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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO CORE SHROUD CRACKING

COMMONWEALTH EDISON COMPANY

DRESDEN NUCLEAR POWER STATION, UNIT 3

DOCKET NO. 50-249

1.0 INTRODUCTION

Commonwealth Edison Company (ComEd, the licensee) identified cracks in the circumferential welds of the core shrouds at Dresden, Unit 3, and Quad Cities, Unit 1, in April 1994. The staff performed a review of the initial submittal documents and issued a safety evaluation (SE) regarding these cracks on July 21, 1994. In the conclusion of the SE, the staff approved operation of Dresden, Unit 3, and Quad Cities, Unit 1, for a total of 15 months, commencing from the initial restart of the units out of their respective refueling outages. However, in the July 21, 1994, SE, the staff noted several areas where uncertainties existed and requested that ComEd provide confirmatory analyses to verify its conclusions. ComEd submitted the confirmatory analysis results on December 14, 1994. The staff issued an SE regarding these results on August 16, 1995, indicating that the conclusions of the previous SE for Dresden, Unit 3, remained valid.

Subsequently, in ComEd's submittal of November 10, 1995, ComEd requested an extension of the operating period from 15 months to 18.5 months due to changes in the current refueling outage start dates. The staff reviewed the loads and load combinations that were used in the calculation of the required ligament at the critical weld locations and the required factors of safety for the proposed 18.5-month cycle. The only loads that are different from the previous submittals are the seismic loads. During the review of the seismic analysis for the Quad Cities, Units 1 and 2, shroud repair hardware, ComEd discovered a discrepancy in the nodal mass of the seismic model. This error also had an impact on loads used in the previous flaw evaluations for Dresden, Unit 3. Based on its review of the licensee's submittal of November 10, 1995, the staff finds that ComEd has utilized the seismic loads with the corrected nodal mass along with appropriate loading combinations.

A key issue that was resolved prior to ComEd's submittal of its revised flaw evaluation was that the ultrasonic testing (UT) equipment (i.e., General Electric O.D. Tracker) and procedure used by ComEd for the inspections of the Dresden, Unit 3, core shroud were subsequently qualified by Electric Power Research Institute (EPRI) on core shroud mockups designed and fabricated at the EPRI NDE Center, in Charlotte, North Carolina. These qualification tests were performed by EPRI to establish the UT equipment's capability to

Enclosure

size a core shroud crack of known dimension and to establish the NDE positioning and measurement uncertainties of the equipment. The results of EPRI qualification tests on this UT technology were subsequently submitted to Boiling Water Reactor Vessel and Internals Project (BWRVIP), and formed the basis for the BWRVIP's uncertainty values cited in the "BWR-VIP Core Shroud NDE Uncertainty and Procedure Standard," dated November 21, 1995, and submitted to the staff on November 22, 1995. The staff accepted these uncertainty values in its generic SE regarding the "BWR-VIP Core Shroud NDE Uncertainty and Procedure Standard," dated June 16, 1995. It should be noted however, that these NDE uncertainty values are less than the NDE uncertainty values assumed by ComEd in the original flaw evaluations of the Dresden, Unit 3, shroud welds and assumed by the staff in its SEs of July 21, 1994, and August 16, 1995.

Since the NDE technology used by ComEd was qualified by EPRI, and since the results of EPRI's qualification tests were accepted by the staff, the staff concludes that the reduced NDE uncertainty values are acceptable for use in ComEd's revised flaw evaluation of the Dresden, Unit 3, H-5 shroud weld. The staff's assessments of the revised loads and of ComEd's revised flaw evaluation of the Dresden, Unit 3, H-5 weld based these loads are provided in the evaluation that follows.

2.0 EVALUATION

2.1 ComEd's Revised Core Shroud Loads for Dresden, Unit 3

The original General Electric (GE) design basis seismic analyses of reactor pressure vessel (RPV) internals at the Dresden, Unit 3, and Quad Cities, Units 1 and 2, (Quad Cities, Unit 1, and Quad Cities, Unit 2) were performed in early 1970. The seismic models that were used in the design and analysis of the core shroud repair hardware were based on the data in the 1970 GE report. During the recent review of the seismic analyses for the Quad Cities, Unit 1, and Quad Cities, Unit 2, shroud repair hardware design, a discrepancy was discovered in the original 1970 GE seismic report that was used to reconstruct the primary structure seismic models utilized in those analyses. In the 1970 GE report, the mass corresponding to the top guide node was incorrectly listed as 1.73E3 slugs as opposed to the correct value of 17.3E3 slugs. Consequently, a new analysis was performed to reconfirm the seismic design adequacy of the existing shroud repair hardware design, RPV internals (e.g., core shroud, fuel, guide tubes, CRDs, etc.) and major vessel supports. The seismic analysis discrepancy also affected the SEs issued by the staff relating to the flaw evaluations of the core shroud cracking at Dresden, Unit 3.

A preliminary assessment of the nodal mass discrepancy in the seismic analysis for Quad Cities, Unit 1, and Quad Cities, Unit 2, was submitted to the staff on September 5, 1995. The completed core shroud repair seismic analysis was submitted to the staff on October 2, 1995. The original seismic loads with the incorrect nodal mass were previously used for the analysis and evaluation of the core shroud flaws identified at Dresden, Unit 3, during the spring 1994 refueling outage. The effect of the discrepancy in the mass of the top guide is primarily concentrated in the response of the core shroud. This has been determined based on a review of the new seismic analyses utilizing the revised seismic model with the corrected nodal mass. The change in the seismic response of the core shroud has resulted in an increase in the safe shutdown earthquake (SSE) induced moment to 1.624E5 in-kips from an earlier value of 8.20E4 in-kips at the critical H-5 weld location. The licensee has appropriately used the corrected value in combination with other previously-approved loads in the current flaw assessment.

The revised seismic analysis for a partially-degraded core shroud indicates that the primary impact in the seismic response is confined to the elements representing the core shroud. A review of the total mass modeled for the core shroud elements versus the other structural elements indicates that although the change is significant at the core plate location, the magnitude of the change is small in comparison to the total mass of the RPV internals (17%), and is insignificant in comparison to the mass of the rest of the RPV and building structures (0.1%). A comparison of the modal frequencies and participation factors from the seismic analyses of Dresden, Unit 2, and Dresden, Unit 3, (with the mass discrepancy) versus the revised analysis results (with the corrected mass) for the east-west and north-south seismic models has been provided. These results illustrate that, except for the impact on the shroud and other RPV internals, the overall effect of the mass discrepancy is minimal with respect to the seismic response. The stresses in the RPV internals and the vessel supports have been shown to be within allowable values.

Based on a review of the revised loads and load combinations to assess the flaw sizes at critical weld locations in the core shroud at Dresden, Unit 3, the staff finds that the loads have been appropriately developed and correctly combined in accordance with the Dresden, Unit 3, Updated Final Safety Analysis Report. The revised loads and moments (after correcting the error in nodal mass of the earlier seismic models) has resulted in an increase in the seismic moments and loads on some RPV internals. However, the effect of these load increases has been evaluated and found to be within the design margin.

2.2 <u>Overview of the Staff's Confirmatory Evaluation of August 16, 1995</u>

In the summer of 1995, the staff performed a supplemental flaw evaluation of the Dresden, Unit 3, H-5 core shroud weld to confirm that the conclusions stated in the staff's SE of July 21, 1994, remained valid. The H-5 weld was the most severely cracked circumferential weld in the Dresden, Unit 3, core shroud. Therefore, the staff concluded that the results of the staff's flaw evaluation of the H-5 weld would bound the results of any flaw evaluations previously preformed regarding the other circumferential welds in the Dresden, Unit 3, core shroud. The staff based its confirmatory evaluation of the Dresden, Unit 3, H-5 weld on the following conservative assumptions:

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

2. The reduced dead weight and buoyancy forces provided in ComEd's submittal of December 14, 1994, were used in the loading combinations. These reduced forces lowered the loadings that were previously evaluated by factors in the range of 2.0-4.0.

3. The flaw indications at the H-5 weld were assumed to extend entirely around the circumference of the weld (this equates to treating the indications as one 360° circumferential crack).

4. Crack depths were adjusted by 0.3 inches to account for uncertainties in the ability of the non-destructive examination (NDE) instrument to size near surface flaws and in instrument positioning. This resulted in an adjusted crack depth of 1.3 inches. This depth was assumed to be indicative of the worst case depth of the H-5 flaw indication. This depth bounded the worst case depth determined by the licensee (i.e., 1.24 inches).

5. A bounding crack growth rate of $5x10^{-5}$ in/hr was used to account for crack growth of the indication in the depth direction during the current operating cycle. This bounding crack growth rate has been used by the NRC, since the industry has not convincingly demonstrated the qualification of slower crack growth rates.

6. No credit was given for the structural load-carrying capacity of the fillet welds at the H-5 locations. This results in a load carrying thickness of the shroud of 2.00 inches.

These assumptions were consistent with the staff's method of performing its independent flaw evaluation in the July 21, 1994 SE. The staff concluded in its SE of August 16, 1995, that the amended loading conditions provided in the ComEd submittal of December 14, 1994, would not change any information or results which would invalidate the staff's previous assessment or change the staff's conclusions in the SE of July 21, 1994.

2.3 Flaw Evaluation Regarding the H-5 Weld, Submitted November 10, 1995

For this SE, the staff performed a second confirmatory analysis to assess the H-5 shroud weld based on the contents of ComEd's submittal of November 10, 1995. In contrast to the analysis summarized in the staff's SE of August 16, 1995, which was based on the conservative assumption that cracking extended 360° around the circumference of the H-5 weld, this second confirmatory analysis is based on the actual crack dimensions obtained from UT inspection results of the H-5 weld and ComEd's revised loading combinations, as provided by the licensee and discussed previously in Section 2.1 of this SE.

The change in the staff's analysis methodology is based on the fact that ComEd's assumption to treat the flaw indications in the Dresden, Unit 3, H-5 shroud weld as one 360° crack (based on the results of the original enhanced visual examinations [VT-1] of the weld) adds conservatism in ComEd's original analysis of the Dresden, Unit 3, core shroud. The results of ComEd's confirmatory automated UT examinations of the H-5 weld during Refueling Outage (RFO) No. DR3R13 indicated that the weld was uncracked in the following six regions: 31°—52.5°, 113.5°—129°, 144°—150°, 158°—170.5°, 214.5°—225°, and 297.5°—310.5°.

The BWRVIP has stated in its "BWR Core Shroud Inspection and Evaluation Guidelines," Revision 1, that UT by automated instruments is the preferred NDE method for performing examinations of Category "C" type core shrouds (as opposed to performing examinations by UT suction cup scanners or enhanced visual testing equipment). The staff has accepted the BWRVIP position that automated UT is the preferred method for performing inspections of circumferential shroud welds. Therefore, the staff concludes that ComEd's automated UT examinations of the H-5 weld provide a more accurate and reliable indication of the extent of cracking in the weld than ComEd's enhanced VT-1 examinations of the weld during RFO No. DR3R13. The staff concludes that using adjusted crack dimensions obtained from UT inspection results[1] as the basis for performing the flaw evaluations (structural margins analyses) of the Dresden, Unit 3, H-5 weld is technically acceptable.

It needs to be emphasized that, prior to ComEd's submittal of November 10, 1995, EPRI qualified the UT equipment (i.e., General Electric O.D. Tracker) and procedure that were used by ComEd for its automated UT inspections of the Dresden, Unit 3, core shroud during RFO No. DR3R13. EPRI's qualification tests were performed to establish the UT equipment's capability to size a core shroud crack of known dimension and to establish the NDE positioning and measurement uncertainties of the equipment. The results of EPRI qualification tests on this UT technology were subsequently submitted to BWRVIP, and formed the basis of the BWRVIP's uncertainty values listed for the technology in the "BWR-VIP Core Shroud NDE Uncertainty and Procedure Standard," which was submitted to the staff on November 22, 1995. The staff accepted these uncertainty values in its generic SE regarding the "BWR-VIP Core Shroud NDE Uncertainty and Procedure Standard," dated June 16, 1995. These NDE uncertainty values are less than the NDE uncertainty values assumed by ComEd in the original flaw evaluations of the Dresden, Unit 3, shroud welds, and assumed by the staff in its SEs of July 21, 1995, and August 16, 1995.

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[1]After adjusting the original crack dimensions (as determined from the UT inches results) for NDE uncertainties determined from the qualification tests of the UT equipment and procedure, and for crack growth over the projected operating cycle.

Since the NDE technology used by ComEd was qualified by EPRI, and since the results of EPRI's qualification tests were accepted by the staff, the staff concludes that the reduced NDE uncertainty values are acceptable for use in ComEd's revised flaw evaluation of the Dresden, Unit 3, H-5 shroud weld. The staff used the following conservative assumptions and adjustments as its basis for its review:

1. All flaw indications in the H-5 weld were assumed to be through-wall cracks.

2. All areas in the H-5 weld which were inaccessible to inspection equipment were assumed to contain through-wall cracks.

3. All areas treated as containing through-wall cracks were adjusted for crack growth in the length (circumferential) direction. The adjustments were based on crack growth at both ends of the areas using a bounding crack growth rate of 5.0×10^{-5} in/hr over a 18.5 month operating cycle. As stated earlier, this bounding crack growth rate has been used by the NRC, since the industry has not convincingly demonstrated the qualification of crack growth rates of lesser magnitudes (slower growth rates.

4. All areas treated as containing through-wall cracks were also increased in length by a total of 0.8 inches. This equates to adding 0.4 inches to both ends of the cracked areas in order to account for NDE measurement and positioning uncertainties in the circumferential (length) direction. The value of 0.4 inches represents the NDE uncertainty value qualified by the EPRI on their single-J, submerged arc weld, ring-to-cylinder qualification mockup (BWRVIP-A mockup). This value was approved by the staff in their generic SE to the BWRVIP, dated June 16, 1995. Use of 0.8 inches in ComEd's analysis is twice EPRI's qualified NDE uncertainty value for the automated UT equipment and represents an added conservatism in both ComEd's and the staff's revised flaw evaluations.

5. Remaining unflawed ligaments were decreased 0.3 inches in the depth direction to account for uncertainties in detecting and sizing near-surface flaws in the depth (shroud thickness) direction. As stated earlier, this value represents the default NDE uncertainty value proposed by the BWRVIP and approved by the staff in the absence of establishing more accurate, qualified NDE uncertainty values regarding the detection and sizing near side surface flaws. This default value was assumed by ComEd in its revised flaw evaluation instead of the qualified NDE uncertainty value of 0.15 inches that was approved by the staff. Use of this default NDE uncertainty value represents a conservative adjustment in both ComEd's and the staff's revised flaw evaluations of the H-5 weld.

6. The remaining ligaments were also decreased by a total of 0.676 inches to account for growth of an assumed near surface flaw in the depth

direction. This value assumes growth at a bounding crack growth rate of 5.0×10^{-5} in/hr over the projected period of 18.5 months.

7. No credit was given for the structural load-carrying capacity of the fillet welds at the H-5 locations. This results in a load carrying thickness of the shroud of 2.00 inches.

The staff's confirmatory analysis method used the computerized limit load analysis (LLA) model developed by the BWRVIP for structural integrity evaluations of circumferential welds in BWR core shrouds. This LLA computer code is based upon the limit load methodology provided in the BWRVIP "BWR Core Shroud Inspection and Evaluation Guidelines," Revisions 0 and 1, and is consistent with the evaluations method established by the BWRVIP for evaluating partial through-wall cracks in circumferential shroud welds. This evaluation method was approved by the staff in its generic SEs of December 28, 1994, and June 16, 1995. It should be noted that the assumptions and adjustments listed above are conservative and ensure that the staff's confirmatory analysis of the Dresden, Unit 3, H-5 weld is also conservative.

The staff's LLAs were based on the SSE, recirculation line break (RLB) plus SSE, and main steam line break (MSLB) plus SSE loading combinations. These postulated loading combinations represent the worst case postulated seismic or accident conditions for the Dresden, Unit 3, plant. Of these, only the loading condition postulated for the SSE alone is required by the Dresden, Unit 3, licensing basis. Loads postulated for RLB concurrent with an SSE, and for MSLB concurrent with an SSE, are beyond the licensing basis of the facility. Flaw evaluations based on these later loading combinations represent an added conservatism in the staff's analysis of the Dresden, Unit 3, H-5 weld.

The NRC's confirmatory LLA's were performed for a major axis of bending rotated at 5° increments over the entire circumference of the shroud. The LLAs were run based on 1.084–inch thick ligaments[2] after the actual ligaments had been decreased in length (by approximately 1.076 inches or 0.6° at each end) to account for possible growth over the projected 18.5 month cycle and for NDE uncertainties (i.e., crack growth and NDE uncertainty adjustments in the length direction). This resulted in adjusted ligaments at the following azimuthal locations being used as inputs to the LLA computer code: 31.6°–51.9°, 114.1°–128.4°, 144.6°–149.4°, 158.6°–169.9°, 215.1°–224.4°, and 298.1°–309.9°.

The results of the staff's LLAs were compared to a minimum required safety factor of 1.39, as required by Section XI of the ASME Code for faulted loading

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[2] 2.000 inch (shroud thickness)
- 0.300 inch (NDE uncertainty adjustment)
- 0.676 inch (adjustment for growth at 5E-5 in/hr over 18.5 months)

1.084 inch (remaining ligament after adjusting for NDE and growth) conditions. Table 2.2-1 (attached) provides a summary of the results of the staff's LLAs which were performed to evaluate the Dresden, Unit 3, H-5 shroud weld. It should be noted from Table 2.2-1 that the minimum achieved safety factors calculated by the staff are slightly higher than those calculated by ComEd for comparable inputs (~ 2.10 vs. ~1.83). The results of the staff's LLA's indicate that the analysis and safety margins provided by ComEd are conservative, and that the Dresden, Unit 3, has sufficient structural margin to justify an additional 3.5 months beyond the 15-month operational period above 212°F which was approved in the staff's SE of July 21, 1994, and later confirmed in the staff's SE of August 18, 1995. On the basis of the above structural margin analysis, the staff concludes that operation of the Dresden, Unit 3, reactor is justified until the September 1996 refueling outage for the facility.

3.0 CONCLUSION

The staff has performed a confirmatory re-analysis of the loading conditions and flaw evaluations regarding the Dresden, Unit 3, and core shroud. The staff has determined that ComEd's revised loading combinations are acceptable and have been used in a manner consistent with the loading methodology previously accepted by the staff. Furthermore, the staff has determined that the latest information provided by ComEd indicates that the Dresden, Unit 3, core shroud has sufficient structural margin to justify operation of the unit above 212°F for an additional three and a half months beyond the allotted 15-month operating time frame stated in the staff's SE of July 21, 1994. Therefore, the staff concludes that operation of the Dresden, Unit 3, reactor is justified for a total of 18.5 months above 212°F, commencing from the time of the Dresden, Unit 3, restart out of RFO No. DR3R13 (1994 RFO). The additional 3.5 months amends the staff previous position approving 15 months of operation above 212°F from commencement out of the last Dresden, Unit 3, refueling outage, as stated in the staff's SEs of July 21, 1994, and August 16, 1995.

Attachment: Table 2.2-1

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Date: February 8, 1996

Table 2.2-1 Limit Load Analysis Results Regarding the Dresden, Unit 3, H-5 Weld[1,2]

LOADING CONDITION	MEMBRANE STRESS (psi)[3]	BENDING STRESS (psi)[3]	SHROUD THICKNESS (inches)	MEAN RADIUS (inches)	MATERIAL	NEUTRON FLUENCE (n/cm^2)[4]	MINIMUM REQUIRED SAFETY FACTOR[5]	MINIMUM ACHIEVED SAFETY FACTOR
SSE	- 24.4	2457.0	2.00	102.56	ASTM TYPE 304	3.0E16	1.39	2.18 at 10°
RLB + SSE[6]	- 24.4	2543.2	2.00	102.56	ASTM TYPE 304	3.0E16	1.39	2.08 at 10°
MSLB + SSE[6]	86.3	2457.0	2.00	102.56	ASTM TYPE 304	3.0E16	1.39	2.10 at 10°

Footnotes:

1. Analyses based on unflawed ligaments at 31.6°–51.9°, 114.1°–128.4°, 144.6°–149.4°, 158.6°–169.9°, 215.1°–224.4°, and 298.1°–309.9°, after adjusting ligaments in the length direction for crack growth, NDE uncertainties and crack proximity associations.
2. Analyses use a final ligament thickness of 1.084 inches. This takes into account the potential for crack initiation and growth, and NDE uncertainties during a projected 18.5 month operating cycle. Limit load analyses performed for a major axis of bending rotated at 5° increments over the entire circumference of the shroud in order to find the minimum loading capacity.
3. Positive stresses represent loading in tension; negative stresses represent loading in compression. This is opposite of the convention used in ComEd's analyses.
4. Neutron fluence level at the H-5 shroud weld.
5. As required by Section XI of the ASME Code for faulted conditions. Minimum achieved safety factor must be greater than the minimum required safety factor for the analysis to be acceptable.
6. These postulated loading conditions go beyond the licensing basis loading conditions for Dresden, Unit 3.