 4.6 for the RPV skirt & the RPV stabilizer, and Reference 4.5 for the star truss.

RPV Skirt. From Table A1, the maximum shear and moment at the base of the RPV skirt are [[ ]], respectively. Referring to Reference 4.6, these values were different than the original design values of [[ ]], which were used in the original skirt stress analysis. Consequently, the RPV skirt stresses were recalculated for the shroud repair loads. The maximum recalculated normal and shear stresses were [[ ]] and [[ ]] of the respective allowable stresses. It then follows that the seismic structural design of the RPV skirt is adequate for the 1994 shroud repair loads.

RPV Stabilizer. Referring to Table A1, the [[ ]] seismic load in the RPV stabilizer, calculated in the 1994 shroud repair analysis, is 39.6% greater than the corresponding [[ ]] design load ([[ ]]) calculated in the 1967 seismic analysis. Furthermore, the RPV stabilizer loads calculated in the 1967 analysis were obtained from simplified primary structure models in which "*the entire Quad-City structure (i.e., reactor building, turbine building, drywell, reactor pressure vessel and shield* wall and pedestal*) was mathematically modeled as a 23 mass coupled system*". Four mass nodes in the Blume primary structure seismic model represent the RPV and internals.

The RPV stabilizer lugs on the vessel wall were identified as the critical RPV stabilizer assembly component, Reference 4.6, for the Quads shroud repair project. Referring to Reference 4.6, the maximum bounding stress intensity in the RPV stabilizer lug assembly is only [[ ]] of the allowable stress. It then follows that the seismic structural design of the RPV stabilizer is adequate for the 1994 shroud repair loads.

Star Truss. Again referring to Table A1, the [[ ]] star truss load calculated in the 1994 shroud repair analysis is [[ ]] greater than the corresponding [[ ]] star truss seismic design load ([[ ]]) calculated in the 1967 seismic analysis. As for the RPV stabilizer discussed above, the star truss loads in the Blume analysis were obtained from simplified primary structure models in which "*the entire Quad-City structure (i.e., reactor building, turbine building, drywell, reactor pressure vessel and shield* wall and pedestal*) was mathematically modeled as a 23 mass coupled system*". Four mass nodes in the Blume primary structure seismic model represented the RPV and internals.

The star truss member forces were then calculated from the star truss load by approximate Mechanics of Materials methods. Stresses calculated from the resulting star truss member loads exhibited small margins. In an effort to remove conservatism in the original start truss hand calculations, Commonwealth Edison contracted GE Nuclear Energy to perform a finite element stress analysis of the composite top ring plate/ star truss assembly in 1994-1995, using the shroud repair seismic loads generated in the star truss. The results of the GE Finite Element analysis are summarized in the Reference 4.5. Based on the bounding star truss load ([[ ]]), generated for the 1994 Reference 4.2 shroud repair program and tabulated in Table A1, the maximum calculated stress was [[ ]] below the material allowable stress. The maximum calculated stress corresponds to a composite extreme fiber stress in bending in the top ring plate due to flexure about two orthogonal horizontal axes and due to the normal in-plane stress component.

Consequently, it was concluded from the Reference 4.2 evaluation, in conjunction with the Reference 4.6 stress analysis, that the introduction of the Quad Cities 1 & 2 1994 shroud repair did not significantly impact the plant seismic/dynamic qualification that existed at that time.

3.2 <u>2001-2 Plant Seismic Qualification for Seismic Reanalysis.</u> The Quad Cities 1 and 2 overall plant seismic qualification, demonstrated subsequent to the implementation of the 1994 shroud repair program, Reference 4.2, is summarized in Subsection 3.1 above. Numerous corrections and upgrades to the primary structure analytical models have been incorporated since the implementation of the 1994 shroud repair. The chronology of the model corrections and upgrades is detailed in Section 2 above. All analytical model corrections and upgrades have been evaluated and the present report provides the final reconciliation.

The most significant correction, based on the change in the primary structure seismic/dynamic responses, was the correction in the turbine building & reactor building section properties discussed in Subsection 2.5. The most significant analytical model upgrade corresponded to the implementation of the improved methodology for calculating the equivalent rotational spring stiffness when each shroud weld-crack is more realistically represented as a pin connected joint with an equivalent rotational spring.

The benefit of the improved methodology is illustrated by referring to Table A1 and comparing the peak loads tabulated in the table from the 1994 shroud repair project and the same corresponding loads generated for the improved methodology for representing the shroud weld-cracks in the primary structure model. The significance of the error in the turbine & reactor building section properties is illustrated by comparing the component loads in Table A1 from the 1994 shroud repair project to the corresponding values from the 1998 analysis in which the turbine & reactor building section properties were corrected. From these comparisons, it is seen that the benefits of the improved methodology were essentially cancelled out by the negative impact of the incorrect turbine & reactor building section properties.

It was generically indicated in Subsection 3.1 above that, for significant future plant modifications, the overall plant seismic qualification for the plant configuration just prior to the installation of the steam dryers is demonstrated if the 2001-2 seismic reanalysis design loads in Table A1 are enveloped by the corresponding component loads tabulated in Table A1 for the 1994 shroud repair. Referring to Table A1, all loads for the RPV & internals and the shroud repair hardware components generated for the 1994 shroud repair project envelop the corresponding 2001-2 seismic reanalysis loads. The RPV major supports loads, from the 2001-2 seismic reanalysis, are the only loads not enveloped by the corresponding 1994 shroud repair loads. These are individually discussed below.

<u>RPV Skirt.</u> Then, based on Reference 4.6 and as discussed in Subsection 3.1 above, the maximum normal and shear stresses calculated for the RPV skirt were less than [[ ]] of the allowable stress. From Table A1, the shear and the moment in the RPV skirt for the 2001-2 seismic reanalysis are both less than [[ ]] greater than the corresponding loads from the 1994 shroud repair analysis. Therefore, the [[ ]] margin inherent to the RPV skirt structural design is considerably more than is required to offset the [[ ]] overload. It then follows that the seismic structural design adequacy of the RPV skirt is also demonstrated for the 2001-2 seismic reanalysis loads.

<u>RPV Stabilizer.</u> Again, based on Reference 4.6, and as discussed in Subsection 3.1 above, the bounding critical stress in the RPV stabilizer assembly is only [[ ]] of the allowable stress. From Table A1, the RPV stabilizer load from the 2001-2 seismic reanalysis is [[ ]] greater than the corresponding RPV stabilizer load from the 1994 shroud repair project. Therefore, the [[ ]] margin inherent to the RPV stabilizer structural design is significantly more than is required to offset the [[ ]]. It then follows that the seismic structural design adequacy of the RPV stabilizer is also demonstrated for the 2001-2 seismic reanalysis loads.

<u>Star Truss.</u> Finally, based on Table A1 and the discussion in Subsection 3.1 above, the [[ ]] star truss load calculated in the 1994 shroud repair analysis is [[ ]] greater than the corresponding [[ ]] star truss seismic design load ([[ ]]) calculated in the 1967 seismic analysis. Also, from Reference 4.5 (as discussed in Subsection 3.1 above), the corresponding minimum stress margin in the 1994

shroud repair star truss loads is [[ ]]. From Table A1, the star truss load calculated for the 2001-2 seismic reanalysis is [[ ]], which is [[ ]] greater than that calculated for the 1994 shroud repair project. Therefore, the [[ ]] margin inherent to the star truss structural design is not great enough to offset the [[ ]]. It then follows that additional evaluation (provided below) is required to demonstrate the seismic structural design adequacy of the star truss for the 2001-2 seismic reanalysis loads.

Star Truss Additional Evaluation. As discussed in Subsection 3.1 above, the maximum calculated stress in the star truss assembly for the 1994 shroud repair loads was only [[ ]] below the material allowable. The maximum calculated stress corresponds to a composite extreme fiber stress in bending in the top ring plate of the star truss assembly due to flexure about two orthogonal horizontal axes and due to the corresponding in-plane, normal stress component. The corresponding AISC Code calculations performed, Reference 4.5, to demonstrate code compliance for the shroud repair project loads, is reproduced by Equations (4) through (6) in Appendix B.

Referring to Table A1, and as described above, the maximum star truss load calculated for the 2001-2 seismic reanalysis is [[ ]] greater than the corresponding maximum star truss load calculated for the 1994 shroud repair analysis. Therefore, without making significant changes in the structural characteristics of the star truss or significant reductions in the 2001-2 seismic reanalysis star truss load, it is not possible to perform a linear analysis of the star truss assembly in which all calculated composite maximum stresses (i.e., combination of two bending and one in-plane axial collinear stress contributions) at discrete points in the ring plate continuum are below the yield stress.

In practice, the local excursions in to the plastic range will yield locally and redistribute the star truss load, which will, in turn, change the star truss stress distribution. However, the star truss assembly will remain structurally stable and will maintain its structural integrity safety function. This is a fundamental characteristic of all hyper-static (i.e., statically indeterminant) structures that are fabricated from ductile steel (e.g., skyscrapers, bridges, etc).

Furthermore, both elastic-plastic and idealized-plastic (e.g., ultimate strength) analyses (both allowed by the AISC Code) analyses could be performed to quantify the qualitatively known high dynamic reserve margin associated with hyper-static structures fabricated from ductile steel.

The Ultimate Strength Analysis process described in Subsection 3.3 below for the Quad Cities 1 and 2 steam dryer replacement program seismic loads can be qualitatively applied to approximate a conservative lower bound on the stress dynamic reserve margin, inherent to the star truss critical element. Referring to Table A1, the star truss load from the dryer replacement seismic analysis ([[ ]]) is greater than the corresponding star truss load from the 2001-2 Seismic Reanalysis ([[ ]]). Therefore, if the Ultimate Strength Analysis process is successful for the dryer replacement program it follows that star truss is also qualified for the 2001-2 Seismic Reanalysis SSE loads. Referring ahead to Subsection 3.3, it is noted that the approach was successful.

From the foregoing discussion, it then follows that the seismic structural design adequacy of the star truss is also demonstrated for the 2001-2 seismic reanalysis loads. The seismic reanalysis loads were the last primary structure seismic loads generated before the initiation of the replacement dryer project.

3.3 **2005 Plant Seismic Qualification for Replacement Dryer.** Quad Cities 1 & 2 overall plant seismic qualification for the plant configuration just after the installation of the steam dryers is demonstrated if the 2005 replacement dryer primary structure loads tabulated in Table A1 are enveloped by: (i) the corresponding component loads tabulated in Table A1 for the 1994 shroud repair, or (ii) the corresponding component loads tabulated in Table A1 for the 2001-2 seismic reanalysis. Referring to Table A1, all loads for the RPV & internals and the shroud repair hardware components generated for the 1994 shroud repair project envelope the corresponding 2005 replacement dryer analysis loads. The RPV major supports loads, from the 2005 replacement dryer analysis, are the only loads not enveloped by the corresponding 1994 shroud repair loads.

RPV Skirt. Then, based on Reference 4.6 and as discussed in Subsection 3.1 above, the maximum normal and shear stresses calculated for the RPV skirt were less than [[ ]] of the allowable stress. From Table A1, the shear and the moment in the RPV skirt for the 2005 steam dryer seismic analysis are both less than [[ ]] greater than the corresponding loads from the 1994 shroud repair analysis. Therefore, the [[ ]] margin inherent to the RPV skirt structural design is considerably more than is required to offset the [[ ]]. It then follows that the seismic structural design adequacy of the RPV skirt is also demonstrated for the 2005 replacement dryer seismic analysis loads.

RPV Stabilizer. Again, based on Reference 4.6, and as discussed in Subsection 3.1 above, the bounding critical stress in the RPV stabilizer assembly is only [[ ]] of the allowable stress. From Table A1, the RPV stabilizer load from the 2005 replacement dryer seismic analysis is [[ ]] greater than the corresponding RPV stabilizer load from the 1994 shroud repair project. Therefore, the [[ ]] margin inherent to the RPV stabilizer structural design is significantly more than is required to offset the [[ ]]. It then follows that the seismic structural design adequacy of the RPV stabilizer is also demonstrated for the 2005 replacement dryer seismic analysis loads.

Star Truss. Finally, based on Table A1 and the discussion in Subsection 3.1 above, the [[ ]] star truss load calculated in the 1994 shroud repair analysis is [[ ]] greater than the corresponding [[ ]] star truss seismic design load ([[ ]]) calculated in the 1967 seismic analysis. Also, from Reference 4.5 (as discussed in Subsection 3.1 above), the corresponding minimum stress margin in the 1994 shroud repair star truss loads is [[ ]]. From Table A1, the star truss load calculated for the 2005 replacement dryer seismic analysis is [[ ]], which is [[ ]] than that calculated for the 1994 shroud repair project. Therefore, the [[ ]] inherent to the star truss structural design is not great enough to offset the [[ ]]. It then follows that additional evaluation is required to demonstrate the seismic structural design adequacy of the star truss for the 2005 steam dryer replacement program loads. The additional evaluation is provided in the following subsection.

Star Truss Additional Evaluation. As discussed in Subsection 3.1 above, the maximum calculated stress in the star truss assembly for the 1994 shroud repair loads was only [[ ]] the material allowable. The maximum calculated stress corresponds to a composite extreme fiber stress in bending in the top ring plate due to flexure about two orthogonal horizontal axes and due to the corresponding in-plane, normal stress component. The corresponding AISC Code calculations performed, Reference 4.5, to demonstrate code compliance for the shroud repair project loads, is reproduced by Equations (4) through (6) in Appendix B.

Referring to Table A1, and as described above, the maximum star truss load calculated for the 2005 replacement dryer seismic analysis is [[ ]] than the corresponding maximum star truss load calculated for the 1994 shroud repair analysis. Therefore, without making significant modifications in the structural characteristics of the star truss or significant reductions in the 2005 replacement dryer star truss seismic load, it is not possible to perform a linear analysis of the star truss assembly in which all calculated composite maximum stresses (i.e., combination of two bending and one in-plane collinear stress contributions) at discrete points in the ring plate continuum are below the yield stress.

In practice, the local excursions in to the plastic range will yield locally and redistribute the star truss load, which will, in turn, change the star truss stress distribution. However, the star truss assembly will remain structurally stable and will maintain its structural integrity safety function. This is a fundamental characteristic of all hyper-static (i.e., statically indeterminant) structures that are fabricated from ductile steel (e.g., skyscrapers, bridges, etc).

Furthermore, both elastic-plastic and idealized-plastic (e.g., ultimate strength) analyses (both allowed by the AISC Code) analyses could be performed to quantify the qualitatively known high dynamic reserve margin associated with hyper-static structures fabricated from ductile steel.

Beyond yield stresses for SSE loading of safety related structures and components are allowed by the Quad Cities 1 and 2 UFSAR. This is contingent only on being able to scram the reactor and being able to maintain the plant in a safe shutdown condition. Specifically for the star truss, this is demonstrated based on maintaining structural integrity (stability) during and after the seismic event. The following procedure can be conservatively applied to demonstrate the structural stability of the star truss which experiences local yielding during the seismic SSE excitation.

A lower bound on the stress dynamic reserve margin for the star truss can be approximated as follows. Consider an idealized linear analysis of the star truss assembly in which the maximum calculated linear stresses can be one-third greater than the yield stress, Equation (7) in Appendix B. The corresponding linear stress distribution and moment per unit length capability are depicted in Figure B3 of Appendix B, Equation (2). It is clear that the moment per unit length capability for such an idealized linear condition will be significantly greater than the corresponding moment per unit length capability of an ordinary elastic analysis in which the extreme fiber stresses must be below the material allowable stress. Next, consider the idealized-plastic case. The stress distribution and moment per unit length for the idealized-plastic case are illustrated in Figure B3, Equation (1). This plastic moment exceeds the idealized linear elastic moment by [[ ]], Equation (3) of Appendix B.

A lower bound to the dynamic reserve margin stress is now approximated. This is accomplished by substituting the allowable stress from Equation (7) into Equation (4) to yield Equation (8). Based on Equation (8), it is expected that there will be at least [[ ]] on the star truss maximum combined (composite) calculated stress if an idealized-linear elastic analysis is performed for the star truss in which the extreme fiber stresses are allowed to reach [[ ]] of the yield stress. This represents a lower bound on the dynamic reserve margin because the maximum equivalent elastic moment, given by Equation (2) in Appendix B, is less than the idealized plastic moment, given by Equation (1) in Appendix B. In the ultimate strength analysis of hyper-static structures, elastic stability is maintained if the number of full plastic hinges that develop do not form a mechanism that renders the star truss assembly structurally unstable.

From the foregoing discussion, it then follows that the seismic structural design adequacy of the star truss is also demonstrated for the 2005 replacement dryer seismic analysis loads. The 2005 replacement dryer seismic analysis is the last primary structure seismic conducted for Quad Cities 1 and 2.

3.4 <u>Impact of Replacement Dryer Added Mass on Plant Seismic Qualification.</u> Based on the foregoing discussion, in conjunction with the theoretical qualitative evaluation, it is concluded that the added weight of the Quad Cities 1 & 2 replacement steam dryer assemblies will not negate the existing overall plant seismic qualification. The work scope of the present evaluation does not include the seismic/dynamic qualification (e.g., structural integrity and fatigue design adequacy) of: (i) the replacement steam dryer assembly itself, (ii) the steam dryer support lugs on the RPV, and (iii) the ASME stress analysis of the RPV vessel wall. The conclusion does apply to: (i) all other RPV and internals components, (ii) the RPV major supports (i.e., the RPV stabilizer and the RPV skirt), (iii) all Nuclear Steam Supply System (NSSS) safety related piping and equipment, (iv) the star truss, and (v) all Balance-of-Plant (BOP) safety related piping and equipment.

Seismic RRS have been generated at the mounting locations of the safety related equipment and piping which are located throughout the Quad Cities 1 and 2 entire primary structure. The RRS were generated for the plant configurations, which were analyzed for the 2001-2 primary structure seismic reanalysis. All primary structure model error corrections and model upgrades (i.e., installation of shroud repair hardware and introduction of GE14 nuclear fuel) identified in Section 2.0 of the present report, with the exception of the primary structure modification corresponding to the replacement dryer, were included in the analytical models. Member end loads have also been generated for the plant configuration that will exist after the installation of the replacement steam dryer.

4.0 REFERENCES

4.1 GE Nuclear Energy Report No. GE-NE-523-A169-1194, Rev. 0, " Commonwealth Edison Company - Quad Cities Nuclear Power Station, Units 1 & 2 – Primary Structure Seismic Models", November 16, 1994

4.2 GE Nuclear Energy Report No. GENE-771-71-1094, Rev. 0, "Quad Cities 1 & 2 – Shroud Repair Seismic Analysis", November 16, 1994. **(Or Rev. 1 dated January 5, 1995)**

4.3 GE Nuclear Energy Report No. GE-NE-523-A100-0995, Rev. 0, " Commonwealth Edison Company – Dresden, Units 2 & 3 and Quad Cities Units 1 & 2 – Analyses of the Dresden and Quad Cities Shroud Repair Hardware Seismic Design with Improved Tie Rod and Shroud Weld Crack Equivalent Rotational Stiffness", September 1995.

4.4 GE Nuclear Energy eDRF No.0000-0034-8826, "Quad Cities - Impact of Replacement Dryer Added Mass on Existing Primary Structure Seismic Response", Created: November 24, 2004.

4.5 GE Nuclear Energy Report No. GE-NE-523-203-1294, Rev. 0, " Commonwealth Edison Company - Quad Cities, Units 1 & 2 – Top Ring Plate and Star Truss Stress Analysis", January 9, 1995.

4.6 GE Nuclear Energy Document No. 25A5672, Rev. 1, "Quad Cities 1 and 2 – Pressure Vessel Stress Report", January 6, 1995.

APPENDIX A

Quad Cities

Effect of Replacement Steam Dryer Assembly Added Mass
On Primary Structure Seismic Response

TABLES

Table A1. Quad Cities 1&2 - History of Primary Structure Dynamic Models and Related Seismic Analysis Peak SSE Responses. (Units: kip-ft-sec)

	Quad Cities 1&2 - History of Primary Structure Dynamic Analyses							
Year	1994	1995	1996	1998	2000	2001-1	2001-2	2005
RPV Major Supports								
RPV Skirt Shear	[[							
RPV Skirt Moment								
RPV Stabilizer Load								
Star Truss Load								
RPV & Internals								
Fuel								
Total Fuel Shear at Top Guide								
Total Fuel Shear at Core Plate								
Total Fuel Moment								
Internals								
Total CRD Moment								
Shroud Shear at Support Plate								
Moment in Support Plate								
Shroud Repair Hardware								
Upper Spring Force								
Middle Spring Force								
Lower Spring Force								
Tie Rod Force								]]

LEGEND:

1994	Shroud Repair Analysis
1995	Improved Methodology for Shroud Crack Modeling
1996	Top Guide Mass Correction in Model
1998	Turbine Building and Reactor Building Shear Area Correction
2000	Errors Resolution
2001-1	GE14 Fuel Introduction Impact Analysis
2001-2	Primary Structure Analysis including all previous corrections and GE14 Fuel
2005	Impact of 40K Dryer Weight increase on Response

Note 1: Star truss loads not generated in computer runs.

Note 2: [[ ]]

Note 3: Tie Rod Forces are based on detailed hand calculations, which utilize the moments developed in the shroud tie rod and weld-crack rotational springs. The detailed hand calculations were not performed for these evaluations because they will be very nearly the same as were calculated for the 2000 and 2001-1 analyses, which are, in turn, essentially equal to the 1998 values.

Table A2. Quad Cities 1&2 – Member Forces (SSE / EW Model / GE14 Fuel)
(Units: kip-ft-sec)

	Housner Ground Excitation					Golden Gate Ground Excitation					EW Envelopes (Housner / Golden Gate)	
	Shroud Crack Condition					Shroud Crack Condition						
Member Forces	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	Cracked	Uncracked
RPV Major Supports												
RPV Skirt Shear	[[											
RPV Skirt Moment												
RPV Stabilizer Load												
Star Truss Load												
RPV & Internals												
Fuel												
Total Fuel Shear at Top Guide												
Total Fuel Shear at Core Plate												
Total Fuel Moment												
Internals												
Total CRD Moment												
Shroud Shear at Support Plate												
Moment in Support Plate												
Shroud Repair Hardware												
Upper Spring Force												
Middle Spring Force												
Lower Spring Force												
Tie Rod Moment												]]

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Table A3. Quad Cities 1&2 – Member Forces (SSE / NS Model / GE14 Fuel)
(Units: kip-ft-sec)

	Housner Ground Excitation					Golden Gate Ground Excitation					NS Envelopes (Housner / Golden Gate)	
	Shroud Crack Condition					Shroud Crack Condition						
Member Forces	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	Cracked	Uncracked
RPV Major Supports												
RPV Skirt Shear	[[											
RPV Skirt Moment												
RPV Stabilizer Load												
Star Truss Load												
RPV & Internals												
Fuel												
Total Fuel Shear at Top Guide												
Total Fuel Shear at Core Plate												
Total Fuel Moment												
Internals												
Total CRD Moment												
Shroud Shear at Support Plate												
Moment in Support Plate												
Shroud Repair Hardware												
Upper Spring Force												
Middle Spring Force												
Lower Spring Force												
Tie Rod Moment												]]

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Table A4. Quad Cities 1&2 – Member Forces (SSE / EW Model / GE14 Fuel / 40 Kip Dryer Added Weight)
(Units: kip-ft-sec)

	Housner Ground Excitation					Golden Gate Ground Excitation					EW Envelopes (Housner / Golden Gate)	
	Shroud Crack Condition					Shroud Crack Condition						
Member Forces	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	Cracked	Uncracked
RPV Major Supports												
RPV Skirt Shear	[[											
RPV Skirt Moment												
RPV Stabilizer Load												
Star Truss Load												
RPV & Internals												
Fuel												
Total Fuel Shear at Top Guide												
Total Fuel Shear at Core Plate												
Total Fuel Moment												
Internals												
Total CRD Moment												
Shroud Shear at Support Plate												
Moment in Support Plate												
Shroud Repair Hardware												
Upper Spring Force												
Middle Spring Force												
Lower Spring Force												
Tie Rod Moment												]]

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Table A5. Quad Cities 1&2 – Member Forces (SSE / NS Model / GE14 Fuel / 40 Kip Dryer Added Weight)
(Units: kip-ft-sec)

	Housner Ground Excitation					Golden Gate Ground Excitation					NS Envelopes (Housner / Golden Gate)	
	Shroud Crack Condition					Shroud Crack Condition						
Member Forces	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	H3 Hinge	H4 Hinge	All Cracked	Cracked Envelope	Uncracked	Cracked	Uncracked
RPV Major Supports												
RPV Skirt Shear	[[											
RPV Skirt Moment												
RPV Stabilizer Load												
Star Truss Load												
RPV & Internals												
Fuel												
Total Fuel Shear at Top Guide												
Total Fuel Shear at Core Plate												
Total Fuel Moment												
Internals												
Total CRD Moment												
Shroud Shear at Support Plate												
Moment in Support Plate												
Shroud Repair Hardware												
Upper Spring Force												
Middle Spring Force												
Lower Spring Force												
Tie Rod Moment												]]

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APPENDIX B

Quad Cities

Effect of Replacement Steam Dryer Assembly Added Mass
On Primary Structure Seismic Response

FIGURES

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Figure B1. Quad Cities - Primary Structure Seismic Model with Shroud Weld-Crack Repair Hardware Installed

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Figure B2. Quad Cities – Shroud Portion of Primary Structure Seismic Model with Shroud Weld-Crack Designation and Location

[[

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Figure B3. Plastic and Elastic Bending Moment, Per Unit Width, in a Thin Plate Section of Unit Width

SSE + JET LOADS

[[

]]

OBE WITH JET LOADS

[[

]]

OBE WITHOUT JET LOADS

[[

]]

[[ ]]