SAFETY EVALUATION

RANCHO SECO COOLDOWN INCIDENT OF 3/20/78

Background

A loss of a non-safety grade instrument power supply caused reactor and turbine trips at 4:25 A.M. on March 20, 1978. As a result of operator action in restarting the main feedwater pumps, plus actuation of the safety injection system, the reactor coolant temperature dropped to about 280°F in 75 minutes. The cooldown during a one hour period was about 305°F, dropping from 590°F at 4:35 A.M. to 285°F at 5:35 A.M. Because the rate of cooldown was more rapid early in the transient, the maximum cooldown rate was 470°F per hour for the first 30 minutes (590 to 355°F at 5:05 A.M.). Pressure in the reactor coolant system remained above 1400 PSI throughout the event.

The rapid cooldown rate violated the Technical Specifications for primary system cooldown rate, and the pressure-temperature limits were also violated. In addition, it appears that actual Appendix G limits were exceeded very slightly, although this depends on details of the analysis. The technical specification pressure-temperature limits for cooldown conditions prohibit a pressure over 1400 PSIG at a temperature of 280°F. According to chart records, the lowest temperature the reactor coolant got to was 280°F, but the pressure was about 2000 PSIG at that time (about 65 minutes into the transient). Therefore, they violated their technical specification by 600 PSIG.

As a point of interest, 280°F is the temperature where a step change in pressure is permitted. Between 280°F and 185°F, the maximum permitted pressure is only 550 PSIG. If the operator had delayed action to stop the cooldown only slightly, the temperature would surely have gone below 280°F, and he would have violated the pressure limit by 1450 PSIG instead of only 600 PSIG.

Babcock & Wilcox Analyses

B&W performed a fracture mechanics analysis for the reactor vessel in general accordance with the methods in Section XI of the code, but using some of the assumptions in Section III, Appendix G. They concluded that even if there were a flaw 1/4T deep in the worst weld in the beltline region, (Appendix G requirement) it would not have initiated rapid fracture. They also performed an analysis for the higher stressed nozzle region, with the same conclusion.

The c[illegible]itions considered to be limiting by B&W were those when the pressure was 21[illegible] PSI, and the temperature was 468°F. Using their calculations for heat transfer, and code methods for calculating stress intensity factors, they arrived at the following for the beltline weld.

K_I Pressure = 64.45 Ksi$\sqrt{in}$

K_I Thermal = 45.47 Ksi$\sqrt{in}$

Their analysis considered "emergency" conditions where no safety factor is required on pressure stress. It shows that the K_I applied, 110 Ksi$\sqrt{in}$, is well below their assumed toughness (on the upper shelf) of 200 Ksi$\sqrt{in}$. Even considering the more conservative Appendix G value of 170 Ksi$\sqrt{in}$ for upper shelf toughness, the safety factor is still 1.5..

The temperature used in this analysis, 468°F, is certainly well above the minimum upper shelf temperature of even the irradiated limiting weld metal in the beltline.

Independent Staff Analysis

We have performed an Appendix G analysis using the stress intensity factor values calculated by B&W. There are two important differences between the "Emergency" condition analysis and the Appendix G analysis. These are

a. A safety factor of 2 must be applied to pressure stresses.

b. The maximum allowable upper shelf toughness is 170 Ksi$\sqrt{in}$

The K_I to be considered is then (2)(64.45) + 45.47, or 174.37 Ksi$\sqrt{in}$., which is above the maximum permitted.

We calculated the maximum pressure that would be permitted by Appendix G with the high thermal stresses present to be about 2000 PSIG, so they violated Appendix G by only about 100 PSIG, by this analysis.

We have also performed independent analyses to determine if a more severe state would have occurred at longer times into the transient, and also to check their calculations for thermal stresses and stress intensity factors. For this analysis, we also considered the most severe radiation damage that we could assume, using the "worst" reported chemical analysis of the limiting beltline weld.

We performed these calculations for 1/8T as well as the usually assumed 1/4T deep flaw. In this case, the 1/4T flaw was always more severe. With a steeper temperature gradient, and more radiation damage, shallower flaws could be more severe.

Even with our most pessimistic predictions of radiation damage, the temperature of the vessel at 1/4T remained above the minimum upper shelf temperature, and the upper shelf toughness was over 50 ft. lb. Therefore, the upper shelf toughness value of 170 Ksi$\sqrt{in}$ given in Appendix G is appropriate for the analysis.

Our calculated worst case occurred at 47 minutes into the transient when the pressure was 2000 PSI and the 1/4T temperature was about 410°F. The pressure allowed by Appendix G was determined using our calculations for thermal stress and stress intensity factor. This allowable pressure was 1560 PSIG, so at 2000 PSIG, our calculations indicate they violated Appendix G by 440 PSIG.

Our calculations also confirmed that even using the conservative upper shelf toughness of 170 Ksi$\sqrt{in}$, and assuming an extremely improbable 1/4T deep flaw the safety factor was still about 1.26.

Discussion

Although the actual safety implications of this particular transient were minimal, this is only true because it occurred very early in plant life. We strongly recommend that positive steps be taken to prevent transients of this kind, and that the generic implications be reviewed promptly.

Steam Generator

A preliminary assessment of the potential damage to the SMUD Steam Generators during the 3/20/78 rapid cooldown transient at Rancho Seco has been completed by Babcock & Wilcox. Based on that assessment, B&W feels that the steam generators have not been adversely affected.

This evaluation is based on an analysis of the stresses imposed on the tubes, tube-to-tubesheet welds, and head-to-tubesheet weld. To assess whether or not the tube yield strengh was exceeded, an estimate of average shell temperature vs. time was made. From this calculation, the maximum tube-to-shell temperature differential (ΔT) is 170°F at 0515 hours (50 minutes into the transient).

A structural analysis was performed by the Component Designer which demonstrated that a 200°F ΔT is acceptable without exceeding tube yield strength or without imposing unacceptable stresses in any of the welds and further meets the requirements of ASME Code Section III.

In addition, B&W has evaluated the fatigue usage factor and they are convinced that the usage has not been appreciably increased. This will be determined and reported in the final report of this incident.

Conclusions

1. During the transient, the technical specifications on cooldown rate and pressure-temperature limits were exceeded.

2. Appendix G limits were exceeded.

3. Because the vessel had limited service and radiation damage, appropriate limits for emergency conditions were not exceeded.

4. We conclude that the reactor vessel was not damaged by the transient to the extent that it reduced its expected service life.

5. Positive steps should be taken to preclude similar transients, and generic implications should be reviewed.

6. We conclude that B&W considered the appropriate regions of the steam generators and accept their findings.