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

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

Subject: Response to Request for Additional Information Concerning Risk Informed Inservice Inspection Program Alternative to the ASME Boiler and Pressure Vessel Code Section XI Requirements for Class 1 and 2 Piping Welds

References:

(1) Letter from U.S. NRC to O.D. Kingsley (EGC), "Quad Cities – Request for Additional Information Regarding Risk-Informed Inservice Inspection Plan," dated July 11, 2001

(2) Letter from J.P. Dimmette, Jr. (Commonwealth Edison Company) to U.S. NRC, "Risk Informed Inservice Inspection Program Alternative to the ASME Boiler and Pressure Vessel Code Section XI Requirements for Class 1 and 2 Piping Welds," dated November 30, 2000

The purpose of this letter is to provide the Quad Cities Nuclear Power Station (QCNPS) response to the Request for Additional Information (RAI), Reference 1, regarding our submittal, Reference 2. The attachment to this letter contains our response to the RAI.

A047

Should you have any questions concerning this letter, please contact Mr. Wally Beck at (309) 227-2800.

Respectfully,

George P. Barnes, for

Timothy J. Tulon
Site Vice President
Quad Cities Nuclear Power Station

Attachment : Response to Request for Additional Information, Risk Informed Inservice Inspection Program Alternative to the American Society of Mechanical Engineers Boiler and Pressure Vessel Code, Section XI, Requirements for Class 1 and 2 Piping Welds

cc: Regional Administrator – NRC Region III
NRC Senior Resident Inspector – Quad Cities Nuclear Power Station

# ATTACHMENT

## Response to Request for Additional Information, Risk Informed Inservice Inspection Program Alternative to the American Society of Mechanical Engineers, Boiler and Pressure Vessel Code, Section XI, Requirements for Class 1 and 2 Piping Welds

**NRC Question #1:**

Please provide the following information for each unit:

a) When does the current inspection period start and end?
b) What cumulative percentage of inspections have been completed for the current interval?

**Exelon Generation Company (EGC) Response:**

Columns (a) and (b) in the following table provide a response to each question respectively.

| Unit | (a) Third Inspection Period | (b)[1] Third Inspection Interval Inspections | | | | |
|---|---|---|---|---|---|---|
| | | B-F | B-J | C-F-1 | C-F-2 | Total |
| Unit 1 | 10/01/00 to 02/17/03 | 61% | 71%[2] | 60% | 63% | 63% |
| Unit 2 | 03/10/00 to 03/09/03 | 60% | 67% | 67% | 69% | 65% |

Notes:
1. Cumulative percentage of Code inspections completed for the third inspection interval under the current ASME Section XI ISI program.
2. Includes examinations performed during the first outage of the third period.

**NRC Question #2:**

The implementation of a Risk Informed Inservice Inspection (RI-ISI) program for piping should be initiated at the start of a plant's 10-year Inservice inspection interval consistent with the requirements of the American Society of Mechanical Engineers (ASME) Code Section XI, Edition and Addenda committed to by the Owner in accordance with 10 CFR Part 50.55a. However, the implementation may begin at any point in an existing interval as long as the examinations are scheduled and distributed to be consistent with ASME XI requirements, e.g., the minimum examinations completed at the end of the three inspection intervals under Program B should be 16 percent, 50 percent, and 100 percent, respectively, and the maximum examinations credited at the end of the respective periods should be 34 percent, 67 percent, and 100 percent.

It is our view that it is a virtual necessity that the programs for the RI-ISI inspections (RI-ISIs) and for the balance of the inspections be on the same interval start and end dates. This can be accomplished by either implementing the RI-ISIs at the beginning of the interval or merging RI-ISIs into the program for the balance of the inspections if the RI-ISIs are to begin during an existing ISI Interval. One reason for this view is that it eliminates the problem of having different Codes of record for the RI-ISIs and for the balance of the inspections. A potential problem with using two different interval start dates and hence two different Codes of record would be having two sets of repair/replacement rules depending upon which program identified the need for repair (e.g., a weld inspection versus a pressure test).

In addition, with the change to a RI-ISI program, the Code minimum and maximum percentages of examination per period still apply to the RI-ISIs. For example, if a licensee is interested in starting the RI-ISIs during the second period, either the RI-ISIs or the Code required inspections should satisfy the second period minimum/maximum percentages. The code required percentages would have already been satisfied for the first period.

Please describe your implementation plan with respect to the above discussion.

**EGC Response:**

The RI-ISI program will start with the 3rd Period at 64% and 65% percentage of inspections complete for Unit 1 and 2 respectively (see Quad Cities Response to Question 1.B). Component selections during the 1st and 2nd Period were not subject to the criteria of the RI-ISI Program. For the 3rd Period, the remaining 36% and 35% will be satisfied using the RI-ISI program. Specifically, 36% of Unit 1 and 35% of Unit 2 populations that are selected for RI ISI examination will be inspected at the completion of the 3rd Period.

This method of RI-ISI incorporation would result in the completion of 100% of the RI-ISI components selected for examination within a ten-year time frame as would occur if the RI-ISI program were started at the beginning of the Inspection Interval. The current period and interval dates will not be altered by this method.

**NRC Question #3:**

**Will the RI-ISI program be updated every 10 years and submitted to the Nuclear Regulatory Commission (NRC) consistent with the Current ASME XI requirements?**

**EGC Response:**

The RI-ISI program is an alternative to the requirements of ASME Section XI requirements for Class 1 and 2 piping welds implemented through the use of a relief request in accordance with 10 CFR 50.55a(a)(3)(i). Therefore, a relief request for implementation of a RI-ISI program during subsequent 10-year inservice inspection intervals will be submitted concurrent with the update to the latest edition and addenda of the Code every ten years in accordance with 10 CFR 50.55a(g)(4)(ii).

**NRC Question #4:**

Under what conditions will the RI-ISI program be resubmitted to the NRC before the end of any 10-year interval?

**EGC Response:**

It is not our intent to resubmit the RI-ISI program to the NRC before the end of a 10-year interval. The RI-ISI program will be maintained as a living program and updated consistent with EPRI TR 112657, "Revised Risk-Informed Inservice Inspection Evaluation Procedure."

Changes that could impact the RI-ISI program include major changes to the Quad Cities PRA or changes to weld selection. Our Risk Management program requires a review of past applications following a PRA update. This requirement will be applied the RI-ISI program. If the review determines that a change to the RI-ISI program is required, the change would be performed consistent with the EPRI methodology. Likewise, a change to the welds selected would cause a revision to the RI-ISI program consistent with the EPRI methodology. These changes to the RI-ISI program would not be resubmitted to the NRC.

It should be noted that requirements for RI-ISI program maintenance are being developed by EPRI. The EPRI "Living Program Criteria" document is expected to be published by the end of 2001.

**NRC Question #5:**

Relief Request CR-33, page 3 states that in lieu of the evaluation and sample expansion requirements of Section 3.6.6.2 contained in EPRI TR-112657, Quad Cities will utilize the requirements of Subarticle-2430 of Code Case N-578-1. Please clarify if any of these requirements deviate form the approved EPRI methodology for necessary additional examinations. Please provide the basis for this deviation. Please also state if your interpretation of the Code Case is in agreement with recent interpretations presented and discussed at the ASME XI Risk Based Working Group meetings. Also, there is a description of additional examinations when unacceptable flaws are found. Additionally, please clarify that if there are not enough high safety significant elements with the same failure mode, lower safety significant elements will be selected such that the number of additional elements is at least equal to the number of elements with the same postulated failure mode originally scheduled for examination.

**EGC Response:**

EPRI TR-112657, Section 3.6.6.2 states the following regarding additional examinations, "Additional examinations will be performed on these elements up to a number equivalent to the number of elements required to be inspected on the segment or segments initially. If unacceptable flaws or relevant conditions are found similar to the initial problem, the remaining elements identified as susceptible will be examined. No additional examinations will be performed if there are no additional elements identified as being susceptible to the same service related root cause conditions or degradation mechanism." Quad Cities intends to use the additional examination criterion outlined in Subarticle-2430 of Code Case N-578-1. The Code Case does not deviate from the EPRI TR-112657 regarding additional examinations; rather, N-578-1 builds on the EPRI TR by providing additional details. Specifically, for High and Medium Risk category piping structural elements (i.e., Risk Group Categories 1 through 5 as defined in Table I-8 of N-578-1), Quad Cities will use the following criteria:

(a) Examinations performed that reveal flaws or relevant conditions exceeding the referenced acceptance standards shall be extended to include additional examinations. The additional examinations shall include piping structural elements with the same postulated failure mode and the same or higher failure potential.

   (1) The number of additional elements shall be the number of piping structural elements with the same postulated failure mode originally scheduled for that fuel cycle.

   (2) The scope of the additional examinations may be limited to those high safety significant piping structural elements (i.e., Risk Group Categories 1 through 5) within systems, whose material and service conditions are determined by an evaluation to have the same postulated failure mode as the piping structural element that contained the original flaw or relevant condition.

(b) If the additional required examinations reveal flaws or relevant conditions exceeding the referenced acceptance standards, the examination shall be further extended to include additional examinations.

   (1) These examinations shall include all remaining piping elements whose postulated failure modes are the same as the piping structural elements originally examined.

(2) An evaluation shall be performed to establish when those examinations are to be conducted. The evaluation must consider failure mode and potential.

(c) For the inspection period following the period in which the original examination discovering the flaw or relevant condition was completed, the examinations shall be performed as originally scheduled.

Quad Cities believes that the rules for additional examinations described above are consistent with the intent of Code Inquiry IN00-010a which was discussed at the ASME Section XI Risk Based Working Group meeting and approved at the recent ASME Section XI Inquiry Session. However, it should be noted that the aforementioned Code Inquiry provides clarification for Code Case N-577/N-577-1 and not specifically for Code Case N-578/N-578-1. Consistent with the intent of IN00-010a, if there are not enough high safety significant elements (i.e., in the same and higher "Risk Group Categories") with the same postulated failure mode, lower safety significant elements (i.e., in lower "Risk Group Categories"-other than Risk Group Categories 6 and 7) with the same postulated failure mode will be selected such that the number of additional elements is at least equal to the number of elements with the same postulated failure mode originally scheduled for that fuel cycle.

The description of additional examination requirements described in Section 3.5 of the Reference 2 letter, is expanded by the additional examination requirements described in this response to RAI question #5.

**NRC Question #6:**

Relief Request CR-33, page 3 states that to supplement the requirements listed in Table 4-1 of EPRI TR-112657, Quad Cities will utilize the provisions listed in Table 1 of Code Case N-578-1. Please clarify if any of these requirements deviate from the approved EPRI methodology. If so, please provide your justification for the deviation.

**EGC Response:**

Quad Cities plans to supplement the requirements listed in Table 4-1 of EPRI TR-112657 with the provisions listed in Table 1 of Code Case N-578-1 specifically as described below:

- The categorization of parts to be examined under RI ISI from Table 1 of Code Case N-578-1 (i.e., Examination Category R-A designation and corresponding Item Numbers) will be used in conjunction with Table 4-1 of EPRI TR-112657. Additionally, the provisions of Table 1 of Code Case N-578-1 for Piping Elements Not Subject to a Damage Mechanism (i.e., item numbers, parts examined, examination methods, acceptance standards, examination extent and frequency) will be used. However, the Examination Requirements/Figure No. for Piping Elements Not Subject to a Damage Mechanism will be consistent with the examination requirements that are applicable to those elements subject to Thermal Fatigue as described in Table 4-1 of TR-112657. The use of Code Case N-578-1's provisions identified in this paragraph does not constitute a deviation from those of EPRI TR-112657 since these provisions are not addressed in Table 4-1 of EPRI TR-112657, Revision B-A.

- Code Case N-578-1 Table 1, "Examination Category R-A, "Risk-Informed Piping Examinations" does deviate from Table 4-1 of EPRI TR-112657 regarding guidance for the examination method applicable to socket welds. Specifically, N-578-1 allows a VT-2 examination of socket welds to be performed each refuel outage in lieu of a volumetric or surface examination, regardless of the degradation mechanism. The VT-2 examination method is a more meaningful examination method considering the nature of flaw propagation and the socket weld configuration.

**NRC Question #7:**

Page 4 states that "The potential for synergy between two or more damage mechanisms working on the same location was considered in the estimation of pipe failure rates and rupture frequencies which was reflected in the risk impact assessment." Specifically how was this synergy reflected in the risk impact? Was synergy also reflected in the safety significant categorization and if so how?

**EGC Response:**

The delta risk assessment for the Quad Cities Units 1 and 2 RI-ISI evaluations were performed by ERIN Engineering and Research, who co-authored the EPRI RI-ISI Topical Report (EPRI TR-112657) and was the lead author of the supporting reports that developed failure rates and rupture frequencies and the Markov Model to delta risk evaluations in the EPRI method (EPRI TR-111880 and EPRI TR-110161, respectively). Neither the EPRI RI-ISI procedure described in the Topical Report, nor the supporting analysis of failure rates and rupture frequencies performed in EPRI TR-11880, nor any other source of failure rates that we are aware of addresses the situation in which a segment is found to be susceptible to two or more damage mechanisms. The following excerpt from the Tier 2 documentation describes how failure rates and rupture frequencies were impacted by synergy for the conservative assumptions in the delta risk evaluation.

The failure rates and rupture frequencies used in this evaluation are taken from EPRI TR-111880, Table A-11, "Conditional Failure Rates and Rupture Frequencies for General Electric Plants". These rupture frequencies are a function of (conditioned on) the system and combination of damage mechanisms identified for that segment and do not take credit for any pipe inspections. These failure rates and rupture frequencies were applied as follows.

- Conditional core damage probabilities (CCDPs) and conditional large early release probabilities (CLERPs) from the consequence analysis and application of the existing plant specific PRA models are used for all of the delta risk evaluations. Separate calculations were performed for delta CDF and delta LERF for each pipe location in the scope of the RI-ISI evaluation.
- For segments with no assessed damage mechanism, the failure rates and rupture frequencies associated with design and construction errors for the appropriate system category are used.
- For segments with one and only one ISI amenable damage mechanism, the failure rates and rupture frequencies for that mechanism were summed with the rates and

frequencies for design and construction errors which could occur at any location. The exception is when the associated damage mechanism is IGSCC or FAC and these mechanisms are covered in an augmented inspection program that is not being changed in the RI-ISI program. Only those mechanisms associated with a change to the inspection in the RI-ISI program are considered. Note that for consistency with the treatment of damage mechanisms in EPRI TR 111880 which used Thermal Fatigue as a general category to include both TT and TASCS, these two mechanisms occurring singly or in combination were simply regarded as susceptible to Thermal Fatigue. Hence no synergy between TT and TASCS was assumed.

- For segments with two or more ISI amenable damage mechanisms, the associated failure rates and rupture frequencies for these and design and construction errors are summed, with the exception that IGSCC and FAC contributions are not added if the weld is part of the associated augmented inspection program for IGSCC or FAC. These contributions were not added as the associated augmented inspection programs will not change. Only those damage mechanisms whose inspection programs are changed in the RI-ISI program were included. However, when there are two or more damage mechanisms, including IGSCC or FAC, the failure rates and rupture frequencies for the applicable ISI amenable damage mechanisms are increased by a factor of 3 to consider the possible effects of synergy, i.e., to consider the potential that through wall cracks would occur more quickly when two or more mechanisms were present at the same location.

The above treatment was made because the service data upon which the EPRI methodology for damage mechanism assessment was based does not explicitly address multiple damage mechanisms. Two examples serve to better explain the procedure that was followed. If a segment was found to be susceptible to both thermal fatigue ( TT, TASCS or both) and corrosion cracking and the corrosion cracking is not covered in the augmented program for IGSCC (hypothetical case), the failure rates for design and construction errors, thermal fatigue, and stress corrosion cracking from EPRI TR-111880 would be summed and then this result would be multiplied by a factor of 3 for synergy. The rupture frequencies would be determined in the same way. But if the segment was found susceptible to the same three damage mechanisms and the stress corrosion cracking was covered in the augmented IGSCC program, the stress corrosion cracking contribution would not be included in the failure rate or rupture frequency, but its synergy effects would be included by the factor of 3.

While as explained above the potential for synergy was considered using engineering judgement in the delta risk evaluation as explained above, the assignment of failure potential categories in the application of the EPRI RI-ISI risk matrix was not changed as a result of this consideration of synergy. Hence if a location was susceptible to say two or more ISI amenable damage mechanisms other than FAC, the failure potential category was not increased from Medium to High due to consideration of synergy. Our judgement was that a factor of 3 increase in rupture frequency would provide a conservative upper bound on the possible effects of synergy. The assumption in the risk classification matrix in the EPRI methodology was that the difference in frequency between Medium and High failure potential was more than an order of magnitude. In summary, our approach to treatment of synergy effects from two or more damage mechanisms was thought to be both reasonable and beyond the requirements set forth in RG 1.174, RG 1.178, and the EPRI RI-ISI Topical Report.

**NRC Question #8:**

Please provide references to all the equations that you are using to calculate the change in risk. Please also provide references from which all the input parameters required by the equations were developed and justified (except for the conditional core damage and condition large early release probabilities). Please provide specific references, e.g. equation numbers, table numbers, page numbers, and report references.

**EGC Response:**

The requested information on equations and data sources is provided in the Table below.

| **Model/Equation** | **Report Reference** | **Page, Table, Equation References** |
|---|---|---|
| Equations for Calculating changes in CDF and LERF | EPRI TR-112657 | Equation 3-9 on p. 3-86 |
| Equation for Calculating CDF and LERF | EPRI TR-110161 | Equation 3.40 on p. 3-34 |
| Markov Model used for ISI amenable damage mechanisms | EPRI TR-110161 | Figure 3-9 on p. 3-24<br>Equations (3.26) though (3.38) on pp. 3-24 to 3-27 |
| Definition of Inspection effectiveness Factor for use in delta risk equation | EPRI TR-110161 | $I = \frac{h_{40}\{\omega_{NEW}\}}{h_{40}\{\omega_{OLD}\}}$<br><br>This is similar to Equation (3.41) on p. 3-37 except that 40 year vs. steady state hazard rates are used. NEW corresponds with RI-ISI and OLD with ASME Sec. XI. |
| Definition of the flaw inspection repair rate, $\omega$ | EPRI TR-110161 | Equation (3.23) on p. 3-18 |
| Definition of the leak detection repair rate, $\mu$ | EPRI TR-110161 | Equation (3.24) on p. 3-18 |
| Failure rates and rupture frequencies | EPRI TR-111880 | Table A-11 |
| Plant specific documentation of all other input data needed to quantify above equations | Quad Cities Units 1 and 2 RI-ISI Evaluation (Tier 2 Documentation) | Section 7 (See Attachment) |

**NRC Question #9:**

It is our understanding that you are calculating an inspection effectiveness factor (IEF) for use in equation 3-9 of EPRI TR-112657. Please provide a table identifying the probability of detection, the time to detect a leak, and the resulting IEF for all the IEFs used in the submittal.

**EGC Response:**

The inspection effectiveness factor is the ratio of the inspected weld rupture frequency to the non-inspected rupture frequency. The EPRI Topical Report TR-112657, in Section 3.7.2 discusses two methods for determining these factors, one based on an application of the Markov model and the other based on an assumption that the factor is proportional to the complement of the probability of detection of the ISI exam, or POD. The POD is the conditional probability of detection of damage in a pipe element, given the existence of a detectable flaw or crack in the pipe element that exceeds the pipe repair criteria. When the effectiveness factor is developed from the Markov model, the following variables impact its numerical value: the POD which may be different whether the exam is done per ASME Section XI or per EPRI RI-ISI examination criteria, the assumed failure rates and rupture frequencies which are taken to be dependent and conditional on the system, pipe size, and applicable ISI amenable damage mechanisms. There are other inputs to the Markov model that are not varied between EPRI and ASME Section XI programs that describe the frequency and effectiveness of pipe leaks when leak before break applies.

A tabulation of all the unique inspection effectiveness factors for all pipe segments evaluated within the scope of the RI-ISI evaluation for QC Units 1 and 2 is presented in Table RAI 9-A. For comparison purposes, the corresponding POD values that were used were presented along with their complements that provide the alternative method of computing the inspection effectiveness factor. A plot that compares the two approaches to computing the inspection effectiveness factors is provided in Figure RAI 9-A for the RI-ISI exams.

As seen in these exhibits, there is fairly good agreement between these alternative approaches to estimating the inspection effectiveness factors. When the POD values are around 0.50, the Markov model predicts a somewhat higher level of inspection effectiveness, as reflected in somewhat lower inspection effectiveness factors. For higher POD values, the Markov model predicts a somewhat lower level of inspection effectiveness, as reflected in somewhat higher inspection effectiveness factors. Details documenting the inputs to computing these factors are discussed in response to question 8 above.

The inspection effectiveness factors developed using the Markov model are viewed as a more realistic assessment of inspection effectiveness for several reasons, including:

- The use of the (1-POD) model for inspection effectiveness is simply an assumption and has no real logical or scientific basis,
- Whereas the Markov model is based on an explicit model of the interactions between degradation phenomena and inspection processes. The results of the Markov model are a function of the POD as well as many other parameters that account for the

relative frequency of cracks, leaks, and ruptures, the possibility for leak before break and leak detection and repair prior to rupture, the fraction of the weld that is accessible, the possibility for synergy between different damage mechanisms, the time intervals between inspections etc.

Having stated this, it is noted that in the context of developing order of magnitude estimates of risk impacts, both methods provide comparable results as seen in the presented exhibits.

**Table RAI 9-A**
**Probability of Detection (POD) and Inspection Effectiveness Factors Used for QC Units 1 and 2 Delta Risk Evaluations**

| System | Damage Mechanism(s) | EPRI RI-ISI Exams | | | ASME Section XI Exams | | |
|---|---|---|---|---|---|---|---|
| | | POD | Inspection Effectiveness Factor per Markov Model | Inspection Effectiveness Factor per (1-POD) | POD | Inspection Effectiveness Factor per Markov Model | Inspection Effectiveness Factor per (1-POD) |
| CRD | D&C[1] | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| ECCS | D&C[1] | 0.500 | 0.438 | 0.500 | 0.500 | 0.438 | 0.500 |
| | TASCS | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| | TT | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| | IGSCC | 0.750 | 0.322 | 0.250 | 0.500 | 0.438 | 0.500 |
| | TASCS, TT | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| | TASCS, TT, IGSCC | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| | TT, IGSCC | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| FW | D&C[1] | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| | FAC | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| | TASCS, FAC | 0.900 | 0.273 | 0.100 | 0.500 | 0.436 | 0.500 |
| | TASCS, TT | 0.900 | 0.273 | 0.100 | 0.500 | 0.436 | 0.500 |
| | TASCS, TT, FAC | 0.900 | 0.273 | 0.100 | 0.500 | 0.436 | 0.500 |
| | TT, FAC | 0.900 | 0.273 | 0.100 | 0.500 | 0.436 | 0.500 |
| HPCI | D&C[1] | 0.500 | 0.438 | 0.500 | 0.500 | 0.438 | 0.500 |
| | TT | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |
| | IGSCC | 0.750 | 0.322 | 0.250 | 0.500 | 0.438 | 0.500 |
| MS | D&C[1] | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| | IGSCC | 0.750 | 0.319 | 0.250 | 0.500 | 0.435 | 0.500 |
| | TASCS | 0.900 | 0.274 | 0.100 | 0.500 | 0.437 | 0.500 |
| | TT, TASCS | 0.900 | 0.272 | 0.100 | 0.500 | 0.435 | 0.500 |
| | TASCS, IGSCC | 0.900 | 0.275 | 0.100 | 0.500 | 0.437 | 0.500 |
| | TASCS, TT, FAC | 0.900 | 0.274 | 0.100 | 0.500 | 0.437 | 0.500 |
| RCS | D&C[1] | 0.500 | 0.439 | 0.500 | 0.500 | 0.439 | 0.500 |
| | IGSCC | 0.750 | 0.322 | 0.250 | 0.500 | 0.439 | 0.500 |
| | TASCS | 0.800 | 0.306 | 0.200 | 0.500 | 0.439 | 0.500 |
| RWCU | D&C[1] | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| | IGSCC | 0.750 | 0.319 | 0.250 | 0.500 | 0.435 | 0.500 |
| | FAC | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| SBLC | D&C[1] | 0.500 | 0.435 | 0.500 | 0.500 | 0.435 | 0.500 |
| | TASCS | 0.800 | 0.305 | 0.200 | 0.500 | 0.438 | 0.500 |

1) Design and construction errors were included for all welds and are shown here only for cases with no other damage mechanism present.

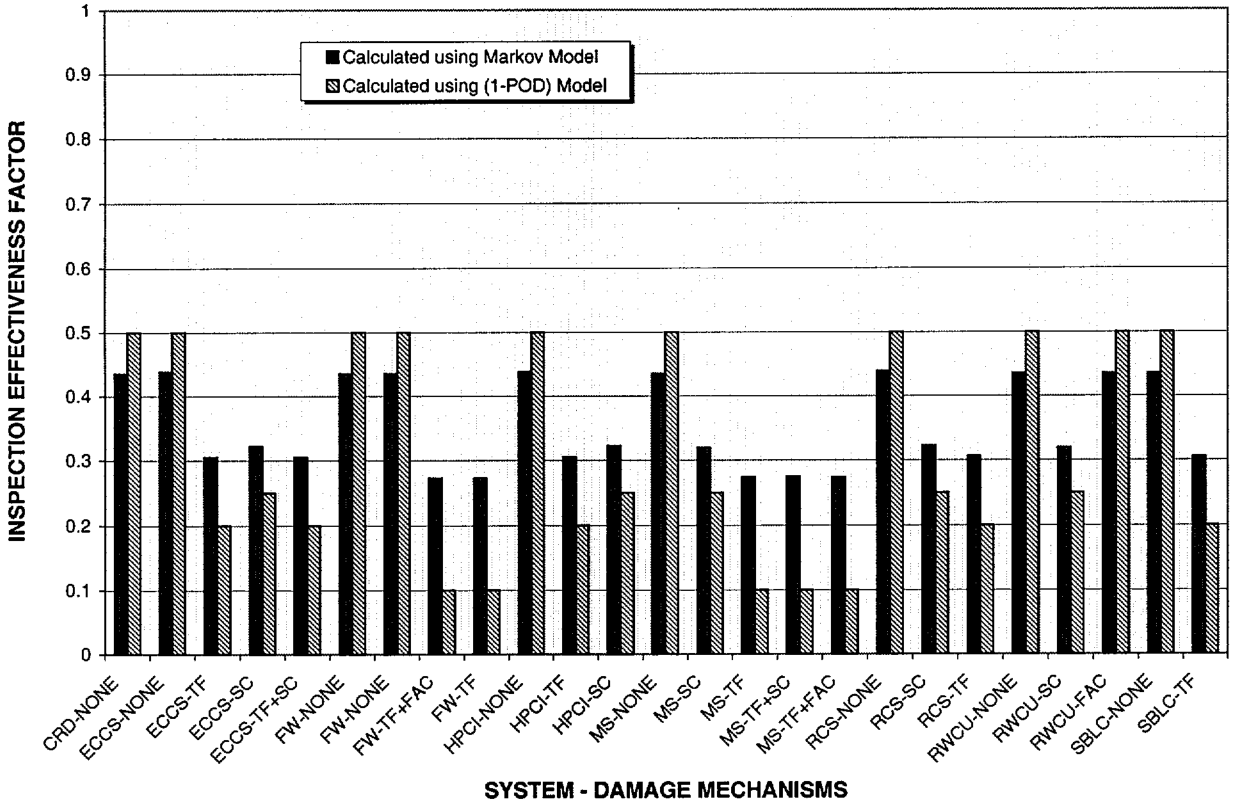


**Figure RAI 9-A Comparison of Inspection Effectiveness Factors for EPRI RI-ISI Exams at QC Units 1 and 2**

According to the ASME Code Section XI, all Class 1 piping systems must be inspected for leaks by performing a system leak test and observing for leaks at least once per refueling cycle. For Class 2 piping the requirement is perform these leak tests once per ISI inspection period. In between these leak tests there are other opportunities to identify leaks via routine plant walkdowns and other test and maintenance activities on the piping systems that occur much more frequently than the ASME Section XI imposed leak tests. The following default values used for all segments in this evaluation for the probability of detecting a leak ($P_{LD}$) and the time interval between opportunities for detecting leaks ($T_{LD}$) are:

$$P_{LD} = 0.90$$

$$T_{LD} = 1.5 \text{ years}$$

The same values are used for both Class 1 and Class 2 segments and were not varied between the Section XI and RI-ISI evaluation cases. Since the Markov model results are not sensitive to variations in this parameter and because the parameter does not differentiate between ASME Section XI and RI-ISI programs, it was not necessary to develop segment dependent inputs for this parameter.

**NRC Question #10:**

Please provide the estimates of the change in core damage frequency (CDF) and large early release frequency (LERF) calculated using the bounding failure frequencies without the IEF.

**EGC Response:**

A simplified and conservative risk impact calculation, not using the Markov model calculation of pipe break frequency, was performed for Quad Cities Units 1 and This calculation was performed using the same approach as was implemented forthe previously approved relief request for South Texas Project which was performed by ERIN. The change in risk for a particular system was calculated using the following:

$$\Delta CDF_j = \sum_i [FR_{i,j} * (SXI_{i,j} - RISI_{i,j}) * CCDP_{i,j}] \qquad (1)$$

where

$\Delta CDF_j$ = Change in CDF for system j
$FR_{i,j}$ = Rupture frequency per element for risk segment i of system j
$SXI_{i,j}$ = Number of Section XI inspection elements for risk segment i of system j
$RISI_{i,j}$ = Number of RISI inspection elements for risk segment i of system j
$CCDP_{i,j}$= Conditional core damage probability given a break in risk segment i of system j

The total change in risk for all systems within the RI-ISI evaluation scope is calculated by summing the changes in risk for each individual system, as follows:

$$\Delta CDF_{TOTAL} = \sum_j \Delta CDF_j \qquad (2)$$

Similar calculations were performed using the CLERP (conditional large early release probability) to determine the change in LERF for each system and the total change in LERF due to implementing the RI-ISI program. The risk impact calculations were also performed excluding the Low risk category welds from the calculation. Results of these calculations are presented in Tables 10A and 10B, for Quad Cities Unit 1 and Unit 2, respectively. Also shown in Table 10A and Table 10B are the results of the Markov model calculation of the change in risk, for comparison purposes.

Using this method to calculate the change in risk requires making several assumptions. Those assumptions are as follows:

- Inspections are 100% successful at finding flaws and preventing ruptures.
- Increased probability of detection (POD) due to inspection for cause is not credited.
- Pipe failure rates and rupture frequencies are constant, not age dependent.

## RESULTS

The results of the Quad Cities 1 risk impact calculation are shown in Table 10A. Even using the simplified risk impact approach and including all of the welds in the RI-ISI scope, none of the systems came close to the change in CDF criterion of 1.0E-07 per system. The largest change in CDF came from the feedwater system, at 8.34E-09. The total change in CDF was 1.27E-08, well below the criterion of risk significance from Regulatory Guide 1.174 of 1.0E-06 for all systems combined. Similarly, the change in LERF values were all well below the criterion of 1.0E-08 per system. Again, the largest change came from the feedwater system, at 2.15E-09. The total change in LERF was 4.63E-09, well below the criterion of risk significance from Regulatory Guide 1.174 of 1.0E-07 for all systems combined.

The results of the Quad Cities 2 risk impact calculation are shown in Table 10B. Even using the simplified risk impact approach and including all of the welds in the RI-ISI scope, none of the systems came close to the change in CDF criterion of 1.0E-07 per system. The largest change in CDF came from the feedwater system, at 4.39E-09. The total change in CDF was 1.01E-08, well below the criterion of risk significance from Regulatory Guide 1.174 of 1.0E-06 for all systems combined. Similarly, the change in LERF values were all well below the criterion of 1.0E-08 per system. Again, the largest change came from the feedwater system, at 1.30E-09. The total change in LERF was 4.48E-09, well below the criterion of risk significance from Regulatory Guide 1.174 of 1.0E-07 for all systems combined.

Compared to the more realistic calculation of risk impact using the Markov model, the simplified method produced changes in CDF for a single system as much as a factor of 3 higher than the Markov model results. The largest differences between the simplified approach and the Markov method are observed in the feedwater system. These differences are mainly due to a single risk segment at each unit with a relatively high CCDP that credited an enhanced POD in the Markov model calculation that is not credited in the simplified approach. The simplified risk impact calculation for other systems results in ΔCDFs and ΔLERFs that are generally less than a factor of 2 higher than the Markov model results.

In preparation of this RAI response, supplements to the Tier 2 documentation were prepared to document these calculations on a segment by segment basis. In most cases, the conservative values are less than a factor of 2 higher than the associated realistic values, but in a few cases, the increase is as much as a factor of 3 or so. Nonetheless, the risk acceptance criteria for all analyzed systems at Quad Cities Units 1 and 2 are still met with a large margin.

These conservative results are regarded as a sensitivity study as they only reflect upper bounds on the expected risk impacts. The results obtained using the Markov model are considered more reasonable and realistic for the following reasons.

- There were many cases in which the effectiveness of the inspection will be increased as a result of the application of the "inspection for cause" principle in which the knowledge of the applicable damage mechanisms and the application of mechanism specific inspection methods provide a reasonable basis to expect enhanced inspection effectiveness. A good example is the case of locations susceptible to thermal fatigue in which the EPRI RI-ISI exams call for an expanded examination volume into the Heat Affected Zone (HAZ) of the weld in comparison with ASME Section X examination requirements. This expanded volume recommendation is based on insights from service experience that indicate the location of cracks in the areas of welds caused by thermal fatigue. These inspection for cause effects are ignored in the bounding evaluations.

- The conservative calculation assumes that all the change in risk in a given risk segment comes from the net change in the number of exams; which implies that there can be no change from redistributing a fixed number of welds. This does not reflect the true philosophy of risk management as expressed in RG 1.178, RG 1.174, or the EPRI Topical Report regarding the balancing of resources away from areas with marginal risk impact toward areas of more significant risk impact.

- The risk impact of changing the inspection strategy of a given weld is one of the factors that was considered in the element selection. If that input to the selection is skewed by conservative assumptions that do not uniformly impact across the elements in the program, the goal of an optimized program is not as well supported in comparison with the case where realistic assumptions are used for all the welds in the examination.

- The inspection effectiveness factors obtained using the Markov model provide a more realistic perspective on the benefits of ISI exams. This permits better tradeoffs in balancing the combined influences of removing exams, redistributing exam locations, and enhancing the effectiveness of exams through the inspection for cause principle.

- This approach of performing a realistic risk impact assessment provides a better basis to normalize risks and risk impacts across different risk informed initiatives such as RI-ISI, RI-IST, and risk informed technical specifications, in contrast to limiting the analysis for RI-ISI to a conservative bounding assessment. If one of these applications uses conservative bounding estimates and the remaining ones use realistic treatment, the balancing of resources expected from risk informed regulation is not as well supported as when all applications aspire for a comparable level of realism.

Table 10A. Comparison of Risk Impact Results for Quad Cities Unit 1

| Quad Cities 1 Risk Impact Report * | | | | | | |
|---|---|---|---|---|---|---|
| System | CDF | | | LERF | | |
| | Conservative Delta CDF for All Welds | Conservative Delta CDF Excluding Low Risk Welds | Realistic Delta CDF using Markov Model | Conservative Delta LERF for All Welds | Conservative Delta LERF Excluding Low Risk Welds | Realistic Delta LERF using Markov Model |
| CRD | 1.29E-10 | 0.00E+00 | 7.29E-11 | 4.30E-11 | 0.00E+00 | 2.43E-11 |
| ECCS | -1.60E-09 | -1.60E-09 | -3.49E-09 | -9.39E-10 | -9.45E-10 | -2.25E-09 |
| FW | 8.34E-09 | 8.34E-09 | 4.04E-09 | 2.15E-09 | 2.15E-09 | 1.06E-09 |
| HPCI | -1.19E-10 | -1.21E-10 | -9.36E-11 | -2.24E-11 | -2.43E-11 | -9.36E-11 |
| MS | 2.56E-09 | 2.21E-09 | 1.55E-09 | 6.47E-10 | 4.42E-10 | 3.87E-10 |
| RCS | 1.49E-09 | 0.00E+00 | 8.35E-10 | 9.30E-10 | 0.00E+00 | 5.22E-10 |
| RWCU | 1.86E-09 | 1.72E-09 | 1.05E-09 | 1.81E-09 | 1.72E-09 | 1.03E-09 |
| SBLC | 1.28E-11 | 0.00E+00 | 7.25E-12 | 1.09E-11 | 0.00E+00 | 6.14E-12 |
| Total | 1.27E-08 | 1.05E-08 | 3.97E-09 | 4.63E-09 | 3.34E-09 | 6.76E-10 |

* Positive values indicate a risk increase while negative values denote a risk decrease

Table 10B. Comparison of Risk Impact Results for Quad Cities Unit 2

| Quad Cities 2 Risk Impact Report * | | | | | | |
|---|---|---|---|---|---|---|
| | CDF | | | LERF | | |
| System | Conservative Delta CDF for All Welds | Conservative Delta CDF Excluding Low Risk Welds | Realistic Delta CDF using Markov Model | Conservative Delta LERF for All Welds | Conservative Delta LERF Excluding Low Risk Welds | Realistic Delta LERF using Markov Model |
| CRD | 1.29E-10 | 0.00E+00 | 7.29E-11 | 4.30E-11 | 0.00E+00 | 2.43E-11 |
| ECCS | -2.01E-09 | -4.71E-10 | -4.30E-09 | -1.21E-09 | -2.96E-10 | -2.67E-09 |
| FW | 4.39E-09 | 4.39E-09 | 1.32E-09 | 1.30E-09 | 1.30E-09 | 4.75E-10 |
| HPCI | -7.18E-11 | -7.49E-11 | -4.57E-11 | -1.23E-11 | -1.50E-11 | -7.96E-12 |
| MS | 3.55E-09 | 3.28E-09 | 2.18E-09 | 8.31E-10 | 6.56E-10 | 5.05E-10 |
| RCS | 1.38E-09 | 0.00E+00 | 7.77E-10 | 8.67E-10 | 0.00E+00 | 4.87E-10 |
| RWCU | 2.68E-09 | 2.58E-09 | 1.51E-09 | 2.64E-09 | 2.58E-09 | 1.50E-09 |
| SBLC | 1.28E-11 | 0.00E+00 | 7.25E-12 | 1.09E-11 | 0.00E+00 | 6.14E-12 |
| Total | 1.01E-08 | 9.70E-09 | 1.52E-09 | 4.48E-09 | 4.23E-09 | 3.13E-10 |

* Positive values indicate a risk increase while negative values denote a risk decrease

**NRC Question #11:**

Page 4 states that, "If no other damage mechanism was identified, the element was removed from the RI-ISI element selection population and retained in the appropriate augmented program." When Section XI inspections for elements removed from the RI-ISI population are discontinued, how is this discontinued inspection reflected in the change in risk calculation? How are the augmented program inspections credited in the RI-ISI inspection program?

**EGC Response:**

Quad Cities Unit 1 has a total of 172 Class 1 IGSCC Category B through G welds. From the 172 Class 1 welds, 127 welds were removed from the RI-ISI element selection population since no other damage mechanism was identified, and 7 welds are categorized as low risk welds and removed from the RI-ISI element selection population. The remaining 38 Class 1 IGSCC Category B through G welds are included in the RI-ISI element selection population. Of the 38 Class 1 welds remaining in the RI-ISI element selection population, 20 welds are selected under the RI-ISI program, therefore are credited in both the RI-ISI and IGSCC programs. When inspections are credited under the RI-ISI and IGSCC programs, all inspection requirements for both programs are met. The Class 1 welds removed from the RI-ISI program continue to be addressed by the IGSCC program.

Quad Cities Unit 2 has a total of 172 Class 1 IGSCC Category B through G welds. From the 172 Class 1 welds, 131 welds were removed from the RI-ISI element selection population since no other damage mechanism was identified, and 9 welds are categorized as low risk welds and removed from the RI-ISI element selection population. The remaining 32 Class 1 IGSCC Category B through G welds are included in the RI-ISI element selection population. Of the 32 Class 1 welds remaining in the RI-ISI element selection population, 20 welds are selected under the RI-ISI program, therefore are credited in both the RI-ISI and IGSCC programs. When inspections are credited under the RI-ISI and IGSCC programs, all inspection requirements for both programs are met. The Class 1 welds removed from the RI-ISI program continue to be addressed by the IGSCC program.

FAC elements which have no other degradation mechanism are modeled and inspected in accordance with the FAC program. Inspection locations within a FAC element are selected in accordance with the FAC program. The extent of examination for selected inspection points is in accordance with Section 4.7, "Flow Accelerated Corrosion" of EPRI TR 112657. Welds identified as having FAC as the only degradation mechanism are removed from the RI-ISI population for element selection. FAC-only welds currently inspected under Section XI will not be selected for inspection under the RI-ISI program, but will continue to be addressed by the FAC program.

Quad Cities 1 has a total of 42 welds identified as having FAC as the only degradation mechanism and QC2 has 39 FAC-only welds. The 42 QC1 and 39 QC2 FAC-only welds were removed from the element selection population and no RI-ISI exams were selected for any of these welds. Quad Cities 1 and Quad Cities 2 each have 21 welds identified as having FAC and at least one other damage mechanism. These welds remained in the element selection population. Of the 21 welds remaining in the population for QC1, 5 Risk Category 1 welds and 1 Risk Category 3 weld were selected for examination under the RI-ISI program. Quad Cities 2 RI-ISI program also selected 5 Risk Category 1 welds and 1 Risk Category 3 weld for examination.

The FAC-only and IGSCC welds that are not included in the selection population for the RI-ISI program are all included in the delta risk calculations. Welds for which Section XI examinations are eliminated are still retained in the delta risk calculation. These welds result in a slight increase in risk and contribute to the overall delta risk that was quantified for the system.

**NRC Question #12:**

Please provide a reference to the version of the probabilistic risk assessment (PRA) used to support the RI-ISI submittal. What are the CDF and the LERF estimates in this version of the PRA?

**EGC Response:**

The Quad Cities PRA models used to support the RI-ISI are documented in the following:

Quad Cities Nuclear Stations 1999 Updated PRA Model, Rev. 0 Calculation #QDC-0200-M-0803

Quad Cities Nuclear Stations 1999 LERF (Large Early Release Frequency) Model, Rev. 0 Calculation #QDC-1600-N-0981

The PRA results for CDF and LERF are identical between Unit 1 and Unit 2 at Quad Cities; CDF is 4.6E-6/yr and LERF is 3.1E-6/yr.

**NRC Question #13:**

The July 1998, staff evaluation report on your IPE noted a concern that your method to estimate common cause factors (CCF) may have undercounted CCFs and that the values developed tended to be less than generic CCF values. Your RI-ISI submittal states that the current PRA, including the CCF analysis, has been upgraded. How was the CCF analysis upgraded?

**EGC Response:**

The Quad Cities common cause failure (CCF) modeling was completely revised for the Quad Cities 1999 PRA Upgrade. The CCF modeling used the Multiple Greek Letter (MGL) methodology. CCF groups were defined according to INEL-94/0064 (December 1995 - draft). (INEL-94/0064 was subsequently finalized as part of NUREG/CR-6268). MGL parameters were based on INEL-94/0064, Vol. 6 data. The Quad Cities CCF evaluation is documented in the "Quad Cities Component Data Notebook, Vol. 2 - Common Cause Data Analysis", Rev. 1, Doc. No. QC PSA-010, dated October 18, 1999.