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Subject: Arkansas Nuclear One - Unit 2
Docket No. 50-368
License No. NPF-6
Additional Information Related to Proposed License Change For Cycle 14 Risk-Informed Operation (TAC NO. MA8418)

Gentlemen:

On March 9, 2000 (2CAN030003), Entergy Operations submitted a proposed license change to allow risk-informed operation for the remainder of the 14th operational cycle for Arkansas Nuclear One, Unit 2 (ANO-2). Entergy Operation was recently made aware of NRC Staff concerns over the probability of a pressure induced steam generator tube rupture. The attached material is provided to address this concern.

1. Evaluation of Margin to Burst at Main Steam Line Break (MSLB) Conditions for ANO-2 Steam Generator (SG) Tubing
2. Modeling of Main Steam Safety Valves for SG Tube Rupture Risk Analysis
3. Effect of Increasing the Probability of Steam Generator Tube Failure at MSLB Conditions

Entergy Operations believes the probability of a pressure induced tube rupture at the end of the current cycle of operation is well within acceptable limits with appropriate conservatism considered. We also believe, based upon the detailed risk informed evaluation presented in our March 9, 2000, license amendment application, that the risk to public heath and safety due to a pressure induced tube rupture is extremely low and well within the NRC acceptance criteria, even considering uncertainties in the projected flaw distribution at the end of the current cycle of operation.

Entergy Operations believes the most compelling evidence that exists to indicate that a pressure induced tube rupture will not occur at the end of the current cycle of operation is the results of the extensive in-situ pressure testing previously performed on the ANO-2 SG tubes. Since in-situ pressure testing was first conducted in 1992, ANO-2 has never had a tube fail at

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or below MSLB pressure. Typically, tubes have demonstrated their ability to withstand pressures in excess of 1800 psi above the differential pressure associated with a MSLB. Since the early 1990s when stress corrosion cracking became of concern, Entergy Operations has conservatively conducted mid-cycle steam generator inspection outages to ensure the continued safe operation of the facility. Since the forced outage in 1996 when axial cracking at the eggcrates became a structural concern, extensive in-situ testing has been conducted of these type flaws. In-situ candidates are selected based upon a rigorous 100% inspection of both steam generators. These candidates represent the most limiting flaws detected in the campaign. To date, 22 in-situ and 4 laboratory pressure tests have been conducted on eggcrate axial flaws. Over the last four years only two flaws have failed to meet the 3ΔP criteria: one failing at 3669 psi and the other conservatively estimated to have failed at 3900 psi. In both cases, the burst pressure was substantially in excess of the 2500 psi conservatively established main steam line break pressure.

To demonstrate adequate margin for the pressure induced tube failure at the end of the current cycle of operation Entergy Operations has performed conservative estimates of the potential burst pressure. These estimates have been performed using the lower 95/95 material properties value of the steam generator tubing, and the upper 95/95 values for flaw growth rate and axial flaw extent. Using these variables, the flaw is grown from a depth representing a 95% probability of detection. Using these conservative inputs, which represent substantial margin in and of themselves, the analysis shows an additional margin of 300 psi to tube failure under main steam line break conditions at the end of cycle 14. This model was benchmarked against past in-situ pressure test results and always over-predicts the actual burst pressure by 400 to 700 psi.

Therefore, Entergy Operations contends that adequate margin to tube failure under MSLB conditions will exist at the end of cycle 14. Additionally, the risk associated with a pressure induced tube failure is extremely low and shows acceptable results even considering uncertainties in the final flaw distribution.

Should you have any questions concerning the information provided, please contact me.

Very truly yours,

CGA/jjd
attachments

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Attachment 1

Evaluation of Margin to Burst at MSLB Conditions for ANO-2 SG Tubing

Evaluation of Margin to Burst at Main Steam Line Break
Conditions for ANO2 Steam Generator Tubing

The ANO-2 license basis identifies the limiting accident scenario as the main steam line break (MSLB) accident for SG tubing integrity. This creates an elevated pressure differential across the steam generator tubing of 2500 psi.

In recent discussions with the Nuclear Regulatory Commission (NRC), a question was raised relative to the margin above MSLB the current steam generator tubing would be expected to maintain by the end of the current operating cycle. This document provides substantial evidence that SG tube integrity will be maintained in the unlikely event of a MSLB. The approach described here provides a very conservative approach to assess tube integrity.

The approach being used utilizes deterministic methods to predict the expected behavior of the tubing flaws at the subsequent outage. The first step is to determine the structural limit, or the flaw size that would result in a burst pressure below the limit. For this evaluation, the limit is the MSLB ΔP of 2500 psi (license basis MSLB ΔP is defined as 2250 psi). The structural limit is calculated at a 95/95 level using the following version of the Framatome equation:

Equation 1: $P_B = 0.58\ (\sigma_Y + \sigma_u)\ t\ /\ R_i\ \ [1 - \{L\ /\ (L + 2\ t)\}\ h]$

where

Φ = 1.0 for OD cracking
$(\sigma_Y + \sigma_u)$ = Yield + Ultimate Material Stress
t = Tube wall thickness (0.048 inch)
R_i = Inside radius (0.327 inch)
L = Structural Length
h = Ratio of Degradation Depth to Tube Thickness

To obtain a flaw size at the MSLB pressure of 2500 psi, the length of the flaw must be known or assumed. For this calculation, the length to be used is the 95/95 value from the ANO-2 length distribution, which is 1.34 inches. The flow stress is taken from the ANO-2 CMTR's, and the 95/95 value is equal to 122,990 psi. Applying these values in the above equation gives a MSLB limit of 81.9% TW structural average depth.

The next step is to determine the beginning of cycle flaw size. This is performed using a POD curve from the ANO-2 Site Specific Performance Demonstration, which was benchmarked against pulled tube data. At the 95 percentile, the maximum depth, converted to structural average depth by a form factor of 1.25, is 56.6% TW. The last piece of information is the flaw growth rate, which is 27.6% TW/EFPY structural average depth at the 95/95 level (value includes ECT uncertainty). The deterministic evaluation can now be calculated based on an operating interval from 2P99 to 2R14 of 0.80 EFPY, as follows:

BOC flaw size + flaw growth rate * run time < MSLB structural limit

56.6 + 27.6*0.80 = 78.7, which is less than the structural limit of 81.9% TW, providing margin above the most limiting design basis accident for ANO-2. The expected burst pressure for that flaw is 2844 psi.

Given the beginning of cycle flaw depth, the other input values used for the analysis are taken at a 95% probability at a 95% confidence level. Using these values results in a conservative prediction of the burst pressure of the flaws seen at ANO-2.

To further investigate if the above method provides a conservative prediction of the burst pressure, previous worst case insitu pressure tests at ANO were used to provide a benchmark. The predicted vs. actual values are shown below:

Outage	EFPY	Actual Burst Pressure	Predicted Burst Pressure	Burst?
2F96	12.43	2966	2350	Yes
2R12	12.80	4311	4093	No
2P98	13.50	4589	3134	No
2R13	14.27	3669	2931	Yes
2P99	14.96	3615	3163	See Note 1
2R14	15.76	N/A	2844	N/A

Note 1: Assumed that tube 72-72 burst at 3900 psi room temperature, adjusted to operating temperature yields 3615 psi.

In each case, the predicted burst pressure is below the actual pressure of the limiting tube based upon a 100% inspection of each steam generator, resulting in a conservative prediction for each interval. This is also shown in Figure 1, below:

Figure 1

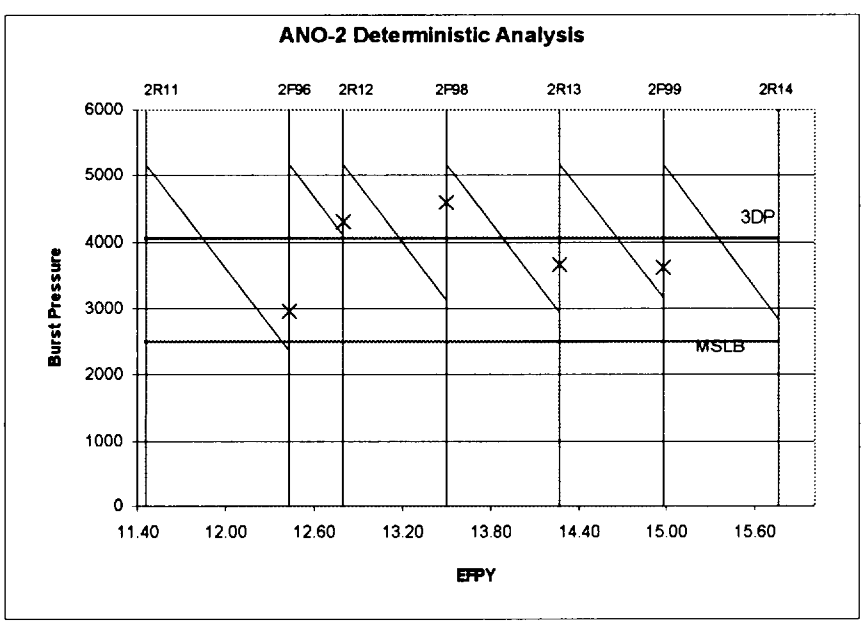

Figure 1 is a representation of this deterministic analysis applied to previous cycles. In this case, burst pressure instead of flaw size is used to compare to the applicable limits. The beginning of cycle burst pressure is that calculated for a flaw 1.34 inches long and 56.6% TW average structural depth. The flaw is then grown to the end of the operating interval, a flaw size determined, and a corresponding burst pressure calculated. That value is represented by the end point of the line at a given outage. The X's represent the actual worst case burst pressure achieved. In two cases the tube did not burst and the X's represent the peak insitu pressure test. A line terminating below the X indicates a predicted burst pressure lower than actual, which is conservative. This provides a benchmark of the deterministic approach applied above to show compliance with MSLB conditions at the end of the current cycle.

The two main areas of interest are the benchmarking of the model to predict the burst pressure of tube R72L72 at 2P99, and using that model to assess the tubing condition relative to MSLB pressure. As seen on the graph, the model conservatively predicts that tube R72L72 would have burst at 3163 psi while the actual pressure was at least 3669 psi (temperature corrected and conservative assumption that tube 72-72 burst pressure was 3900 during the insitu test). Using this model, the current tubing would meet MSLB conditions with added margin at the end of the current cycle.

2.0 Comparison to Previous Insitu Test Results

In-situ testing has been performed on the ANO2 tubing since 1992. Specific to eggcrate indications, 22 tests have been performed since 1995. During that time, there have been no flaws that have burst at MSLB conditions, and most were above 3ΔP. There have also been 4 pulled tubes removed from the generator and burst tested in the laboratory. All four burst at pressures above MSLB. Even after operating for 12 months, these bounding flaws were approximately 300 psi above MSLB or greater.

3.0 Comparison to Probabilistic Model

A probabilistic model was developed as part of the risk assessment. The model used a POD value combined with both depth and voltage. The reason for this was to better predict the values since a flaw's detection is dependent on both voltage and depth. This bi-variate POD curve was previously described in the June 20, 2000 memo. The overall result of the probabilistic model was an end of cycle probability of burst value of approximately 0.008 at MSLB conditions, which is conservative when compared to the acceptance criteria of 0.01. This further confirms the conservative deterministic model presented above.

4.0 Conclusion

A conservative model using various inputs was developed to show if the ANO-2 SG's would meet postulated MSLB conditions at the end of the current cycle. The model was benchmarked against previous ANO-2 cycles and insitu pressure test values, and consistently provided a conservative prediction of the burst pressure of the worst case flaw.

A probabilistic model was developed to predict the overall performance of the SG's. The result was a probability of burst at the end of the operating cycle of <0.01.

ANO-2 has tested 26 eggcrate flaws either insitu or in the laboratory, and none of these have failed MSLB. This is significant and supports the above results obtained from both the deterministic and probabilistic models that MSLB will not be challenged at the end of the current cycle (2R14).

Attachment 2

Modeling of Main Steam Safety Valves for SG Tube Rupture Risk Analysis

Question:

Were stuck-open Main Steam Safety Valves (MSSVs) modeled in the ANO-2 Pressure Induced (PI) and Temperature Induced (TI) Steam Generator Tube Rupture (SGTR) risk analyses?

Response:

The effect of a stuck-open Main Steam Safety Valve (MSSV) is explicitly included as a contributor to the ANO-2 Temperature Induced SGTR (TI-SGTR) risk. The effect of a stuck-open MSSV is also accounted for in the ATWS induced portion of the ANO-2 Pressure Induced SGTR (PI-SGTR) risk analysis. However, the effect of a stuck-open MSSV is not explicitly included as a contributor to the Feed Line Break/Steam Line Break (FLB/SLB) induced portion of the ANO-2 PI-SGTR risk analysis.

Section 4.3 of the ANO-2 SGTR risk analysis attached to Entergy's letter 2CAN030003 to the NRC on March 9, 2000 notes that Pressure Induced SGTR risk contributors involving "transients with a stuck open secondary relief valve are assumed to be dominated by the risk associated with the Temperature Induced SGTR risk." Although the explicit inclusion of the probability of a stuck-open MSSV event in the FLB/SLB-induced SGTR risk analysis would have increased the FLB/SLB-induced portion of the PI-SGTR risk, its inclusion would have little effect on the overall results and conclusions, since the FLB/SLB portion of the PI-SGTR risk is very small relative to the ATWS-induced portion of the PI-SGTR risk and to the TI-SGTR risk. In addition, it should be noted that any increase in the PI-SGTR risk due to a stuck-open MSSV would reduce the Temperature Induced SGTR risk involving a stuck-open MSSV. Thus, the exclusion of the stuck-open MSSV in the FLB/SLB induced PI-SGTR risk analysis has no significant impact on the overall risk results.

Attachment 3

Effect of Increasing the Probability of Steam Generator Tube Failure at MSLB Conditions

Question 2:

Assess the effect of increasing the probability of a Steam Generator (SG) tube failure at Main Steam Line break conditions on the ANO-2 Feed Line Break/Steam Line Break (FLB/SLB) portion of the ANO-2 Pressure Induced Steam Generator (PI-SGTR) risk results.

Response:

The effect of increasing the probability of a Steam Generator (SG) tube failure at Main Steam Line break conditions on the ANO-2 Feed Line Break/Steam Line Break (FLB/SLB) portion of the ANO-2 Pressure Induced Steam Generator (PI-SGTR) risk results was assessed by replacing the best-estimate values of the SG pressure fragility curves with the higher 95/95 values. Both the best estimate and the 95/95 SG pressure fragility curves were presented in Appendix B of the ANO-2 SGTR risk analysis attached to Entergy's letter 2CAN030003 to the NRC on March 9, 2000. The ANO-2 SGTR risk results were not significantly increased by this substitution. This is due to the relatively small contribution of the FLB/SLB PI-SGTR risk (i.e., LERF ~ 1E-10/rx-yr) to the overall ANO-2 SGTR risk results.

This sensitivity analysis was also performed with the stuck-open Main Steam Safety Valve accounted for in the FLB/SLB portion of the ANO-2 PI-SGTR risk analysis. Again, the ANO-2 SGTR risk results were not significantly increased.