Evaluation of the Core Shroud Flaws at the H5 Horizontal Weld For Dresden Unit 3 For 20.5 Months of Hot Operation

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ATTACHMENT 1

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1.0 Introduction and Background

In April of 1994 ComEd identified cracks in the circumferential welds of the core shroud at Dresden Unit 3. Throughout the Spring of 1994 ComEd performed various inspections, analyses and safety assessments of the identified weld flaws to determine that adequate margin existed to support the decision to restart the Unit and operate until a permanent repair could be installed at the next refueling outage. The NRC performed a review of the initial submittal documents and issued a Safety Evaluation (Reference 1) on July 21, 1994 providing concurrence that the Unit could be returned to operation for 15 months. In this safety evaluation the NRC requested ComEd to provide additional confirmatory analyses. ComEd performed several additional analyses and submitted additional responses to the NRC throughout the summer and fall of 1994. A comprehensive summary report including the latest analysis results was submitted to the NRC on December 14, 1994 (References 2 and 3). The NRC reviewed the revised submittal documents and issued a Safety Evaluation on January 31, 1995 indicating that the conclusions of the previous Safety Evaluation for Dresden Unit 3 remained valid (Reference 4).

In the fall of 1995, ComEd prepared a revised flaw evaluation for the critical H5 crack location at Dresden Unit 3. The results of this new flaw evaluation were documented in a report (Reference 5) and were submitted to the NRC on November 10, 1995. This assessment requested an extension of the current D3 cycle 14 duration from a maximum of 15 months of operation above cold shutdown to 18.5 months in order to support the rescheduling of the D3R14 refueling outage. This report provided the latest results of the ongoing ComEd efforts to more clearly define the loadings and flaw evaluations associated with the evaluation of the indications identified as part of the core shroud inspections at Dresden Unit 3 in the Spring of 1994. This report also provided a resolution to the uncertainties that were identified during the previous reviews by the NRC staff. This report specifically addressed the structural assessment of the H5 weld location as it was the location with the most significant amount of cracking discovered during the inspections. This report included two methods of evaluating the identified core shroud cracking. The first method was termed the "crack free exclusion zone approach, and was based on evaluating a 1.24" thick remaining ligament. This method was utilized to demonstrate consistency with the initial methodology as outlined in the July 21, 1994 Safety Evaluation (Reference 1). The second method was termed the "UT flaw detection approach" and utilized the qualified UT examination results as the basis for the evaluation. This method represents a more accurate assessment of the actual conditions of the H5 weld. The NRC performed a review of this submittal and issued a Safety Evaluation (Reference 9) authorizing the requested hot operating cycle extension from 15 months to 18.5 months. In this Safety Evaluation (SE) the staff also concluded that the UT flaw detection approach was the appropriate method to evaluate the identified core shroud cracking.

Following NRC approval of the 18.5 month operating period, unplanned events have impacted the Dresden Unit 3 operating cycle. The most significant event was the decision by ComEd to perform a comprehensive review and refurbishment of the safety-related 4KV circuit breakers at Dresden. In addition, ComEd decided to implement modifications to the Unit 3 Low Pressure Coolant Injection room structural steel to restore conformance to Dresden's design and licensing basis. These events, in conjunction with others, have resulted in a shutdown of Dresden Unit 3 which began on June 21, 1996. Start-up of Unit 3 is currently planned for mid September. Although these events and ComEd's actions have enhanced the safety and reliability of Unit 3 operations, they have necessitated a review of the planned Dresden Unit 3 operating cycle. ComEd has concluded that, for meeting the ComEd fuel utilization and materiel condition improvement objectives, operation of Dresden Unit 3 for 20.5 months above cold shutdown during the current operating period is warranted.

The attached report demonstrates that with a ligament excluding the fillet weld and including the bounding analysis parameters, significant operating margins will remain after a 20.5 month operating cycle. This report and its supporting calculations are based on the design input and methodology that was previously approved in the February 8, 1996 SE (Reference 9) and represents a conservative and technically accurate assessment. Section 2 of this report provides a summary of the current Dresden Unit 3 operating status. Section 3 of this report provides a description of the load definition for the critical events. Section 4 provides a summary of the revised flaw evaluations that were performed. A summary and conclusion is provided in Section 5 and a complete list of references is provided in Section 6. The key calculations that will be necessary to substantiate this report are included as attachments in Section 7 of this report.

2.0 Dresden Unit 3 Current Operating Status

Dresden Unit 3 restarted from the D3R13 refueling outage on August 5, 1994. Since the date of this restart through September 5, 1996, the unit has operated for a total of 10,728 hot operating hours. Using a conversion factor of 730 hours per month, the unit has been in cold shutdown for 10.3 months (313 days) and in hot operation for 14.7 months (447 days) resulting in a plant availability of 59%. At the time of this report the unit is in a forced maintenance outage and is scheduled for a mid September, 1996 start up. Provided in Table 2.1 below is a summary of the key primary system water chemistry during hot operation since the identification of the cracks in the core shroud during the D3R13 refueling outage.

Table 2.1 Summary of Reactor Water Chemistry

Water Chemistry Parameters	Dresden Technical Specification Limits	Dresden Cycle 13 Actual Values	EPRI TR-103515 Guidelines
Conductivity	5.0 μS/cm	0.078 μS/cm Average 0.198 μS/cm Maximum	0.3 μS/cm
Chlorides	500 ppb	0.33 ppb Average 3.31 ppb Maximum	5.0 ppb
Sulfates	No Limit	1.48 ppb Average 13.62 ppb Maximum	5.0 ppb
Sum of Cl + SO_4	No Limit	1.82 ppb Average 16.93 ppb Maximum	5.0 ppb

3.0 Load Definition

The original evaluations of the H5 flaws were based on estimated core shroud loads for the RRLB and MSLB events. The revised flaw evaluation submitted on November 10, 1995 (Reference 5) incorporated all of the results from the finalized thermal-hydraulic and seismic analyses. This evaluation utilizes the same loadings and resultant stresses as were used in the previous submittal. Note that in the NRC SE (Reference 9) it was concluded that these loads were appropriately developed and correctly combined in accordance with the UFSAR requirements. Provided in Table 3.1 are the primary membrane and bending stresses under the design basis and beyond design basis load combinations considering all of the applicable loading inputs.

TABLE 3.1 DRESDEN UNIT 3 SUMMARY OF STRESSES AT H5

Loading Combination	Primary Membrane Stresses P_m (psi) (Notes 1 & 2)	Primary Bending Stresses P_b (psi) (Notes 1 & 2)
Normal	+ 49.72	0
OBE	+36.94	- 1228.51
SSE	+ 24.36	- 2457.02
MSLOCA	- 60.91	0
$RRLOCA_{Acoustic}$	+ 49.72	- 86.17
$RRLOCA_{Blowdown}$	+ 49.72	- 79.51
MSLOCA + SSE	- 86.27	- 2457.02
RRLOCA + SSE	+ 24.36	- 2543.19

Notes:

1. Positive sign indicates compression and negative sign indicates tension.
2. The stresses indicated are based on the plate wall thickness without taking into consideration the existing fillet weld.

4.0 Structural Margin Assessment

The structural margin assessment is based on the same type of limit load evaluations and methodology as was used for the previous core shroud assessments and directly follows the BWRVIP guidance for flaw evaluations (References 12 and 13). Table 4.1 provides a summary of the compliance with the BWRVIP Inspection and Assessment criteria. The UT flaw detection approach utilizes a limit load analysis of the sections of the weld that were found to be unflawed (all other sections are conservatively ignored). The crack growth rate used for these flaw evaluations is based on the NUREG-0313 bounding crack growth rate of 5×10^{-5} inches/hour (Reference 14). This crack growth rate is intended to be a bounding value that covers both intergranular stress corrosion cracking (IGSCC) and irradiation assisted stress corrosion cracking (IASCC).

Table 4.1 Summary of Compliance With BWRVIP Inspection and Assessment Criteria

Inspection and Flaw Assessment Criteria	BWRVIP Approach	UT Flaw Detection Approach
Analysis Method	Use Limit Load, LEFM or EPFM Where Appropriate	Satisfied, Used Limit Load Based on Low Fluence Levels
Inspection Uncertainty • Depth • Length	Use Factors to Reduce Ligament Based on Uncertainty	Satisfied, Deducted 0.3" for near surface flaw depth and 0.4" from each end for Inspection Uncertainty
Flaw Separation	Account for Potential Overlap of Adjacent Flaws	Satisfied, Neglected Any Areas With Detected Flaws and Included Proximity Rules
Qualified Inspection Techniques	Use Qualified UT or VT Techniques	Satisfied, Used Both Qualified UT and VT

4.1 Determination of Structural Margin

The structural margin assessment is based on the revised design inputs as defined in the November 10, 1995 submittal (Reference 5) and thus reflects the results of all currently available design inputs and industry information.

This analysis uses the results of the UT examinations (see Table 4.2) without taking any credit for the depth sizing, and is a bounding conservative approach as only the portions of the weld that were UT examined are considered (see Figure 4.1). The assumption that all areas not examined with UT are flawed through wall introduces a significant amount of conservatism. This approach is based on the methodology as defined in the BWRVIP "Core Shroud Inspection and Flaw Evaluation Guidelines" (Reference 13). A 0.3" near surface flaw has been assumed for all areas that were examined by UT and found to be unflawed. This 0.3" reduction bounds the largest undetected near surface flaw at both Dresden Unit 3 and Quad Cities Unit 1 which was revealed by boat samples (i.e., 0.285"). A 0.4" reduction has been taken from the start and stop of the unflawed ligament to account for the BWRVIP defined inspection uncertainty factor for single placement with UT examination performed from both sides of the weld. The following conservative assumptions were used as the basic inputs to the limit load analysis performed:

1. All flaw indications identified in the H-5 weld were assumed to be through-wall cracks.
2. All areas in the H-5 weld that were inaccessible for examination with UT have been conservatively assumed to contain through-wall flaws.
3. Areas that were examined with UT, and in which no recordable indications were identified, were assumed to have a near surface flaw depth of 0.3 inches.
4. The assumed through-wall flaws were grown circumferentially, and the assumed near surface flaws were grown circumferentially and in depth using a bounding crack growth rate of 5×10^{-5} inches/hour.
5. The lengths of the unflawed ligaments were reduced by 0.4" from each end to account for the inspection uncertainty.
6. The additional structural capacity of the H-5 fillet welds was conservatively ignored, resulting in a thickness of 2.0".

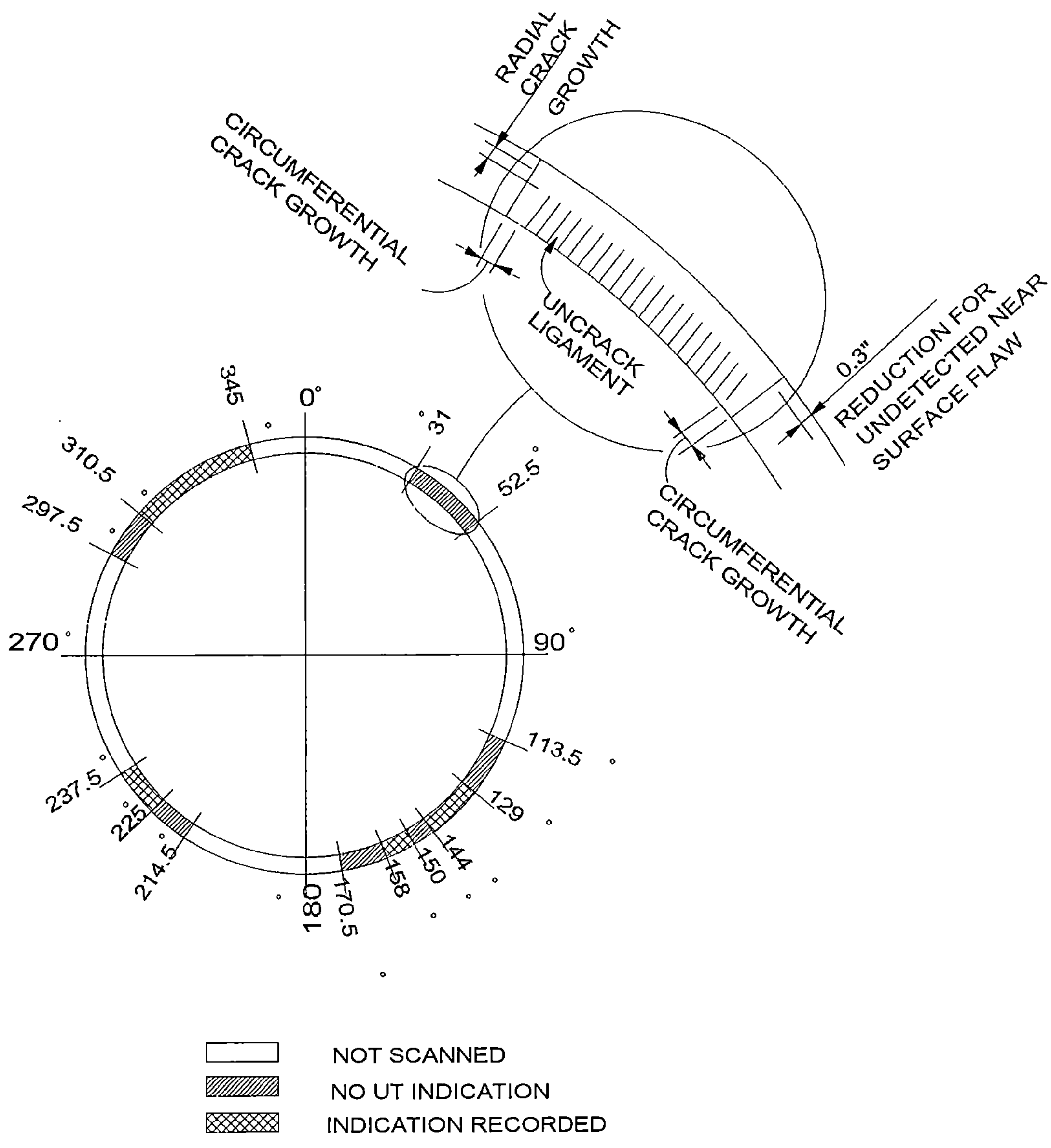

FIGURE 4.1: THE RESULTS OF THE H5 UT EXAMINATION FOR DRESDEN UNIT 3 CORE SHROUD

TABLE 4.2 SUMMARY OF THE RESULTS OF THE H5 UT EXAMINATION

Area (Note 1)	Flaw Length	Flaw Size Assumed for Analysis Purposes
0° - 31°	Not Scanned	Through Wall
31° -52.5°	No Recordable Indications	0.3"
52.5° - 113.5°	Not Scanned	Through Wall
113.5° - 129°	No Recordable Indications	0.3"
129° - 144°	Indications Recorded	Through Wall
144° - 150°	No Recordable Indications	0.3"
150° - 158°	Indications Recorded	Through Wall
158° - 170.5°	No Recordable Indications	0.3"
170.5° - 214.5°	Not Scanned	Through Wall
214.5° - 225°	No Recordable Indications	0.3"
225° - 237.5°	Indications Recorded	Through Wall
237.5° - 297.5°	Not Scanned	Through Wall
297.5° - 310.5°	No Recordable Indications	0.3"
310.5° - 345°	Indications Recorded	Through Wall
345° - 360°	Not Scanned	Through Wall

Note:

1. Azimuthal locations shown are the direct UT results and thus do not reflect the reductions made to account for circumferential crack growth or inspection uncertainty. The values of unflawed ligament used in calculating the remaining structural margin were reduced to account for crack growth and inspection uncertainty.

The amount of unflawed material as defined based on the above criteria, was reduced by a projected 20.5-month crack growth (14,965 hours) to establish the remaining ligament at the end of the operating cycle. The bounding crack growth rate of 5×10^{-5}

inches/hour was used and the results of the limit load analysis for all critical loading conditions are summarized in Table 4.3.

TABLE 4.3 DRESDEN UNIT 3 STRUCTURAL MARGIN RESULTS USING UT FOR FLAW DETECTION, A 2.0" THICKNESS AND A 0.3" MAXIMUM UNDETECTED FLAW

Loading Case	ASME Defined Safety Factor	Calculated Safety Factor At End of 20.5 Months[1&2]	Time Until Allowable Depth is Reached (Hours)	Time Until Allowable Depth is Reached (Months)
OBE	2.77	3.78	19710	27.0
SSE	1.39	1.89	19710	27.0
MSLOCA	1.39	75.95	33398	45.75
RRLOCA	1.39	53.87	33398	45.75
MSLOCA + SSE	1.39	1.83	19163	26.25
RRLOCA + SSE	1.39	1.83	19163	26.25

Notes:

1. Calculated values are based on a crack growth rate of 5×10^{-5} in./hr. for a 20.5 month operating cycle, resulting in a crack growth length of 0.748" (subtracted from each end and radially) and a final flaw depth of 1.252".
2. The Safety Factor is the value calculated per the limit load analysis based on the 2.00" material thickness less the final flaw depth (including a 20.5-month crack growth cycle).

5.0 Summary and Conclusions

In the previous submittals, ComEd provided a structural margin assessment of the H5 flaw based on a limit load analysis of the remaining ligament as established using the "Crack Free Exclusion Zone" approach as well as the "UT Flaw Detection Approach". Based on the previous NRC staff reviews as well as current BWRVIP guidance the crack free exclusion zone approach was utilized for this evaluation. In the assessment provided in Section 4, it was demonstrated that with a ligament excluding the fillet weld and including the bounding analysis parameters, a significant margin of safety will remain after a 20.5 month operating cycle.

The methodology and results of the November 10, 1995 revised flaw evaluation (Reference 5) were reviewed by the staff and found to be conservative and appropriate (Reference 9). This assessment utilizing the Dresden plant specific revised loading and key design input parameters satisfactorily resolves the open items from Reference 1. This same methodology and acceptance criteria has been utilized in this flaw evaluation with the only change being the increase in the operating cycle from 18.5 to 20.5 months. As noted in ComEd's previous flaw evaluation (Reference 5, page 30), the UT flaw detection approach is a conservative and technically acceptable methodology for the assessment of core shroud flaws.

This evaluation uses a limit load analysis of the portion of the weld that was demonstrated by UT to be free of flaws. This approach is conservative as all uninspected areas were assumed to have through-wall flaws. This UT Flaw Detection Approach is consistent with the BWRVIP criteria (Reference 13) and thus represents the most current information regarding flaw assessment. Using the bounding conservative crack growth rate of 5×10^{-5} inches per hour and without consideration of the fillet weld, a minimum of 20.5 months of operating margin exists considering all design basis and beyond design basis load combinations.

<u>Conclusions</u>

The methodology used to determine the remaining ligament size using the UT Flaw Detection Approach provides the most accurate assessment of the actual conditions. The conservative approach taken to account for near field limitations of the UT examination results and the inspection uncertainty provides a significant margin of safety on the sizing of the ligament. With consideration of this information, and the knowledge that a portion of the weld area was not inspected (i.e., assumed to be fully cracked), ComEd believes that the UT Flaw Detection Approach is an accurate method to define the remaining structural margin. Table 4.3 provides a summary of the structural margin assessment for the governing design basis and beyond design basis loading cases.

For Design Basis Load combinations, a safety factor of 1.89 (versus the 1.39 ASME Code requirement) exists for a 20.5 month operating cycle. For beyond design basis loading conditions, a 1.83 safety factor exists. Considering these results for the conservative lower bound limits using the most limiting input parameters and analysis approaches, ComEd concludes that safe operation of Dresden Unit 3 for 20.5 months can be achieved while maintaining a significant margin of safety.

6.0 References

1. NRC Safety Evaluation for Dresden Unit 3 and Quad Cities Unit 1, dated July 21, 1994.

2. ComEd Letter, P. Piet to the U.S. NRC Document Control Desk, Subject- Response to NRC request for additional information concerning Generic Letter 94-03, Dated December 14, 1994, Attachment D -"Final Evaluation of the Core Shroud Flaws at the H5 Horizontal Weld for Dresden Unit 3", Revision 0.

3. ComEd Letter, P. Piet to the U.S. NRC Document Control Desk, Subject- Response to NRC request for additional information concerning Generic Letter 94-03, Dated December 14, 1994, Attachment B -"Safety Assessment of Horizontal Core Shroud Welds H1 Through H7 for Cycle 14 Operation of Dresden Unit 2", Revision 0.

4. NRC Safety Evaluation for Dresden Units 2 and 3 and Quad Cities Units 1 and 2, dated January 31, 1995.

5. ComEd Letter (Bob Rybak) to the NRC Document Control Desk, "Extension of the Operating Period for Dresden Unit 3 Due to the Core Shroud Cracking Issue", dated November 10, 1995.

6. ComEd letter (M. Lyster) to the NRC (W. Russell), "Dresden Nuclear Power Station Units 2 and 3, Quad Cities Nuclear Power Station Units 1 and 2, Response to Request for Additional Information (RAI)", dated June 6, 1994.

7. ComEd letter (M. Lyster) to the NRC (W. Russell), "Analytical Evaluation of Core Shroud Cracking Identified at Dresden Nuclear Power Station Unit 3", dated June 13, 1994.

8. ComEd (P. Piet) letter to the NRC (W. Russell), "ComEd Response to Request for Additional Information Regarding NRC Generic Letter 94-03", dated October 7, 1994 and ComEd (P. Piet) letter to the NRC (W. Russell), "ComEd Additional Response to Request for Additional Information Regarding NRC Generic Letter 94-03", dated October 13, 1994.

9. NRC Safety Evaluation for Dresden Unit 3, dated February 8, 1996.

10. GENE-523-A100-0995, Rev. 0, "Analyses of the Dresden and Quad Cities Shroud Repair Seismic Design With Improved Tie Rod and Shroud Weld Crack Equivalent Rotational Stiffness".

11. ComEd Report, "Evaluation of the Discrepancy in the RPV Internals Seismic Analysis, Dresden Units 2 and 3 and Quad Cities Units 1 and 2", October 25, 1995

12. BWRVIP "Core Shroud NDE Uncertainty and Procedure Standard", November 21, 1994.

13. General Electric Company Report GENE-523-0894, Rev. 0, DRF 137-0010-07, "BWR Core Shroud Inspection and Flaw Evaluation Guidelines", dated September 1994.

14. NUREG-0313, "Technical Report on Material Selection & Processing Guidelines for BWR Coolant Pressure Boundary Piping", Revision 1, dated July 1980.

15. EPRI Topical Report TR-103515, Project 2493, "BWR Water Chemistry Guidelines -- 1993 Revision, Normal and Hydrogen Water Chemistry", Electric Power Research Institute. BWR Water Chemistry Guidelines Revision Committee, dated February 1994.

7.0 Attachments

7.1 Calculation No. 9389-64-DQ, "Core Shroud/Reactor Internals", Dresden and Quad Cities, Section 31.