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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

SUPPORTING AMENDMENT NO. 54 TO LICENSE NO. DPR-49

IOWA ELECTRIC LIGHT AND POWER COMPANY
CENTRAL IOWA POWER COOPERATIVE
CORN BELT POWER COOPERATIVE

DOCKET NO. 50-331

DUANE ARNOLD ENERGY CENTER

Introduction

By letter dated December 27, 1978 (Reference 1) and as supplemented by letters dated May 23, 1979, August 15, 1979 and August 17, 1979 (References 2, 3 and 4 respectively), Iowa Electric Light and Power Company, the licensee, applied for amendment of DPR-49 and the Technical Specifications (Appendix A to License) for the Duane Arnold Energy Center (DAEC)

The original submittal, Reference 1, consisted of two separate change requests to the Technical Specifications: (1) application of measured scram times; and (2) reclassification of transients that involve failure of the turbine bypass system.

These changes were precipitated by power generation restrictions at DAEC. For the past several cycles DAEC's power generation capabilities have been restricted by Technical Specification requirements on operating limit minimum critical power ratios (OLMCPR's). OLMCPR's are established from transient analyses. In DAEC's case, the rapid pressurization transients have generally been OLMCPR limiting. These changes were proposed to provide additional operating margin.

This safety evaluation applies only to the former of these changes, measured scram times. The review of the latter of these changes has several generic implications which have not been resolved between the General Electric Company, the licensee's consultant in this matter, and ourselves. We have discussed these unresolved issues with the licensee and the licensee is aware of the status of this review.

The licensee has proposed a change to the scram insertion time specifications and to the OLMCPR specifications. The scram time specifications would be modified to require a faster scram than the current specifications. The licensee would verify by periodic testing that such faster times would not be exceeded during an actual scram. The OLMCPR specifications would be modified to be less restrictive than the current specifications. The OLMCPR limits would correspond to, and take credit for, the faster scram insertion time specifications.

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The licensee has provided a safety analysis, employing methodology we have previously approved, for the limiting pressurization transients which use the faster scram times. The faster scram reduces the positive reactivity insertion and thereby decreases the transient power rise and change in critical power ratio (ΔCPR). (OLMCPR is established as the sum of the limiting ΔCPR and the safety limit minimum critical power ratio, so that the safety limit would not be violated by the most severe transient.)

Evaluation

1. Demonstration of Scram Insertion Time

In order to get credit for the faster scram insertion times the licensee must demonstrate reasonable assurance that the scram insertion times will not be exceeded (i.e., fail to insert in the specified time). To address this concern the licensee has presented a statistical analysis of control rod scram data from both DAEC and other boiling water reactor (BWR) operating plants similar to DAEC in scram system and control rod design. This statistical analysis presented mean scram insertion times and associated standard deviations for the data. The licensee used only full core scram test data in the statistical analysis since this group of data is a conservative representation of actual transient scram behavior. From this analysis the licensee concluded that the probability of exceeding the proposed specification limits is acceptably low and is unlikely to be exceeded during any scram.

In order to verify the licensee's conclusion we requested a description of the statistical analysis and a compilation of the data for this analysis. The licensee provided this information in Reference 2. For each insertion position the licensee: (1) compared the DAEC data with the other BWR data using a t-test to determine if these data belong to the same population, (2) pooled the data when the t-test showed no significant difference, and (3) showed that the proposed specification limits are unlikely to be exceeded.

Our auditing methods have been outlined in the Appendix to this evaluation. The results are given in Table 1, together with the scram time limits used by the licensee in pressurization transients analyses. (The proposed Technical Specification scram time limits correspond to control rod notch positions rather than percent control rod insertion). The proposed Technical Specification limits are the maximum measured scram insertion times which will be allowed and the calculated tolerance limits show that there is a high degree of assurance that these time limits will be satisfied.

We have estimated the effect of using the integrated reactivity versus a single insertion time and have concluded that the difference is negligible. Based upon our investigation of pressurization transient reactivity response, we determined that the scram reactivity associated with insertion times from 0.6 to 1.4 seconds is the most important to transient ΔCPR. This time period corresponds to about the 13% to the 44% insertion points. The integrated negative scram reactivity through this time period is the most appropriate parameter for the evaluation of scram effectiveness. However, we have determined that a single parameter, insertion time to 20% insertion, will provide an adequate basis. The 20% insertion time is the most influential of the proposed Technical Specification times on pressurization transient results.

By the analysis in the Appendix, we have independently concluded that it is unlikely that the proposed scram time specification will be exceeded by any scram for the 5% and 20% insertion points. The only non-conservative scram points are at 50% and 90% insertion which we have concluded are neither significant in magnitude nor consequence for the current evaluation. Our conclusion is based on our evaluations of the impact of a delayed scram on pressurization transient results. We conservatively assumed that the 50% and 90% insertion points would be delayed by 0.014 seconds. We also conservatively assumed that this delay would also be in effect back to the 20% insertion point. We then estimated the effect of the delayed negative scram reactivity on the net transient reactivity response by a comparison of the integrated net reactivity without and with the scram delay. The result was about a 2% increase in the net reactivity with the delayed scram. For a ΔCPR of 0.2, this corresponds to about 0.004 increase in ΔCPR. This is a conservative evaluation of the effect of the delayed scram. We estimate that a more realistic evaluation, i.e., actual 95/95 scram times would yield less than approximately 0.001 increase in ΔCPR. Therefore, the effect of this scram delay is negligible and need not be considered for OLMCPR evaluations. Thus, we are assured that the transient consequences for the limiting pressurization transient will bound actual plant response in relation to scram effectiveness.

Therefore, as long as the application of measured scram times is restricted to pressurization transients, as is the case for DAEC, the DAEC proposed scram times are acceptable. An extension of the use of faster scram times to other transients is beyond the scope of this evaluation.

Based upon our review of control rod drive system reliability and recent BWR scram data (References 2 and 3), there is no degradation of scram insertion times over cycles of operation. To provide confirmatory assurance that our acceptance criteria will be satisfied, i.e., an acceptably high degree of confidence that any scram will result in a faster scram than Technical Specification limits, new scram data will be evaluated. The licensee has agreed to perform control rod scram time tests near the end of cycle. The licensee will evaluate the effect of the new data on the probability of satisfying the scram time specifications. We have concluded that this confirmatory testing and evaluation should be performed for several cycles.

2. The Effect of Scram Time on Operating Limits

The licensee has calculated the effect of faster scram times with a methodology we have accepted in several previous actions (e.g., Reference 8).

The ΔCPR credit was calculated with the REDY code. The REDY code employs a two node steamline thermal hydraulic model and a point kinetics neutronics model. Several pressurization experiments at Peach Bottom Unit 2 (Reference 5) were designed to check validity of these REDY models. The experimental results showed that the REDY steamline model did not accurately predict pressurization rate. Also, the REDY point kinetics model did not simulate tha axial reactivity variation in the core. GE provided calculational comparisons of REDY and test results, and attempted to demonstrate that although REDY did not accurately model some transients effects, it did provide a conservative basis for current licensing calculations. We agree with GE's general conclusion that REDY provides a conservative calculation for the current licensing basis transients on operating reactors. However, we also recognized that REDY limits simulation of margin improvement options, such as faster scram times by its inability to accurately predict pressurization rate and axial reactivity response. The Peach Bottom tests demonstrated the existence of a pressure wave phenomenon in the steamlines. In addition, it was noted that the power rise associated with pressurization was significantly greater in the upper portion of the core than in the lower portion.

Quantitative comparison of the tests with REDY calculations indicated that the REDY model underpredicted the pressurization rate but overpredicted the core's response to pressurization effects. Thus, there are two discrepancies between REDY simulated effects. One is non-conservative and the other is conservative. It is impossible to state from these comparisons which effect would dominate for a given transient.

After the analysis of the tests, comparisons were made between REDY simulations and simulations using detailed steamline modeling and a time-varying axial power distribution. These comparisons, although rather limited, suggest a trend in which REDY-based calculations conservatively predicted ΔCPR for more severe transients but underpredicted for less severe transients (Reference 6). These calculations also showed that the ΔCPR benefits for the faster scram time feature may be overpredicted by REDY as compared to the detailed steamline and core modeling predictions. On this basis, we find that full credit for the faster scram times cannot be justified solely on a REDY analysis.

The licensee provided additional justification for the proposed specification. The more sophisticated transient simulator code, ODYN, has more modes to model steamline dynamics than REDY and also has a one-dimensional axial core neutronics model. Its development has been verified by Peach Bottom tests. The staff review of this more sophisticated transient simulator is not yet complete. ODYN will be used as the calculational model for pressurization events when it is approved.

We find that ODYN simulates the sensitivity of the effects to faster scram times and, thereby, provides assurance of the ΔCPR benefit. As with other margin improvement packages (Reference 7), we accept the greater ΔCPR of either REDY or the ODYN calculations. Once ODYN receives generic approval, we will accept its calculated ΔCPR.

The licensee's calculations with ODYN show that the limiting ΔCPR for 8x8 fuel would increase to 0.20 for the limiting pressurization transient. Thus, the appropriate OLMCPR for the 8x8 fuel to EOC is 1.26 rather than the initially proposed 1.21. We have informed the licensee of this by telephone conversation and he has agreed to this change. With this change the operating limit MCPR can be specified as 1.22 for 7x7 fuel and 1.26 for 8x8 fuel. The limiting transients are the rod withdrawal error for 7x7 and the load rejection w/o bypass for 8x8. Thus when the reactor is operating in accordance with the above OLMCPRs, the recommendations of Standard Review Plan 4.4 NUREG-75/087 are satisfied in the event of the most severe transient. On the above basis, we find the modification to be acceptable.

(In the ODYN review, GE has taken credit for faster than Technical Specification scram times. This credit was not beyond the credit by the use of measured scram times. GE has provided an evaluation of the impact of measured scram times with the ODYN code on ΔCPR (Reference 8). This evaluation shows that there is adequate margin to maintain an acceptable licensing basis ΔCPR calculation. Therefore, this measured scram time specification will not need to be modified once the ODYN review is complete.)

Conclusion

The proposed scram time changes are acceptable. The changes to OLMCPR specification have been modified to include the effect of the ODYN sensitivity analysis and with this modification are acceptable. The licensee will be required to evaluate the impact of the additional data on the probability of satisfying proposed scram time Technical Specifications as outlined in the discussion of this evaluation.

We have determined that this amendment does not authorize a change in effluent types or total amounts nor an increase in power level and will not result in any significant environmental impact. Having made this determination, we have further concluded that the amendment involves an action which is insignificant from the standpoint of environmental impact and pursuant to 10 CFR Section 51.5(d)(4) that an environmental impact statement, or negative declaration and environmental impact appraisal need not be prepared in connection with the issuance of this amendment.

We have concluded, based on the considerations discussed above, that: (1) because the amendment does not involve a significant increase in the probability or consequences of accidents previously considered and does not involve a significant decrease in a safety margin, the amendment does not involve a significant hazards consideration, (2) there is reasonable assurance that the health and safety of the public will not be endangered by operation in the proposed manner, and (3) such activities will be conducted in compliance with the Commission's regulations and the issuance of this amendment will not be inimical to the common defense and security or to the health and safety of the public.

Dated:

TABLE 1

Comparison of Scram Insertion Times

Control Rod Percent Insertion (%)	Proposed Limits[1] (seconds)	95/95 Upper Tolerance Limit on Mean Insertion Time for DAEC (seconds)
5	.375	.364
20	.776	.759
50	1.570	1.584
90	2.750	2.756

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(1) This column gives the scram times used in the analysis of the pressurization transient to determine the OLMCPR. (Technical Specification time limits correspond to control rod notch positions rather than percent insertion.)

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References

1. Letter from L. Liu (Iowa Electric Light and Power Company) to H. Denton (USNRC), IE-78-1879, December 27, 1978.
2. Letter from L. Liu (Iowa Electric Light and Power Comapny) to T. Ippolito (USNRC) IE-79-795, May 23, 1979.
3. Letter L. D. Root (Iowa Electric Light and Power Company) to T. A. Ippolito (USNRC) LDR-79-149, August 15, 1979.
4. Letter from L. Root (Iowa Electric Light and Power Company) to H. Denton (USNRC) LR-79-154, August 17, 1979.
5. L. A. Carmichael and R. O. Niemi, "Transient and Stability Tests at Peach Bottom Atomic Power Station Unit 2 at End of Cycle 2," EPRI-NP-564, June 1978.
6. "Impact of One Dimensional Transient Model on Plant Operating Limits," enclosure to GE letter (E. D. Fuller) to USNRC dated June 26, 1978.
7. Letter to H. G. Parris (Tennessee Valley Authority) from T. A. Ippolito (NRC), Amendment No. 48 to Facility License No. DPR-33 for Browns Ferry Nuclear Plant Unit 1, Febraury 1979.
8. NEDE-24154-P, "Qualification of One-Dimensional Core Transient Model for Boiling Water Reactors, Volume 3," General Electric Company, October 1978.

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Appendix

Statistical Evaluation Methodology

This Appendix outlines our statistical methodology. We have reviewed the licensee's statistical analyses and independently established this statistical methodology based on our review of the available data. The results of our analysis have been presented in Table 1 of the body of this evaluation and an outline of our calculations follows.

A key assumption in the statistical analysis of the scram time data is that the other BWR data is normally distributed for each insertion position. This assumption, which the licensee failed to check, does not hold for all the insertion positions. Our analysis follows that of the licensee, but was modified to accommodate the non-normality of some of the other BWR data.

First, the rod scram data from the other BWRs were tested for normality for each insertion position. We used the W-test, a standard statistical test for normality (Reference 1). Typically, the rod scram data from the other BWRs appear to come from a normal distribution with the exception of a few points which appear to be outliers. Accordingly, for each insertion position, we applied the W-test both to all the other BWR data and to the data without the suspected outliers. The results, presented below, were also subjected to a statistical test specifically designed to detect outliers (Reference 2).

IDENTIFICATION OF OUTLIERS

INSERTION POSITION	OUTLIERS
5%	None
20%	A2, J*
50%	A2, J
90%	A2, C1, J

*Marginal (See text)

In this table, A2 refers to test #2 at plant A in enclosure 2 to Reference 2, J refers to the single test at plant J, and C1 refers to test #1 at plant C. For 20% insertion, point A2 was a clear outlier but point J fell on the normal curve approximating the other data points (except for A2), although it was the largest of all the data points (except for A2). Thus, point J was not an outlier with respect to the data points for 20% insertion. However, point J was a clear outlier for 50% and 90% insertion. Therefore, we conservatively assumed it an outlier for 20% insertion as well.

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Next, the DAEC data was compared with the other BWR data, excluding the outliers, using a t-test to determine the appropriateness of pooling. The t-test assumes that both samples being compared are normal with a common standard deviation but with possibly different means. Since there were only four data points for DAEC, a test for normality was not performed because it would be very insentive to departures from normality.

Since an F-test showed that the sample standard deviations for DAEC were very close to the sample standard deviations for the other BWRs (excluding the outliers), it was assumed that the requisite t-test conditions were satisfied. The results of the t-tests showed no significant differences (at the 5% level) between the means of DAEC and the other BWRs (excluding outliers) for any of the four insertion positions. However, the observed DAEC mean insertion times were all larger than the observed mean insertion times for the other BWRs, indicating that the true mean insertion times for DAEC might be larger than the true means for other BWRs. Accordingly we made the conservative decision <u>not</u> to pool the DAEC means with the other BWR means.* If the observed DAEC means had been smaller than the observed means of the other BWRs we could have either used the DAEC means by themselves or taken a conservative approach and pooled the means.

The presence of outliers at 20%, 50% and 90% insertion positions indicates that an appropriate model for the average insertion time X is a mixture of two normal distributions,

$$Y \sim N\ (\mu,\ \sigma^2) \text{ and}$$

$$Y \sim N\ (\nu,\ \tau^2),$$

with some mixing fraction Q. That is, with probability Q the mean insertion time is normally distributed with mean μ and variance σ^2 and with probability (1-Q) it is normally distributed with mean ν and variance τ^2. Here, Z is the outlier distribution. For any Technical Specification limit T, the probability that the average insertion time X is less than T can be written as

$$\Pr\ \{X \le T\} = Q\ \ \Pr\ \{Y \le T\} + (1 - Q)\ \ \Pr\ \{Z \le T\}.$$

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*It should be noted that the fact that the t-test did not reject the hypothesis of equal means does not prove that the means are, in fact, equal. They might be unequal, but the t-test might not be sensitive enough to detect the difference.

For each insertion position, we based our estimate of μ on the DAEC measurements only, and we used the pooled* standard deviation (excluding the outliers) to estimate σ. For the outlier distribution Z, we used the sample mean of the outliers to estimate ν and the pooled standard deviation to estimate τ. The mixing fraction, Q, was bounded by a 99.5% lower confidence limit on a binomial distribution based on the observed number of outliers.

For each insertion position, we calculated a conservative 95/95 tolerance limit based on the above. That is, we calculated $T_{.95}$, so that, with 95% confidence,

$$Pr\{X \leq T_{.95}\} \geq 0.95.$$

The results of these calculations are given in Table 1.

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*In this case, pooling is justified because the sample standard deviation for DAEC were very close to the sample standard deviations for the other BWRs.

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References

1. Gerald J. Hahn and Samuel S. Shapiro (1967), Statistical Models in Engineering, John Wiley and Sons, 295-298.

2. Gary L. Tietjen and Roger H. Moore (1972), "Some Grubbs-Type Statistics for the Detection of Several Outliers," Technometrics, Vo. 14, No. 3, 583-597.

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