YANKEE ATOMIC ELECTRIC COMPANY

REGULATORY GUIDE 1.97

NUCLEAR INSTRUMENTATION ANALYSIS

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1.0 INTRODUCTION

1.1 Background and Report Purpose

Background

In response to the TMI Action Plan (NUREG-0737, Supplement 1), Yankee Atomic Electric Company (YAEC) was required to address Regulatory Guide 1.97 (Reference 1). Each requirement has been resolved, except those related to design and qualification of Nuclear Instrumentation (NI). Reference 2 stated the most recent staff position:

> ... post-accident neutron flux monitoring is a 'key variable' for detecting an uncontrolled approach to criticality, be it inadvertent boron dilution or other reactivity addition situation resulting from accidents, and for the determination that an accident has been and is maintained mitigated. Since key variables are classified as Category 1, the licensee should commit to installation ...

Report Purpose

This report reviews the need for changes to NI using a risk-based analysis. This risk-based approach is based on methods previously used to support resolution of SEP Topic III-2, "Wind and Tornado Loadings," and SEP Topic III-4A, "Tornado Missiles." Reference 3 provided the staff safety evaluation of these SEP Topics and concluded:

1. "The licensee has appropriately assessed the risk from wind/tornado events at Yankee."

2. "The modifications proposed by the licensee result in an acceptable level of risk from high wind/tornadoes for the Yankee plant."

1.2 Issue Review

NI issues are related to range, redundancy, and environmental qualification. These issues are:

- o Is full range NI necessary to meet the objectives of Regulatory Guide 1.97 for post-accident conditions at the Yankee Nuclear Power Station (YNPS)?
- o Is redundant NI necessary to meet the objectives of Regulatory Guide 1.97 for post-accident conditions at the YNPS?
- o Is environmentally qualified NI necessary to meet the objectives of Regulatory Guide 1.97 for post-accident conditions at the YNPS?

1.3 Summary

The potential for a core damage event induced by inadequate reactivity control was assessed to be extremely low, less than 1E-07 per year. If a cost-benefit value of $1,000 per person-rem were used, the maximum cost that could be justified to reduce this frequency to 0.0 is less than $1,000.

Yankee believes that current design and operational characteristics of the YNPS meet the intent of Regulatory Guide 1.97. Because the cost of plant changes required to explicitly meet Regulatory Guide 1.97 exceeds $750,000, these changes are not required based on the above assumption. These resources would be better used if retained to be applied to other activities aimed at maintaining or improving overall plant safety and reliability. There are, however, several procedural changes which will be made to ensure the concerns associated with reactivity addition are minimized.

2.0 APPROACH AND RESULTS

2.1 General

Table 2.1 summarizes the general technical approach. Each step and associated results are described in the following sections. Where possible, previous evaluations in the Yankee Nuclear Power Station Probabilistic Safety Study (YNPS PSS) and those described in Reference 3 were used.

2.2 Establish Current Risk Level Attributable to Inadequate Reactivity Control

The issues related to NI requirements are based on ensuring that the risk attributable to inadequate reactivity control is sufficiently small. Therefore, this eva tion concentrated on sequences that could result in inadequate reactivity control by first establishing the current risk level attributable to such sequences (Step 1 in Table 2.1).

Table 2.2 delineates the nine basic steps used to establish the current risk level. Each step and the results from each step are provided below. (Figure 2-1 is a flow chart of the process.)

2.2.1 Establish Candidate Sequences (Step 1)

Successful core cooling requires adequate reactivity control during all modes of plant operation, from normal, at power conditions to post-accident conditions (e.g., main steam line rupture conditions). Hence, a comprehensive set of sequences, including those that were not initiated by reactivity control problems, were investigated.

A comprehensive set of representative sequences was selected by:

1. Reviewing event sequences in the Yankee Nuclear Power Station Probabilistic Safety Study (YNPS PSS).

2. Reviewing analyses of design basis events.

3. Reviewing the possible failure causes of instrumentation or systems that might cause a reactivity control problem or be available to detect and mitigate the problem to determine if they could also cause a plant transient (i.e., dependent-type initiating events).

The set of sequences considered were reviewed for the effects of NI range, redundancy, and equipment qualification. Plant Operating Modes 1-3 were considered.

Table 2.3 lists the candidate sequences (initiating events) considered and their estimated yearly frequencies (mean values). These sequences provide comprehensive coverage of all possible sequences.

Main Steam Line Rupture

This event results in a cooldown of the Main Coolant System (MCS) (directly challenging reactivity control) and an adverse containment environment if the rupture occurs inside containment.

Loss-of-Coolant Accident

This event causes adverse containment conditions, and depending on the rupture size, location, and operations personnel response, the possible need to recirculate MCS and Emergency Core Cooling System (ECCS) fluid from the containment sump.

Normal Plant Trip

This relatively frequent event (several times per year on average) was investigated to assess the significance on reactivity control of random and human failures in the absence of abnormal containment conditions.

Loss of Vital Bus No. 1

A loss of Vital Bus No. 1 will result in a plant trip and loss of power to the normal Nuclear Instrumentation System. In approximately 15 minutes the neutron count rate will be well within the source range, and alternate channels of source-range count rate will be available if containment conditions are not severe and other failures have not occurred.

Loss of 480 Volt Bus No. 1

Failure of this bus results in a plant trip and loss of power to normal and backup NI. Operations personnel could transfer the back-up NI to 480 V Bus No. 2 by repositioning a switch in the Switchgear Room.

Loss of Off-Site Power

This event causes a plant trip and decreases on-site power reliability.

Steam Generator Tube Rupture

This event provides a path for unborated water from the ruptured steam generator to the MCS.

2.2.2 Develop Logical Categorization (Step 2)

Prior to identifying hardware or personnel-related problems that might adversely impact reactivity control, a review of design and operational factors that influence reactivity control was performed to develop a logical categorization of reactivity control parameters, such as temperature, rod position, boron concentration, etc. This logical, "high level" development assures that important reactivity addition events are identified.

The following reactivity addition categories were identified by a consensus of Transient Analysis, Systems Engineering, and PRA/Systems Analysts with independent peer review by plant operations personnel.

For each group, the manner in which reactivity could be increased is described. Methods which cannot substantially reduce shutdown margin were eliminated from further consideration at this level. Table 2.4 summarizes the reactivity addition categories examined and the disposition of each. Each category is explained in more detail below.

2.2.2.1 MCS Void

The Yankee core has a negative void coefficient of reactivity and operates without voids during normal operation. Voiding in the form of steam bubbles reduces reactivity. Void decrease increases reactivity. Since the core remains subcooled during normal power operation, the collapse of voids formed during any event will only offset the reactivity decrease resulting from the formation of the voids. Therefore, changes in the amount of core voiding cannot decrease the original pre-event shutdown margin and, in fact, will aid in the mitigation of other reactivity increase events. Therefore, this group was eliminated from further consideration in this study.

2.2.2.2 MCS Pressure

The Yankee core has a small positive pressure coefficient of reactivity. Pressure increases would increase reactivity. An MCS pressure increase to greater than 16,000 psi above the pretrip pressure would be required before a complete loss of shutdown margin would occur. The two events which will result in a harsh containment environment, a LOCA or Main Steam Line Break (MSLB) inside containment, cause pressure to decrease. Therefore, the effect of pressure on the reactivity state for these events will be beneficial, i.e., an increase in the shutdown margin. Since the two pressurizer safety valves are set at 2485 psig and 2560 psig, along with the four loop relief valves at 2735 psig (not crediting the pressurizer power-operated relief valve which opens at 2400 psig), the pressure coefficient is not a credible positive reactivity addition event. The maximum possible reactivity addition through pressure increase is inconsequential. Therefore, this group can be eliminated from further consideration in this study.

2.2.2.3 Samarium-149 Concentration

Samarium-149 is a thermal neutron absorber which is produced by the decay of fission products. Reduction in the Sm-149 concentration will increase reactivity. However, Sm-149 is a stable isotope not subject to radioactive decay. Its concentration can be reduced only by neutron absorption. Following a reactor trip, the neutron flux is reduced to negligible levels, eliminating the only means of reducing the Sm-149 concentration. Because fission products decay following a trip, the Sm-149 concentration actually increases. Since this decreases reactivity and increases the shutdown margin, this method of reactivity increase can be eliminated from further consideration.

2.2.2.4 Core Geometry

A change in core geometry, specifically the fuel-to-water ratio, may affect the reactivity state of the core. The fuel-to-water ratio is affected by changes in the spacing between fuel rods (rod pitch). The rod pitch in the Yankee core is slightly less than the optimum value for neutron economy in order to provide a negative moderator temperature coefficient.

The Final Safety Analysis Report (FSAR) analysis documents that a coolable core geometry is maintained following a LOCA. Thus, the changes in rod pitch would not be large enough to significantly affect the core's reactivity state. Even if a significant fraction of the core were to be degraded or melt, the tendency would be toward a reduction in the rod pitch. This would reduce the reactivity state of the core. Therefore, this potential method of reactivity addition can be eliminated from further consideration.

2.2.2.5 Boron Concentration (Boron Dilution)

A reduction in the Main Coolant System (MCS) boron concentration increases reactivity. Since a reduction in the boron concentration can occur through the injection of unborated water, this method of increasing reactivity is addressed directly.

2.2.2.6 Control Rod Position (Control Rod Withdrawal/Inadequate Insertion)

Withdrawal of control rods increases reactivity. This can be accomplished by normal rod withdrawal, via a rod ejection from the core, or through stuck rods failing to insert. These events are addressed directly.

2.2.2.7 MCS Temperature (Cooldown Events)

Due to the negative moderator temperature coefficient of reactivity and the negative fuel temperature coefficient of reactivity, at End-of-Cycle (EOC) condition a significant amount of positive reactivity can be added by reducing the MCS temperature. Therefore, this method of reactivity addition is addressed directly.

2.2.2.8 Xenon Concentration (Xenon Decay)

Xenon-135 is a thermal neutron absorber. Reduction of the Xe-135 concentration increases reactivity. Reduction occurs naturally following a reactor trip due to radioactive decay. (Note that Xe-135 is not a stable isotope.) Since the equilibrium worth of Xe-135 during full power operation exceeds three percent delta rho, complete decay of Xe-135 can significantly increase reactivity. Therefore, this method of reactivity addition is addressed directly.

2.2.3 Identify Specific Events (Step 3)

For each of the four reactivity addition categories retained in Step 2, plant design and operational characteristics were reviewed to determine failures that could cause an increase in reactivity. Specific event scenarios were then developed for each category. The basis for the development of the individual event scenarios is given below:

1. MCS Boron Concentration - Plant drawings were reviewed to determine all connections to the Main Coolant System (MCS) through which unborated water may be added. In addition, for post-LOCA conditions, connections to the Vapor Container (VC) which could supply unborated water to the VC sump were evaluated. With the Safety Injection (SI) System in the recirculation mode following a LOCA, any dilution of the VC sump may eventually result in a dilution of the core region boron concentration.

2. Control Rod Position - All possible means of withdrawing control rods were considered, including manual withdrawal by the operator, and rod drive system malfunctions resulting in a continuous withdrawal of the selected rod group. A control rod ejection and a failure of one or more of the control rods to insert on a reactor trip signal were also considered.

3. MCS Cooldown - Plant drawings were reviewed to locate all connections to the main steam lines through which steam may be drawn. Systems capable of injecting cold water into the MCS were also considered.

4. Xenon-135 Concentration - A variety of plant power maneuvers prior to the initiating event were considered to ensure that the most limiting post-trip Xenon transient was included.

Table 2.5 summarizes the event scenarios considered, giving a description of each scenario. The event scenarios are grouped by reactivity category.

2.2.4 Screen Specific Events (Step 4)

The reactivity categories and the specific event scenarios were screened separately. As described earlier, the reactivity categories were first screened following their identification on the basis of whether the maximum possible change in reactivity in each category could result in a significant reduction in shutdown margin. Categories incapable of a significant reduction in shutdown margin were eliminated from further consideration at this level of screening.

Specific event scenarios were then developed for the remaining categories, as described in previous sections. These event scenarios were then screened, based on the conditions necessary for the event to occur (e.g., equipment failures, operator errors, etc.).

Table 2.6 provides a summary of the screening criteria used at both stages in the screening process. Table 2.7A lists the conditions required for each boron dilution event to occur, as well as the basis for disposition for each event considered. Tables 2.7B, 2.7C, and 2.7D provide the same information for the control rod, MCS cooldown, and Xenon-135 decay events, respectively.

In Tables 2.7A through 2.7D, the initiating event listed as "normal" considers: (1) normal plant trip, (2) loss of Vital Bus No. 1, (3) loss of 480 volt Bus 1, (4) loss of NI, and (5) loss of off-site power candidate sequences listed in Table 2.3. These candidate sequences include the various ways in which power can be lost to the NI. The "LOCA" initiating event listed in the tables includes both the loss-of-coolant accident, and steam generator tube rupture candidate sequences in Table 2.3. Lastly, the "MSLB" initiating event in the tables corresponds to the main steam line break candidate sequence in Table 2.3.

Figure 2-2 depicts the event tree used through the screening and analysis process to evaluate the probability of core melt for those selected scenarios.

2.2.5 Steps 6 Through 9

Following the final screening of the reactivity addition event scenarios, none of the scenarios were found to pass the screening criteria. No "credible" event scenarios were identified. (The Total Frequency of Core Melt was estimated to be less than 1.0E-7 per year.) The most likely event, while still highly improbable, was found to be a charging dilution of the MCS initiated from normal plant conditions with a coincident loss of NI.

Hence, formal implementation of Steps 6 through 9 of Table 2.2 was not required. However, to demonstrate the process, the charging dilution event is described qualitatively below.

Charging Dilution of MCS

Table 2.8 provides the sequence of events that would be expected as the charging dilution progresses. The dilution is assumed to occur sometime following the reactor trip caused by the loss of NI. It begins when the valves necessary to align the charging pump suction to a source of unborated water are inadvertently opened.

As shown in Table 2.8, numerous alarms and main control board indications are available to alert the operator that the charging system is in an off-normal lineup, and that a dilution should be expected. These indications and alarms are spread out in time and, therefore, are readily discernable. The only operator action credited in this scenario is that a boiler feed pump be started (either normal or emergency) upon receipt of a steam generator low level alarm. This would be a normal response to that alarm. Core melt is conservatively assumed when the core power rises above the capacity of an auxiliary feed pump to provide water to the steam generators.

Over 20 hours of continuous dilution is required to cause a return to criticality. Thus, at least two different operating shifts would have to fail to notice the indications available. (Since this is an event that could staff the Technical Support Center, it could also be credited but is not for conservatism.) In addition, the LPST level, LPST pressure, and charging temperature are recorded hourly on the Control Room primary log sheet. The PWST level is recorded once per shift.

The charging dilution of the MCS can be terminated quickly and easily from the Main Control Board. The necessary operator actions to accomplish this, both before and after criticality, are given in Table 2.9.

2.3 Potential Improvements

While no "credible" event scenarios were discovered, several procedure improvements were identified in the process of evaluating the different scenarios which could enhance maintenance of the reactivity control critical safety function in the absence of NI indication. These candidate improvements are not justified on a cost-benefit basis. The changes, however, are considered prudent and will be made within three months of the NRC's concurrence with the conclusions of this report.

1. OP-3000, "Emergency Shutdown From Power" - Insert an additional step in the procedure to check for a loss of NI. If two or more NI indicators are lost, the operator would be directed to take the following actions, assuming the reactor trips:

   a. Borate the MCS to the Mode 5 (cold shutdown) shutdown margin requirements.

   b. Energize the refueling source range channel to provide alternate source range indication.

2. OP-3106, "Loss of Main Coolant" - Insert a caution following the step directing the operator to restore steam generator levels. In performing this task, the operator should monitor for excessive feed water flow. Excessive flow would be indicative of a leaking steam generator, which could dilute MCS boron concentration if the event (LOCA) caused steam generator tube leakage.

3. OP-3201, "Steam Line Break" - Relocate the step directing the operators to perform an emergency boration upon a steam line break. It would be prudent to move this step to a more prominent location to stress the desirability of emergency boration for large steam line breaks.

4. OP-2153, "Boric Acid Control" - Add a step to the prerequisites beneath the Shift Supervisor permission, directing the Nuclear Auxiliary Operator to remain in the vicinity of the manual demineralized water supply valve, while a dilution or make up is in progress, to close the valve in the event of <u>any</u> off-normal condition. This places additional redundancy on the preclusion of an inadvertent boron dilution event.

TABLE 2.1

General Technical Approach

1. Establish current risk attributable to inadequate reactivity control.

2. On the basis of the current risk level, identify candidate changes to reduce the probability and/or consequences of the key sequences.

3. Perform an analysis of candidate changes, including those required to explicitly meet Category I requirements.

TABLE 2.2

Establishing Logical Search, Categorization, and Investigation of Risk Attributable to Inadequate Reactivity Control

1. Establish candidate sequences for evaluation using the YNPS PSS as a basis.

2. Develop a logical categorization of possible ways of changing core reactivity.

3. Identify specific ways of changing core reactivity for each category developed in Step 2 by reviewing plant design and operation.

4. Qualitatively screen possible reactivity addition events identified in Step 3 on the basis of probability and consequences to identify candidates for quantitative evaluation.

5. Develop a core melt event tree for examining each candidate reactivity addition event from Step 4.

6. Develop fault trees for each event tree top event established in Step 5 considering:

7. Quantify each event tree sequence considering dependencies among events.

8. Establish the consequences of each core-melt sequence. Consequences are assessed on a person-rem basis so that cost-benefit evaluations can be performed.

9. Establish current risk level by combining results of Steps 7 and 8.

TABLE 2.3

Candidate Sequences

Sequence	Yearly Frequency
1. Main Steam Line Break	3×10^{-4}
2. Loss of Coolant Accidents	2×10^{-3}
3. "Normal" Plant Trip	3
4. Loss of Vital Bus No. 1	10^{-2}
5. Loss of 480 Volt Bus No. 1	10^{-2}
6. Loss of NI	10^{-2}
7. Loss of Off-site Power	0.05
8. Steam Generator Tube Rupture	.02

FIGURE 2-1
Flowchart of Cost Benefit Analysis Methodology

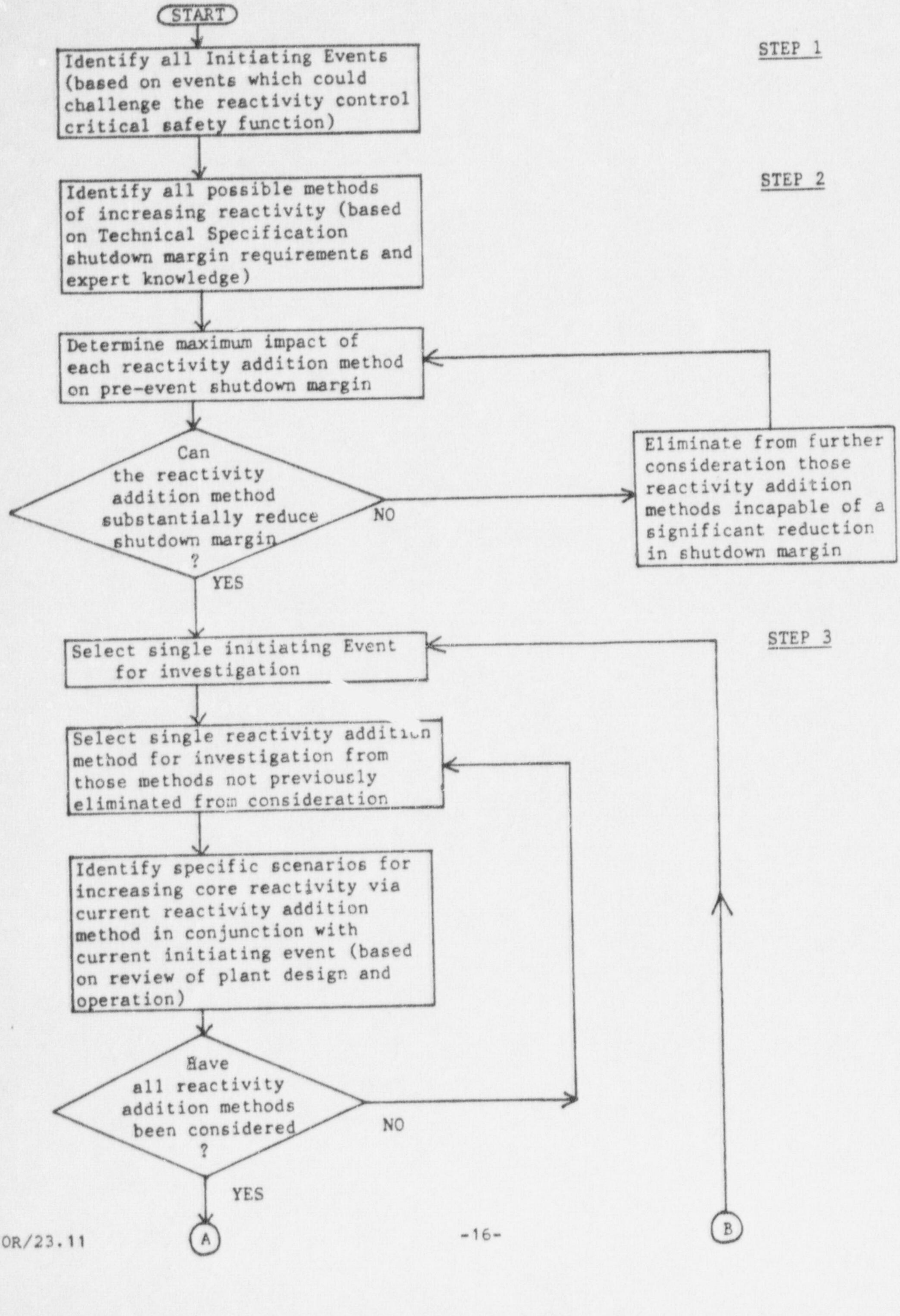


FIGURE 2-1
(continued)

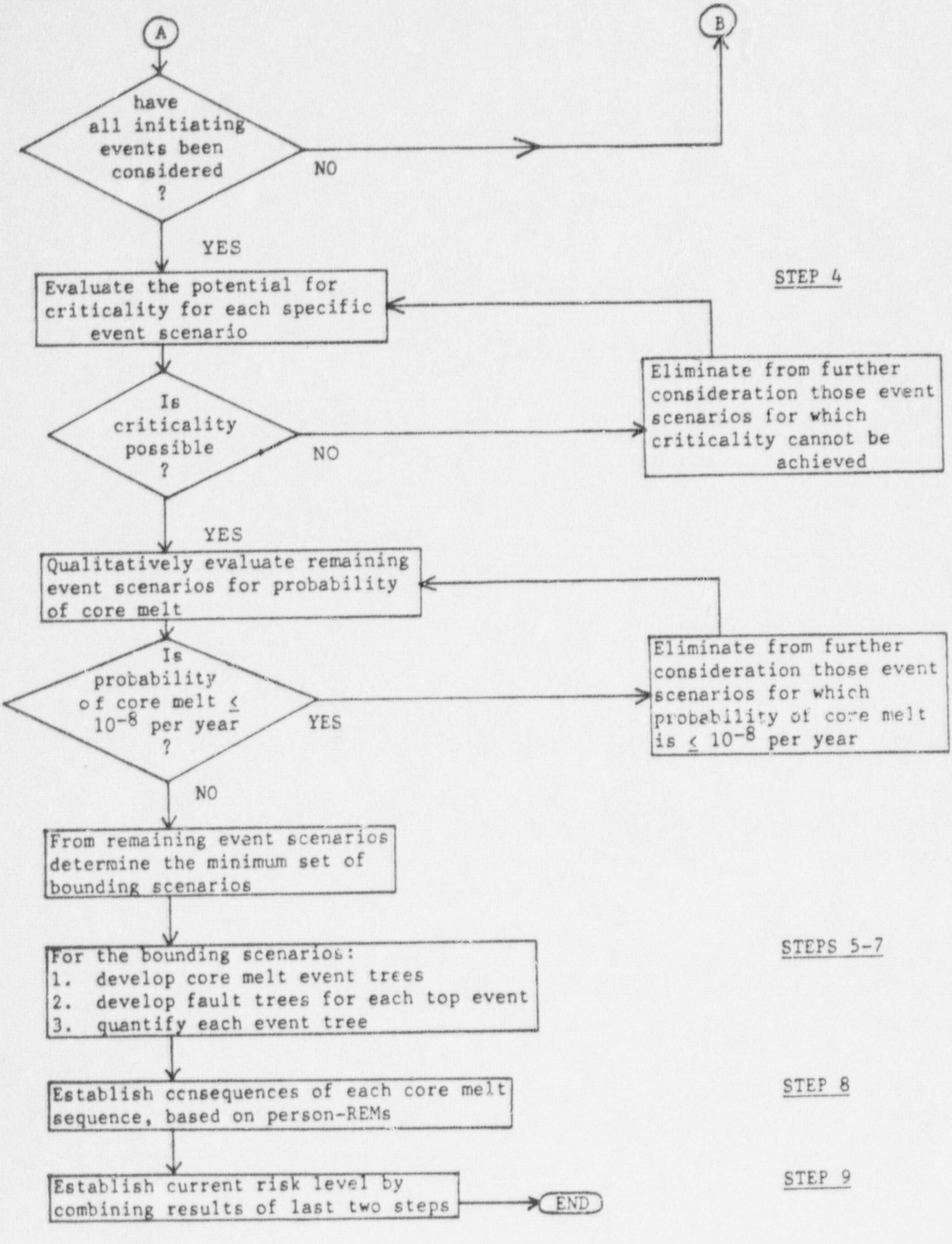


TABLE 2.4

Summary of Reactivity Addition Methods Considered

Applicable Report Section	Reactivity Addition Method	Disposition
2.2.2.1	MCS Voids	Eliminated from further consideration. Since the core is subcooled during normal operation, void reactivity is incapable of reducing the pre-event shutdown margin.
2.2.2.2	MCS Pressure	Eliminated from further consideration. The maximum reduction of the pre-event shutdown margin by pressure reactivity is inconsequential.
2.2.2.3	Samarium-149 Concentration	Eliminated from further consideration. Since Sm-149 is a stable isotope, it cannot reduce the pre-event shutdown margin by post-trip radioactive decay.
2.2.2.4	Core Geometry	Eliminated from further consideration. Since FSAR analyses show that a coolable geometry is maintained, the maximum reduction in the pre-event shutdown margin is inconsequential.
2.2.2.5	MCS Boron Concentration	Examined possible event scenarios (see Table 2.5). Addition of boron reactivity via MCS dilution could significantly reduce the pre-event shutdown margin.
2.2.2.6	Control Rod Position	Examined possible event scenarios (see Table 2.5). Addition of rod reactivity could significantly reduce the pre-event shutdown margin.
2.2.2.7	MCS Cooldown	Examined possible event scenarios (see Table 2.5). Addition of Moderator/Doppler reactivity could significantly reduce the pre-event shutdown margin.
2.2.2.8	Xenon-135 Concentration	Examined possible event scenarios (see Table 2.5). Post-trip decay of Xe-135 could significantly reduce the pre-event shutdown margin.

TABLE 2.5

Summary of Specific Event Scenarios Examined

Reactivity Addition Category	Event Identifier	Event Description
Boron Concentration	MCS Dilution via Safety Injection	Direct, continuous dilution of Main Coolant System (MCS). Safety Injection (SI) pumps inject unborated water to cold legs, taking suction from the Primary Water Storage Tank (PWST) rather than the normal suction from the SI Tank. Flow path from PWST to SI pump suction is the normal path used for blended makeup to the SI Tank. Although the flow from the SI pumps was conservatively assumed to be entirely unborated water, the actual flow would be a mix of water from the SI tank and the PWST.
Boron Concentration	MCS Dilution via Charging Line	Direct, continuous dilution of MCS. Charging pumps inject unborated water to the Loop 4 hot leg (the normal charging flow path), taking suction from the PWST rather than the normal suction from the Low Pressure Surge Tank (LPST). Flow path from PWST to charging suction is the normal path used for large dilutions near End-of-Life (EOL).
Boron Concentration	MCS Dilution via Safe Shutdown System	Direct, continuous dilution of MCS. The Safe Shutdown System primary makeup pump injects unborated water to the charging line upstream of the feed & bleed heat exchangers. The unborated water then follows the normal charging flow path to the Loop 4 hot leg. The primary makeup pump takes suction from the primary makeup tank, which is normally empty unless the Safe Shutdown System is in use. If the system is in use, procedures require that the primary makeup water be borated.
Boron Concentration	MCS Dilution via Shutdown Cooling	Direct, continuous dilution of MCS. Either the shutdown cooling or LPST cooling pump injects unborated water to the Loop 4 cold leg thru the normal shutdown cooling return line to the MCS. The pump takes suction from the LPST, which is, in turn, supplied with unborated water from the PWST. The flow path from the PWST to the LPST is the normal flow path used for small dilutions from Beginning-of-Life (BOL) to approximately Middle-of-Life (MOL).
Boron Concentration	MCS Dilution via Aux. Pressurizer Spray	Direct, continuous dilution of MCS. The charging pumps inject unborated water to the pressurizer through the auxiliary spray connection off the normal charging line downstream of the feed & bleed heat exchangers. This flow path is normally used only during the final stages of a plant cooldown. The charging pumps take suction from the PWST through the normal flow path used for large dilutions near EOL.
Boron Concentration	MCS Dilution via Steam Generator Tubes	Direct, continuous dilution of MCS through a ruptured steam generator (SG) tube. The MCS is diluted via secondary to primary system leakage if the MCS pressure is below SG pressure. The operator is assumed to feed the leaking SG to maintain level.
Boron Concentration	MCS Dilution via Component Cooling Leak	Direct, continuous dilution of MCS through a ruptured component cooling line inside a main coolant pump. The component cooling pumps inject unborated component cooling water past the main coolant pump's labyrinth seal and into the cold leg if MCS pressure is below component cooling pressure. The component cooling pumps take suction from the component cooling surge tank.

TABLE 2.5 (cont'd)

Summary of Specific Event Scenarios Examined

Reactivity Addition Category	Event Identifier	Event Description
Boron Concentration	VC Sump Dilution via Shutdown Cooling	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. Either the shutdown cooling or the LPST cooling pump injects unborated water to the Vapor Container (VC) sump through a ruptured shutdown cooling return line. The pump takes suction from the LPST, which is, in turn, supplied with unborated water from the PWST. The flow path from the PWST to the LPST is the normal flow path used for small dilutions from BOL to approximately MOL. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via LPST Safety Valve	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. The LPST safety valve is assumed to be open, and the discharge is directed to the VC sump through a rupture diaphragm. The LPST is supplied with unborated water from the PWST. The flow path from the PWST to the LPST is the normal flow path used for small dilutions from BOL to approximately MOL. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via Shield Tank Cavity Fill Line	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. During injection mode, the SI pumps inject unborated water to the VC sump through a ruptured shield tank cavity fill line and/or mispositioned valves, taking suction from the PWST rather than the normal suction from the SI Tank. Although the flow from the SI pumps was conservatively assumed to be entirely unborated water, the actual flow would be a mix of water from the SI tank and the PWST. Flow path from PWST to SI pump suction is the normal path used for blended makeup to the SI Tank. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via Safety Injection	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. During injection mode, the SI pumps inject unborated water to the VC sump through a ruptured SI line, taking suction from the PWST rather than the normal suction from the SI Tank. Although the flow from the SI pumps was conservatively assumed to be entirely unborated water, the actual flow would be a mix of water from the SI tank and the PWST. Flow path from PWST to SI pump suction is the normal path used for blended makeup to the SI Tank. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via Charging Line	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. Charging pumps inject unborated water to the VC sump through a ruptured charging line, taking suction from the PWST rather than the normal suction from the LPST. Flow path from PWST to charging suction is the normal path used for large dilutions near EOL. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.

TABLE 2.5 (cont'd)

Summary of Specific Event Scenarios Examined

Reactivity Addition Category	Event Identifier	Event Description
Boron Concentration	VC Sump Dilution via Service Water Line	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. The service water pumps inject unborated water to the VC sump through a ruptured service water line, taking suction from Sherman Pond. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via Feed/Steam Lines	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. A rupture in either a feedwater or main steam line dilutes the VC sump. The operator is assumed to continue feeding the faulted SG. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via SG Blowdown Line	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. A rupture in a SG blowdown line dilutes the VC sump. The operator is assumed to continue feed to the faulted SG. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Boron Concentration	VC Sump Dilution via Component Cooling	Indirect, continuous dilution of the MCS, applicable only to post-LOCA conditions with SI in recirculation mode. The component cooling pumps dilute the VC sump through a ruptured component cooling line. The component cooling pumps take suction from the component cooling surge tank. Once recirculation is established, the SI pumps will pump the diluted sump water back into the MCS.
Control Rods	Control Rod Withdrawal	Continuous withdrawal of the highest worth control rod bank initiated by operator error and/or a malfunction of the control rod drive system.
Control Rods	Control Rod Ejection	Failure of a control rod drive housing resulting in the instantaneous ejection of the highest worth control rod. The rod is ejected from the core by the pressure differential between the MCS and the VC.
Control Rods	Failure of Control Rods to Insert	Failure of one or more of the highest worth control rods to insert upon receipt of a scram signal resulting from the initiating event. The stuck rods could be caused by mechanical interference or excessive friction.

TABLE 2.5 (cont'd)

Summary of Specific Event Scenarios Examined

Reactivity Addition Category	Event Identifier	Event Description
MCS Cooldown	Cooldown via Excessive SG Feed	Post-trip cooldown of the MCS caused by feeding the SG's with cold water from the PWST, significantly lowering the average SG temperature and increasing heat removal from the MCS. Note that PWST temperature may be as low as 40 degrees during the winter months. The operator is assumed to feed all 4 SG's from the minimum post-trip level to normal in restoring levels following a trip.
MCS Cooldown	Cooldown via Emergency Atmospheric Steam Dump Valves	Post-trip cooldown of the MCS caused by inadvertent opening of the emergency atmospheric steam dump valves upstream of the non-return valves on each steam line to full travel. The steam released to the atmosphere increases heat removal from the MCS.
MCS Cooldown	Cooldown via Normal Atmospheric Steam Dump Valve	Post-trip cooldown of the MCS caused by inadvertent opening of the normal atmospheric steam dump valve on the main steam header to full travel. The steam released to the atmosphere increases heat removal from the MCS.
MCS Cooldown	Cooldown via Condenser Steam Dump	Post-trip cooldown of the MCS caused by inadvertent opening of the condenser steam dump valve to full travel. The steam released to the atmosphere increases heat removal from the MCS.
MCS Cooldown	Cooldown via Supply to Emergency Boiler Feed Pump	Post-trip cooldown of the MCS caused by inadvertent opening of the steam supply valve to the turbine-driven emergency boiler feed pump to full travel. The steam drawn from the SG increases heat removal from the MCS.
MCS Cooldown	Cooldown via Stuck Main Steam Safeties	Post-trip cooldown of the MCS caused by the opening of a main steam safety valve. Once open, the valve is assumed to remain open. The steam released to the atmosphere increases heat removal from the MCS.
MCS Cooldown	Cooldown via Shutdown Cooling System	Post-trip cooldown of the MCS by excessive component cooling water supplied to the shutdown cooling heat exchanger in conjunction with excessive service water flow to the component cooling heat exchanger. A cooldown could also occur if either the shutdown cooling or LPST cooling pump injects cold water from the LPST into the MCS via the shutdown cooling return line. The LPST is assumed to be supplied with cold water from the PWST through the normal flow path for small dilutions from BOL to approximately MOL. Note that the PWST temperature may be as low as 40 degrees during the winter.
MCS Cooldown	Cooldown via Charging System	Post-trip cooldown of the MCS by excessive component cooling water supplied to the LPST heat exchanger in conjunction with excessive service water flow to the component cooling heat exchanger. A cooldown could also occur if the charging pumps inject cold water from the PWST. The flow path from the PWST to the charging pump suction is the normal path used for large dilutions near EOL. Note that the PWST temperature may be as low as 40 degrees during the winter.

TABLE 2.5 (cont'd)

Summary of Specific Event Scenarios Examined

Reactivity Addition Category	Event Identifier	Event Description
MCS Cooldown	Cooldown via Safety Injection	Cooldown of the MCS caused by the injection of either cold SI water, or cold water from the PWST. The flow path from the PWST to the SI pumps suction is the normal path used for blended makeup to the SI tank. Note that the PWST temperature may be as low as 40 degrees during the winter.
MCS Cooldown	Cooldown via Steam Line Break	Cooldown of the MCS caused by complete blowdown of a single SG. A double-ended rupture of a main steam line upstream of the non-return valve is assumed to bound all possible break sizes. The steam released to the atmosphere increases heat removal from the MCS.
Xenon Concentration	Normal Post-Trip Xenon-135 Decay	Addition of positive reactivity due to the decrease in Xenon-135 concentration following a reactor trip. Note that Xenon-135 is a thermal neutron absorber. It is assumed that, prior to the initiating event, the reactor is at full power with equilibrium Xenon-135. The reactor then trips, and is restarted just at the point of peak Xenon-135 following the initial trip. At this point, the initiating event is assumed to occur. This scenario results in an immediate decline in the Xenon-135 concentration following the reactor trip caused by the initiating event, rather than the normal increase in Xenon-135 immediately following a trip. This bounds all possible Xenon transients following a reactor trip.

Table 2.6

Summary of Screening Criteria

A two step screening process was utilized. First, all possible methods for adding positive reactivity to the core (e.g. MCS boron concentration, control rod position, etc.) were identified. These reactivity addition categories were then screened:

Screening Criterion for Reactivity Addition Categories

- o Will the maximum possible reactivity added cause a significant reduction of the pre-event shutdown margin?

Specific reactivity addition event scenarios were then developed for the remaining reactivity addition categories. The remaining categories were MCS Boron Concentration, Control Rod Position, MCS Cooldowns, and Xenon-135 Concentration. These specific event scenarios were then screened:

Screening Criteria for Specific Event Scenarios

- o Is the probability of core melt less than 1E-08 per year?
- o Is it possible for the event scenario to result in criticality?
- o Is the probability of core melt for the event scenario clearly bounded by another event scenario?
- o Is the event scenario included in or bounded by the YNPS Probabilistic Safety Study?

Table 2.7-A

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(1) MCS Dilution via Safety Injection	(A) Normal	(1) Safety Injection (SI) pumps must be running. This requires an inadvertent SI actuation. (2) Main Coolant System (MCS) pressure must be below SI shutoff head (1550 psig) to inject water. This requires a failure or gross misoperation of the pressure control system. (3) SI pump suction must be aligned to a source of unborated water. This requires either: (a) Makeup to SI tank in progress upon initiating event and failure of operator to close makeup valve from Primary Water Storage Tank (PWST), either DW-V-662, 634, or 635, whichever path is in use. Administratively, operator is directed to close the valve on any off-normal event. OR (b) Two normally closed manual valves must be open, DW-V-640 and one of the 3 valves in 1-A-3-a, above.
	(B) MSLB	(1) SI pumps must be running. This is assumed to occur as a result of the Main Steam Line Break (MSLB), the initiating event. (2) MCS pressure must be below SI shutoff head (1550 psig) to inject water. This is assumed to occur for a short period of time (< 10 minutes) following the MSLB, the initiating event. (3) SI pump suction must be aligned to a source of unborated water. In SI injection mode, this requires the same conditions as 1-A-3, above. SI recirculation will not be considered since SI will be terminated without establishing recirculation for the worst case MSLB.
	(C) LOCA	(1) SI pumps must be running. This is assumed to occur as a result of the Loss of Coolant Accident (LOCA), the initiating event. (2) MCS pressure must be below SI shutoff head (1550 psig) to inject water. This is assumed to occur as a result of the LOCA, the initiating event. (3) SI pump suction must be aligned to a source of unborated water. In SI injection mode, this requires the same conditions as 1-A-3, above. In SI recirculation mode, an additional valve must be open (SI-MOV-518). The procedure for establishing SI recirculation flow directs the operator to close SI-MOV-518.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves necessary for a dilution to occur, in conjunction with the initiating event, is less than 1E-08 per year.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(2) MCS Dilution via Charging Line	(A) Normal	(1) Charging pumps must be running. At least one of three charging pumps will be running during normal operation. (2) Charging pump suction must be aligned to source of unborated water. This requires either: (a) A normal MCS dilution in progress upon the initiating event and a failure of the auxiliary operator to close the supply valve from the PWST to the charging header, either DW-V-662, 634, or 635, whichever path is in use. Administratively, operator is directed to close this valve on any off-normal event. In addition, the control room operator must fail to close DW-MOV-655. Position indication for DW-MOV-655 is available on the Main Control Board. OR (b) Two normally closed valves must be open. These are the same valves as indicated in 2-A-2-a, above.
	(B) MSLB	(1) Charging pumps must be running. Since SI actuation will lock out all charging pumps, this requires that SI be reset and the charging pumps turned on. This is assumed to occur since SI will eventually be terminated for a MSLB. (2) Charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2, above.
	(C) LOCA	(1) Charging pumps must be running. Since SI actuation will lock out all charging pumps, this requires that SI be reset and the charging pumps turned on. This action would only be taken if the break has been isolated. (2) Charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2, above.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves necessary for a dilution to occur, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(3) MCS Dilution via Safe Shutdown System	(A) Normal	(1) The Safe Shutdown System must be in operation, with the primary makeup pump running. This requires a severe earthquake, tornado, or fire which threatens the ability of normal plant systems to maintain MCS heat removal, or which threatens the habitability of the control room. (2) The boron concentration of the primary makeup tank must be less than that of the MCS. This requires multiple procedure violations to fail to add the required boron to the primary makeup tank upon initial filling, and on subsequent makeup to the tank.
	(B) MSLB	(1) The Safe Shutdown System must be in operation, with the primary makeup pump running. This requires the same conditions as 3-A-1 above. (2) The boron concentration of the primary makeup tank must be less than that of the MCS. This requires the same conditions as 3-A-2 above.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) The Safe Shutdown System must be in operation, with the primary makeup pump running. This requires the same conditions as 3-A-1 above. (2) The boron concentration of the primary makeup tank must be less than that of the MCS. This requires the same conditions as 3-A-2 above.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of a severe earthquake, tornado, or fire, in conjunction with the initiating event and the procedure violations necessary to inject unborated water, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(4) MCS Dilution via Shutdown Cooling	(A) Normal	(1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires either: (a) Normal plant cooldown to cold shutdown or normal heatup in progress upon the initiating event, with MCS pressure < 300 psig and MCS temperature < 330 degrees. Note that under these conditions, the MCS will have been borated to the mode 5 shutdown margin requirements prior to beginning the cooldown (required by procedure), extending the time required to achieve critcality due to a dilution. During a plant heatup, boron concentration is not reduced until beginning a critical approach. OR (b) The pump was started inadvertently, with SC-MOV-551 and SC-MOV-553 both open. Note that these val as are key operated and are normally closed. For the LPST cooling pump discharge to be lined up to the MCS, an additional valve, CH-V-661 (normally closed), must be open. (2) The pump suction must be aligned to the LPST. The LPST cooling pump suction is normally lined up to the LPST. To line up the shutdown cooling pump suction to the LPST, SC-V-614 must be open (normally closed). (3) The LPST must be supplied with a source of unborated water. This requires that 3 normally closed valves be open, DW-V-652A, DW-LCV-221, and either DW-V-662, 634, or 635.
	(B) MSLB	(1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires the same conditions as 4-A-1 above. (2) The pump suction must be aligned to the LPST. This requires the same conditions as 4-A-2 above. (3) The LPST must be supplied with a source of unborated water. This requires the same conditions as 4-A-3 above.
	(C) LOCA	(1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires the same conditions as 4-A-1 above. (2) The pump suction must be aligned to the LPST. This requires the same conditions as 4-A-2 above. (3) The LPST must be supplied with a source of unborated water. This requires the same conditions as 4-A-3 above.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves (2 of which are key operated) or simultaneous events required, in conjunction with the initiating event is less than 1E-08 per year.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(5) MCS Dilution via Aux. Pressurizer Spray	(A) Normal	(1) A charging pump must be running. At least 1 charging pump will be running under normal conditions. (2) The auxiliary pressurizer spray valve must be open. This requires either that CH-V-613 be open (normally closed) or that the plant be in the late stages of a normal cooldown to cold shutdown (when Ch-V-613 is open) upon the initiating event. (3) The charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2 above. Note that a dilution would not be in progress on a plant cooldown.
	(B) MSLB	(1) A charging pump must be running. This requires the same conditions as 2-B-1 above. (2) The auxiliary pressurizer spray valve must be open. This requires the same conditions as 5-A-2 above. (3) The charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2 above. Note that a dilution would not be in progress on a plant cooldown.
	(C) LOCA	(1) A charging pump must be running. This requires the same conditions as 2-C-1 above. (2) The auxiliary pressurizer spray valve must be open. This requires the same conditions as 5-A-2 above. (3) The charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2 above. Note that a dilution would not be in progress on a plant cooldown.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves or simultaneous events required for a dilution to occur, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(6) MCS Dilution via Steam Generator Tubes	(A) Normal	(1) A leak must exist in an SG tube. This requires the random failure of a SG tube. Note that the dilution resulting from the total leakage allowed by Technical Specifications (1 GPM primary to secondary leakage plus 1 GPM unidentified leakage) is inconsequential. (2) MCS pressure must be below SG pressure. Since MCS pressure is normally maintained > SG pressure in all plant modes, a failure or gross misoperation of the pressure control system is required.
	(B) MSLB	(1) A leak must exist in an SG tube. A leak is assumed to occur as a result of the thermal hydraulic stresses caused by the rapid cooldown. (2) MCS pressure must be below SG pressure. For the worst case MSLB, MCS pressure remains > SG pressure. Therefore, a failure or gross misoperation of the pressure control system is required.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) A leak must exist in an SG tube. A leak is assumed to occur as a result of the thermal hydraulic stresses caused by the LOCA. (2) MCS pressure must be below SG pressure. This is assumed to occur as a result of the initiating event. (3) For criticality to occur, the operator must continue to feed the faulted SG for > 2 hours. This requires that the operators and the Emergency Response personnel fail to recognize the excessive feed required to maintain level in the faulted SG, compared with the intact SG's. Note that the Technical Support Center will be fully staffed well before the 2 hour point at which criticality may be achieved.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the equipment failures, operator errors, or simultaneous events required for criticality to occur, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(7) MCS Dilution via Component Cooling Leak	(A) Normal	(1) A leak must exist in the component cooling line inside a main coolant pump. This requires a random pipe failure. (2) MCS pressure must be below component cooling pressure. This will occur for a short time during plant startup from cold shutdown, between the time component cooling flow is established to the main coolant pumps and the time that a pressurizer steam bubble is drawn. At all other times, a failure or gross misoperation of the pressure control system is required. (3) For criticality to occur, the dilution must continue for > 50 minutes. However, the component cooling surge tank will empty in approximately 43 minutes, causing a loss of NPSH to the component cooling pumps and terminating the dilution.
	(B) MSLB	(1) A leak must exist in the component cooling line inside a main coolant pump. This is assumed to occur as a result of the thermal hydraulic stresses caused by the rapid cooldown. (2) MCS pressure must be below component cooling pressure. For the worst case MSLB, MCS pressure remains > component cooling pressure. Thus, a failure or gross misoperation of the pressure control system is required. (3) For criticality to occur, the operator must fail to perform the emergency boration required by procedure. Note that if the boration is completed, criticality cannot occur, since the component cooling surge tank will empty prior to criticality.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) A leak must exist in the component cooling line inside a main coolant pump. This is assumed to occur as a result of the thermal hydraulic stresses caused by the LOCA. (2) MCS pressure must be below component cooling pressure. This is assumed to occur as a result of the initiating event (LOCA). (3) For criticality to occur, the dilution must continue for > 6 hours. However, the component cooling surge tank will empty in approximately 43 minutes, causing a loss of NPSH to the component cooling pumps and terminating the dilution.

DISPOSITION: This event scenario will be eliminated from further consideration. For both normal and post-LOCA initial conditions, criticality cannot be achieved, since the component cooling surge tank will empty prior to criticality, causing a loss of NPSH to the component cooling pumps and terminating the dilution. For post-MSLB initial conditions, the probability of the operator errors and equipment failures necessary to reach criticality, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(8) VC Sump Dilution via Shutdown Cooling	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires either: (a) Normal plant cooldown to cold shutdown in progress, with MCS pressure < 300 psig and MCS temperature < 330 degrees. Note that under these conditions, the MCS will have been borated to the mode 5 shutdown margin requirements prior to beginning the cooldown, extending the time required to achieve critcality due to a dilution. OR (b) The pump was started inadvertently. The discharge of the shutdown cooling pump is normally lined up to the shutdown cooling return line to the MCS. For the LPST cooling pump discharge to be lined up to the MCS, CH-V-661 (normally closed) must be open. (2) The pump suction must be aligned to the LPST. This requires the same conditions as 4-A-2 above. (3) The LPST must be supplied with a source of unborated water. This requires the same conditions as 4-A-3 above. (4) There must be a rupture of the shutdown cooling return line to the MCS inside containment. This requires either a random pipe failure or that pipe whip or jet impingement due to the LOCA cause a failure of the shutdown cooling return line to the MCS.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves required, in conjunction with the initiating event and a random failure of the shutdown cooling return line, is less than 1E-08 per year.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(9) VC Sump Dilution via LPST Safety Valve	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) The LPST safety valve must be open. This requires a random failure of the safety valve or a failure of the pressure regulator supplying the hydrogen cover gas to the LPST. (2) A source of unborated water must be lined up to the LPST. This requires the same conditions as 4-A-3 above. (3) The LPST must be filled with water. This requirement represents only a time delay to the start of the sump dilution, since the initial discharge from the safety valve will be hydrogen gas. A sump dilution will not begin until the LPST becomes water solid. This requirement will eventually be fulfilled if requirements 9-C-1 and 9-C-2 above are fulfilled.
DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the equipment failures and mispositioned valves necessary to cause a dilution, in conjunction with the initiating event, is less than 1E-08 per year.		
(10) VC Sump Dilution via Shield Tank Fill Line	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) SI pumps must be running. This is assumed to occur as a result of the Loss of Coolant Accident (LOCA), the initiating event. (2) SI pump suction must be aligned to a source of unborated water. This requires the same conditions as 1-C-3 above. (3) A portion of the SI flow must be directed to the shield tank cavity fill line. This requires either a random failure of the shield tank cavity fill line inside containment, or that CS-V-601 (normally locked closed) be open.
DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves or random pipe failure required for a dilution to occur, in conjunction with the initiating event, is less than 1E-08 per year.		
(11) VC Sump Dilution via Safety Injection	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) SI pumps must be running. This is assumed to occur as a result of the Loss of Coolant Accident (LOCA), the initiating event. (2) SI pump suction must be aligned to a source of unborated water. This requires the same conditions as 1-C-3 above. (3) There must be a rupture in an SI cold leg injection line inside containment. This requires either a random pipe failure or that pipe whip or jet impingement due to the LOCA cause a failure of the SI cold leg injection line.
DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves and pipe failure necessary to cause a dilution, in conjunction with the initiating event, is less than 1E-08 per year.		

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(12) VC Sump Dilution via Charging Line	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) Charging pumps must be running. This requires the same conditions as 2-C-1 above. (2) Charging pump suction must be aligned to a source of unborated water. This requires the same conditions as 2-A-2, above. (3) There must be a rupture in the charging line inside containment. This requires either a random pipe failure or that pipe whip or jet impingement due to the LOCA cause a failure of the charging line.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the mispositioned valves and pipe failure necessary to cause a dilution, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(13) VC Sump Dilution via Service Water Line	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) A service water pump must be running. Service water pumps normally operate under all plant conditions. (2) The service water pumps must develop a large enough head to raise the service water to the level of the containment. This is unlikely due to the other plant demands for service water flow. (3) A containment isolation must be open. This requires either a failure of SW-TV-412 to close on receipt of a containment isolation signal from the initiating event, or a gross operator error to re-open SW-TV-412 after it has closed automatically. Note that this requires 2 VC isolation channels to be reset. (4) There must be a rupture in the sevice water line inside containment. This requires a random pipe failure.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of a failed or mispositioned containment isolation valve and the random pipe failure necessary to cause a dilution, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(14) VC Sump Dilution via Feed/Steam Lines	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) Either a feedwater or main steam line must rupture inside containment. This requires a random pipe failure. (2) For criticality to occur, the operator must continue to feed a SG which exhibits a rapidly decreasing level and pressure. This requires a gross operator error.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the random failure of a large diameter pipe and the gross operator error necessary to achieve criticality, in conjunction with the initiating event, is less than 1E-08 per year.

Table 2.7-A (cont'd)

Basis for Disposition of Boron Dilution Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(15) VC Sump Dilution via SG Blowdown Line	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) There must be a rupture of a SG blowdown line inside containment. Thi requires either a random pipe failure or that pipe whip or jet impingement due to the LOCA cause a failure of the blowdown line. (2) For criticality to occur, the operator must continue to feed a SG which exhibits a decreasing level and pressure for > 50 minutes. This requires an operator error.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the pipe failure and operator error necessary to achieve criticality, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(16) VC Sump Dilution via Component Cooling	(A) Normal	-- Applicable only to post-LOCA conditions under SI recirculation --
	(B) MSLB	-- Applicable only to post-LOCA conditions under SI recirculation --
	(C) LOCA	(1) The component cooling pumps must be running. These pumps normally operate under all plant conditions. (2) The component cooling containment isolation valve must be open. This is assumed to occur since the LOCA procedure directs the operator to re-open this valve following containment isolation. (3) There must be a rupture in the component cooling supply line inside containment. This requires either a random pipe failure or that pipe whip or jet impingement due to the LOCA cause a failure of the component cooling line. (4) For criticality to occur, > 2500 gallons of unborated water must be added to the VC sump. However, the normal content of the component cooling surge tank is 2500 gallons. Therefore, the component cooling surge tank will empty prior to criticality, causing a loss of NPSH t the component cooling pumps and terminating the dilution.

DISPOSITION: This event scenario will be eliminated from further consideration. Criticality cannot be achieved, since the component cooling surge tank will empty prior to criticality, causing a loss of NPSH to the component cooling pumps and terminating the dilution.

Table 2.7-B

Basis for Disposition of Control Rod Withdrawal Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(1) Control Rod Withdrawal	(A) Normal	(1) The scram breakers must be closed to provide power to the rod drive system. Since a loss of nuclear instrumentation is assumed to have occurred as part of the initiating event, this requires a gross operator error. Note that scram breakers are normally only closed as the first step in a critical approach. A critical approach without nuclear instrumentation is both a Technical Specification and a procedure violation. (2) The MCS shutdown margin must be near or below the minimum allowable Technical Specification value. This requires a MCS dilution in excess of 2.5 hours at the maximum flow of a single charging pump (33 GPM) following the trip caused by the initiating event. This action constitutes a gross operator error, since shutdown margin is never purposely reduced following a trip. (3) For criticality to occur, the Group D control rod bank must be withdrawn to > 50 inches. This requires either a failure of the control rod drive system or a gross operator error to withdraw rods with no nuclear instrumentation available. Note that the only control rod group containing enough reactivity worth to cause a return to criticality is Group D.
	(B) MSLB	(1) The scram breakers must be closed to provide power to the rod drive system. This requires the same conditions as 1-A-1 above. (2) The MCS shutdown margin must be near or below the minimum allowable Technical Specification value. This requires a procedure violation for the operators to fail to perform an emergency boration of the MCS. (3) For criticality to occur, any control rod group must be withdrawn to > 5 inches. This requires the same conditions as 1-A-3 above.
	(C) LOCA	(1) The scram breakers must be closed to provide power to the rod drive system. This requires the same conditions as 1-A-1 above. (2) The MCS shutdown margin must be near or below the minimum allowable Technical Specification value. Due to the borated SI water added as a result of the initiating event, this would require numerous gross operator errors and procedure violations to perform an extended dilution of the MCS. (3) For criticality to occur, the Group D control rods must be withdrawn to > 50 inches. This requires the same conditions as 1-A-3 above.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the numerous gross operator errors and procedure violations necessary to cause criticality, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(2) Control Rod Ejection	(A) Normal	(1) There must be a gross failure of a control rod drive housing on the reactor vessel head. This requires a random failure. (2) MCS pressure must be significantly > VC pressure. This condition is assumed to exist. (3) For criticality to occur, the reactivity worth of the ejected rod must be > the shutdown margin. Under normal plant conditions, assuming that the minimum Technical Specification shutdown margin requirements are met, this is impossible. Note that the initiating event, a loss of power to nuclear instrumentation during normal conditions, will result in a reactor trip.

Table 2.7-B (cont'd)

Basis for Disposition of Control Rod Withdrawal Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(B) MSLB	(1) There must be a gross failure of a control rod drive housing on the reactor vessel head. This requires a random failure. (2) MCS pressure must be significantly > VC pressure. This condition is assumed to exist. (3) For criticality to occur, the reactivity worth of the ejected rod must be > the shutdown margin. This requires a gross operator error to fail to perform an emergency boration as directed by procedure.
	(C) LOCA	(1) There must be a gross failure of a control rod drive housing on the reactor vessel head. This requires a random failure. (2) MCS pressure must be significantly > VC pressure. This condition is assumed to exist. (3) For criticality to occur, the reactivity worth of the ejected rod must be > the shutdown margin. Due to the borated SI water added to the MCS as a result of the initiating event, this is impossible.

DISPOSITION: This event scenario will be eliminated from further consideration. For both normal and post-LOCA initial conditions, criticality is not possible. For post-MSLB conditions, the probability of the random failure and operator error necessary to achieve criticality, in conjunction with the initiating event, is less than 1E-08 per year.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(3) Failure of Control Rods to Insert	(A) Normal	(1) For criticality to occur, there must be > 3 stuck control rods upon receipt of the scram signal from the initiating event. Note that the initiating event, a loss of power to nuclear instrumentation during normal conditions, will result in a reactor trip. (2) For core melt to occur, the operator must fail to perform the emergency boration required by procedure.
	(B) MSLB	(1) For criticality to occur, there must be at least 2 stuck control rods upon receipt of the scram signal from the initiating event. (2) For criticality to occur, the MSLB must occur past 50% of core life. (3) For core melt to occur, the operator must fail to perform the emergency boration required by procedure.
	(C) LOCA	(1) For criticality to occur, there must be > 3 stuck control rods upon receipt of the scram signal from the initiating event. No credit is taken for the injection of borated SI water. (2) For core melt to occur, the operator must fail to perform the emergency boration required by procedure.

DISPOSITION: This event scenario will be eliminated from further consideration. The probability of the number of stuck rods and operator errors necessary for core melt, in conjunction with the initiating event, is less than 1E-08 per year.

Table 2.7-C

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(1) Cooldown via Excessive SG Feed	(A) Normal	(1) The temperature of the Demineralized Water Storage Tank (DWST) must be low. This requires that the initiating event occur during the winter months (DWST temperature may be as low as 40 degrees). (2) The operator must batch feed all 4 SG's. This is a normal action following a trip and is assumed to occur. (3) For criticality to occur, the operator must fail to note a significant decrease in the MCS temperature.
	(B) MSLB	(1) The temperature of the Demineralized Water Storage Tank (DWST) must be low. This requires the same conditions as 1-A-1 above. (2) The operator must batch feed all 4 SG's. This is assumed to occur, since the procedure directs the operator to restore normal SG level. (3) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.
	(C) LOCA	(1) The temperature of the Demineralized Water Storage Tank (DWST) must be low. This requires the same conditions as 1-A-1 above. (2) The operator must batch feed all 4 SG's. This is assumed to occur, since the procedure directs the operator to restore normal SG level. (3) For criticality to occur, the operator must fail to note a significant decrease in the MCS temperature.

DISPOSITION: This event scenario will be eliminated from further consideration. It is included in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(2) Cooldown via Emergency Atmospheric Steam Dump Valves	(A) Normal	(1) The Emergency Atmospheric Steam Dump Valves (MS-MOV-659, 670, 681, and 692) must be opened inadvertently. This requires a gross operator error, since remote operation of the valves requires a key to supply power to the motor operator, and the valve handwheel for local operation is normally locked closed. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.
	(B) MSLB	(1) The Emergency Atmospheric Steam Dump Valves must be opened inadvertently. This requires the same conditions as 2-A-1 above. (2) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.
	(C) LOCA	(1) The Emergency Atmospheric Steam Dump Valves must be opened inadvertently. This requires the same conditions as 2-A-1 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.

DISPOSITION: This event scenario will be eliminated from further consideration. It is bounded by the steam line rupture event in the Yankee Nuclear Power Station Probabilistic Safety Study.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(3) Cooldown via Normal Atmospheric Steam Dump Valve	(A) Normal	(1) The normal atmospheric steam dump valve (MS-TV-411) must be inadvertently opened. This requires either a failure of the dump valve or an operator error to open the valve. In addition, 2 normally closed manual valves must be open. Note that, due to the small size of the valve, it would have to be open for an extended period of time to cause a significant MCS cooldown. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.
	(B) MSLB	(1) The normal atmospheric dump valve (MS-TV-411) must be inadvertently opened. This requires a either failure of the dump valve or a gross operator error to open the valve, which closed on a containment isolation signal caused by the initiating event. In addition, 2 normally closed manual valves must be open. Note that, due to the small size of the valve, it would have to be open for an extended period of time to cause a significant MCS cooldown. (2) For criticality to occur, the operator must fail to perform an emergency boration required by procedure.
	(C) LOCA	(1) The normal atmospheric steam dump valve (MS-TV-411) must be inadvertently opened. This requires the same conditions as 3-B-1 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.

DISPOSITION: This event scenario will be eliminated from further consideration. It is bounded by the steam line rupture event in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(4) Cooldown via Condenser Steam Dump	(A) Normal	(1) The condenser steam dump valve (MS-PCV-402) must be open more than is necessary to provide decay heat removal. This requires either a failure of the valve or misoperation of the valve by the operator along with a failure of the operator to correct the overcooling situation. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.
	(B) MSLB	(1) The condenser steam dump valve (MS-PCV-402) must be open. This requires a gross operator error to open one or more steam line non-return valves, which closed on the containment isolation signal caused by the initiating event. In addition, either a dump valve failure, or misoperation of the valve by the operator along with a failure of the operator to correct the overcooling situation, is necessary. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) The condenser steam dump valve (MS-PCV-402) must be open. This requires the same conditions as 4-B-1 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.

DISPOSITION: This event scenario will be eliminated from further consideration. It is included in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(5) Cooldown via Supply to Emergency Boiler Feed Pump	(A) Normal	(1) The steam supply to the steam driven Emergency Boiler Feed Pump must be opened inadvertently. This requires that [illegible]-V-719 and AS-V-758 (normally locked closed) be opened. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.
	(B) MSLB	(1) The steam supply to the steam driven Emergency Boiler Feed Pump must be opened inadvertently. This requires the same conditions as 5-A-1 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.
	(C) LOCA	(1) The steam supply to the steam driven Emergency Boiler Feed Pump must be opened inadvertently. This requires the same conditions as 5-A-1 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature, as well as decreasing SG levels and pressures.

DISPOSITION: This event scenario will be eliminated from further consideration. It is included in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(6) Cooldown via Stuck Main Steam Safeties	(A) Normal	(1) A main steam safety valve (SV-409A through SV-409L) must open. This requires either a failure of a safety valve, or a valve failure or operator error which closes the condenser steam dump valve (MS-PCV-402). (2) For criticality to occur, the safety valve must stick open. This requires a random failure. (3) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.
	(B) MSLB	(1) A main steam safety valve (SV-409A through SV-409L) must open. This requires the same conditions as 6-A-1 above. (2) For criticality to occur, the safety valve must stick open. This requires a random failure. (3) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) A main steam safety valve (SV-409A through SV-409L) must open. This requires either a random failure of the safety valve, or an operator error to fail to maintain SG pressure below the safety valve setpoint with the emergency atmospheric steam dump valves as required by procedure. (2) For criticality to occur, the safety valve must stick open. This requires a random failure. (3) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.

DISPOSITION: This event scenario will be eliminated from further consideration. It is included in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(7) Cooldown via Shutdown Cooling System	(A) Normal	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires all of the following: (1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires the same conditions as 4-A-1 in Table 2.7-A. (2) The pump suction must be aligned to the LPST. This requires the same conditions as 4-A-2 in Table 2.7-A. (3) The LPST must be supplied with a source of cold water. This requires the same conditions as 4-A-3 in Table 2.7-A. OR (b) Overcooling of the shutdown cooling flow. This requires all of the following: (1) The shutdown cooling or LPST cooling pump must be running with the pump discharge aligned to the MCS. This requires the same conditions as 4-A-1 in Table 2.7-A. (2) The shutdown cooling temperature controller (CC-TCV-200) must provide excess component cooling flow to the shutdown cooler. This requires a random valve failure or misadjustment by the operator. (3) There must be excess service water flow to the component cooling heat exchanger. This requires an operator error. Service water flow to the heat exchanger is manually throttled. (2) For criticality to occur, the operator must fail to notice a significant decrease in the MCS temperature.
	(B) MSLB	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires the same 3 conditions as 7-A-1-a above. OR (b) Overcooling of the shutdown cooling water. This requires the same 3 conditions as 7-A-1-b above. (2) For criticality to occur, the operator must fail to perform the emergency boration required by procedure.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires the same 3 conditions as 7-A-1-a above. OR (b) Overcooling of the shutdown cooling water. This requires the same 3 conditions as 7-A-1-b above. (2) For criticality to occur, the operator must fail to notice a significant decrease in MCS temperature.

DISPOSITION: This event scenario will be eliminated from further consideration. It is bounded by the excessive cooldown event in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(8) Cooldown via Charging System	(A) Normal	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires all of the following: (1) A charging pump must be running, injecting water to the MCS. At least 1 charging pump will be running during normal operation. (2) The pump suction must be aligned to a source of cold water. This requires the same conditions as 2-A-2 in Table 4.4-A. OR (b) Overcooling of the LPST. This requires all of the following: (1) A charging pump must be running, injecting water to the MCS. At least 1 charging pump will be running during normal operation. (2) The LPST temperature controller (CC-TCV-200) must provide excess component cooling flow to the LPST cooler. This requires a random valve failure or misadjustment by the operator. (3) There must be excess service water flow to the component cooling heat exchanger. This requires an operator error. Service water flow to the heat exchanger is manually throttled. (2) For criticality to occur, the operator must fail to notice a significant decrease in the MCS temperature.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(B) MSLB	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires all of the following: (1) A charging pump must be running, injecting water to the MCS. Since SI actuation will lock out the charging pumps, this requires that SI be reset and the charging pumps turned on. This is assumed to occur since SI will eventually be terminated for a MSLB. (2) The pump suction must be aligned to a source of cold water. This requires the same conditions as 2-A-2 in Table 4.4-A. OR (b) Overcooling of the LPST. This requires all of the following: (1) A charging pump must be running, injecting water to the MCS. This requires the same conditions as 8-B-1-a-1 above. (2) The LPST temperature controller (CC-TCV-200) must provide excess component cooling flow to the LPST cooler. This requires the same conditions as 8-A-1-b-2 above. (3) There must be excess service water flow to the component cooling heat exchanger. This requires the same conditions as 8-A-1-b-3 above. (2) For criticality to occur, the operator must fail to notice a significant decrease in the MCS temperature.
	(C) LOCA	(1) A cooldown must occur as a result of either: (a) Injection of cold water. This requires the same 2 conditions as 8-B-1-a above. OR (b) Overcooling of the LPST. This requires the same 3 conditions as 8-B-1-b above. (2) For criticality to occur, the operator must fail to notice a significant decrease in the MCS temperature.

DISPOSITION: This event scenario will be eliminated from further consideration. It is bounded by the excessive cooldown event in the Yankee Nuclear Power Station Probabilistic Safety Study.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(9) Cooldown via Safety Injection	(A) Normal	(1) SI pumps must be running. This requires an inadvertent SI actuation. (2) MCS pressure must be below SI shutoff head (1550 psig) to inject water. This requires a failure or gross misoperation of the pressure control system. (3) SI pump suction must be aligned to a source of cold water. This requires the same conditions as 1-A-3 in Table 2.7-A.
	(B) MSLB	--- Criticality is not possible via the cooldown caused by injection of cold SI water. The worst case MSLB analysis presented in the FSAR already includes the effect of the cold SI water, and demonstrates that no return to critical will occur.

Table 2.7-C (cont'd)

Basis for Disposition of MCS Cooldown Event Scenarios

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
	(C) LOCA	--- Criticality is not possible via the cooldown caused by injection of cold SI water. The LOCA analyses presented in the FSAR already include the effect of the cold SI water, and demonstrate that no return to critical will occur.

DISPOSITION: This event scenario will be eliminated from further consideration. It is bounded by the excessive cooldown event in the Yankee Nuclear Power Station Probabilistic Safety Study. Note that criticality is not possible for post-LOCA or post-MSLB initial conditions.

Reactivity Addition Event	Initiating Event	Detailed Requirements for Occurrence
(10) Cooldown via Steam Line Break	(A) Normal	--- Criticality is not possible. The worst case MSLB analysis presented in the FSAR demonstrates that no return to critical will occur.
	(B) MSLB	(1) An additional steam line rupture must occur on one of the intact steam lines, upstream of the non-return valves. Note that the non-return valves would already have closed due to the initiating event. This requires a random pipe failure. NOTE: An additional rupture of the largest pipe upstream of the non-return valve on the faulted loop was also considered. However, the 2% increase in the original break flow due to the additional pipe rupture was found to be inconsequential.
	(C) LOCA	--- Criticality is not possible. Due to the large amount of boron injected via SI in response to the initiating event, the initial shutdown margin prior to a postulated MSLB would be significantly larger than for a MSLB initiated from normal plant conditions. The MSLB analysis presented in the FSAR demonstrates that a return to critical is not possible if initiated from normal initial conditions. With the larger initial shutdown margin for a MSLB initiated from post-LOCA conditions, a return to critical will also be precluded.

DISPOSITION: This event scenario will be eliminated from further consideration. It is included in the Yankee Nuclear Power Station Probabilistic Safety Study. Note that criticality is not possible for normal or post-LOCA initial conditions.

Table 2.7-D

Basis for Disposition of Xenon-135 Decay Event Scenarios

Reactivity Addition Event	Initiating Event		Detailed Requirements for Occurrence
(1) Normal Post-Trip Xenon-135 Decay	(A) Normal	---	Criticality is not possible. The maximum positive reactivity added from the complete decay of Xenon-135 following a reactor trip is significantly less than the minimum post-trip shutdown margin. Additionally, the shutdown margin is normally verified without taking credit for the negative reactivity of the Xenon-135.
	(B) MSLB	(1)	The Xenon-135 concentration must decay enough to offset the minimum subcriticality following the initiating event, a MSLB. This requires that the operator fail to perform the emergency boration required by procedure within 3 hours of the MSLB.
	(C) LOCA	---	Criticality is not possible. The boron injected by SI upon the initiating event substantially increases the post-trip shutdown margin above that following a normal trip. The maximum positive reactivity added from the complete decay of Xenon-135 following the trip is significantly less than the minimum post-trip shutdown margin.

DISPOSITION: This event scenario will be eliminated from further consideration. For both normal and post-LOCA initial conditions, criticality is not possible. For post-MSLB initial conditions, the gross operator error necessary for criticality to result, in conjunction with the initiating event, is less than 1E-08 per year.

Table 2.8

Sequence of Events for Charging Dilution of MCS

Time (HH:MM)	Event
00:00	o Valves DW-MOV-655 and DW-V-662, 634, or 635 are inadvertently opened. They are assumed to remain for the duration of the event. The unplanned dilution begins.
	Plant Initial Conditions: (normal post-trip)
	o All control rods inserted o MCS Boron = 1415 ppm (BOL) o T-avg = 515 degrees (controlled by steam dump) o Charging = Letdown = 30 GPM o Charging Temperature = 450 degrees o LPST Level = 44 inches (50% full) o LPST Pressure = 10 psig o PWST Level = 30 feet o All Steam Generator Levels = 23 feet
00:05	o Charging temperature has decreased to approximately 400 degrees due to the cold PWST water supplied to the charging pump suction. The charging temperature will remain at this value for the duration of the event.
00:15	o LPST high level alarm occurs at 50 inches. The operator will be unable to reset the alarm since level is still increasing.
	o LPST Pressure = 17 psig
00:27	o LPST high pressure alarm occurs at 25 psig. The operator will be unable to reset the alarm since pressure is still increasing due to the level increase.
00:30	o LPST Level = 56 inches o LPST Pressure = 28 psig
00:45	o LPST Level = 62 inches o LPST Pressure = 48 psig
00:56	o LPST safety valve opens at 75 psig o LPST safety valve discharge high pressure alarm occurs. o LPST pressure will remain relatively constant at about 75 psig for the remainder of the event. The safety valve will open repeatedly over the next 37 minutes until the high level dump valve opens. This will also result in repeated high safety valve discharge pressure alarms.

Table 2.8 (cont'd)

Sequence of Events for Charging Dilution of MCS

Time (HH:MM)	Event
01:00	o LPST Level = 68 inches
01:15	o LPST Level = 75 inches
01:33	o The LPST is full. o The LPST high level dump valve opens to dump the excess water to Waste Disposal.
03:00	o PWST Level = 28.9 feet
06:00	o PWST Level = 27.8 feet
09:00	o PWST Level = 26.7 feet
12:00	o PWST Level = 25.6 feet
15:00	o PWST Level = 24.5 feet
18:00	o PWST Level = 23.4 feet
20:23	o The reactor returns to critical. o PWST Level = 22.6 feet o Steam Generator Levels = 23 feet
20:30	o Steam Generator Levels = 20.7 feet
20:35	o Steam Generator low level alarm occurs at 19 ft. o The operators are assumed to respond to the alarm by initiating auxiliary feed. o Steam Generator levels will initially increase after auxiliary feed is started. The rate of increase will drop to zero as the assumed point of core melt is reached.
20:45	o Core melt is conservatively assumed to occur, since core power exceeds the capacity of the auxiliary feed pump to maintain Steam Generator level. o Steam Generator levels will decrease continuously until the secondary heat sink is lost, unless operator action is taken to shut down the reactor or re-establish normal feed with the boiler feed and condensate pumps.

TABLE 2.9

Termination of the Charging Dilution Event

The dilution event can be terminated quickly from the main control board, or as directed from the Control Room, either prior to criticality or between criticality and core melt. The following operator actions are necessary to accomplish this:

Prior to Criticality

1. Trip all operating charging pumps from the main control board, or

2. Close DW-MOV-655 on main control board, or

3. Have the auxiliary operator close either DW-V-662, 634, or 635, whichever flow path was in use.

Following Criticality, But Prior to Core Melt

1. Terminate the dilution by either Method 2 or 3 above.

2. Begin an emergency boration from the main control board by:

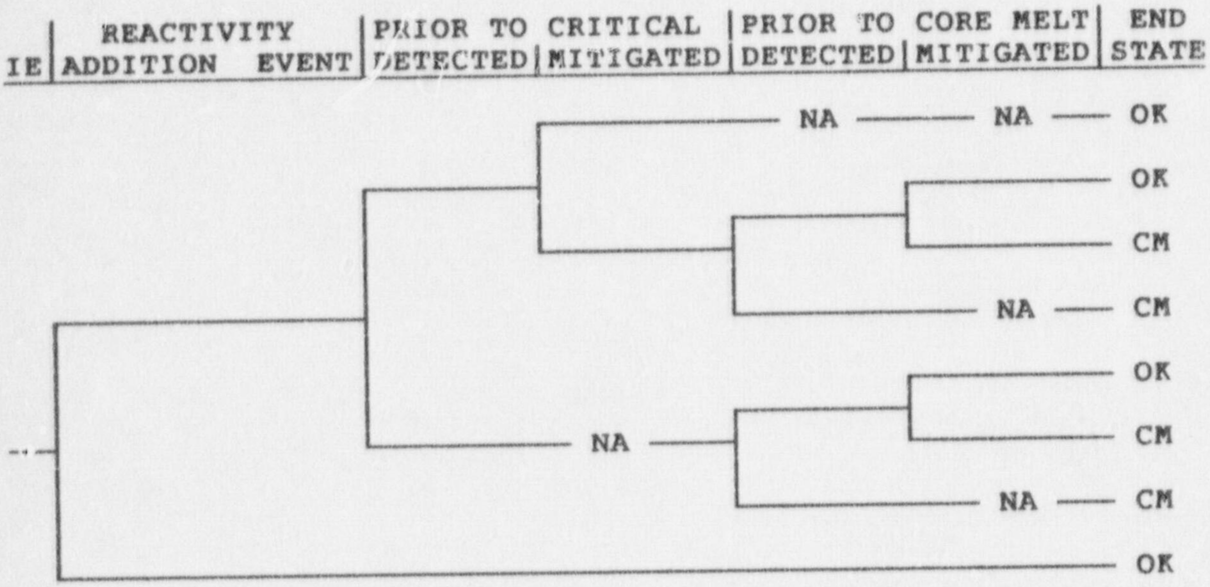
   - Open CS-MOV-529, charging suction to boric acid mix tank, and

   - Start all charging pumps at maximum flow, and

   - Close CH-MOV-521, CS-MOV-540, PU-FICV-202, and DW-MOV-655. This isolates the charging pump suction from all sources except the boric acid mix tank.

FIGURE 2-2

EVENT TREE



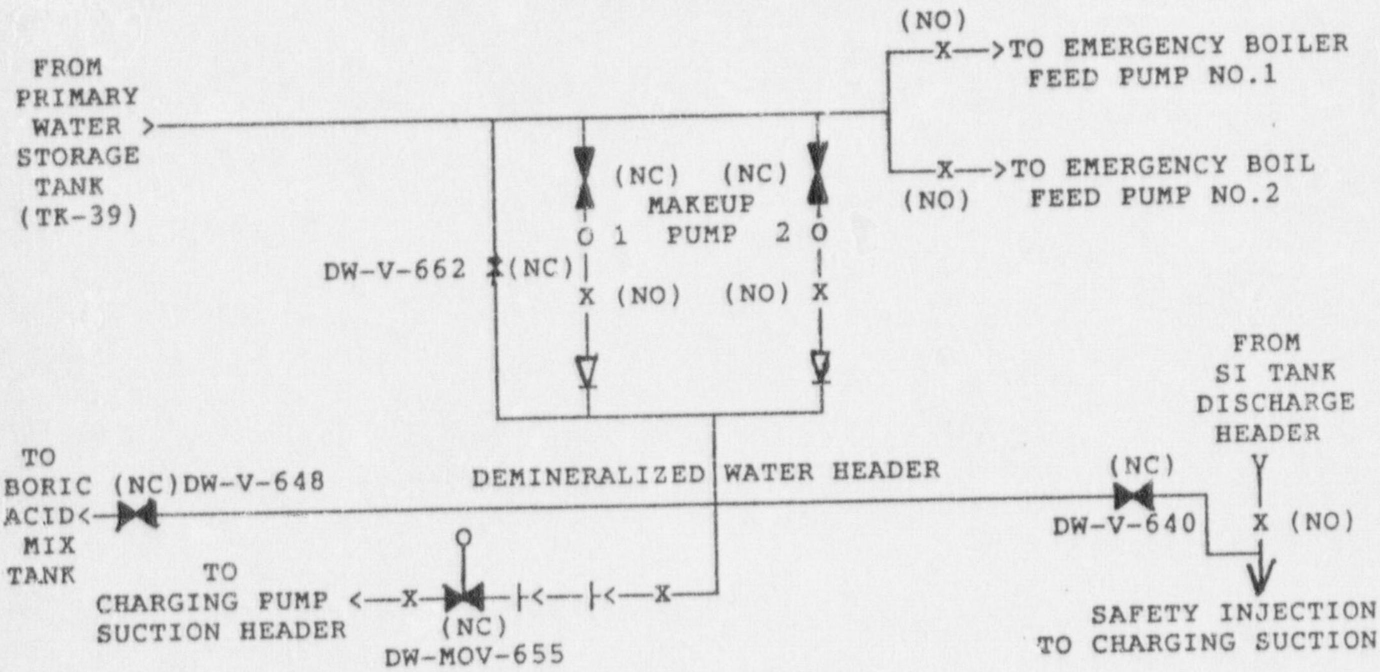
NOTE: CM = CORE MELT

IE = ORIGINAL INITIATING EVENT OFF-NORMAL/ACCIDENT CONDITION.

NA = STEP NOT APPLICABLE FOR THIS SEQUENCE

FIGURE 2-3

BORON DILUTION FLOW PATH



NOTE: (NO) = NORMALLY OPEN
X = NORMALLY OPEN VALVE
(NC) = NORMALLY CLOSED

3.0 NUCLEAR INSTRUMENTATION SYSTEM DESCRIPTION

A Westinghouse type FN design using magnetic amplifiers and vacuum tube electronics for signal conditioning is provided to serve as the primary means of monitoring the level of and rate of change of reactivity in the reactor core. This design does not readily lend itself to a redundant power supply design, since the outputs of the magnetic amplifiers (bistables) are used to input both of the scram amplifiers and, therefore, the power supplies must be from the same source.

Three of the four source range channels are located in the Main Control Room and two of these (the normal source range channels) are displayed on the main control board. The third channel is normally de-energized and is described below. Both normal channels of instrumentation are provided power from a single safety class, vital ac bus which, in turn, is powered from an Uninterruptible Power Supply (UPS) fed from two independent and diverse sources. Safety Class Emergency Motor Control Center No. 5 provides the standby source and the No. 1 Station Battery dc bus provides the normal source of power to the Uninterruptible Power Supply (UPS). Selection of the power source is controlled by a static switch in the UPS which automatically transfers the vital bus to the standby source (ultimately, safety class emergency 480 V ac Bus No. 1) upon sensing a degrading condition on the normal supply. A manual switch on the UPS is provided if a transfer is so desired.

For the other two channels of source range instrumentation, the refueling channel and the Safe Shutdown System (SSS), independent power supplies are used. The refueling channel is powered from transformer "A" bus off the Emergency Motor Control Center No. 1 (EMCC No. 1). For this EMCC, the normal source of power is ultimately from the same source as the standby source for the normal source range channels (Safety Class Emergency 480 V ac Bus No. 1). It can be readily transferred to the alternate standby source by means of a manual throwover switch located in the Switchgear Room directly beneath and immediately accessible from the Main Control Room, to safety class emergency 480 V ac, Bus No. 2. For the SSS source range channel, the instrument is normally supplied from a non-safety class 480 V ac MCC which is backed by a dedicated SSS diesel generator. This diesel generator is totally independent of, and redundant to, the non-SC source upon local manual startup.

Thus, the operators and supervisors have available three redundant channels of source range NI powered from safety class power supplies (as discussed above) and one additional remote source range channel powered from a dedicated, redundant, and diverse power source and instrument. Note that the refueling source range NI power supply can be transferred to the No. 2 480 V ac emergency bus via a manual throwover switch (see Figure 3-1).

A description of the NI and Reactor Protection System is provided in Attachment A.

The power supply configuration for the critical components is contained in Figures 3-1 and 3-2.

In addition to this NI, other normal instruments and procedures provide the operating crew with the status of the reactivity control critical safety function continually. Among these, the most important are:

- o Rod position indication
  - o Indicated on the Main Control Board
  - o Powered from the transformer "A" Bus, as is the refueling nuclear instrument
- o Core exit thermocouple(s) and saturation monitor
  - o Indicated on the Main Control Board
  - o Indicated and trended on the Safety Parameter Display System
- o Pressurizer level
  - o Indicated on the Main Control Board
  - o Indicated and trended on the Safety Parameter Display System

- Direct boron sampling periodically or as directed by the Operating Crew or Technical Support Staff

- A standard plant procedure is performed routinely on every shutdown or in the event of a LOCA, rod ejection, stuck rod(s), or excessive cooldown events. This routine procedure and the other emergency procedures direct the operator on how much 12-weight percent boric acid to inject for greater than or equal to 5% delta-rho shutdown margin during 1) normal shutdown, 2) off-normal events (listed above), and 3) any time the operator and his supervisor deem that an emergency boration is necessary.

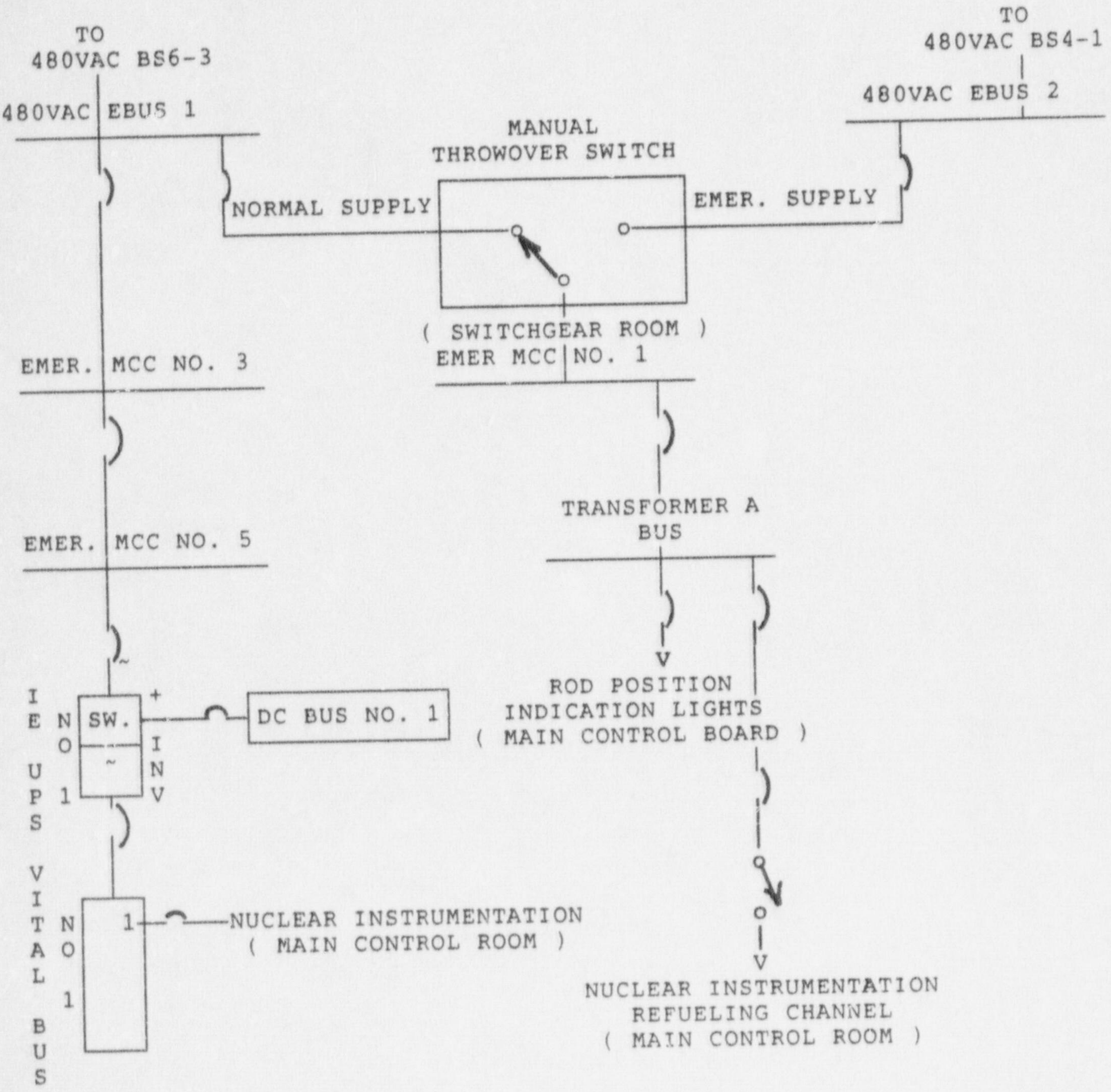
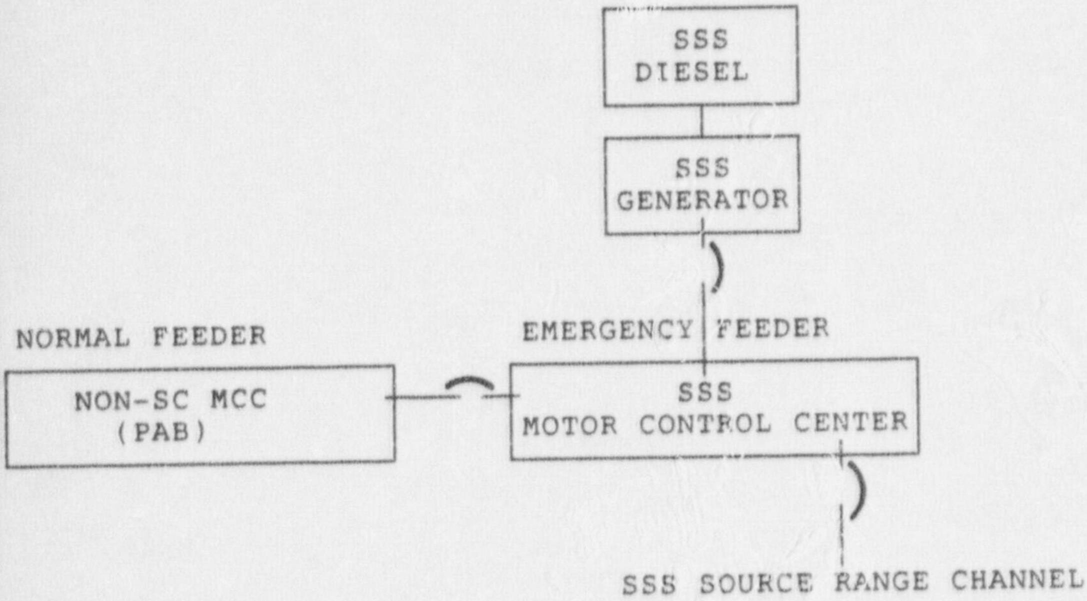


FIGURE 3-1

YNPS NUCLEAR INSTRUMENTATION AND ROD POSITION POWER SUPPLY



<u>FIGURE 3-2</u>

<u>SAFE SHUTDOWN SYSTEM (SSS) NUCLEAR INSTRUMENT AND POWER SUPPLY</u>

4.0 CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

For the issues being reviewed, the following was concluded:

1. Is full range NI necessary to meet the objectives of Regulatory Guide 1.97 for post-accident conditions?

   Full range NI would not yield any further information more useful than that provided by source range instrumentation. Full range instrumentation would only increase the stress level on the operating crew if it failed high during conditions when reactivity was being adequately controlled. Operations personnel are in a better situation with source range indicators in this case. An abundance of secondary indicators to power level are available and the indicators are direct indications of the primary critical safety functions which must be controlled to prevent core damage.

   Therefore, full range NI is not necessary to ensure that the Reactor System is properly controlled following an accident and it may be detrimental in that it could place unnecessary stress on the operators attempting recovery actions. Full range NI is not a key variable in mitigating a return to criticality event.

2. Is redundant NI necessary to meet the objectives of Regulatory Guide 1.97 for post-accident conditions at the Yankee Nuclear Power Station? and

3. Is environmentally qualified NI needed?

From the results of this study, no "credible" events were identified that could result in an inadvertent increase in reactivity leading to criticality; Source range NI is not necessary to detect the occurrence of such an event. Due to the simplicity of the YNPS Main Control Board, its design for human control and the diversity and redundancy of indications, including their motive force (some are pneumatic as well as electric), the actual <u>need</u> for source range NI is greatly diminished.

In view of the results and conclusions of this investigation and the cost involved in changing NI, we conclude that the resource in terms of hardware and personnel costs could (and should) be more appropriately applied to other activities aimed at maintaining and improving overall plant safety.

4.2 Recommendations

Section 2.3 identifies possible changes that would reduce the risk associated with postulated reactivity control problems. Although these changes would not "pass a cost-benefit test," they should be implemented if agreement can be reached with the NRC on the need for NIs.

5.0 REFERENCES

1. Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant and Environs Conditions During and Following an Accident."

2. Letter, USNRC to YAEC, "Yankee Nuclear Power Station - Regulatory Guide 1.97" (Revision 2), NYR 86-273, dated December 9, 1986.

3. Letter, USNRC to YAEC, "Yankee Nuclear Power Station - Integrated Plant Safety Assessment Report (IPSAR), NUREG-0825, Section 4.5, Wind and Tornado Loading, and 4.8, Tornado Missiles," NYR 87-86, dated May 13, 1987.

4. Swain, et. al., NUREG/CR-4772, SAND 86-1996, February 1987, "Accident Sequence Evaluation Program Human Reliability Analysis Procedure."

ATTACHMENT A

Nuclear Instrumentation and Reactor Protection System

General

The NI and Reactor Protection System monitors the nuclear reactor flux from source levels to above maximum power levels and provides the necessary indications, alarms, and controls for safe and efficient operation of the reactor. This equipment incorporates provisions for initiating a reactor and turbine shutdown in the event of conditions which may be hazardous for plant operation.

Reactor shutdown signals which originate in the turbine-generator protection equipment and main coolant flow (main coolant pump current) trip system are connected through relay contacts directly to the control rod scram air circuit breakers. The relay contacts are open below 15 MWe.

The NI and Reactor Protection System equipment contains ten nuclear information channels, two scram amplifiers, and various auxiliary equipment, all mounted in three cabinets in the Control Room. The nuclear detectors themselves are installed in the neutron shield tank around the reactor vessel. The detectors are connected directly to the equipment in the Control Room by triaxial and coaxial cables. Each nuclear channel is indicated locally at the three cabinets as well as on the nuclear section of the Main Control Board (MCB). A two-pen recorder on the Main Control Board may be used to record any two of the source, intermediate, and power range channels. Also included on the nuclear section of the MCB are various selector and reset switches, indicating lights, and two reactor shutdown push buttons.

The ten nuclear information channels consist of two source range, two intermediate range, three intermediate power range, and three power range channels. The source and intermediate channels are designated as the startup range.

Source Range Nuclear Instrumentation

The source range (Channel Nos. 1 and 2) detectors are high sensitivity BF_3 proportional counters. There are four detectors, located around the reactor vessel, any two of which may be connected to Channel Nos. 1 and 2. The third detector is connected to Safe Shutdown System instrumentation during normal operations. During refueling periods, the third and fourth detectors are used in the Control Room to indicate source range count level and alarms on an increasing level. The third and fourth detector channels are normally de-energized and must be turned on by the operator when needed.

The detectors have a sensitivity of approximately 40 counts/neutron cm^2-second. Counter output of 1 to 100,000 counts per second correspond to a flux range of 2.5×10^{-2} to 2.5×10^3 neutron/cm^2-second, and the counter high voltage is automatically cut off by the intermediate range channels above this flux level to prevent counter burn-out.

The signal output of the BF_3 counter consists of pulses which are proportional in number to the neutron and gamma flux present at the detector location. These pulses are fed over a triaxial cable to the panel unit in the Control Room. The first panel unit (pulse integrator) separates the pulses from the high voltage, amplifies the pulse, provides an adjustable discriminator which rejects the gamma pulses and pulses resulting from noise, and converts the neutron pulses to a direct current which is proportional to the reactor neutron flux.

The direct current signal from the pulse integrator is fed into a second panel unit (log microammeter). This circuit converts the linear input signal to an output which is proportional to the logarithm of the neutron flux level. An output is also provided which is proportional to the rate of change of the logarithm of the neutron flux level. The source level meter is calibrated from 1 to 100,000 counts per second and the startup rate meter is calibrated from -1 to +10 decades per minute.

The log level (counts per second) and the rate of change signal (decades per minute) are indicated at the nuclear section of the MCB as well as at the NI cabinets. The log level signal may be switched to the nuclear recorder. The startup rate meter at the MCB is calibrated -0.2 to +2.0 decades per minute.

Startup and Power Range Auxiliary Panel

The startup and power range auxiliary panel receives signals from the NI to provide the necessary signals for the appropriate annunciator circuits and the Rods Stop Signal circuit. This panel also contains the power range coincidence-single scram switch, the turbine load cutback relaying (not used), and the source range BF_3 high voltage disconnect relays.

The high startup rate annunciator circuit is normally set to trip when the reactor startup rate reaches 1.0 decade per minute (adjustable between 0.5 and 5 decades per minute) and the rods stop circuit is set to trip at 1.5 decades per minute (adjustable between 0.5 and 5 decades per minute). These circuits are of the manual reset type and must be reset by operating the manual reset switch, which is located on the nuclear section of the MCB. The source range and intermediate range signals actuate the 1.0 decade per minute annunciator circuit, but only the intermediate range signals operate the 1.5 decades per minute rods stop circuit.

The startup rate scram and alarm (Channel Nos. 3 and 4 intermediate range only) is normally set to trip at $\leq$5.2 decades per minute and is adjustable from three to ten decades per minute. The source range and intermediate range signals can actuate individual channel bistable magnetic amplifiers to initiate the scram; however, Channels 1 and 2 are normally not in use.

In addition to these signals, there exists from each one of the log microammeter units in the intermediate range channels an automatic signal, which disconnects the high voltage from the source range BF_3 proportional counters when the reactor neutron flux is increasing between 5 x 10^4 and 10^5 nV and reconnects the high voltage on decreasing flux at approximately the same value. A source range high voltage light is mounted on the nuclear section of the MCB. The light is off when the high voltage is off. A manual switch disconnecting the BF_3 source range high voltage is also available at the NI cabinets.

The coincidence feature makes it necessary for two out of six power range channels to initiate high neutron flux level signals in order to cause the scram amplifiers to trip. The high neutron flux level trip setpoint is adjustable for various reactor operation conditions. For reactor 100 percent full power operation (i.e., 600 MWt), with four loops in service, the level trip set point is set at $\leq$108 percent. For reactor operation between 0 and 15 MWe the level trip setpoint is manually adjusted to $\leq$35 percent of full power. A power range coincidence single switch is provided to allow for coincidence scram or any single channel scram. The low power scram set switch is located on the nuclear section of the MCB.

Signals not fed through the high neutron flux level coincidence circuit but operating on the scram amplifiers through the alarm and scram panel are those initiated from high startup rate. Provision is made in the alarm and scram panel to accommodate additional signals for memory light indication only.

Additional scram signals which directly actuate the control rod breaker shunt trip coils are provided from the nonreturn valve (NRV) trip, the low Main Coolant System pressure trip or the high Main Coolant System pressure trip. The NRV trip is actuated by either a main steam line low pressure trip or a Containment Isolation Signal (high containment pressure).

A permissive relay circuit is provided which is operated by two millivolt bistables activated from the thermal converters which monitor the generator output. Operation of the circuit occurs at a generator output equivalent to 15 MWe. This circuitry provides for an optional manual bypass for the low steam generator level scram, low flow scram and turbine-generator scram signals when the power is below 15 MWe. At 15 MWe and above, the scram bypass is automatically removed. The high startup rate scram signal is automatically connected at 15 MWe and below and automatically bypassed above 15 MWe.

A second permissive relay circuit is activated at approximately 130 MWe power level, which provides for automatic cut-in of a manual single step rods-out reset circuit. At power levels of approximately 130 MWe and above, the reset circuit requires the control switch to be returned to the neutral or reset position before making each additional rods-out step. Below approximately 130 MWe output, the reset circuit becomes ineffective and thus a controlled but continuous rods-out motion may be effected.

Alarm and Scram Panel

The scram signals for high intermediate range startup rate, and high neutron flux levels, are connected to the magnetic amplifier alarm and scram panel that acts as the control center for indicating the individual signals that may have caused the scram and for operating the scram amplifiers directly.

Scram Amplifiers

The two scram magnetic amplifiers operate individual scram relays whose contacts are connected to the shunt trip coil circuitry of the rod scram circuit breakers. The scram relays are energized at all times except when a scram signal is sent to the scram amplifiers. When the scram amplifier outputs are zero, the scram relays are de-energized and the contacts in the control rod breaker shunt trip coil circuits close causing both breakers to open. The circuit is such that any one scram relay can trip either circuit breaker.

Meter and Test Panel

Two meter and test panels provide local indication for Channel Nos. 1, 2, 3, and 4 level and rate at the NI cabinets, and the 60 cps test calibration signals to accurately test the source range channels.

Auxiliary Meter Panel

The auxiliary meter panel contains three meters which were used during early plant life to measure the uncompensated signal from the three intermediate power range ion chambers. They have been short circuited because intermediate power range channels now measure this signal with greater accuracy.

The switches used to select (from the low voltage power supply or from the power supply on the power range panel) which high voltage is to be used for the intermediate range detectors are located on the auxiliary meter panel. In addition, the relay to select the high or low power scram setpoints of Channels Nos. 6, 7, and 8 is also located on the auxiliary meter panel.

Recorder

The recorder used with the NI is a two-pen, twc-speed instrument with two switching circuits. The switching allows for full-scale deflection for a two-decade change in reactor flux. This recorder is mounted on the front of the nuclear section of the MCB.

Power Supply

The instrument bus power supply is 120 volts and 60 cycles, normally supplied by the vital bus No. 1.

The instrument bus power supply for the refueling channel source range count meter is supplied from Class IE Bus - Transformer A.

The instrument bus power supply for the Safe Shutdown System (SSS) source range instrument is the SSS Motor Control Center which is powered by a dedicated diesel generator.