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

SAFETY EVALUATION BY THE OFFICE OF NUCLE/R REACTOR REGULATION

SUPPORTING STUD TENSIONING A' 70 F

ARKANSAS POWER AND LIGHT C(MPANY
ARKANSAS NUCLEAR ONE, UNIT NO. 1
DOCKET NO. 50-313

1. Introduction

In a letter to the NRC dated December 7, 1978, supported by letter dated April 16, 1979, the Arkansas Power and Light Company requested that the minimum temperature for stud tensioning (detensioning) at Arkansas Nuclear One Unit 1 (ANO-1) be reduced from 120 F to 70 F. We have reviewed the technical basis for the request and find that the change can be allowed.

The technical basis for the above finding is discussed in the following sections.

2. Background

Babcock and Wilcox (B&W) discovered that some of a weldment prepared for the purpose of supplying reactor pressure vessel weld metal surveillance specimens exhibited a significant deviation from the typical chemical analysis. Specifically, several segments of the weldment were found to have about 1% Si and about 0.1% Ni whereas typical concentrations for MnMoNi/Linde 80 submerged arc weld metals are:

Si: 0.30 to 0.65 w/o

Ni: [illegible].5 to 0.80 w/o

Other elements fel' within the ranges generally observed.

B&W notified the NRC on August 4, 1978, that the descrepancy had been found. The cause was ascribed to a mixup in Mn-Mo-Ni weld filler wire. It was determined that the twelve nuclear reactor pressure vessels may have been assembled using some of the irregular wire and the specific suspect welds in each vessel were identified. For the ANO-1 RPV, the weld locations were the inlet and outlet nozzel-to-nozzle belt and the closure head-to-flange.

Mechanical property tests were conducted by B&W and reported to us by letter dated August 18, 1978. Dropweight tests resulted in an NDT of -20 F. Charpy tests at temperatures from +10 F to 300 F resulted in a 50 ft-lb. transition temperature of 180 F from which the RT_{NDT} of 120 F was established. The Charpy data exhibited considerable scatter in the transiton region, e.g. E_{C-V} ranged from 38 to 74 ft-lb.

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at 150 F. The upper shelf energy (reached at about 300 F) was relatively high, roughly 81 ft-lb. Tensile results at room temperature were: 72.5 ksi yield strength; 90 ksi UTS.

The values of Nil Ductility Temperature (NDT) (-20 F) and Reference Temperature (RT_{NDT}) (120 F) would appear to be at odds with each other. The scatter in the Charpy data, alone, would not resolve the discrepancy since the upper bound Charpy curve would lower the 50 ft-lb. transition only to about 110 F or an RT_{NDT} of 50 F, a full 70 F above the dropweight NDT.

Applying the RT_{NDT} of 120 F to the ANO-1 closure head-to-flange weld resulted in that temperature being the lowest at which stud tensioning (detensioning) could take place. Previously, stud tensioning at ANO-1 had been done at room temperature, nominally 70 F. The August 18, 1978, letter requested permission to allow stud tensioning to continue at 70 F and presented an analysis supporting the conclusion that such a procedure would be safe from a fracture viewpoint.

3. Fracture Mechanics Analysis

The basis for the analysis was the B&W topical report BAW-10046A, Rev. 1, "Methods of Compliance with Fracture Toughness and Operational Requirements of 10 CFR 50, Appendix G", March 1976. The factors of safety applied to the stresses were those required by 10 CFR 50, Appendix G. The assumed surface flaw size was (1/6) T X T. The resulting stress intensity factor was 51.6 ksi $(in)^{1/2}$.

The August 18, 1978, letter provided a range of calculated stress intensity factors for a variety of conditions including bolt preload, normal 100 F/hr heat up, inservice hydrostatic leak testing and preservice hydro testing. However, the most recent submittal from Arkansas P&L Co., a letter dated April 16, 1979, which presented the latest atypical weld metal test results, narrowed the issue to stud tensioning, only. Therefore, our analysis likewise was limited to that procedure.

Safety in a fracture mechanics analysis is demonstrated by comparing a conservatively large calculated value of K_I with the measured material fracture toughness, K_{IC}. The ANO-1 August submittal derived K_{IC} values by using the B&W Charpy impact energy results and published conversion procedure. In a subsequent letter, dated December 6, 1978, Arkansas P&L Co. noted that direct fracture toughness measurements using compact fracture specimens were to be conducted by B&W within the next few months. Realizing that K_{IC} determined by direct measurement is to be preferred over that derived from impact test results and acting on the belief that the preferred data would be available prior to the startup of ANO-1 from the Spring 1979, refueling outage, the NRC delayed reviewing the original submittal.

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4. Fracture Toughness Results

Two 1T CT specimens were machined from blocks of weldments including atypical weld metal. The specimens had face grooves cut to 10% of the thickness and were tested at 68 F using J test instrumentation. Fracture occurred at the instant of instability; since there was no stable crack growth, the only value of the J-integral which could be calculated was that at maximum load. The resulting J-integrals were converted to K_{Ic}:

Specimen Number	K_{Ic}, ksi(in)$^{1/2}$
826 - 1T4	145.7
826 - 1T5	148.3

The first part of the specimen identification refers to the block from which it was cut. Block No. 26 (=826) had been sampled at three locations (top, middle and bottom) for chemical composition and the results were reported in Table 1 of Appendix A of the ANO-1 August 18, 1978, submittal. The significant results were:

Location	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	V
top	.07	1.02	.021	.013	1.01	.07	.094	.48	.37	.006
mid.	.07	1.01	.021	.012	1.04	.07	.092	.48	.40	.004
bot.	.07	1.73	.021	.012	1.00	.07	.094	.48	.40	.005

The chemical analyses showed: (1) block No. 26 definitely had the atypical chemistry including about 1% Si and about 0.1% Ni; (2) the through-thickness variation was negligible. Since ANO-1 selected the low K_{Ic} value (from specimen 826-1T4) as the standard in the safety analysis, it is safe to assume that 145.7 ksi(in)$^{1/2}$ fairly represents the atypical weld metal.

5. Safety Analysis

According to 10 CFR 50, Appendix G, Section IV, para. A.2.a, alternative calculation procedures are permitted if approved by the Commission. Also, the ASME Code, Section III, Appendix G, Para. G-2110 allows the use of higher K_{Ic} values than the lower limit curve included in the Code when the higher values truly represent the material and conditions under review. This situation is applicable to the ANO-1 stud tensioning problem.

Comparison of the stress intensity factor to the fracture toughness:

$$K_I \ (=51.6 \text{ ksi(in)}^{1/2} \ll K_{Ic} \ (=145.7 \text{ ksi (in)}^{1/2}),$$

leads to the conclusion that there is no potential fracture problem related to ANO-1 stud tensioning at 70 F. Therefore, we find that stud tensioning (detensioning) at 70 F provides no decrease in the margin of safety and can be allowed.