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

ENCLOSURE

SAFETY EVALUATION BY THE OFFICE OF SPECIAL PROJECTS

SHUTDOWN MARGIN

TENNESSEE VALLEY AUTHORITY

SEQUOYAH NUCLEAR POWER PLANT UNITS 1 AND 2

DOCKET NOS. 50-327 AND 50-328

1. INTRODUCTION

During scrams at Sequoyah Unit 2 on May 19, 1988 and June 6, 1988, NRC inspectors noted and brought to the attention of TVA operational management an anomaly in the behavior of the core average temperature (Tav) immediately after a scram. Immediately after both of these scrams, Tav dropped substantially (at least 25°F) below the no load Tav of 547°F. This drop was much greater than the values the inspectors were familiar with at other Westinghouse plants. Sequoyah operators told the inspertors that these drops were typical at Sequoyah.

Sequoyah, like all American PWRs, exhibits a markedly negative moderator temperature coefficient at the end of core life. A temperature drop of this magnitude adds significant reactivity to the core and may compromise the minimum reactivity shutdown margin requirement of the Technical Specifications (TS). Therefore, the NRC conducted an inspection at Sequoyah of the core shutdown margin on July 11-14, 1988. The results of that inspection are documented in Inspection Report 50-327,328/88-33 dated September 12, 1988. TVA also addressed the shutdown margin issue in a Licensee Event Report (LER 50-328/88-030) dated July 14, 1988 and in a submittal dated August 31, 1988.

2. EVALUATION

During the July 11-14, 1988 inspection, an NRC team determined for Sequoyah Unit 2 Core 3 that after a reactor trip, Tav decreased to an average value of 519°F. This is a drop of 28°F. The minimum temperature reached was 506°F. There was no significant difference in the average minimum post-trip temperature before and after the 1985-88 shutdown.

During Sequoyah's initial test program, a post-trip plant performance test was run. During that test, minimum Tav only dropped to 537°F. During the July, 1988 inspection, TVA attributed the current larger drop to increased leakage in the auxiliary steam systems. While this undoubtedly could be a factor, the team observed that changes in the main feedwater pump trip functions to prevent water hammer which had the consequence of starting the steam driven auxiliary feedwater pump earlier in the post-trip transient could also be a factor. Similarly, changes in control loop tuning for main and auxiliary feedwater

and for steam dump could influence core Tav behavior. Therefore, the staff felt that no single factor could be judged a priori to be the cause of the current greater post-trip drop in Tav and that only a comprehensive examination of all possible causes would be sufficient to address the problem. In an August 31, 1988 letter, TVA described a study they were undertaking to address these various factors. The results of that study and a program for long-term corrective action will be submitted by TVA by October 14, 1988.

During the inspection, TVA provided an analysis by Westinghouse that concluded that for all trips to date the TS 3/4.1.1 shutdown margin of 1600 pcm for Unit 2 had been maintained. The inspection team independently calculated the shutdown margins for the five scrams that occurred after restart on May 13, 1988 and examined the input data for the earlier pre-shutdown scrams. Based on this independent review, the staff concurs in Westinghouse's conclusion that, in terms of the actual physics of the core, the TS minimum shutdown margin has been maintained for Unit 2.

However, for the scram occurring on June 6, 1988, calculations by the team using the approved TVA shutdown margin procedure then in place, showed that the TS minimum allowable shutdown margin requirement had been violated. TVA's recalculation, which was done at the team's request, confirmed this finding. The team noted, during its inspection, that the TVA shutdown margin instruction (TI-22) was in error in the conservative direction in that the procedure required use of a 600 pcm reactivity penalty to account for power Xenon worth effects. According to Westinghouse's June 17, 1987 letter to TVA, this penalty needed only to be taken when the reactor core was not at equilibrium prior to the scram. The procedure in effect on June 6, 1988 did not reflect this caveat. The procedure has since been corrected. For the particular scram in question, the staff agrees with Westinghouse that the penalty need not have been applied and, had it not been applied, the TVA calculation would have shown adequate TS shutdown margin. The staff notes that had this scram occurred before the xenon had stabilized or if the temperature had, during this trip, dropped as low as the lowest value in the past (i.e., 506°F), the TS margin requirement would have been violated.

As part of its review, the staff examined the Sequoyah Final Safety Analysis Report (FSAR) and the underlying Westinghouse calculations. It discussed the calculations with Westinghouse on July 13 and 14, 1988 to determine the details of the basis on which the shutdown limit was based. The steam line break accident controls the minimum core shutdown margin. Westinghouse calculations indicate that a steam line break will cause localized recriticality due to excess cooling and that without adequate shutdown margin this can lead to departure from nucleate boiling (DNB) in the core and consequent fuel clad failure in the accident. The accident is most severe at no-load Tav at 0% power and at end of core life. According to Westinghouse, its calculations assume a power defect reactivity equivalent to that for 2°F above full load Tav to 2°F below no load, and, therefore, do not include margin for large excursions below no load Tav.

The team, during the inspection, examined the process by which accident input data was developed by TVA for Westinghouse and determined that the system provided formal methods for plant personnel including the plant reactor engineer to concur in the data. Nonetheless, even though the post-trip Tav undershoot was well-known, it was not identified in the reload checklist provided to Westinghouse.

The consequences of Tav undershoot are more severe during Cycle 3 operation since this was the first low leakage core for Sequoyah Unit 2. The fuel loading pattern used for the low leakage core lowers total rod worth. Therefore, the end-of-life calculated shutdown reactivity at 547°F decreases from 2120 pcm in core 1 to 1600 pcm in core 3. This elimination of excess shutdown reactivity eliminates margin between required and actual minimum shutdown reactivity. However, even though this combination of Tav depression and reduction in margin might tend to increase the probability or consequences of a design basis accident, it was not addressed in the analysis by TVA for the Core 3 reload. Under 10 CFR 50.59, TVA must justify not submitting an application for a license amendment for the Core 3 reload.

When TVA began to address this issue in June 1988, there were two options available to assure that Unit 2 remained within the design envelope assumed in the accident analysis. Either the operators could control auxiliary feedwater (AFW) pump flow in manual to maintain Tav as is done at most other PWR plants or they could inject boron to assure that the TS minimum shutdown margin is maintained. Since TVA had installed an automatic AFW control system to address what they perceived were deficiencies in relying on manual action to control AFW, TVA elected to require the operators to add a specified amount of borated water to the plant depending on the post-trip Tav. This alternative is acceptable to the staff as a short-term measure until the restart from the Unit 2 Cycle 3 refueling outage. The same problem exists for Unit 1 Core 4 as the core physics characteristics are virtually identical. Therefore, TVA has proposed to use the same corrective action, manual boration after trip, to address the problem for Unit 1 restart. Early in core life, the calculated shutdown reactivity is much higher and, for temperature undershoots of the range Sequoyah has experienced, the post-trip Tav excursion would not lead to a violation of the TS shutdown margin limits. Therefore, the staff considers manual boration an acceptable interim measure to justify restart of Sequoyah Unit 1. However, the staff will review TVA's corrective action program, to be submitted October 14, 1988, before deciding whether the situation is acceptable for the entire life of Unit 1 core 4.

The team examined the reactor trip procedure which was modified as discussed above and concludes that the actions specified for the operators provide a reasonable method to assure that adequate shutdown margin will be maintained. The staff also examined, at TVA's Fuel Performance Branch in Chattanooga, the TVA calculations that determined the amount of borated water to be injected. The calculations were done using approved methods and techniques, were appropriate and conservative, used documented input data and were controlled and verified in a manner consistent with their safety significance. The staff

notes that the boron additions were calculated using an assumption of a 7% band to account for errors in rod worth determination. The Sequoyah FSAR assumed a 10% band. However, Westinghouse in a Topical Report (WCAP 9217 and 9218 dated October 1977) provided a basis for showing that the 7% was adequate. This Topical Report was approved by the staff in an SER dated June 15, 1978 and is appropriate for application to Sequoyah.

As stated above, the staff considers the compensatory method described above to assure adequate shutdown margin to be an acceptable interim compensatory action. In its August 31, 1988 letter on shutdown margin, TVA states that it will submit details of its specific program to the staff by October 14, 1988 to address long-term corrective actions. This program would presumably address reduction in steam system leakage, improved control of steam dumps and auxiliary feedwater system, modification of core physics parameters or changes to accident analyses.

3.0 CONCLUSION

Based on the reviews, inspections and submittals discussed above, the NRC staff concludes that the procedural changes implemented by TVA for Sequoyah will assure adequate shutdown margin and that, for Unit 2 Core 3 operation and Unit 1 Core 4 restart, the identified excessive undershoot of Tav following a trip does not now constitute an unresolved safety question. This conclusion is limited to short-term operation since it clearly relies on immediate operator action to compensate for identified deficiencies in either the design or system maintenance at Sequoyah. The staff will require the submission and staff review of the TVA corrective action program plan and correction of Unit 2 prior to the restart from Cycle 3 refueling of Unit 2. The acceptability of the present situation for the entire Unit 1 Core 4 fuel cycle will be addressed by the staff when the October 14, 1988 submittal is reviewed. The need and schedule for modifications to systems or core design will be addressed when the TVA corrective action plan is reviewed by the staff.

Principal Contributor: E. Goodwin

Dated: September 30, 1988