UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

SUPPLEMENTAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO CORE SHROUD CRACKING

COMMONWEALTH EDISON COMPNAY

AND

IOWA-ILLINOIS GAS AND ELECTRIC COMPANY

DRESDEN NUCLEAR POWER STATION, UNIT 3

QUAD CITIES NUCLEAR POWER STATION, UNIT 1

DOCKET NOS. 50-249 AND 50-254

1.0 INTRODUCTION

During the spring of 1994, the Commonwealth Edison Company (ComEd, the licensee) discovered a significant degree of cracking in the circumferential welds in the core shrouds of the Dresden, Unit 3, and Quad Cities, Unit 1, nuclear facilities. These cracks were discovered as part of the licensee's scheduled refueling outage activities for the plants. Due to the severity of the cracking (360° at shroud weld location H5), ComEd submitted its safety analyses and flaw evaluations to the NRC on June 13, 1994. The licensee's submittal of June 13, 1994, was supplemented with additional information in numerous responses to the staff during the months of June and July 1994.

On July 21, 1994, the NRC staff issued its safety evaluation (SE) regarding the structural integrity of the core shrouds at Dresden, Unit 3, and Quad Cities, Unit 1. In Section 3.0 of our SE of July 21, 1994, the staff identified several uncertainties in the licensee's analyses:

- uncertainties in the sizing of the relevant flaw indications at the H5 welds;
- loading uncertainties in the licensee's recirculation line break analysis; and
- uncertainties in the degree of shroud movement under postulated accident loads assuming a complete failure of the H5 weld.

The staff's independent evaluations of the cracking in the Dresden, Unit 3, and Quad Cities, Unit 1, shrouds were based on a number of conservative

Enclosure

assumptions which were used to account for the uncertainties identified in the licensee's flaw evaluations and safety analyses. However, the NRC requested that ComEd perform and provide the following confirmatory analyses in order to address these uncertainties:

- a computerized 3-dimensional asymmetric depressurization analysis for the recirculation line break, including assumptions and entry level conditions;

- the WHAM calculations for the recirculation line break, including assumptions and entry level conditions; and

- a detailed analysis of shroud movement, assuming a 360° through-wall crack, following postulated events, including all assumptions, entry level conditions, calculational techniques, and conservatisms. For the evaluation of seismic consideration, the analysis was to be based on the most limiting seismic input motion (in consideration of the response spectra of Golden Gate Park, El Centro, and Housner).

The staff requested that these confirmatory analyses be submitted to the NRC by December 15, 1994. The staff also requested additional information in the "Request for Additional Information [RAI] Concerning Generic Letter 94-03, 'Intergranular Stress Corrosion Cracking of Core Shrouds in Boiling Water Reactors'," dated November 14, 1994. ComEd responded to these RAIs in letters dated September 2, November 15, and December 14, 1994. The following evaluation provides the staff's assessment of the licensee's submittals of September 2, November 15, and December 14, 1994.

2.0 EVALUATION

2.1 Flaw Evaluations: Summary of the Staff SE of July 21, 1994

On July 21, 1994, the staff issued its SE on the structural integrity of the Dresden, Unit 3, and Quad Cities, Unit 1, core shrouds. The staff used the status of the H5 shroud welds as the bounding cases for performing its independent flaw evaluations (limit load analyses) of the Dresden, Unit 3, and Quad Cities, Unit 1, core shrouds. The following items provide a summary of the staff's conservative assumptions for its analyses.

- The flaw indications at the Dresden, Unit 3, and Quad Cities, Unit 1, H5 welds were assumed to be 360° circumferential cracks.

- A bounding remaining ligament of 0.12 inch, the calculated value from the Quad Cities, Unit 1, analysis, was used.

- Crack depths were adjusted by 0.3 inch to account for uncertainties in nondestructive examination (NDE) measurements and instrument positioning. This resulted in a crack depth of 1.3 inches. This depth was assumed to be indicative of the depth of the H5 flaw indications.

This depth bounded the worst-case depth determined by the licensee (i.e., 1.24 inches).

- A bounding crack growth rate of $5x10^{-5}$ in./hr was used to account for crack growth of the indication during the next operating cycle. This bounding crack growth rate has been used by the NRC in the absence of any existing industry data that could be used to qualify less conservative crack growth rates (slower rates).

- No credit for the fillet welds at the H5 locations was used. This conservatively bounds the thickness of the shroud to a value of 2 inches.

Using the conservative assumptions above as the bases for performing the independent analysis, the staff concluded in the SE of July 21, 1994, that the Dresden, Unit 3, and Quad Cities, Unit 1, core shrouds would have sufficient remaining structural ligament for a total of 15 months of operation above cold shutdown.

2.2 Flaw Evaluations: ComEd Submittal of December 14, 1994

In the submittal of December 14, 1994, ComEd provided a summary of the core shroud loads at each horizontal weld location, H1 through H8, for the Dresden, Unit 3, and Quad Cities, Unit 1. These loads include the dead loads, buoyancy forces, normal, upset, and faulted pressure differential loads, the operating basis earthquake (OBE), and safe shutdown earthquake (SSE) loads. These loading conditions for the Dresden, Unit 3, and Quad Cities, Unit 1, core shrouds are listed in Appendices D and E to the ComEd response of December 14, 1994, respectively.

The staff noted that ComEd's submittal of December 14, 1994 amended a number of basic loading conditions that were submitted earlier in July 1994. These amended loads decreased dead weights and buoyancy forces by factors in the range of 2.0-4.0, and increased the acoustic loads by approximately a factor of 3. By conference call with ComEd on June 20, 1995, the staff asked ComEd to discuss its basis for using reduced dead weight and buoyancy forces in its flaw evaluations. ComEd indicated that the previous loading analyses by the General Electric Company (GE) included contributions to the core shroud dead weights from shipping weights and seismic hydrodynamic forces. ComEd also stated that in the previous analysis the buoyancy forces were overestimated since they included the entire volume of the core shroud in the calculations. ComEd stated during the conversation that a re-analysis by GE concluded that these contributions to the dead weight and buoyancy forces were overly conservative and did not give a realistic account of the true core shroud dead weight and buoyancy forces. GE's basis for this was that the shipping weights would have been removed from the core shroud segments prior to installation of the shrouds into the plants. ComEd stated that the weight of the circulating water should be considered only in the seismic analysis. The staff determined that ComEd's basis for using reduced loads in the Dresden, Unit 3, and Quad Cities, Unit 1, flaw evaluations and safety assessments was reasonable.

The staff reviewed the magnitude of the loads used to calculate the primary membrane and primary bending stresses under the design-basis and beyond design-basis load combinations, including the supporting calculations. These calculations have been performed in accordance with the guidance provided in the BWRVIP "Load Definition Guidance." Based on its review, the staff finds the calculations acceptable.

The staff performed an independent flaw evaluation of the Dresden, Unit 3, and Quad Cities, Unit 1, H5 core shroud welds. The staff based its evaluation on the following conservative conditions:

- Loading conditions used in both the Dresden, Unit 3, and Quad Cities, Unit 1, evaluations were conservatively bounded by the seismic loading conditions for the Quad Cities, Unit 1, plant.

- Reduced dead weight and buoyancy forces were used for the loading combinations. These reduced forces lowered the loading combinations that were previously evaluated by factors in the range of 2.0-4.0.

- The flaw indications at the Dresden, Unit 3, and Quad Cities, Unit 1, H5 welds were assumed to be 360° circumferential cracks.

- Crack depths were adjusted by 0.3 inch to account for uncertainties in NDE measurements and instrument positioning. This resulted in a crack depth of 1.3 inches. This depth was assumed to be indicative of the depth of the H5 flaw indications. This depth bounded the worst-case depth determined by the licensee (i.e., 1.24 inch).

- A bounding crack growth rate of 5×10^{-5} in./hr was used to account for crack growth of the indication during the next operating cycle. This bounding crack growth rate has been used by the NRC in the absence of any existing industry data that could be used to qualify less conservative crack growth rates (slower rates).

- No credit for the fillet welds at the H5 locations was used. This conservatively bounds the thickness of the shroud to a value of 2 inches.

These conditions are consistent with the staff's method of performing its independent flaw evaluation in the July 21, 1994, SE. The staff determined that the amended loading conditions would not cause any results that would make the staff's previous assessment nonconservative or change any of the staff's conclusions in the SE of July 21, 1994.

2.3 Systems Assessment: Recirculation Line Break Blowdown Loads

For the reactor recirculation line break (RLB) loss-of-coolant accident (LOCA), the blowdown and acoustic loads associated with the RLB have been calculated. As stated in the staff's SE of July 21, 1994, the staff found that there was significant uncertainty with the RLB blowdown loads calculated

using potential flow theory and concluded that the blowdown loads were not conservative based on the licensee's June 13, 1994, submittal. A scoping calculation utilizing TRAC was performed by the staff which provided loads and tipping moments that were approximately twice as large as the loads calculated by the licensee in the original submittal of June 13, 1994.

Based on this conclusion, the licensee provided a computerized 3-dimensional asymmetrical depressurization analysis for the RLB in its letter of September 2, 1994. The licensee used a TRACG calculation to evaluate the blowdown loads. The most important phenomena in determining the blowdown loads are single-phase pressure drops and the break flow. The calculations used 120% of the nominal break flow which effectively multiplies the nominal load by 1.44. The licensee also performed a nodalization sensitivity study and used conservative loss coefficients to model the jet pumps. The behavior of the RLB is generally consistent with experimental integral facility test data and the independent assessment of the blowdown loads calculated by the NRC staff. Therefore, the staff concludes that the RLB blowdown loads calculated in the September 2, 1994 submittal are acceptable.

2.4 Systems Assessment: WHAM Calculations For the Recirculation Line Break

As stated in our SE of July 21, 1994, the acoustic loads provided by ComEd are calculated by the WHAM computer code and backed up by several different hand calculations to conclude that the short duration acoustic load from the RLB event would result in minimal movement of the shroud in the event of a postulated 360° through-wall crack. In the SE, the staff concurred with the licensee that the acoustic loads need not be included in determining the structural response of the shroud even though the WHAM models and assumptions were not provided to the staff. However, the staff requested that the licensee provide the WHAM models in order to validate the magnitude of the acoustic loads since these loads may be pertinent for other structural evaluations such as permanent repair options.

Since the issuance of the July 21, 1994, SE, ComEd has submitted its proposed core shroud repair for Dresden, Units 2 and 3, and Quad Cities, Units 1 and 2, to the staff. The staff issued the "Quad Cities Nuclear Power Station, Units 1 and 2, Safety Evaluation Regarding Core Shroud Repair," on June 8, 1995. In that SE, the staff evaluated ComEd's analysis of the dynamic nature of the RLB, the design-basis earthquake, and the main steam line break (MSLB) LOCA loads on the repaired core shroud structure. The licensee demonstrated that the RLB LOCA lateral loading fluctuates with time, but the initial acoustic loading has an input frequency much greater than the shroud frequency content such that there is very little response due to the initial acoustic loading. Additionally, ComEd determined that the portion of the RLB loading following the acoustic portion is relatively constant which would result in a static load with no amplification, and that the RLB loads were bounded by the MSLB loads for the design of the stabilizers. Based on this analysis, the staff concluded that the WHAM models and assumptions were not required to validate the magnitude of the acoustic loads.

2.5 Systems Assessment: Main Steam Line Break TRACG Analysis

The MSLB LOCA results in the most limiting reactor vessel depressurization and yields the largest vertical pressure differences. This large upward load on the shroud could impact the ability of the control rods to insert and the ability of the core spray system to perform its safety function, if upward shroud motion occurred. The staff has found that uncertainties exist in the calculation of the differential pressures (dP) due to break flow, two-phase losses, and the TRACG separator model. During the October 14, 1994, meeting between ComEd and the NRC, the staff requested ComEd to provide the MSLB TRACG analysis and its effect on the core shroud. Specifically, the staff requested that the following information be provided:

1. All assumptions used in the calculations.

2. Entry level conditions.

3. Correlations to other calculation techniques and the justification for their use for the plant-specific calculation for Dresden and Quad Cities.

4. Conservatism used in the calculations.

5. Identify all uncertainties and inaccuracies in the TRACG calculation.

The licensee provided the results, including items 1 through 4, of the TRACG analysis for the MSLB in its letter of November 15, 1994. Since the licensee did not fully address item number 5, the staff performed a confirmatory limit load analysis to demonstrate structural integrity of the welds for the 15 months of operation above cold shutdown. The staff's analysis confirmed that acceptable margin existed such that upward shroud motion is not expected during an MSLB LOCA. The staff also notes that the frequency of the MSLB is extremely low. Based on these findings, the staff confirms that operation of Dresden, Unit 3, and Quad Cities, Unit 1, for 15 months above cold shutdown is acceptable.

3.0 CONCLUSION

The staff has performed an independent re-analysis of the loading conditions and flaw evaluations regarding the Dresden, Unit 3, and Quad Cities, Unit 1, core shrouds. The staff has determined that the amended loads are acceptable and consistent with previous loading methodology accepted by the staff. Furthermore, the staff has determined that the amended loads will not result in any assessments that will necessitate the staff to amend its analyses or change the conclusions as stated in the SE of July 21, 1994.

The staff has also evaluated the licensee's response to the staff's RAIs and open items from the July 21, 1994, SE. The licensee adequately addressed the staff's concerns. The staff concluded that the licensee's analyses were consistent with experimental integral facility test data and the staff's

confirmatory analyses and within the allowable ASME Code margins. Therefore, the staff has determined the conclusions in the July 21, 1994, SE remain valid and has concluded that operation of Dresden, Unit 3, and Quad Cities, Unit 1, for 15 months above cold shutdown is still acceptable.

Principal Contributors: J. Medoff, NRR
K. Kavanagh, NRR
J. Rajan, NRR

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