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April 19, 1991

Dr. Thomas E. Murley, Director
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

ATTN: Document Control Desk

Subject: Quad Cities Nuclear Power Station Units 1
Primary Containment Penetration Bellows Assembly
NRC Docket No. 50-254

Dr. Murley:

During the performance of the recent containment integrated leak rate test, for Quad Cities Unit 1, leakage was identified for penetration X-25 (Drywell Ventilation) due to cracks in the bellows. As a result, Commonwealth Edison has conducted an extensive investigation to identify the cause of the leakage.

The investigation revealed that the cracks in the bellows were caused by transgranular stress corrosion cracking (TGSCC) which has been previously identified as a crack mechanism in bellows that have been replaced at Commonwealth Edison facilities. The leakage rate behavior of X-25 is atypical of previously identified deterioration of bellows assemblies in that leakage increased at a greater rate in a single cycle than previously experienced; however, it is believed that the existing TGSCC mechanism of X-25 was aggravated by maintenance activities in the vicinity of the bellows thereby causing the existing cracks to open. In addition to the metallurgical examination of the bellows, Commonwealth Edison has performed a fracture mechanics evaluation which assesses the structural margin to catastrophic failure of the bellows and a leakage rate evaluation to quantify the leakage from the worst-case crack growth during the next operating cycle.

Attachment A provides a brief discussion of our investigation of the X-25 penetration deterioration. Attachment B provides an overview of the fracture mechanics and leakage rate evaluations. Also enclosed are the calculations for your staff's review.

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Finally, Commonwealth Edison is continuing its investigation of the bellows assembly and is developing a program to monitor bellows assembly performance in light of the findings of the X-25 investigation.

If there are any questions or comments, please contact me at (708)515-7283.

Very Truly Yours,

Rita Stols
Nuclear Licensing Administrator

Attachments: (A) Investigation Overview

(B) Overview of Fracture Mechanics and Leakage Rate Evaluations

Enclosures: (1) Bellows Expansion Joint Design Evaluation, Drywell Penetration X-25, Quad Cities Nuclear Power Station Unit 1 dated March, 1991.

(2) Evaluation of Quad Cities Penetration Bellows Assemblies Leakage Rates, revision O dated March, 1991.

Figures: (1) Integrated Leak Ra e Results Quad Cities Unit 1

(2) Integrated Leak Rate Results Quad Cities Unit 2

cc: A.B. Davis, Region III Administrator
L.N. Olshan, Project Manager, NRR
F.A. Maura, Inspector, Region III
T. Taylor, Senior Resident Inspector, Quad Cities

ATTACHMENT A

Investigation Overview

Background

A Type B test was performed on Drywell Ventilation Penetration X-25 on November 19, 1990. The measured leakage rate was 4.3 scfh. After the local leak rate test was performed, a significant amount of maintenance and new construction work was performed in the area surrounding the bellows. Extensive work was performed on valve 1-1601-23 (located in-line with the bellows) and a new penetration (X-109, Reactor Vessel Level Instrumentation Lines) was installed directly above X-25. After the construction and valve maintenance work was completed, a Type B test was again performed on the X-25 penetration bellows. The new measured leakage rate was 6 scfh. Approximately two days later, the primary containment ILRT was performed. While the containment was at pressure, application of soap solution to the surface of the bellows showed one large crack and over a hundred small indications. The ILRT was successfully completed with the leaking bellows (in its as-found condition). Following the ILRT, a Type B test was performed and the results matched the previous LLRT leakage rate. A soap solution was applied to the bellows during this LLRT and showed only a few small leaks.

Next, a "local" ILRT was performed in an effort to quantify actual leakage from the bellows. A steel plate was welded to the vent line inlet which is located inside the drywell. The bellows were pressurized through a threaded hole in the plate and a leakage rate test was performed on the entire penetration. The soap solution indicated a large leak along with many small leaks which was similar to the ILRT results. A leakage rate of 137 scfh was measured.

With the validity of the Type B tests in question, the Station implemented a method of determining the sensitivity of the LLRT procedure to detect and quantify new cracks. A 0.25" hole was drilled through the two bellows from the outer diameter to the inner diameter in the convolute adjacent to the LLRT taps on the bellows. A Type B test was performed and resulted in a small increase in leakage (to 7 scfh). A second 0.25" hole was drilled through each of the bellows. The subsequent Type B test revealed a leakage of 8 scfh.

The results indicate that the Type B test could identify leakage but could not quantify the extent of that leakage. Commonwealth Edison formally notified the Commission of these findings. (Reference: T.J. Kovach to A.B. Davis letter dated March 27, 1991)

Relevant Design Features

The flexible metallic bellows are constructed with two plies of austenitic type 304 stainless steel that are formed together into cylindrical corrugated bellows elements. This design configuration is typical of bellows penetrations which are utilized for both units. Our investigation, which included discussions with the supplier and examination at Argonne Lab, revealed that the forming process can bring the plies into contact, thereby limiting the flow of the local leak rate test medium (inert gas or air) between the inner and outer plies. The X-25 LLRT and ILRT results suggest that leakage of flexible metallic bellows assembly can be detected; however, the actual leakage cannot be accurately quantified.

Investigation

Data which was obtained through field measurement and examinations at Argonne National Laboratory revealed the existence of the following cracks:

Length	Width	Quantity
1.7"	≤0.010	1
0.5"	≤0.001	3
0.187"	≤0.001	36
0.001	≤0.001	200

Metallurgical examination of the bellows revealed that the crack mechanism was transgranular stress corrosion cracking (TGSCC). This mechasim is consistent with previous bellows assembly deterioration which has occurred at Dresden and Quad Cities.

TGSCC is normally characterized by the slow development and propagation of cracks. The X-25 penetration deterioration is unique in that the bellows exhibited a large increase in leakage during one operating cycle. This significant leakage increase may have occurred as a result of maintenance work associated with the replacement of valve 1-1601-23 which is in-line with the bellow. Valve 1-1601-23 is located approximately 12" from the outboard bellows assembly. During the replacement procedure, excessive force was used to remove the valve; therefore, torsional or translational forces to the penetration may have caused a the existing TGSCC cracks to open. During the examination, the corrosive species, which is responsible for the TGSCC, was identified as chlorides, fluorides and sulfides. The original form of this material could not be determined and the method of substance deposit, therefore, is unknown.

The investigation did not reveal any indication that the bellows deterioration was caused by fatigue failure.

History of Bellows Replacement

Commonwealth Edison has initiated a program of penetration bellows leakage evaluation and replacement at Dresden and Quad Cities Stations. To date, Quad Cities Station has replaced four (4) bellow assemblies (including X-25). These penetration bellows include; Unit 1 penetration X-16A and X-16B (Core Spray) and X-25 (drywell ventilation) and Unit 2 penetration X-16B. Metallurgical examination of Unit 2 penetration X-16B revealed that the deterioration was caused by TGSCC. While no formal examination was performed on Unit 1 X-16A and X-16B, the leakage behavior was similar to X-16B and therefore the cracks are believed to be caused by TGSCC.

Five (5) bellows have been replaced at Dresden. Four of the five replacements were performed as a result of extensive penetration work which was associated with the Recirculation Piping Replacement Project on Unit 3. Penetration bellows assembly X-144 (CRD return line) was permanently removed in 1990 due to TGSCC-induced leakage.

Finally, none of the examinations, which have been performed to date, have detected any evidence of crack growth due to fatigue.

Assessment of Existing Bellows Penetrations

As previously indicated, Commonwealth Edison identified the excessive leakage of the X-25 bellows through the performance of the primary containment ILRT. As part of the evaluation for X-25, Commonwealth Edison reviewed the results of the last five (5) as-left ILRT results to identify any indication of gross leakage from the bellows assemblies. The historical results are provided in Figures 1 and 2. Overall, the ILRT results are stable with no significant deviations identified for either unit (with the exception of the test performed with the leaking X-25 bellows).

To further confirm the acceptable condition of the bellows assemblies, liquid penetrant examinations of six (6) bellows assemblies with known positive leakage (based on LLRT results) were conducted to ensure the absence of cracks on the outer ply of the bellows assembly. In order to maintain primary containment integrity, only one ply of the bellows is required. One bellows assembly has two minor surface indications in a weld (classified as manufacturing defect). The remaining bellows assemblies were free of defects. The examination results, therefore, further confirm that, if TGSCC exists for this population of bellows (which have known leakage), the cracks have not progressed to a through-wall condition nor to the extent which was identified on X-25.

Evaluation of the X-25 as-found condition was determined to be the most limiting case. A review of the size, configuration and design movements of all penetrations indicates that the X-25 bellows is among the population of the most highly stressed bellows. Other bellows included in this population include X-16A and X-16B (which have been previously replaced on Unit 1), X-12 (SDC supply) and X-14 (RWCU suction).

Finally, to ensure that the design function of the bellows remains intact during the operating cycle, Commonwealth Edison has performed a fracture mechanics evaluation for the condition of the X-25 bellows. While fatigue failure was not identified as the cause of the bellows deterioration, the fracture mechanics evaluation reviews the effects of fatigue on the bellows (as well as the effects of TGSCC) to ensure a conservative approach. A leakage rate evaluation was performed to assess the impact of bellows deterioration on the leakage limits and to ensure that leakage limits are not exceeded solely on the basis of bellows deterioration.

ATTACHMENT B

Overview of Fracture Mechanics and Leakage Rate Evaluations

Fracture Mechanics Evaluation

A fracture mechanics evaluation for the X-25 bellows was performed to determine the margin to structural failure as a results of crack propogation due to mechanical fatigue and TGSCC. The fracture mechanics evaluation determined the following parameters:

a. the critical length of an axial through-wall crack which would result in unstable crack growth and thereby resulting in catastrophic failure of the bellows assembly,

b. the number of lateral motion cycles which are required to achieve the critical crack length utilizing conventional austenitic fatigue crack growth rate, and

c. the number of lateral motion cycles which are required to achieve the critical crack length with TGSCC crack growth and conventional austenitic fatigue crack growth rate.

The fracture mechanics evaluation determined the critical length of an axial through-wall crack to be 4.99 inches. The evaluation revealed the following:

a. 363 lateral motion cycles would have to occur in order for the 1.7" axial through-wall crack to reach critical crack length. (A lateral motion cycle is defined as the lateral deflection of the bellows through a range of 0-1.785" which is the design condition associated with a loss-of-coolant accident.)

b. for the crack to grow to critical length under more realistic assumptions (i.e., lateral displacements through a range of 0-1.02"), 2, 771 lateral motion cycles would have to occur in order to achieve critical crack length.

c. for the case of conventional austentic fatigue and TGSCC crack growth, 316 lateral motion cycles would be required to reach the critical crack growth.

The fracture mechanics evaluation demonstrates that substantial structual margin exists to ensure that during the operating cycle, catastrophic failure of the containment penetration bellows assemblies should not occur. During a typical operating cycle, the number of lateral displacements which would occur due to normal thermal cycles was conservatively estimated at approximately forty (40). The calculation demonstrates that approximately 363 lateral motion cycles (under the most conservative design condition) would be required.

The evaluation includes the impact of fatigue on the failure of the bellows. To date, there has been no evidence that the cause of the deterioration is associated with fatigue failure, thereby additional conservatisms are provided in the calculation. The evaluation also examines the potential failure due to TGSCC assuming the X-25 bellows conditions. The evaluation concludes that bellows would remain intact and capable of performing its design function through the operating cycle.

Bellows Leakage Rate Evaluation

The X-25 bellows fracture mechanics evaluation demonstrates that catastrophic failure of the bellows would not occur during the operating cycle due to fatigue and/or TGSCC mechanisms. In addition to the fracture mechanics evaluation, Commonwealth Edison has performed a leakage rate evaluation to quantify the leakage rates from potential bellows assembly cracks. The calculation reviews the leakage from two potential category of cracks. The main objectives of the evaluation are as follows:

a. to quantify the leakage from a "worst case" bellows condition (which duplicates X-25 as-found condition) allowing for TGSCC crack growth during an 18-month operating cycle.

b. to quantify potential leakage from a remaining bellows assembly due to TGSCC during an 18-month operating cycle.

Based on the evaluation of historical ILRT results and the liquid penetrant examinations, none of the bellows assemblies which are currently installed duplicate the condition of X-25. While Commonwealth Edison considers X-25 to be a unique case and the result of maintenance activities, Commonwealth Edison has evaluated X-25 as the worst-case impact to the containment function. The evaluation concludes that the worst-case leakage condition from the bellows alone would not exceed the allowable containment leakage. Similarly, the evaluation concludes that if subsurface flaws were to emerge and grow to 3/16" by the end of the cycle, the predicted leakage from the bellows alone is within containment leakage limits.

Finally, Commonwealth Edison recognizes the limitations of the leakage rate calculation. For example, due to the nature of the crack geometry, size and superposition across a curved surface, it is difficult to determine the actual flow through the flaw. Commonwealth Edison conducted a search to identify available research which could be applied to these calculation; however limited information was available. As a result, the flow model results were correlated to the actual bellows test data by proportioning the model results up to the test data. The leak rate evaluation, therefore, provides an accurate prediction of potential leakage quantities.

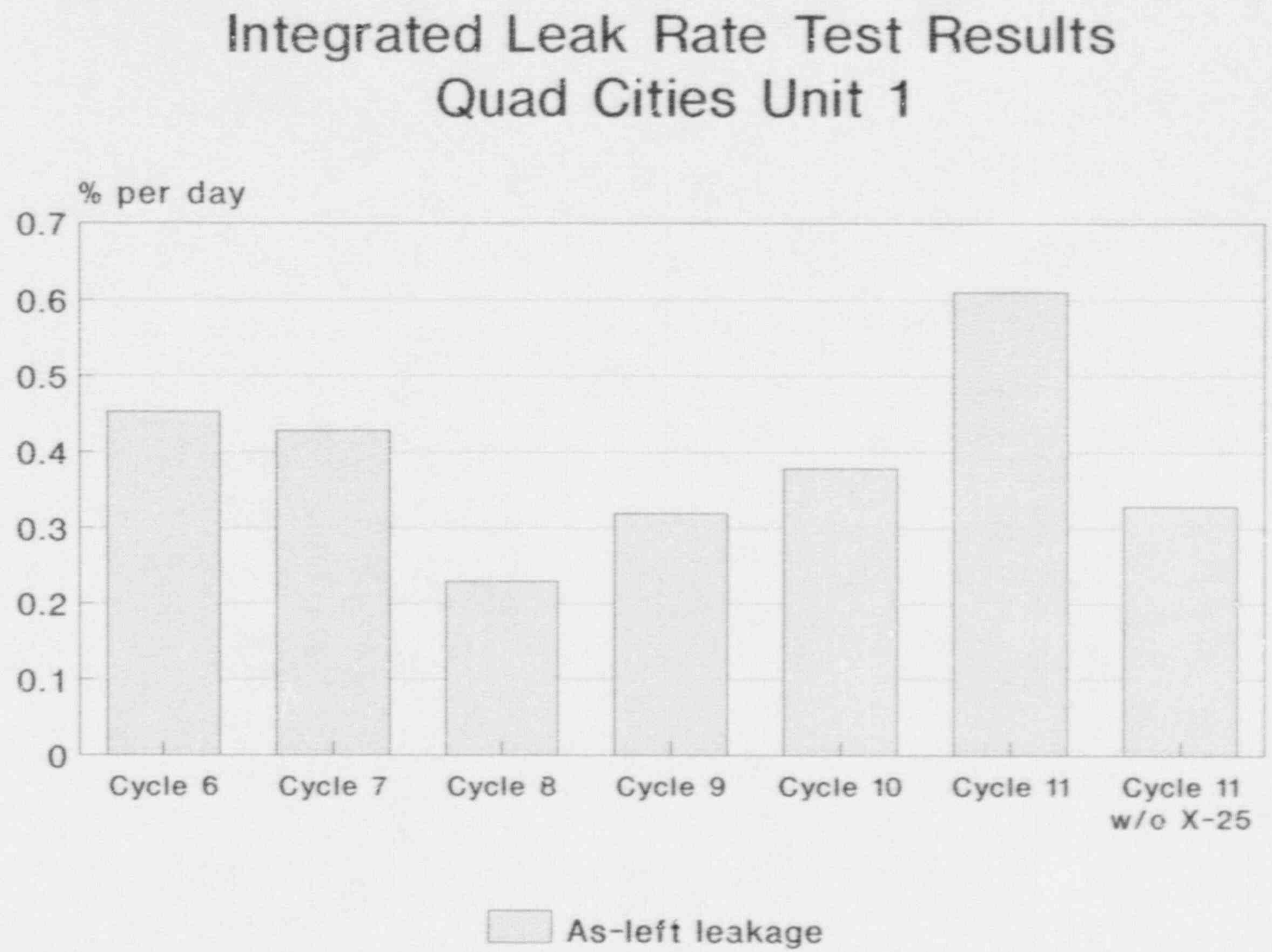
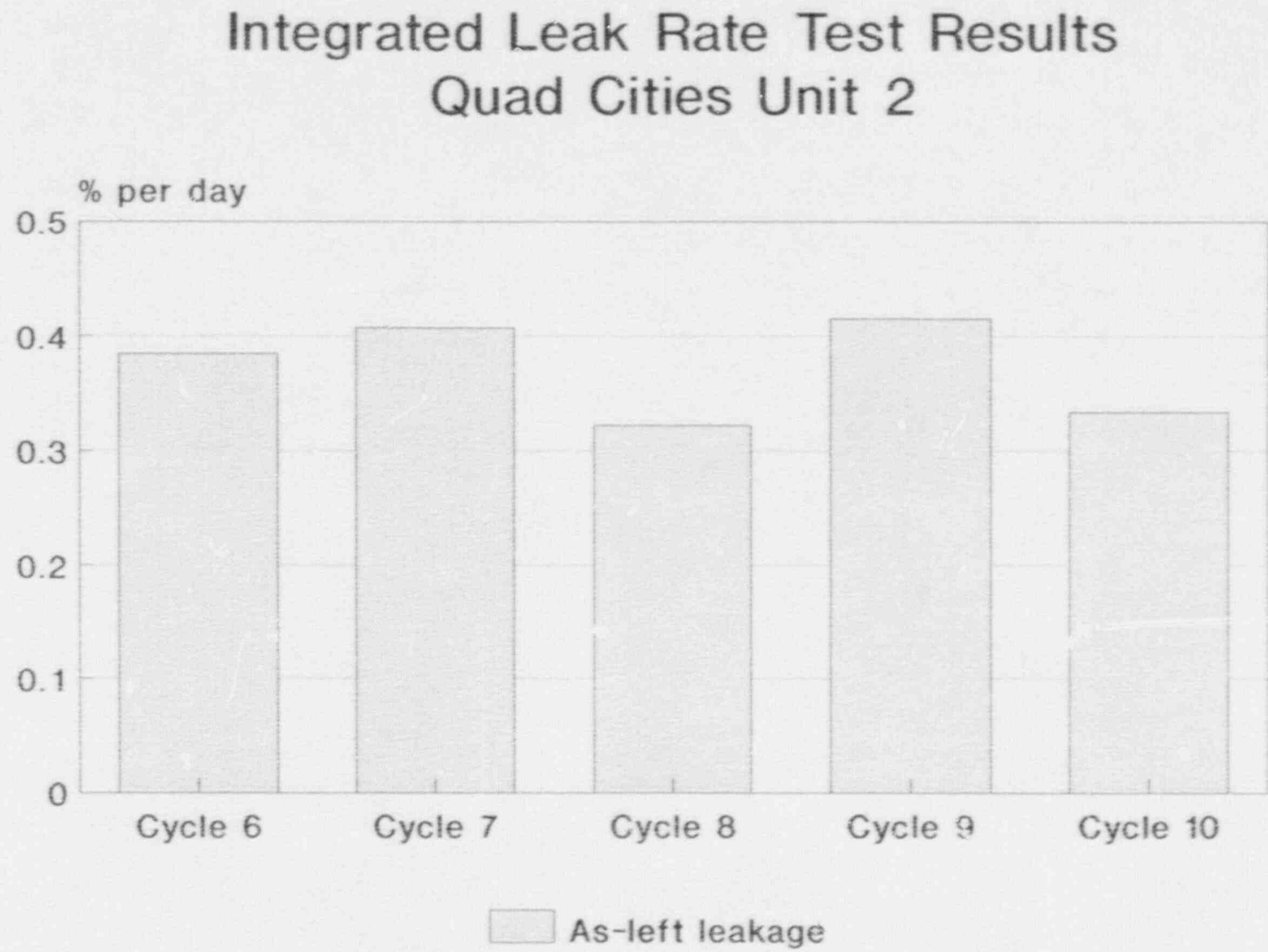

Integrated Leak Rate Test Results
Quad Cities Unit 1
% per day
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Cycle 6
Cycle 7
Cycle 8
Cycle 9
Cycle 10
Cycle 11
Cycle 11 w/o X-25
As-left leakage

Figure 1



Integrated Leak Rate Test Results
Quad Cities Unit 2
% per day
0.5
0.4
0.3
0.2
0.1
0
Cycle 6
Cycle 7
Cycle 8
Cycle 9
Cycle 10
As-left leakage

Figure 2