UNITED STATES
NUCLEAR REGULATORY COMMISSION
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS
WASHINGTON, DC 20555 - 0001

ACRSR-2235

February 16, 2007

The Honorable Dale Klein
Chairman
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

SUBJECT: BROWNS FERRY NUCLEAR PLANT, UNIT 1, 5-PERCENT POWER UPRATE

Dear Chairman Klein:

During the 539th meeting of the Advisory Committee on Reactor Safeguards, February 1–3, 2007, we discussed the Tennessee Valley Authority's (TVA's) application for a 5-percent power uprate for Browns Ferry Nuclear Plant, Unit 1 (BFN1) and the associated safety evaluation. Our Subcommittee on Power Uprates had previously reviewed this matter on January 16–17, 2007. During our review, we had the benefit of discussions with representatives of the staff and the licensee. We also had the benefit of the documents referenced.

CONCLUSIONS AND RECOMMENDATIONS

1. The TVA application for a 5-percent power uprate at BFN1 should be approved.

2. Granting of containment overpressure credit during long-term loss-of-coolant accident (LOCA) and 10 CFR Part 50 Appendix R fire scenarios at 120-percent of the original licensed thermal power (OLTP) will require support by more complete evaluations.

BACKGROUND

BFN1 is a General Electric boiling-water reactor (BWR/4) with a Mark-1 containment, located in Decatur, Alabama. BFN1 is one of three BWR/4 units at the Decatur site. All three units were originally licensed for operation at 3293 MWt. Units 1, 2, and 3 commenced operation in 1973, 1974, and 1976, respectively, and were shut down in 1985 to address management, technical, and regulatory issues. Units 2 and 3 (BFN2 and BFN3) were restarted in 1991 and 1995, respectively, and have been in operation since then. Units 2 and 3 were authorized to increase their maximum power by 5-percent (to 3458 MWt) in 1998. Unit 1 has been shut down since 1985, and TVA plans to restart it in 2007. The license expiration dates for all three units have been extended for 20 more years.

TVA has submitted applications for an extended power uprate (EPU) for each of the three units to 120 percent of OLTP. This will involve a 20-percent power uprate for Unit 1 and a 15-percent power uprate for Units 2 and 3. TVA has performed analyses and evaluations at 120-percent to support the EPU applications.

However, because all of the information necessary to support the review of the EPU is not yet available, the licensee has requested a two-step approach. This approach involves, as a first step, an interim approval of a 5-percent power uprate for Unit 1 to raise its power to the same

level and operating conditions as Units 2 and 3. The second step will involve a 15-percent EPU for all three units later this year.

For the Unit 1 uprate to 105-percent, a higher steam and feedwater flow is achieved by increasing the reactor power along specified control rod and core flow lines and increasing reactor operating pressure by approximately 30 psi. This increase in steam flow will enable the plant to increase its electrical output. Additionally, the TVA application shows that Unit 1 requires containment overpressure credit to ensure adequate net positive suction head (NPSH) for the emergency core cooling system pumps during LOCAs, anticipated transients without scram (ATWS), station blackouts (SBOs), and Appendix R events. It is important to note that the amount of the requested overpressure credit and its requested duration for each of the above events is based on analyses performed at 120-percent power.

With few exceptions, such as core design and steam dryers, the licensee has used the analyses performed at EPU conditions to support the 5-percent power uprate application.

DISCUSSION

When design-basis large-break LOCA, ATWS, SBO, and Appendix R events were analyzed at BFN1 at 120-percent power using current design-basis assumptions and methodologies, the available NPSH was found to be insufficient to avoid cavitation of the residual heat removal (RHR) and core spray pumps. The need for increased NPSH occurs because, at the higher power level, the suppression pool heats up more than at the OLTP. In the calculations performed to support the OLTP at BFN1, containment pressure was assumed to be atmospheric when computing the available NPSH.

In its application, TVA requests approval to change its licensing-basis methodology to include credit for containment accident pressure in determining available NPSH for emergency core cooling pumps for the above scenarios. Using conservative methods and a containment leak rate consistent with its technical specifications, TVA has calculated a conservative lower bound for the time-dependent pressure in containment that would result from each of these scenarios at 120-percent power. The incremental pressure credits that are requested for these scenarios are less than these computed pressures, except for the first 10 minutes of the LOCA scenario.

During the first 10 minutes of the LOCA scenario, a design-basis analysis indicates that the containment accident pressure is not sufficient to prevent cavitation of the RHR pumps for a period of about 4 minutes. The RHR pump manufacturer has stated that this period of cavitation should not inflict sufficient damage to disable the pumps, and a pump cavitation test performed on a similar RHR pump at BFN3 under similar accident conditions has confirmed this assertion. The licensee has also shown that if just two of the many conservatisms associated with this analysis were relaxed, containment overpressure would be sufficient to prevent cavitation of the RHR pumps.

After 10 minutes into the design-basis LOCA scenario, the operator throttles and realigns RHR and core spray pumps. During this long-term phase of the LOCA, the RHR pumps do not need containment overpressure, but the core spray pumps will continue to need an overpressure of up to 3 psi for 23 hours.

The ATWS and SBO scenarios need an overpressure of less than 2 psi for a little more than 1 hour. The licensee indicates that overpressure is not needed in the ATWS scenario when the analysis employs a more realistic model. For the SBO scenario, the licensee indicates that containment overpressure would not be needed for the first 3 hours of the required 4-hour coping duration. The availability of 4 offsite power lines and 8 onsite diesels with interconnecting capability makes it probable that power can be recovered within the first 3 hours of the event.

The Appendix R fire scenario is intended to demonstrate that safe shutdown can be achieved during a fire in any plant location using only protected plant equipment and operator actions that can be taken from several plant locations. This scenario at BFN1 includes the assumptions of loss of offsite power, loss of ultimate heat sink, evacuation of the control room, start of the one protected RHR pump from the remote shutdown panel, and blowdown to the suppression pool. In this bleed-and-feed scenario, up to 10 psi of overpressure are needed for 69 hours. To develop sufficient containment overpressure to allow continued operation of the RHR pumps without cavitation, the licensee will modify procedures to direct the operator to turn off the drywell coolers during the first 2 hours of this scenario. This is the limiting scenario for which overpressure credit is required. Although the thermal-hydraulic evaluations for this scenario are intended to be realistic, the licensee argues that this is an overly conservative scenario, because more equipment is likely to be available than postulated in the scenario. If two or more RHR pumps are available, credit for containment overpressure is not needed.

In determining whether credit for containment overpressure should be granted, we have noted in previous reports a number of important considerations. They include whether practical alternatives exist, such as the replacement of pumps with new pumps with less restrictive NPSH requirements; whether the containment design provides a positive indication of integrity before the event, as is the case in inerted containments; and the length of time for which containment pressure credit is required and the margin between the containment pressure required and the expected minimum containment pressure. The ultimate consideration is the risk significance of granting credit for containment overpressure.

Because of the plant configuration, the extent of modification required, and the worker dose that would be involved, we conclude that there are no practical design modifications that would preclude the need to consider the request for containment overpressure credit for most of the scenarios. However, for the Appendix R scenario, protecting a second RHR pump would eliminate the need for the credit and may be a feasible alternative.

The BFN1 containment is inerted. There is, then, a lower likelihood of significant preexisting containment leakage.

For the ATWS and SBO scenarios, the magnitude of credit and the period of time for which credit is required are small. For the short-term LOCA scenario, pump cavitation is unlikely, and the duration of containment overpressure credit is small.

For the long-term LOCA scenario, the licensee's design-basis analysis assumed the worst single failure, which is the loss of one train of emergency power. Allowing no credit for containment overpressure is equivalent to assuming an additional failure that causes loss of the overpressure. Thus, for all scenarios involving only a single failure, sufficient NPSH is available

to ensure that pump cavitation will not occur. The licensee and the staff have also identified many conservatisms associated with the design-basis analysis of the long-term LOCA scenario. Limited sensitivity calculations provided by the licensee suggest that it is possible that, on a more realistic but still conservative basis, the temperature of the suppression pool would not become high enough to require credit for containment overpressure. Because of the smaller amount of credit required for operation at 105-percent power, these analyses are sufficient to support operation at that power level, but operation at EPU conditions should be supported by more defensible calculations. When realistic analyses are used as an alternative to conservative design-basis calculations, explicit consideration of uncertainties should be included in the analysis.

Because of the amount of time for which credit is required and the amount of credit required, the Appendix R fire scenario is the limiting event for which containment overpressure credit is required. The staff presented a risk evaluation of containment overpressure credit for this scenario that showed that the contribution to core damage frequency associated with this scenario is small and represents a small fraction of the BFN1 core damage frequency. However, this assessment did not include fires initiated by external events, such as earthquakes and tornados. The inclusion of these initiators in the risk evaluation is likely to increase the risk associated with the Appendix R scenario. To use risk arguments to justify overpressure credit for this scenario, the licensee and the staff need to provide a more complete analysis including all initiators. Because of the smaller amount of credit required for operation at 105-percent power, this extensive analysis is not needed to support operation at that power level.

TVA has implemented substantial hardware changes to support successful restart and operation under EPU conditions. Significant portions of several major systems have been replaced, including all recirculation piping and the entire reactor water cleanup system. The licensee stated that a large number of valves and all valve packing materials have been replaced. It has upgraded the condensate and feedwater system to satisfy EPU feedwater demands and replaced all three feedwater pumps and all three condensate booster pumps, as well as the condensate pump impellers. After these changes, sufficient margin exists so that a trip of one feedwater pump will not result in a reactor trip.

As part of the BFN1 restart test program, condensate, condensate booster, and feedwater pump trip tests will be performed at 105-percent power to demonstrate the adequacy of the condensate and feedwater system and to test the integrated response of control systems associated with feedwater level control and reactor pressure control. The staff has made these tests a license condition for this application. In addition, the licensee has agreed to perform two large transient tests at 105-percent power. They are the main steam isolation valve closure and the generator load-reject tests. These tests are also a license condition for this application. Given the number of modifications and upgrades implemented at BFN1, we agree that these large transient tests need to be performed.

Higher steam and feedwater flow rates at uprated conditions may lead to an increase in flow-accelerated corrosion (FAC) for some components. TVA has developed a CHECWORKS-based FAC model that has been successfully used to predict FAC rates in susceptible locations of BFN2 and BFN3 piping. Because Unit 1 is in the process of a recovery effort following an extended shutdown, plant-specific FAC data are not yet available. The licensee argued that Unit 2 and Unit 3 data are reasonably representative of Unit 1 because of similarities in piping

geometry and materials. Based on Unit 2 and Unit 3 data and industry experience with the current materials, the first cycle of operation of Unit 1 is not expected to experience FAC-related failures. Measurements to be performed at the end of the first cycle of operation will provide baseline data for the Unit 1 plant-specific CHECWORKS model for future prediction of FAC rates. We concur with the staff that this represents an appropriate course of action to manage FAC at BFN1.

Increased flow rates have the potential to induce vibrations that could lead to failure of components. Because of the previous experience at Quad Cities, the steam dryers have been the primary focus of attention. After receiving the 5-percent power uprate license amendment, TVA will collect steam dryer data and perform an analysis of the steam dryers.

Confidence in the capability of the BFN1 steam dryers to maintain structural integrity at 105-percent OLTP conditions is based on the similarity of the three BFN units and the successful operating experience of the dryers of BFN2 and BFN3 at 105-percent OLTP since 1998. Before restart, the licensee will add structural reinforcements to the Unit 1 steam dryers based on the operating experience at Units 2 and 3.

The reactor operating domain is defined so that (1) the core will not be operated in an unstable regime, (2) the minimum critical power ratio is low enough to prevent dryout of the fuel pins, and (3) the linear heat generation rate is low enough to ensure the integrity of the fuel cladding during steady-state and transient conditions. The boundaries of this operating domain are based on neutronic and thermal-hydraulic calculations performed by General Electric. The staff has reviewed and approved the computer codes used in these analyses, which were performed at EPU conditions. TVA has submitted to the staff the results of the Supplemental Reload Licensing Topical Report for 105-percent power specifically addressing the safety limit minimum critical power ratio. The staff will review this report to confirm that the analyses remain applicable for the operation throughout the upcoming operating cycle at 105-percent power. Unit 1 will implement the BWR Owners Group Long-Term Stability Solution Option III for the automatic detection and suppression of stability-related power oscillations.

Only minor changes have been made in the emergency and abnormal operating procedures to accommodate the power uprate. A significant change to operator actions required to support the power uprate is the request that credit be given for manual action to terminate drywell cooling within 2 hours of entry into the safe shutdown procedure during an Appendix R event. This manual action can be performed in the control room or in two remote shutdown locations outside of the control room. The operator has 2 hours to perform this action, and the time required to terminate drywell cooling is well within this time frame. We concur with the staff that the revision to the Appendix R fire safe-shutdown operating instructions to terminate drywell cooling within 2 hours of entry into the procedure is acceptable.

TVA has performed a systematic assessment of the time available to perform the actions credited in the Updated Final Safety Analysis Report versus the time necessary to complete such actions before and after the power uprate. The uprate has not significantly affected operator action times. The main impact on operator action time at the EPU level is a decrease in the time available to complete initiation of the containment atmospheric dilution system. The

time available at the current power level is 42 hours. The time available at EPU conditions is 32 hours. Therefore, there is ample time to perform an operator action that requires no more than 5 minutes to complete.

We conclude that the TVA application for a 5-percent power uprate at BFN1 should be approved.

Sincerely,

/RA/

William J. Shack
Chairman

References:

1. Memorandum from J.E. Dyer, Director, Office of Nuclear Reactor Regulation, to John Larkins, Executive Director, Advisory Committee on Reactor Safeguards, "Transmittal of the Browns Ferry 105-Percent Power Level Uprate Safety Evaluation for Unit 1," December 1, 2006.

2. Letter from T. Abney, Manager of Licensing and Industry Affairs, Tennessee Valley Authority, to the NRC, "Browns Ferry Unit 1—Proposed Technical Specifications Change TS–431, Request for License Amendment, Extended Power Uprate Operation," June 28, 2004.

3. Letter from W. Crouch, Manager of Licensing and Industry Affairs, Tennessee Valley Authority, to the NRC, "Browns Ferry Unit 1—Technical Specification Change TS-431, Supplement 1, Extended Power Uprate," September 22, 2006.

4. Letter from G. Wallis, Chairman, Advisory Committee on Reactor Safeguards, to Nils J. Diaz, Chairman, NRC, "Vermont Yankee Extended Power Uprate," January 4, 2006.

5. Letter from G. Wallis, Chairman, Advisory Committee on Reactor Safeguards, to Nils J. Diaz, Chairman, NRC, "R.E. Ginna Extended Power Uprate Application," May 22, 2006.

6. Letter from G. Wallis, Chairman, Advisory Committee on Reactor Safeguards, to Nils J. Diaz, Chairman, NRC, "Beaver Valley Extended Power Uprate Application," May 22, 2006.

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