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28 December 1992

Director of Licensing
U.S. Nuclear Regulatory Commission
ATTN: DOCUMENT CONTROL DESK
Washington, D. C. 20555

Re: Docket 50-156; License R-74
Technical Specification 6.7c.

Subject: Transient Control Rod Malfunction

The following information is submitted in compliance with Technical Specification 6.7c, which requires a written report within 30 days of a significant variation of a "previously measured value of safety-connected operating characteristics occurring during operation of the reactor".

Transient rod clad failure and worth decrease

On December 3,1992 a pulse fired for a class indicated much lower than expected power and fuel temperature for the 1.39%ρ planned reactivity insertion. A smaller (1%ρ) pulse was fired, also indicating a much lower power. A transient rod worth measurement (rod-drop technique) indicated the transient control rod worth was 1.14%ρ rather than the value of 1.39%ρ measured in June,1992. The actual pulse size (403 MW) would be normal for 1.14%ρ insertion, based on our pulse calibration curves. The reactor was shut down at 2:18 P.M., and preparations were made for removing the transient rod and drive for inspection the next morning.

On the morning of December 4, 1992 the core was unloaded to a configuration which is subcritical with all control elements withdrawn, and the transient rod and its drive mechanism were removed from the core. The drive mechanism was examined for indications that might change the reactivity inserted, with all components, including linkages to the transient rod appearing satisfactory.

The transient control rod was a borated graphite control rod manufactured by General Atomics. This transient rod had a radiation level in excess of 3 R/hr at contact with the bottom end fitting, which made extensive examination inappropriate at that time. It was observed, however, that the aluminum clad had several pitting indications, and many of them appeared to penetrate the clad. Probing one of the larger pits revealed that

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it did penetrate the clad. Further, a black liquid began to exude from this pit. At this point the transient rod was removed from the hold-down and linkage assembly, isolated in a plastic bag and placed into a shielded storage location.

Upon determining that the transient rod was defective (December 4), telephone notification was made to General Atomics (manufacturer of the rod and drive assembly; contact was Donna Cowser) and the Nuclear Regulatory Commission (Region III; contact was Jim McCormick-Barger, since our assigned compliance inspector was out of the office).

General Atomics was told of the failure, and that we wanted price and delivery information on a new transient rod, since we did not have an operable spare.

NRC Region III was told that the observations did not appear immediately reportable (not an Abnormal Occurrence, entry into the emergency plan, or violation of a safety limit) but was being reported to them immediately because it appeared to be significant.

NRC Region III communicated the problem to NRC in Washington. There was considerable NRC interest (due to concern that the problem might be generic or that the corrosion might have affected other components), and I had several discussions with personnel from both the Region and Washington. I informed NRC that we planned to complete our annual maintenance shutdown while trying to obtain a replacement transient rod, and probably would not be operating again until January, 1993. An update to the shutdown status was telephoned to Region III (Charlie Cox) on December 7, 1992, and further discussions with NRC in Washington (Ted Michaels) took place during the week of the December 7.

Further discussions with Bill Wittemore, Roger Sclicht, and Brian Thurgood (introduced as head of TRIGA applications, and a metallurgist by profession) talked with me at length about possible causes of pitting. They suggested that, should water get inside a borated graphite transient rod, an electrochemical cell with a potential of more than 2 volts would be produced, and that it would cause corrosion of the clad from the inside. This analysis agrees with the appearance of the pits.

The absorbent paper used to catch the black liquid which leaked out of the transient rod was gamma counted to determine the activities present. HPGE spectra indicated the presence of Na-24, Sc-46, Cr-51, Mn-54, Co-58, Fe-59, Co-60, Zn-65, As-76, and Sb-124. All except Sc-46, As-76, and Sb-124 are typical of activated corrosion products typically found in our demineralizer regenerant effluent.

Since General Atomics indicated they might not be able to provide a new transient rod until the second week in January, we began work on rebuilding the boron carbide transient rod that was hand. Our machinist said repair of the old welds was not recommended, so new end fittings were fabricated so all welds would be on surfaces that had not previously been welded. The repaired rod would likely be ready for use before the end of December. Fuel self-protection requirements made it advisable to return to power operations before the new transient rod would be available. Although a formula quantity would not have lost self-protection, little margin would have been available for contingencies.

After the defective transient rod activity had declined somewhat we photographed the clad and the end fittings in order to send them to General Atomics. While making the photographs we noted black powder coming out the center of the bottom fitting. We discovered that the hole on the bottom fitting axis had apparently never been plugged or welded shut. (The hole is provided to allow for inert gas filling during welding, relief of pressure during welding, and leak testing of welds after welding.) Further examination of this hole (using magnification) on December 14, 1992 revealed that the hole was perfectly round and slightly chamfered on outer end. A 1/16 inch diameter welding rod fits easily into the hole, well up into the poison section. A 3/32 inch diameter welding rod just fits into the outer end of the hole. There is no evidence of corrosion at the hole. From the appearance we believe the hole was center-drilled, then drilled to 1/16 inch diameter (or slightly larger). It was never plugged or welded. The top and bottom end fittings on this rod are identical in appearance. (The rod was designed to allow attachment of a follower) We believe the top fitting originally had an similar hole that was welded shut.

The flats on the top end fitting of the defective rod bear the following:

BG
CR on one top flat
12
77 on other top flat

This rod was installed new on May 29,1990. It had been in storage as a spare since 1978.

Reactivity values, all in %ρ, from measurements completed 6/8/92, were:

Excess reactivity	4.54
Blade 3 worth	2.56,
Regulating blade worth	0.413,
Shutdown Margin	
calculated from bank worth curve	4.04,
measured by rod drop	4.31,

Technical Specifications define a shutdown margin requirement with the most reactive control blade (Blade 3) and the regulating blade full out:

Technical Specification limit ≥	0.2
a. Calculated from worth curves	1.067
b. Calculated from transient rod worth in banked configuration but measured from transient rod position at critical when pulling transient rod while blade 3 and the regulating blade are full out	0.47

The actual shutdown margin per technical specification requirements is between the values in a. and b., but closer to that in a., since the transient rod worth is increased due to the full out position shown of the regulating blade and blade 3, leaving one side of the core unpoisoned and shifting the flux much higher at the transient rod location. In any event, the transient rod worth decrease did not cause the most restrictive shutdown margin requirement to be violated.

After considering the event, and reviewing operating records with the view of supporting the supposed sequence of events, I believe the following occurred.

When the transient rod was installed in May, 1990, the bottom hole was open. Small amounts of water were pumped in and out of the hole as the rod and pool temperature changed, but no substantial loss of rod worth took place. Presence of the water inside the rod began the corrosive attack. Since this attack was from the inside it was not observable when inspected at the annual maintenance shutdowns in January, 1991 and January, 1992. It appears that, some time after the October pulses were fired, clad perforation occurred and water could more easily flow into and out of the transient rod, increasing the rate of boron loss, thus decreasing rod reactivity worth.

Pulses fired on September 11, 1992 and October 15, 1992 may have been slightly smaller than normal, but were within the range of variation of pulse size previously observed. (Note: the present pulse readout instrumentation reads out with greater precision than the previous oscillograph, but our operating staff was not conditioned that the range of pulse sizes observed was due to actual size change rather than the variation observed with the lower precision readout.)

Weekly comparisons of critical control element positions for the first startup of the week (xenon-free, at 300 watts) did not reveal any significant change in total control element bank reactivity, since a variation of a few hundredths of an inch is not significant, due to reactivity changes from diffuser operation and sample reactivity effects. (A bank height variation of 0.01 inch is equivalent to a reactivity change of 0.003%ρ.) A review of logs for the period September 1 through

December 3 showed the critical bank height has changed from 9.55 inches to 9.41 inches, but with values ranging from 9.64 inches to 9.38 inches in between the two dates. [illegible] the total range of change indicated is only about one-half the change in the transient rod worth observed. Full power bank height positions also failed to show any significant reactivity variation during this time period. Nevertheless, the total change in bank height from the time of the last reactivity calibrations in June, 1992 was from 9.59 inches to 9.41 inches, so that almost all of the variation was between September and December. This agrees with the assumption that rate of boron loss accelerated some time during that period.

<u>Recovery</u>
All activities (except for completing reloading of the core) scheduled for the annual maintenance shutdown were completed by 18 December 1992. Inspection and measurements of fuel and all other core components indicated no changes, and no corrosion problems.

The repaired transient rod was successfully leak tested on December 21. The hole in the end fitting was welded shut, and the rod was installed. Transient Rod drive testing and rod release and drop-time testing were completed. The core was reloaded, then made critical at 1319 on 21 December 1992. Transient rod worth was measured by rod-drop to be 1.54%ρ. The worth was adjusted to assure a worth of less than the Technical Specification limit of 1.4%ρ and measured again by rod-drop. The worth was determined to be 1.34%ρ. The shutdown margin with the most reactive control blade and the regulating blade fully withdrawn was measured by rod-drop to be 0.457%ρ. A complete calibration of the transient rod was not performed, since the replacement rod will be installed and calibrated upon receipt.

Power operation to restore the self-protection margin was resumed on 28 December 1992. Normal power operations will continue until the new transient rod is received, installed, and tested. Pulsing operation will be resumed after installation of the new rod, since the priority need now is to restore the self-protection margin.

R. J. Cashwell
Reactor Director

XC: Reactor Safety Committee
Department Chairman
NRC Region III