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

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

RELATED TO LEAK-BEFORE-BREAK ANALYSIS

COMMONWEALTH EDISON COMPANY

BYRON STATION, UNITS 1 AND 2, AND BRAIDWOOD STATION, UNITS 1 AND 2

DOCKET NOS. STN 50-454, STN 50-455, STN 50-456 AND STN 50-457

1.0 INTRODUCTION

By letter dated April 30, 1996 (with enclosure WCAP-14559 [Reference 1]), Commonwealth Edison Company (ComEd, the licensee) requested elimination of primary reactor coolant system (RCS) loop pipe rupture as a design basis for Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2. The request was based on the leak-before-break (LBB) analysis of the primary loop piping as permitted by General Design Criteria 4 (GDC-4) of 10 CFR Part 50, Appendix A. Additional information was provided by ComEd by letter dated September 25, 1996, in response to the staff's request for additional information.

2.0 BACKGROUND

GDC-4 allows the use of analyses to eliminate the dynamic effects of postulated pipe ruptures in high energy piping from the design basis in nuclear power units. Implementation of the LBB technology permits the removal of pipe whip restraints and jet impingement barriers as well as other related changes in operating plants. The acceptable technical procedures and criteria of the LBB evaluation are defined in NUREG-1061, Volume 3 [Reference 2] and summarized, in part, as follows:

The forces and moments due to pressure, deadweight, thermal expansion, and earthquake loadings associated with normal operation and the safe shutdown earthquake (SSE) should be considered. The location(s) at which the highest stresses coincident with poorest material properties for base metals, weldments, and safe ends should be identified. Through-wall flaws for the determination of the leakage flaw and critical flaw size should be postulated at those location(s).

Operating experience should demonstrate that the pipe will not experience stress corrosion cracking, fatigue, or water hammer. The operating history should include system operational procedures; system or component modification; water chemistry parameters, limits, and controls; resistance of

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piping material to various forms of stress corrosion; and performance of the pipe under cyclic loadings.

The materials data provided should include types of materials and material specifications; stress-strain curves and J-R curves (not required if limit load analysis is used in the stability analysis); consideration of long-term effects such as thermal aging; and other limitations to materials data (e.g., J_{max}, and maximum crack growth). The piping materials must be free from brittle cleavage-type failure over the full range of the system operating temperature.

The postulated leakage flaw should be shown to be stable under normal operational plus SSE loads for long periods of time; that is, crack growth of the postulated leakage flaw is minimal during an earthquake. This stability analysis is sufficient if the normal operational plus SSE loads are summed absolutely (a conservative, worst-case loading assumption). A flaw stability analysis should be performed to show that the leakage flaw is stable under larger loads (at least 1.4 times the normal plus SSE loads) if a more detailed sum-of-the-squares combination of the normal operational plus SSE loads is considered.

NUREG-1061, Volume 3, provides the following criteria for assessing the critical and leakage flaw sizes. First, the leakage flaw size should be large enough so that the leakage is assured of detection with at least a margin of 10 using the minimum installed leak detection capability when the pipe is subjected to normal operational loads. Then, under normal plus SSE loads, there should be a margin of at least 2.0 between the leakage-size flaw and the critical-size flaw which would propagate to piping failure to account for the uncertainties inherent in the analyses and leakage detection capability. Finally, the slope of the J_{app} line for the critical-size flaw $(d(J_{app})/da)$ should be less than the slope to the material's resistance curve $(d(J_{mat}/da))$ at the point of intersection to demonstrate flaw stability.

3.0 LICENSEE EVALUATION

The licensee first examined background information on the potential for primary loop piping degradation mechanisms, as required by NUREG-1061, Volume 3. No evidence of stress corrosion cracking, water hammer, or other degradation has been observed in the primary system piping of these four units. Therefore, based on this plant-specific experience and similar histories at other Westinghouse plants, the staff concludes that stress corrosion, water hammer, and other degradation mechanisms are not issues for the primary loop piping in these four units.

The licensee then established the sensitivity of the RCS leak detection system for these four units. The installed systems meet the intent of Regulatory Guide 1.45 such that a leakage of one gallon per minute (GPM) for 1 hour can be detected. The calculated leak rate through the postulated leakage flaw was 10 GPM and, thus, is large relative to the sensitivity of the plant's leak detection systems and consistent with the criteria in NUREG-1061, Volume 3.

The primary loop piping in these four units has a nominal outside diameter (OD) of 34.12 inches with a minimum wall thickness of 2.500 inches at the critical location in the RCS hot leg and a nominal OD of 32.14 inches with a minimum wall thickness of 2.215 inches at the critical location in the RCS cold leg or crossover piping. The piping material is austenitic wrought stainless steel, SA-376 Grade 304N, and the material for the elbows is cast stainless steel, SA351 CF8A. Location 11 (as defined in WCAP-14559), the cold leg weld at the reactor coolant pump outlet nozzle, was the most highly stressed position in the RCS and, therefore, the critical location for the SA-376 Grade 304N piping. Location 3 (again defined in WCAP-14559), in the cast stainless steel elbow near the steam generator, was the critical location for the SA351 CF8A material due to a combination of thermal aging effects and high applied stresses.

The licensee provided material properties data for the primary loop piping, elbows, and weld material based on the certified materials test reports (CMTRs). In the LBB calculations, the minimum material properties at average pipe section temperature were used for the critical flaw size and critical flaw stability evaluations; while the average material properties were used for calculation of the leakage flaw size. For estimating the material toughness parameters (J_{IC} and J_{max}) of the cast stainless steel, the licensee used the results of fracture toughness testing conducted by Westinghouse for a fully-aged cast stainless steel sample. The staff accepts that the fracture toughness data from this sample material [References 4-6] bound the expected properties the cast large diameter primary loop piping of these four units.

The licensee used combined normal operational and SSE loadings in the flaw stability analysis to assess margins against pipe rupture during postulated faulted load conditions. The normal operating loads included internal pressure, deadweight, and normal thermal expansion; and the SSE loads included loads due to inertia and anchor motion related to SSE. In the worst loading case for the stability analysis, all individual components that made up the normal and faulted loads were summed absolutely.

For the stainless steel piping (SA-376 Grade 304N material) and the weld locations therein, a limit load analysis was employed. The welds in this piping were manufactured by a combination of tungsten inert gas (TIG) and shielded metal arc (SMAW) processes. Z factor corrections [Reference 3] to address the weld material properties were used in the limit load analysis for the critical location. The reported margin, which is the ratio of the critical flaw size to the leakage flaw size, at Location 11 was 1.91.

For the cast stainless steel elbow fittings (SA351 CF8A material), an elastic-plastic J-integral evaluation (J/T methodology) was employed. The licensee used the EPRI approach [Reference 7] for estimating the applied J value. The reported margin for this material at Location 3 was greater than 2.0 and the licensee showed that the postulated critical flaw was stable under normal plus SSE loads.

4.0 INDEPENDENT STAFF CALCULATIONS

The staff conducted independent leak rate and flaw stability calculations for Location 11 and found that the licensee's leakage flaw size under a normal operational load (5.87 inches) condition was larger than (and, therefore, more conservative too) that calculated by the staff (5.31 inches) by using the PICEP computer code [Reference 8]. Further, the value of the critical flaw size calculated by the staff using PICEP (11.97 inches) was larger than that calculated by the licensee (11.18 inches). Since the minimum margin (the ratio of the critical flaw size to the leakage flaw size) for the wrought stainless steel piping and the associated SAW and SMAW welds by the staff's calculation is 2.25 (greater than the required margin of 2.0), the LBB criteria in NUREG-1061, Volume 3, are satisfied. While the flaw stability criteria was not explicitly investigated for the wrought stainless steel piping because of this material's high J-resistance values and steep J-resistance curve, it is clear that $d(J_{app})/da$ would be smaller than $d(J_{mat})/da$ for this material and the stability criterion would be satisfied. The information that the staff used in its calculations was derived from data provided in the licensee's submittal [Reference 1] and a stress-strain curve for SA-376 Grade 304N from a standard materials handbook [Reference 9].

The staff also performed independent calculations for the cast stainless steel fitting at Location 3. The licensee's calculated value for the leakage flaw size (6.20 inches) was smaller (less conservative) than that calculated by the staff (7.86 inches). However, the staff used the program NRCPIPE [Reference 10] to evaluate the critical flaw size based upon information provided in the licensee's submittal [Reference 1] and data from Argonne [References 11, 12] on the effects of thermal aging on the stress-strain curves and J-resistance curves for cast stainless steels. The J-R curve used in the staff's analysis was conservative compared to that used by the licensee at all points up to and including J_{max}. The staff confirmed that a critical flaw with a margin of 2.0 on the staff's calculated leakage flaw (15.72 inches) would be stable under the normal operational plus SSE loading conditions given in the licensee's submittal. As to the stability criterion, it is clear that J_{app} line will intersect the J-R curve at the curve's steep rising portion; therefore, $d(J_{app})/da$ is smaller than $d(J_{mat})/da$ and the stability criterion is satisfied.

Therefore, since the independent staff calculations demonstrated that a margin greater than 2.0 exists for both critical locations and that flaw stability requirements are satisfied, the staff accepts the conclusions presented in the licensee's submittal.

5.0 CONCLUSION

The staff concludes that the licensee's LBB analysis is consistent with the criteria in NUREG-1061, Volume 3, and, therefore, demonstrates that the probability of fluid system piping rupture is extremely low under conditions consistent with the design basis for the piping. Thus, per GDC-4, consideration of the dynamic effects associated with primary loop pipe rupture

may be eliminated from the design basis for Byron Station, Units 1 and 2, and Braidwood Station, Units 1 and 2.

Principal Contributor: Matthew A. Mitchell, NRR

Date: October 25, 1996

6.0 REFERENCES

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