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**PROBABILISTIC TREATMENT OF
A LONG-TERM SHUTDOWN EVENT
WITH PEAK XENON AND FAILED RODS
TASK: PRA**

by
S. V. Topp

Authors Signature

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Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

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Stephen V. Joppa Author

Approvals:

DS Cramer

9/30/92

D. S. Cramer, Technical Reviewer

Date

Kenn O'Kula

10-1-92

K. R. O'Kula, Responsible Manager

Date

M. J. Hitchler

10/2/92

M. J. Hitchler, Level 3 Manager

Date

WESTINGHOUSE SAVANNAH RIVER TECHNOLOGY CENTER
NUCLEAR REACTOR TECHNOLOGY AND SCIENTIFIC COMPUTATIONS

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INTRODUCTION

This document describes PRA techniques used to estimate the frequency of occurrence of a chain of events postulated under Section 15.4.4.2 of the K-Reactor SAR, "Other Reactivity Additions During Shutdown". This scenario is related to the requirements in Technical Specification 3.1.3, "Reactivity Requirements-Shutdown"

SUMMARY

The scenario is postulated to proceed as follows: reactor scrams, reactor is restarted near the peak of the xenon transient (after about 3 hours and before about 24 hours), a second scram occurs from AC motor trip from power loss within the 21 hour window after critical when reactor is at power but before xenon burns out, a total of four rods from the control and/or safety complement fail to enter (not counting fully removed partial rods or corner cluster full rods), the operating crew fails to get all but three or fewer of the failed rods into the core within four hours, there is a failure to restore power and start the AC motors within four hours, or if the AC motors have been successfully started, the operating crew fails to actuate the Supplementary Safety System. The attached event tree shows this scenario schematically. The upper branch at each node represents the answer "yes" to the associated event.

The failure end-point in the scenario carries the consequence of a violation of Technical Specifications, and is labeled "VIOL" in the event tree CLASS column. The annual frequency of occurrence is the sum of such sequences, and equals $2.1\text{E-}10/\text{rx-yr}$. There is an even more remote chance of criticality, as discussed below.

CONCLUSIONS

The expected frequency of occurrence places this scenario far outside the range of about $1.0\text{E-}06/\text{rx-yr}$ normally taken as a cutoff for Design Basis consideration and inclusion in Chapter 15 of the Safety Analysis Report. Furthermore, it should be noted that the consequence of the scenario modeled here is limited to a violation of Technical Specifications, not recriticality. For

criticality to occur with so few rods removed from the core, the Mark 22 charge would have had practically zero margin of control at initial startup. This would have been noticed, and the reactor would never have been taken to power, the extra rods would not have been removed to compensate for the temperature coefficient, and xenon precursors would not have built in because no appreciable number of fissions would have taken place. Furthermore, the charge and/or control rod complement would have had to proceed through the 300 Area out-of-specifications without being noticed. Assigning a probability to this overall chain of events is a very conjectural exercise, but the number must be $1.0\text{E-}04$ or lower. If this were multiplied by the already low $2.1\text{E-}10$ derived from the event tree, an incredibly unlikely scenario results. It is therefore recommended that the scenario be deleted from future revisions to the Safety Analysis Report.

DETAILS OF BRANCH PROBABILITIES

The branch probabilities for the event tree were obtained partly from the Level 1, Rev. 1, Reactor PRA data base (Reference 1), and partly from upper-bound best estimates, as discussed below for each event. Timing related to the xenon transient was taken from Reference 2.

Event 1--ANY SCRAM This is the expected number of scrams per year for a Mark 22 in K-Reactor, derived using experience over an 18 year period (Reference 1). Frequency = 7.8/year (for unscheduled scrams followed closely by restart).

Event 2--RESTART PEAK XENON This is the conditional probability that, given a scram, the reactor would be restarted during the time that xenon would have built up enough to have the potential for a significant reactivity transient upon decay. The reactor would have become critical, and if it was taken to power it would not be for long enough to have burned out much of the xenon. Although the worst transient would be expected if the reactor were restarted somewhat after the peak of the xenon curve, at about 15 hours after scram, the whole period from 3 to 24 hours is used here for conservatism. Such a restart is allowed but discouraged, and it normally would take longer than 24 hours to decide what caused the first scram and obtain approval to restart. An upper bound on the probability is estimated to be $1.0\text{E-}01$.

Event 3--AREA POWER SCRAM This is the conditional probability that, given a restart as in Event 2, the reactor scrams a second time within the 21 hour window that xenon effects could be important relative to rod worth. The scram must be from loss of

electric power such that the AC motors trip off, so that failure of effective SSS injection (Event 7) is relevant. From Reference 1 we have that the probability of such scrams is $2.9\text{E-}05/\text{hour}$. The branch probability is then $6.0\text{E-}04$.

Event 4--FOUR RODS FAIL Technical Specifications state that if more than three safety and/or control rods fail to enter the core upon scram, the operators have four hours to insert these rods before they are required to actuate the SSS. (This requirement does not count any fully removed partial rods or corner cluster full rods, which are not supposed to insert in a scram.) Failure of more than three rods could occur from random failures of single rods, dependent failures of control system or safety system rods, failure of rod reversal to respond to transients, or failure of rod reversal to respond to gang driveout. Reference 1 shows that the relevant probability is failure of rod reversal to respond to transients, and equals $9.6\text{E-}04$. Another method of estimating a probability is to use the fact of zero occurrence over 724 scrams experienced at Savannah River; Reference 1 shows this yields a probability of $7.0\text{E-}04$. The higher value is used in the event tree for conservatism.

Event 5--FAIL TO INSERT This is the conditional probability that, given four or more rods have failed to enter, the operating crew will fail to get all but three or fewer into the core within four hours. The human error scenario is an action covered in a procedure subsidiary to a Master Control Procedure, under low stress, as modeled in Chapter 10 of Rev.0 of the Reactor PRA. A generic value of $6.4\text{E-}03$ is used.

Event 6--FAIL TO RESTORE This is the probability that area power would not be restored within four hours of the scram in Event 3, and therefore that the AC motors could not be restarted.- The probability of $6.0\text{E-}02$ is taken from Reference 1.

Event 7--SSS This is the probability that the operating crew would fail to actuate the SSS when the AC motors resumed running, given that four or more rods are still out of the core (Event 5). This failure also includes a failure to restart the AC motors, once power was available. This also is a human error scenario for an action covered in a procedure subsidiary to a Master Control Procedure, under low stress. However, the value used for Event 5 has been doubled to account for the possibility that some complacency has developed because power is restored and the AC motors are now running. Probability thus equals $1.28\text{E-}02$.

REFERENCES

- (1) D. S. Cramer, "Data for Long-Term Shutdown Issue", SRTC-RST-92-0145, September 21, 1992, and Rev. 1, Level 1 Reactor PRA Data Base (in preparation)
- (2) S. K. Skiles, "Control Rod Insertion Requirements for Reactor Shutdown", WSRC-TR-91-036, March, 1991

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