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August 8, 2000

Re: Indian Point Unit No. 2
Docket No. 50-247
NL-00-107

Document Control Desk
US Nuclear Regulatory Commission
Mail Station P1-137
Washington, DC 20555-0001

Subject: July 28, 2000 Steam Generator Inspection Meeting – Additional Question Responses

On July 28, 2000, a meeting was held between Con Edison and the NRC to discuss the results of the Condition Monitoring and Operational Assessment Reports (CMOA), which were based upon steam generator inspections performed in the Spring of 2000. At this meeting, an in-depth technical discussion occurred during which additional information was provided to the NRC to assist in their review of the CMOA. With respect to the additional questions identified by the NRC following the meeting, Con Edison hereby provides as an attachment to this letter the requested information. This information completes our response to the specific questions raised during the meeting.

No new regulatory commitments are being made by Con Edison in this correspondence.

Should you or your staff have any questions regarding this matter, please contact Mr. John F. McCann, Manager, Nuclear Safety and Licensing.

Sincerely,

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ATTACHMENT

Response to Questions Identified During the July 28, 2000 Meeting

CONSOLIDATED EDISON COMPANY OF NEW YORK, INC.
INDIAN POINT UNIT NO. 2
DOCKET NO. 50-247
AUGUST 2000

July 28, 2000 NRC/Con Edison Meeting

Question: *In the calculation of the stresses and comparison of the times to initiate cracking, consider 1) the effects of scatter in the data for crack initiation and 2) the effects of hourglassing greater than the 0.6" (specifically 0.7") analyzed to date.*

Response:

Altran has performed stress analyses of the IP-2 steam generator U-bends in order to determine relative susceptibility to apex PWSCC that has been observed in Row 2. A comparative evaluation is the most accurate approach to predict Row 3 susceptibility because Row 2 and Row 3 have been manufactured from the same group of material heats and have been exposed to the same operating environment. The important differences are the degree of fabrication cold working and the operating stresses in the material.

Analyses using finite element techniques and Monte Carlo statistical techniques have been performed to quantify the relative susceptibility of the two rows. Relative crack initiation time can be predicted by using published relationships between stresses and the time to crack initiation such as that presented in NUREG/CR-5752. The relationship between stress and time to cracking is:

$$t_3/t_2 = \left(\frac{\sigma_2/S_{y2}}{\sigma_3/S_{y3}} \right)^4$$

Where σ is the tube stress, S_y is the tube material yield strength and t is the time to PWSCC initiation.

This relationship is based on laboratory testing. The data scatter band presented in NUREG/CR-5752 was also considered in the analysis by assuming a triangular distribution of data within the published scatter band.

With respect to the degree of hourglassing applied in the analysis, hourglassing of 0.476" was measured in an IP-2 steam generator. A calculation was initially performed for hourglassing up to 0.6" and now has been extended to 0.7" in order to understand the influence of larger assumed hourglassing.

The stress analyses and testing performed as part of this investigation have been described in the CMOA. The investigation included an analysis of the top tube support plate and Row 2 and 3 tubes. U-bend leg closure induced by hourglassing was found to cause high hoop stresses in the area of observed Row 2 crack initiation and thus

considered to be a significant factor in determining the relative susceptibility of Row 3 to Row 2 U-bends. The stress analysis for hourglassing showed that the hoop stresses for the center flow slot Row 2 and Row 3 tubes changed only slightly (maximum increase of 3.3%) as a result of increasing the assumed hourglassing from 0.6" to 0.7".

The Monte Carlo analysis performed a statistical analysis of relative time to crack initiation considering the range of tube material yield strength properties in the two rows. The analysis included every Row 2 and Row 3 tube and associated material properties based on the Certified Material Test Report data of the IP-2 steam generators. The Row 2 tubes plugged prior to the R2C5 leakage event were removed from the analysis population. Several combinations of assumed flow slot hour glassing were considered in an effort to assure sensitivities are understood. The first analysis assumed all flow slots were hourglassed (closed) the amount equal to the measured value of .476". The second assumed that there is an equal chance of a 0.2", 0.3", 0.476", 0.6" and 0.7" hourglassing in the slots. The third assumed twelve slots at 0.476", three flow slots with a closure of 0.2", five slots with 0.3", and two slots each with 0.6" and 0.7".

The Monte Carlo analyses allow several conclusions to be made.

- Based on a 95% probability of occurrence, the worst Row 3 tube is expected to take at least 1.7 times as long as it took for the worst Row 2 tube to crack. This conclusion is the same for each of the hourglassing assumptions. There is also a strong influence of cold work which is expected to make this factor significantly higher based on trends reported in NUREG/CR-5752 and other published sources. Material cold work is induced by the bending of the tubes during initial fabrication. Row 2 with a smaller radius would have incurred more plastic strain and therefore more cold work. Based on a review of the data, lower cold work, as exists in Row 3, significantly increases crack initiation time and decreases crack growth rates, but these factors are not sufficiently developed by laboratory tests to be accurately quantified for this analysis.

- It is also evident that many additional Row 2 tubes would have initiated cracks before any Row 3 tubes would crack. A Monte Carlo case was run assuming 0.2" hourglassing in 4 flow slots, and 0.3", 0.476", 0.6" and 0.7" in 5 slots each. This analysis predicts, at a 95% probability of occurrence, that the 50^{th} most susceptible Row 2 tube would have initiated PWSCC prior to the most susceptible Row 3 tube. Once again, this analysis does not consider U-bend fabrication cold work, which will increase the time difference between Row 2 and Row 3 PWSCC initiation.

- Additionally, it is known that once cracks have initiated, the crack growth rate for cracks in Row 2 tubes would be higher than the crack growth rates for Row 3 tubes. This is due to the higher cold work in Row 2 and the higher stresses in the most susceptible Row 2 tubes as compared to the most susceptible Row 3 tubes.

The fact that so few tubes were detected with cracks in Row 2 in the 2000 inspection, coupled with the results of the analyses discussed here, indicates that many more Row 2 tubes would have been cracked at this time before cracking would initiate in Row 3.

Attachment

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