BWR OWNERS' GROUP

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Director of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Mail Station P1-137
Washington, DC 20555

Attention: Ashok C. Thadani, Director
Div[illegible]ion of System Technology

Subject: **REPORT ON MITIGATION OF INSTABILITY DURING ATWS**

Reference: Letter, CL Tully to AC Thadani, "Submittal of Report on Mitigation of Instability During ATWS", December 16, 1992

Enclosed is a report NEDO 32164 entitled "Mitigation of BWR Core Thermal-Hydraulic Instabilities in ATWS." This report was prepared for the BWR Owners' Group by GE and documents the results of studies of mitigation effectiveness. An unbound version of this report was previously submitted (referenced letter). Typographical errors were identified in the unbound version and these are corrected by the attached errata sheets. The enclosed bound version has been corrected.

The material contained in the attachment to this letter has been endorsed by a substantial number of the members of the BWR Owners' Group, however, it should not be interpreted as a commitment by any individual member to a specific course of action. Each member must formally endorse the BWR Owners' Group position in order for that position to become the member's position.

Very truly yours,

Cynthia L. Tully

C. L. Tully, Chairperson
BWR Owners' Group

EXEC6T/CLT/HCP/rt
Attachment

cc: LA England, BWROG Vice Chairman
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G002
1/10

Errata and Addenda Sheet

GE Nuclear Energy
175 Curtner Avenue
San Jose, CA 95125

Applicable to:

Publication No. NEDO-32164

Title Mitigation of BWR Core Thermal-Hydraulic Instabilities in ATWS

Issue Date December 1992

E&A No. 1

Date January 1993

Note: Correct all copies of the applicable publication as specified below.

Item	References (Section, Page Paragraph, Line)	Instructions (Corrections and Additions)
01	Page 1-1	Replace with new page 1-1.
02	Page 3-1	Replace with new page 3-1.
03	Page 4-1	Replace with new page 4-1.
04	Page 4-3	Replace with new page 4-3.
		NOTE: revised portions of text are indicated by change bars in right-hand margin of page.

1.0 INTRODUCTION

This report presents the results of a BWR Owners' Group (BWROG) sponsored evaluation of postulated anticipated transients without scram (ATWS) combined with thermal-hydraulic instability in a boiling water reactor (BWR). Previous BWROG core thermal-hydraulic stability evaluations relative to the ATWS Rule, 10CFR50.62, are documented in NEDO-32047, "ATWS Rule Issues Relative to BWR Core Thermal-Hydraulic Stability". The bases for the ATWS Rule are summarized in that report, and the underlying acceptance criteria are identified for comparison with the results of the ATWS/stability analyses. Those analyses demonstrate that the potential for core thermal-hydraulic oscillations during an ATWS event:

(1) is not expected to result in any significant core distortion (i.e., that would impede core cooling, prevent safe shutdown, or threaten primary system integrity),

(2) presents no additional threat to primary system integrity, containment, or long-term cooling, and

(3) does not significantly increase the radiological consequences, which remain within 10CFR100 limits.

In addition, it is noted that the modifications required by the ATWS Rule adequately perform their intended function whether or not oscillations are present. It is concluded in NEDO-32047 that the technical basis for the current ATWS Rule is entirely adequate, notwithstanding the possibility of core thermal-hydraulic oscillations.

The potential for instabilities in ATWS events must also, however, be considered from an operational perspective. The BWROG Emergency Procedure Guidelines (EPGs) include, as part of their basis, a provision that all mechanistically possible plant conditions for which generic operational guidance can be provided are addressed, irrespective of the probability of occurrence. This report documents the results of BWROG investigations into options for operator guidance to respond to conditions symptomatic of an ATWS event with oscillations. These evaluations conclude that specific operator actions can indeed both reduce the likelihood of large irregular oscillations during an ATWS event and mitigate the consequences of the oscillations. It is important to note that the timing of the operator actions used in the mitigation analyses was selected with the objective of demonstrating the effectiveness of these actions when taken, not in any attempt to prescribe the actual timing.

3.0 EVALUATION BASES

3.1 SEQUENCES OF EVENTS

As described in NEDO-32047, the system response to a turbine trip without scram will bound the response to all other initiating events with respect to core thermal-hydraulic oscillations. The event is initiated from rated core power at the minimum allowable core flow. Following the turbine trip, the recirculation pump trip results in core flow runback on a high rod line to high power at natural circulation. Because the turbine has tripped, steam is dumped from the turbine bypass to the main condenser, but there is no extraction steam for the feedwater heaters. This results in a long-term supply of cold feedwater which maximizes the core inlet subcooling.

Operator actions modeled in these analyses are intended to identify potential mitigation strategies, and not necessarily to define a precise success path. Based on a review of the existing operator action guidelines in the BWROG EPGs and on the NEDO-32047 ATWS/stability analyses, boron injection and reactor water level reduction were identified as the having the highest potential for mitigating oscillations while minimizing the impact on the operator's ability to respond to the ATWS event. For the purpose of these analyses, the operator is assumed to start boron injection following onset of oscillations greater than 25% peak-to-peak amplitude on the average power range monitors (APRMs). Level reduction is assumed to be initiated after it has been determined that the alternate rod insertion (ARI) function has failed. The event sequences are discussed in Tables 4.1 through 4.5 The assumptions should in no way be interpreted as requirements for or commitments to the assumed operator response times.

3.2 CALCULATIONAL BASES AND METHODOLOGY

The calculations of the system response to the turbine trip ATWS event have been performed using the TRACG computer code on the same basis as that described in NEDO-32047. The analytical bases are therefore consistent with those used in previous ATWS analyses. In general, all inputs represent expected operating conditions with selected conservative parameters. For ATWS/stability calculations, parameters known to have a significant impact on core and fuel channel stability are chosen so as to enhance the likelihood of oscillations.

4.0 RESULTS OF A.'ALYSES

Calculations of the reactor system ATWS/stability response with operator intervention were performed using TRACG by restarting from the BWR/5 turbine trip analysis described in Section 5.2 of NEDO-32047. The reactor system model used in the TRACG simulation is based on a 251-inch BWR/5 reactor vessel and internals. For evaluations of boron injection, the system configuration is consistent with the ATWS Rule boron injection requirements. The model is initialized at rated core power, the minimum licensed core flow in the extended operating domain, and rated feedwater temperature. A bottom-peaked axial power distribution is used, within the constraints of meeting the licensed thermal limits. The three-dimensional neutronics model is configured to simulate a core-wide oscillation using quarter-core symmetry. The initiating event is an inadvertent turbine trip with recirculation pump trip (the end-of-cycle RPT). Core power and core flow coast down to a relatively high power at natural circulation core flow. The feedwater/level controller maintains reactor water level by matching feedwater flow to vessel steam flow. Because there is no extraction steam to the feedwater heaters, feedwater temperature decreases over time to a minimum value defined by the condenser discharge temperature. This section of the report describes the calculated system response to specific operator actions.

4.1 RPV WATER LEVEL REDUCTION

4.1.1 Feedwater Flow Runback

The purpose of this calculation is to characterize the rate and timing of the downcomer water level reduction with no action to maintain level within a particular band. Results of this calculation are used to restart calculations with additional operator actions. The initial response to the turbine trip is identical to that discussed in Section 5.2 of NEDO-32047. As shown in Table 4-1 and Figure 4-1, oscillations begin within 40 seconds. The symptom for initiating operator action, determination that ARI has failed , is reached at about 60 seconds into the event. With a 60 second delay for operator action, feedwater flow starts to ramp down at 120 seconds and terminates completely at 135 seconds (Figure 4-2). Thereafter, the water level drops continuously in the downcomer, reaching the Level 2 set point at about 180 seconds(Figure 4-3). It is assumed that automatic high pressure emergency core cooling system (ECCS) actuation is inhibited, which allows the level to continue to drop. The downcomer water level drops to the top of active fuel (TAF) at about 216 seconds. Oscillation magnitudes start to decrease within 20 seconds of feedwater runback, and are significantly smaller during the level reduction than with level maintained at the normal level in the NEDO-32047 results.

and core flow coast down to a relatively high power at natural circulation core flow. The feedwater/level controller is operating and maintains the reactor water level at the normal water level set point. Oscillations begin within 50 seconds of the turbine trip, and the amplitude of power oscillation reaches 25% at around 60 seconds. The operator is assumed to initiate the standby liquid control system (SLCS) following detection of oscillations. For this calculation, SLCS is activated 90 seconds after the initiating turbine trip. A 30 second transport delay from the boron storage tank to the injection location in the high pressure core spray line is assumed. With an additional 20 second transport delay through the HPCS line to the upper plenum, the sodium pentaborate solution reaches the reactor vessel about 140 seconds after the turbine trip.

Results of this simulation are shown in Figures 4-13 through 4-18. With low boron concentration in the core, the core power and flow oscillations during the first 240 seconds are similar to those shown in NEDO-32047. The oscillations start to subside at about 325 seconds, and the amplitude of power oscillations drop to around 60% at 400 seconds. Oscillations are negligible beyond 500 seconds, after about six minutes of boron injection to the vessel.