BWR OWNERS' GROUP

EVALUATION OF

NUREG-0737 ITEM II.K.3.18

MODIFICATION OF AUTOMATIC

DEPRESSURIZATION SYSTEM LOGIC

TABLE OF CONTENTS

ABSTRACT

A study was performed to determine the feasibility, benefits and drawbacks of extending automatic initiation of the BWR Automatic Depressurization System (ADS). Modifications were developed which would extend ADS operation to transient events which do not result in a release of steam to the drywell but which may require depressurization of the reactor pressure vessel (RPV) to maintain adequate core cooling. Eight different modifications or options, including retaining the current design, were compared.

The current design, given implementation of the BWR Emergency Procedure Guidelines (Revision 2), is adequate for all design basis events which require RPV depressurization to maintain adequate core cooling. However, ADS modifications could extend ADS operation to additional events and, simultaneously, better conform the ADS initiation logic to that employed in the Emergency Procedure Guidelines and that currently proposed for certain ATWS modifications.

1. INTRODUCTION

The feasibility and reliability assessment study reported herein addresses NUREG-0737 Item II.K.3.18 which states, ''The Automatic Depressurization System (ADS) actuation logic should be modified to eliminate the need for manual actuation to assure adequate core cooling. A feasibility and risk assessment study is required to determine the optimum approach. One possible scheme which should be considered is ADS actuation on low reactor vessel water level provided no HPCI or HPCS system flow exists and a low pressure ECC system is running. This logic would complement, not replace, the existing ADS actuation logic.''

This report supplements the previous feasibility study (Reference 1) undertaken by the BWR Owners Group to address NUREG-0737 Item II.K.3.18. That study identified two preferred ADS logic design modifications but did not consider the effects of those modifications on proposed designs for ATWS mitigation and on execution of procedures developed from the BWR Emergency Procedure Guidelines (EPGs). This study addresses these effects.

The automatic depressurization system, through selected safety/relief valves*, functions as a backup to the operation of

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*A few plants have dedicated ADS valves.

the high pressure injection systems [feedwater, High Pressure Core Spray (HPCS)/High Pressure Coolant Injection (HPCI), Reactor Core Isolation Cooling (RCIC)/Isolation Condenser (IC)] for protection against excessive fuel cladding heatup upon loss of coolant over a range of steam or liquid line breaks inside the drywell. The ADS depressurizes the vessel, permitting the operation of the low pressure injection systems [condensate, Low Pressure Coolant Injection (LPCI), Low Pressure Core Spray (LPCS)]. The ADS is currently activated automatically upon coincident** signals of low water level in the RPV, high drywell pressure, and a low pressure ECCS pump running. A time delay of approximately 2 minutes after receipt of the signals allows the operator to reset the logic and prevent an automatic blowdown if RPV water level is being restored or if the signals are erroneous. The ADS can be manually initiated as well.

For transient and accident events which do not directly produce a high drywell pressure signal and are degraded by a loss of all high pressure injection systems, adequate core cooling is assured by manual depressurization of the RPV followed by injection from the low pressure systems. Events which may require manual depressurization can be grouped into two classes:

**A few plants do not require coincident signals.

1) RPV isolations (including breaks outside the drywell) with loss of high pressure makeup systems, and 2) RPV isolations with loss of high pressure make-up systems further degraded by a stuck open relief valve (SORV). Both of these classes of events were considered in the development of proposed modifications to the ADS initiation logic even though the second class is beyond the current system design basis (which assumes only a single failure). For transients that do not cause an isolation, the main condenser is available for depressurization and ADS operation is not required. Therefore such events are not included in this study.

An isolation event that is further degraded by an SORV is considered separately because the inventory loss through the open valve increases the amount of high pressure makeup flow required to maintain RPV water level. The additional inventory loss reduces the time available for the operator to manually depressurize the RPV if that is necessary. However, even for this highly degraded event, the operator has sufficient time to manually depressurize the RPV in order to permit operation of the low pressure injection systems. It was shown in NEDO-24708A, ''Additional Information Required for NRC Staff Generic Report on Boiling Water Reactors'', Section 3.5.2.1, that the operator has at least 30 to 40 minutes to initiate the ADS and prevent excessive fuel cladding heatup for both of the previously described classes of events. This minimum time represents a ''worst case'' situation starting from full power with equilibrium core exposure and complete failure of all the high pressure makeup systems. Lower initial core power, low fuel exposure, control rod drive leakage flow, or partial operation of the high pressure systems would significantly increase the time available for operator action.

The intent of NUREG-0737 Item II.K.3.18 is to provide additional assurance of adequate core cooling for events which do not directly produce a high drywell pressure signal. This study evaluates the feasibility and desirability of various logic modifications or options which further automate RPV depressurization for these events.

Satisfying the intent of NUREG-0737 Item II.K.3.18 may be accomplished in two ways: the ADS logic may be modified to provide further assurance of adequate core cooling for these additional events, or the operator may be given specific guidance and training for performing manual actions under these conditions. Following the accident at Three Mile Island, the second course of action was undertaken, resulting in the development of symptom-oriented EPGs. Implementation of the EPGs will improve the operator response to degraded transients by giving him explicit guidance under these conditions. The EPGs also provide him with a better awareness and understanding of the plant's response to transients as a result of improved training.

Events in each of the previously described classes are slow, well behaved, well understood transients which allow the operator sufficient time to actuate ADS if it is needed. The symptom-oriented procedures lead the operator through conditions of increasing levels of degradation (system failures) and provide specific guidance on when initiation of ADS is required. Thus with the implementation of the new emergency procedures, the operator has increased information on the use of the ADS and can more reliably perform the actions necessary to assure core cooling for a wide range of transient and accident conditions, including events in each of the previously described classes.

Anticipated transient without scram (ATWS) events were also considered in the development of proposed modifications to the ADS initiation logic. For these events it is important to prevent ADS initiation once boron injection has been initiated.

Seven ADS logic modifications are considered, and the current logic is reviewed using the same basis used for evaluating the modifications. These eight options are evaluated as to transient response, compatibility with emergency procedures, reliability, and feasibility of implementation.

This study is an evaluation of the feasibility of concepts as opposed to being a detailed design assessment. The goal is to determine, using simple concepts and arguments, whether or not

ADS should be further automated and, if so, which conceptual options are most favorable for further development.

REFERENCE

1. Letter, D.B. Waters to D.G. Eisenhut, ''BWR Owners' Group Evaluations of NUREG-0737 Requirements II.K.3.16 and II.K.3.18,'' dated March 31, 1981.

2. ADS LOGIC MODIFICATION OPTIONS CONSIDERED

Eight ADS logic options are considered: the current design and seven logic modifications. The seven logic modifications considered incorporate one or more of the following five design features:

1. elimination of the high drywell pressure trip portion of the existing logic,
2. addition of a timer that bypasses the existing high drywell pressure trip logic if RPV water level is low for a sustained period of time,
3. addition of a suppression pool temperature trip in parallel with the existing high drywell pressure trip logic,
4. addition of a manual inhibit switch, and
5. changing the low RPV water level trip setpoint to the top of the active fuel (TAF).

The eight logic options considered in this report are:

1. the current design,
2. elimination of the high drywell pressure trip portion of the existing logic plus addition of a manual inhibit switch,
3. elimination of the high drywell pressure trip portion of the existing logic plus changing the low RPV water level trip setpoint to the top of the active fuel,
4. addition of a timer that bypasses the existing high drywell pressure trip logic if RPV water level is low for a sustained period of time plus addition of a manual inhibit switch,
5. addition of a timer that bypasses the existing high drywell pressure trip logic if RPV water level is low for a sustained period of time plus changing the low RPV water level trip setpoint to the top of the active fuel,
6. addition of a suppression pool temperature trip in parallel with the existing high drywell pressure trip logic plus addition of a manual inhibit switch,
7. addition of a suppression pool temperature trip in parallel with the existing high drywell pressure trip logic plus changing the low RPV water level trip setpoint to the top of the active fuel, and
8. addition of a manual inhibit switch to the current logic.

Each of these logic schemes is described below and summarized in Table 2.1.

2.1 CURRENT DESIGN (OPTION 1)

The first option is the present ADS logic design. With the implementation of the symptom-oriented EPGs, the current logic satisfies the intent of NUREG-0737 Item II.K.3.18 in that additional guidance for use of ADS is provided beyond that which was previously available. It is not obvious that the advantages of further automation outweigh the disadvantages. The current design is thus a viable option in its own right.

Figure 2-1 shows the current ADS logic design for a typical plant. The design requires concurrent high drywell pressure and low RPV water level signals in order to actuate the ADS. Once the high drywell pressure signal is received, it is sealed into the initiation sequence and does not reset even if the high drywell pressure condition subsequently clears. When both signals are present, the ADS initiation logic confirms that RPV water level is below the RPV water level scram setpoint (to prevent spurious actuations) and starts a 120 second** delay timer. Once started the timer is automatically reset if RPV water level is restored above Level 1 before the timer times out.

**Typical value. The time interval can vary depending upon individual plant design, but 120 seconds is the maximum setting.

The timer also permits operator reset to prevent automatic blowdown if RPV water level is being restored or if the signals are erroneous. To complete the ADS initation logic sequence, the status of the low pressure ECCS pumps is checked to provide some assurance that makeup water is available for injection to the RPV once it is depressurized.

2.2 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 2)

The second option eliminates the high drywell pressure trip from the current logic sequence and adds a manual switch which allows the operator to prevent (inhibit) automatic ADS initiation. The logic design for this alternative is shown in Figure 2-2. The ADS sequence would then be activated on low RPV water level only. The remainder of the logic sequence would remain unchanged from the current design. The effect of high drywell pressure on the operation of other safety systems, such as reactor scram and the ECCS that initiate on high drywell pressure, would be unaffected.

2.3 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 3)

The third option eliminates the high drywell pressure trip from the current logic sequence and lowers the low RPV water level trip setpoint to the top of the active fuel (TAF). Figure 2-3 shows the logic design for this alternative. The ADS would then be activated on low RPV water level only. The remainder of the logic sequence would remain unchanged from the current design. The effect of high drywell pressure on the operation of other safety systems, such as reactor scram and the ECCS that initiate on high drywell pressure, would be unaffected.

2.4 BYPASS HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 4)

The fourth option bypasses the high drywell pressure portion of the current logic after a specific time interval and adds a manual switch which allows the operator to prevent (inhibit) automatic ADS initiation. Figure 2-4 shows the logic design for this alternative. The high drywell pressure requirement is bypassed by installing a second (''bypass'') timer that is actuated on low RPV water level (Level 1). When this timer times out, the high drywell pressure trip would be bypassed and the ADS initiated on a low RPV water level signal alone. The additional logic would not affect the high drywell pressure-low RPV water level initiation sequence in so far as it responds to pipe breaks inside the drywell. Once the timer times out, this option becomes the same as that previously discussed in Section 2.2.

A time delay of approximately eight minutes for the high drywell pressure bypass logic was chosen for preliminary evaluations. Calculation of an exact delay setting for the bypass timer would require that a detailed analysis be conducted. This analysis must be based on (1) avoidance of excessive fuel cladding heatup using 10CFR50 Appendix K models and (2) providing sufficient time to allow recovery of RPV water level above Level 1 during an ATWS event. For BWR/2-3, the bypass timer would automatically reset if RPV water level is restored above Level 1. For BWR/4-6, once the bypass timer times out, the bypassing of the high drywell pressure would be sealed in and the bypass timer would not automatically reset. This difference in logic schemes is required to reduce the possibility of repeated partial core uncovery for BWR/4-6 plants because of the lower RPV water level trip setpoint for these plant designs.

2.5 BYPASS HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 5)

The fifth option bypasses the high drywell pressure portion of the current logic after a specific time interval and lowers the low RPV water level trip setpoint to TAF. Figure 2-5 shows the logic design for this alternative. This option functions in the same manner as that discussed in Section 2.4 except the low RPV water level initiation setpoint is lowered to TAF and no manual inhibit is provided.

Once the bypass timer times out, the bypassing of the high drywell pressure would be sealed in for all product lines and the bypass timer would not automatically reset.

2.6 ADD SUPPRESSION POOL TEMPERATURE TRIP AND MANUAL INHIBIT SWITCH (OPTION 6)

The sixth option adds a high suppression pool temperature trip in parallel with the high drywell pressure trip and adds a manual inhibit switch which allows the operator to prevent (inhibit) automatic ADS initiation. Figure 2-6 shows the logic design for this alternative. For this option, the ADS initiation sequence would be initiated by either high drywell pressure or an elevated suppression pool temperature in conjunction with a low RPV water level signal. The remainder of the logic remains unchanged from the current design except for the addition of a manual ADS inhibit switch. Just as high drywell pressure is symptomatic of a loss of RPV inventory through a break inside the drywell, a large increase in suppression pool temperature indicates inventory loss occurring through either the safety relief valves or a break inside the drywell. There are two conditions that could be used to initiate the high suppression pool temperature logic: when the pool temperature reaches a specified value, or when the pool heats up faster than a specified rate.

2.7 ADD SUPPRESSION POOL TEMPERATURE TRIP AND CHANGE LOW REACTOR WATER LEVEL TRIP SETPOINT (OPTION 7)

The seventh option adds a high suppression pool temperature trip in parallel with the high drywell pressure trip and lowers the low RPV water level trip setpoint to TAF. Figure 2-7 shows the logic design for this alternative. For this option the ADS would be initiated by either high drywell pressure or an elevated suppression pool temperature. (Refer to the discussion in Section 2.6 for a description of possible logic schemes for the high suppression pool temperature trip.) The low RPV water level initiation setpoint is also lowered to TAF. The remainder of the logic for this alternative is unchanged from the current design.

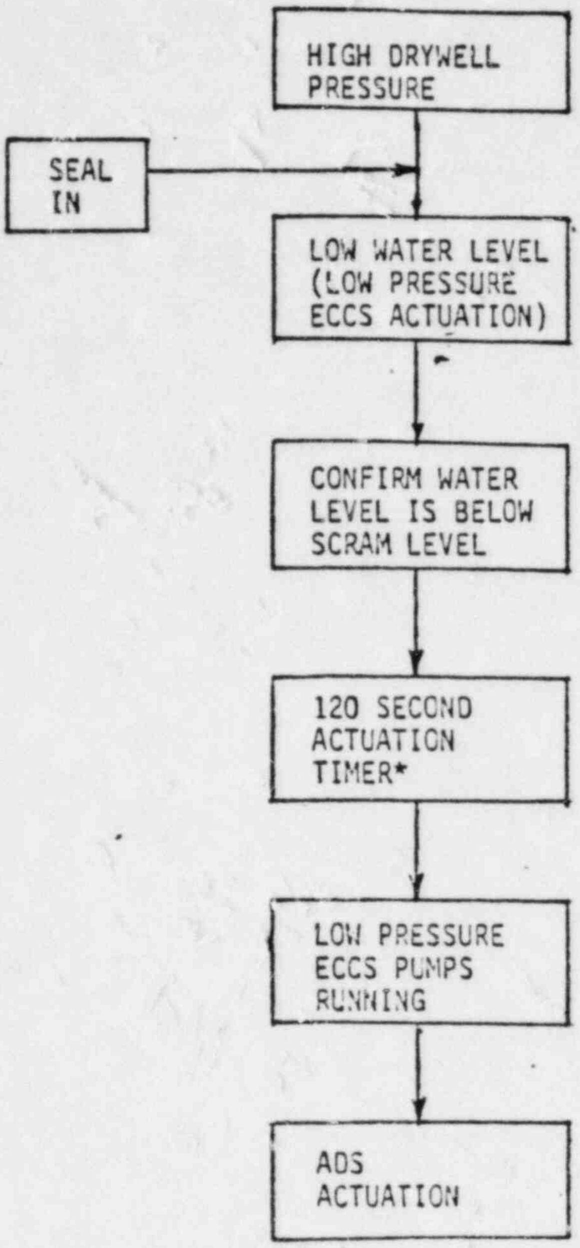
2.8 ADD MANUAL INHIBIT SWITCH (OPTION 8)

The eighth option adds a manual switch to the current logic which allows the operator to prevent (inhibit) automatic ADS initiation. Figure 2-8 shows the logic design for this alternative.

TABLE 2 - 1

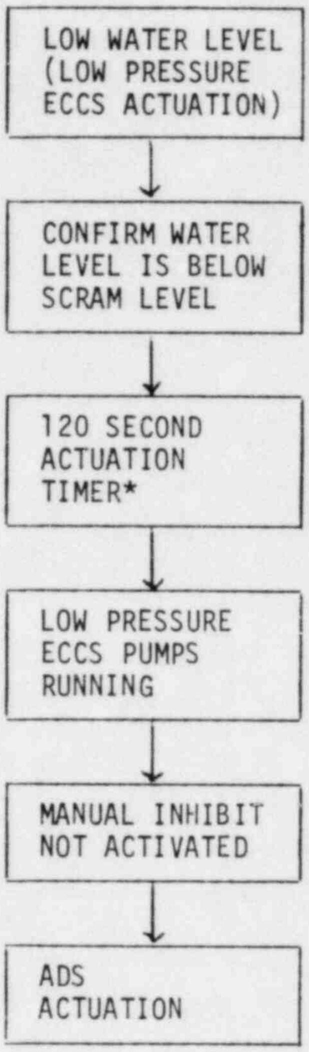
SUMMARY OF ADS LOGIC MODIFICATIONS CONSIDERED

OPTION	HIGH DRYWELL PRESSURE TRIP	TIMER TO BYPASS HIGH DRYWELL PRESSURE TRIP	HIGH SUPPRESSION POOL TEMPERATURE TRIP	WATER LEVEL TRIP SETPOINT	MANUAL INHIBIT SWITCH
1	Yes	No	No	Level 1	No
2	No	No	No	Level 1	Yes
3	No	No	No	TAF	No
4	Yes	Yes	No	Level 1	Yes
5	Yes	Yes	No	TAF	No
6	Yes	No	Yes	Level 1	Yes
7	Yes	No	Yes	TAF	No
8	Yes	No	No	Level 1	Yes



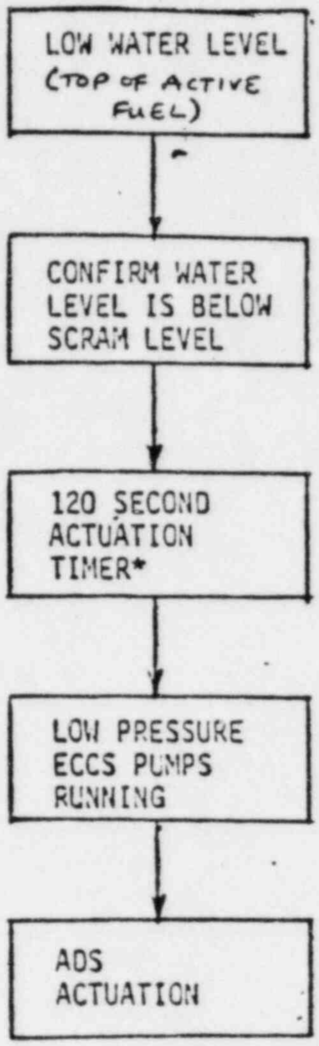
*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-1: CURRENT ADS LOGIC FOR A TYPICAL BWP (OPTION 1)



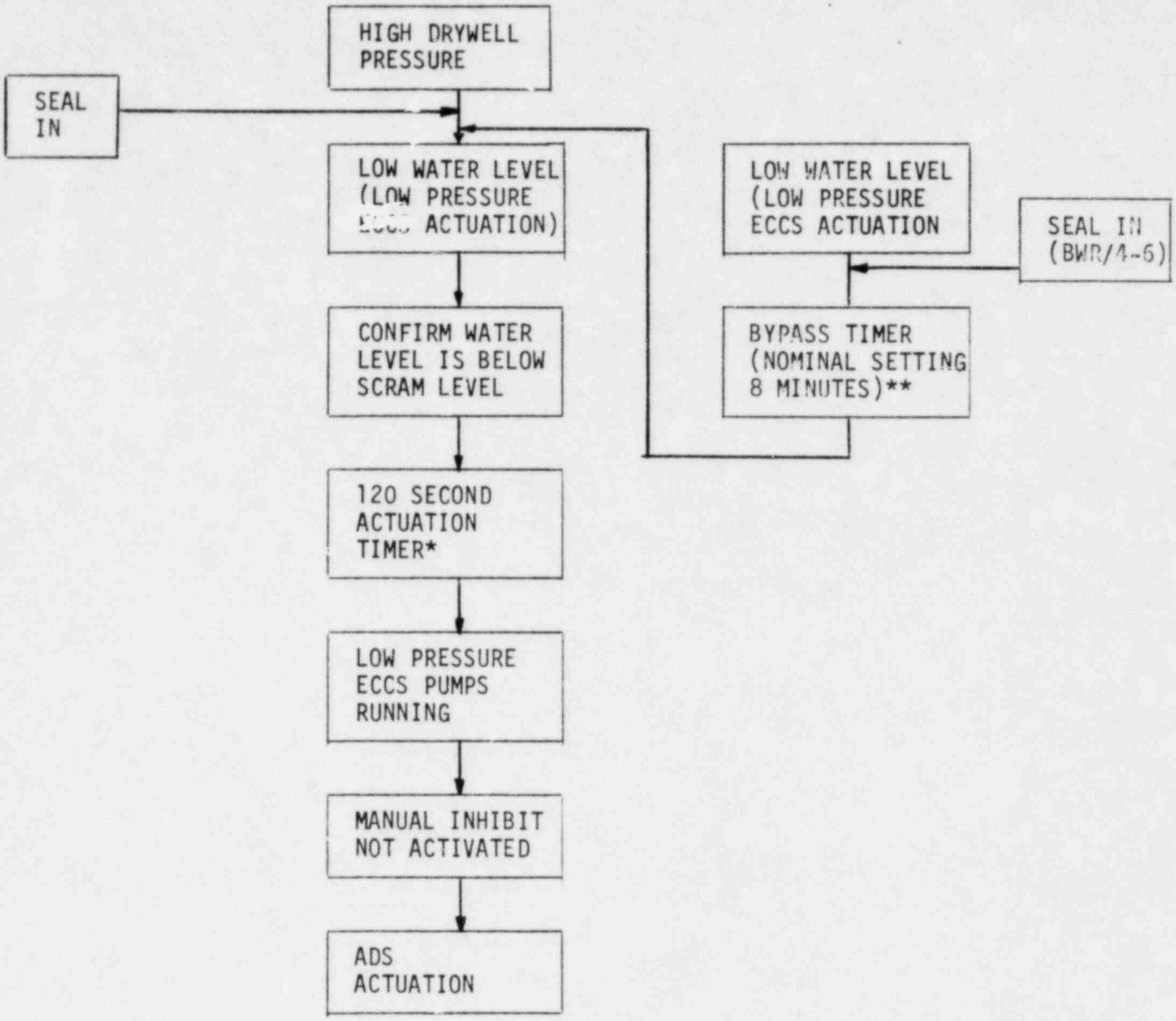
*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-2: ELIMINATE HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 2)



*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

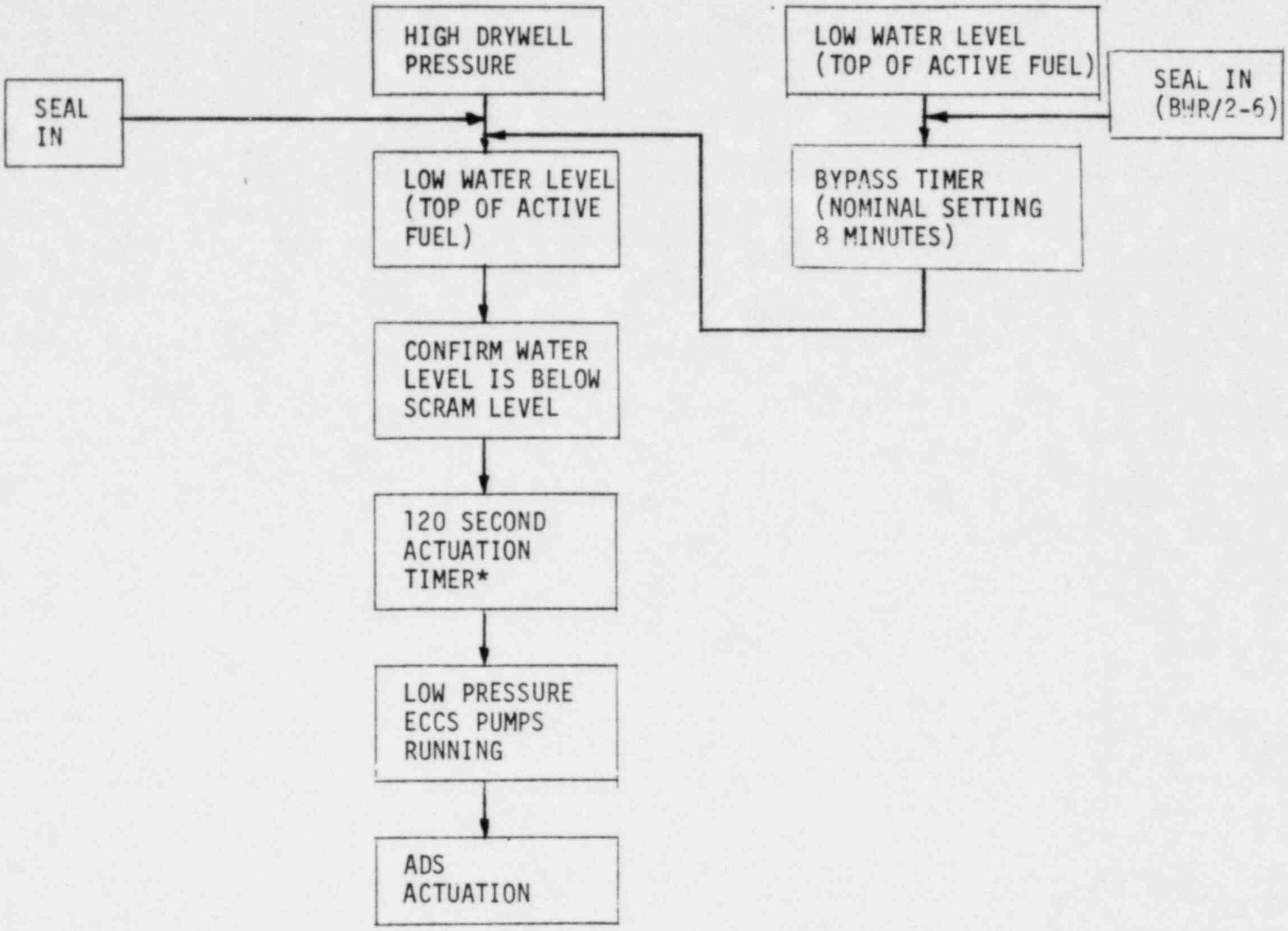
FIGURE 2-3: ELIMINAGE HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW REACTOR WATER LEVEL TRIP SETPOINT (OPTION 3)



*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

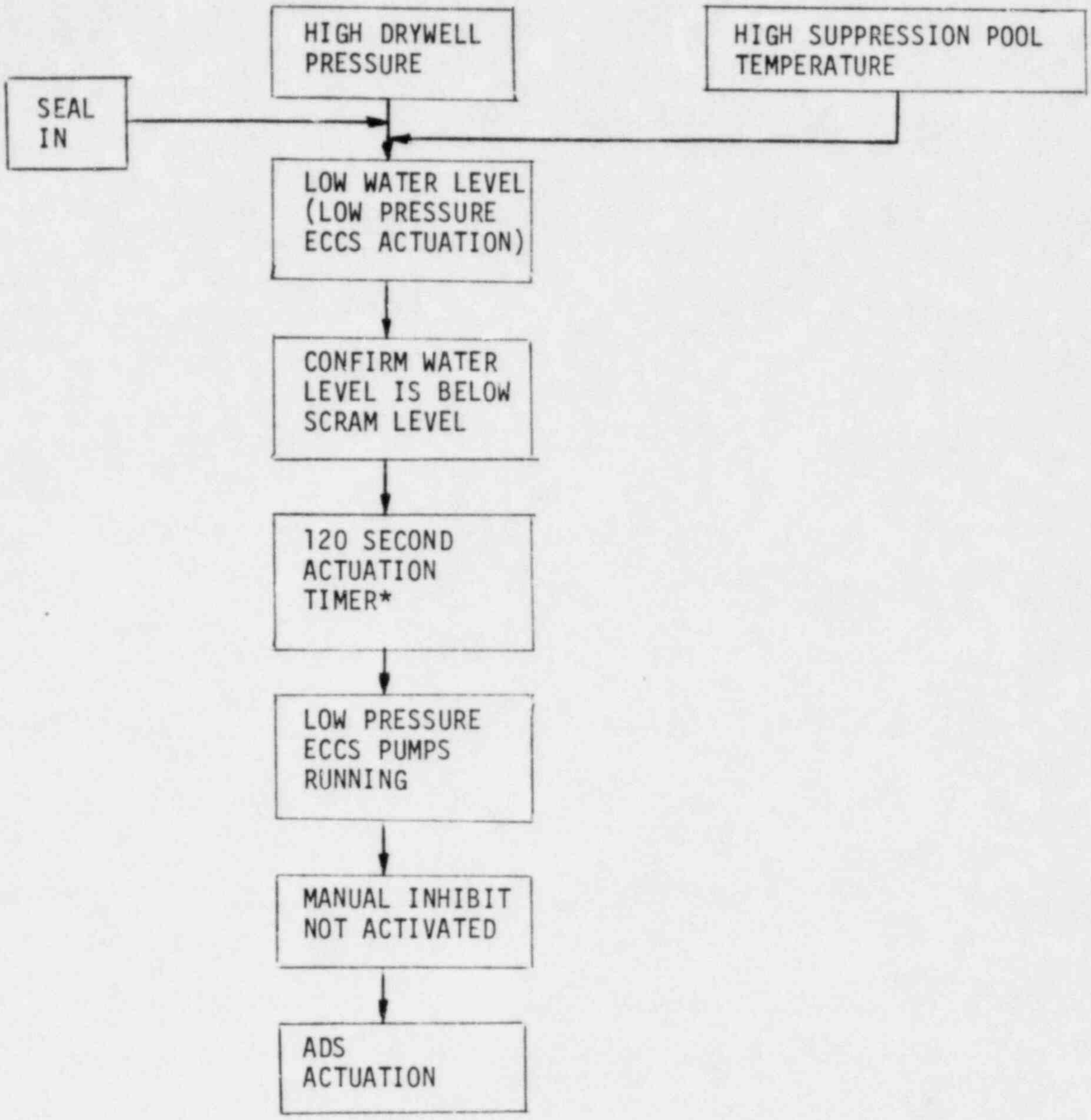
**RESET SAME AS 120 SECOND ACTUATION TIMER FOR BWR/2-3 ONLY

FIGURE 2-4: BYPASS HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 4)



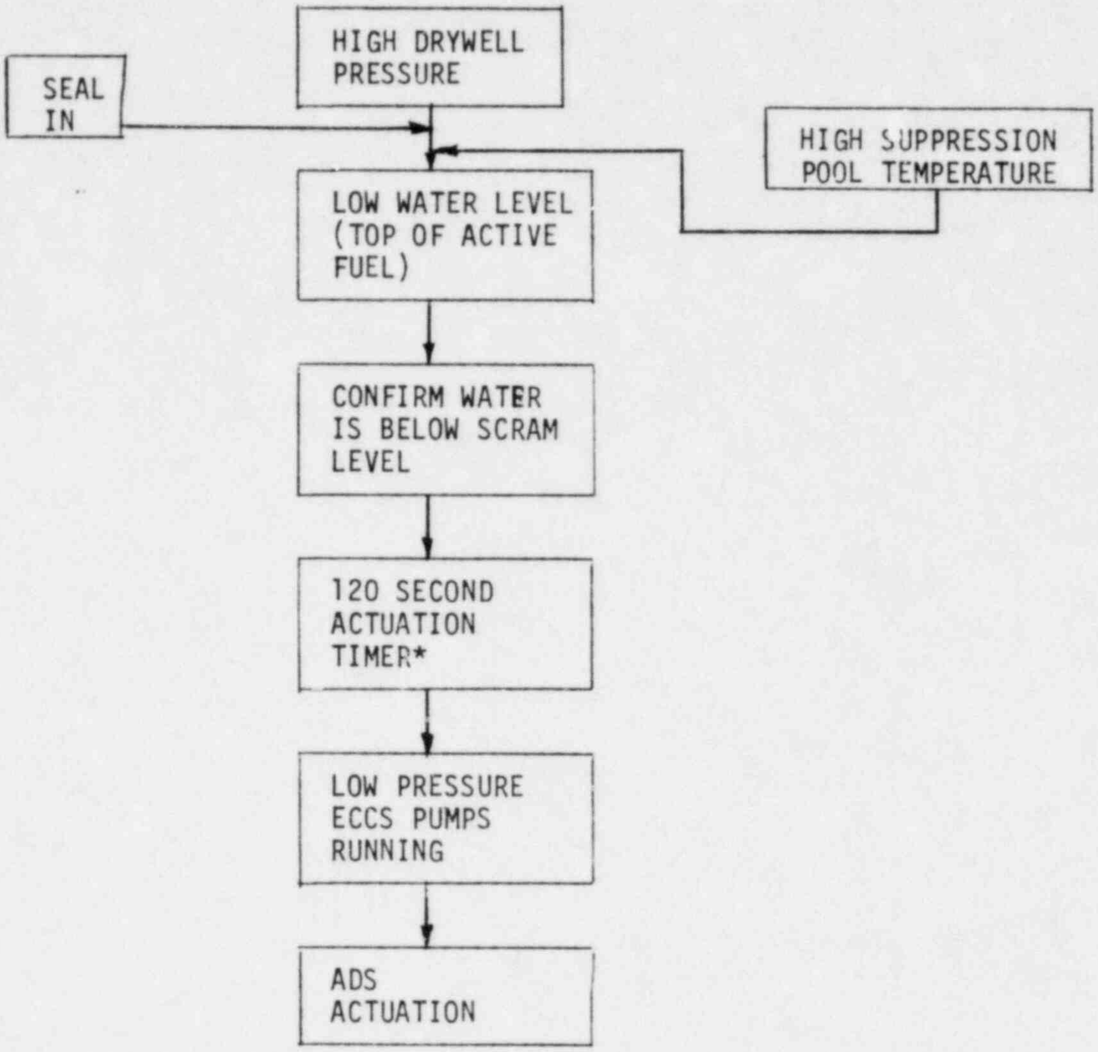
*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-5: BYPASS HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW REACTOR WATER LEVEL TRIP SETPOINT (OPTION 5)



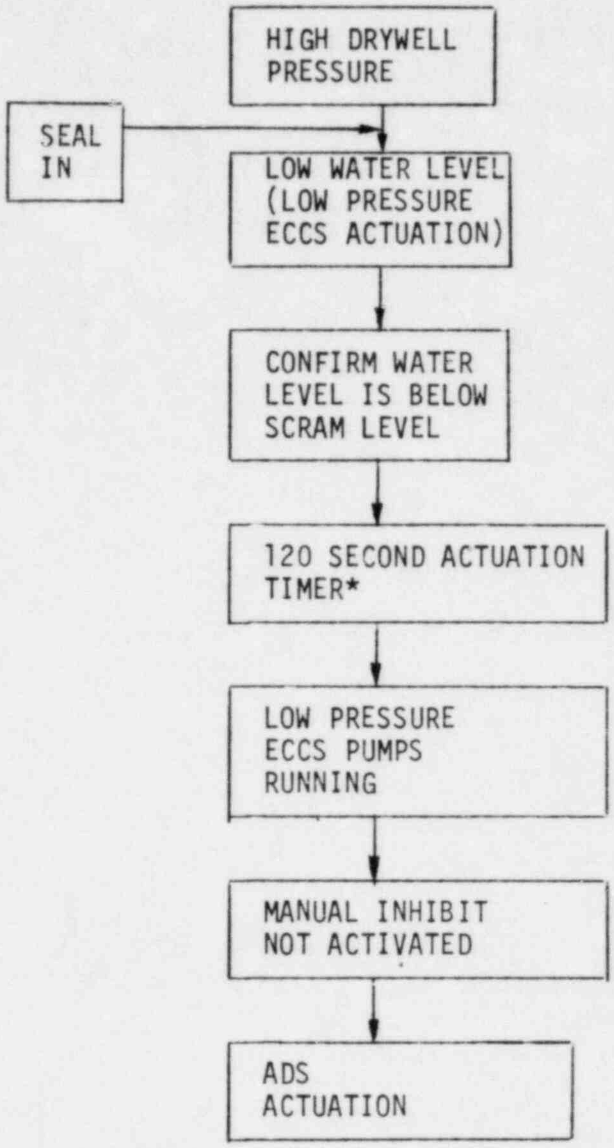
*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-6: ADD HIGH SUPPRESSION POOL TEMPERATURE TRIP AND MANUAL INHIBIT SWITCH (OPTION 6)



*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-7: ADD HIGH SUPPRESSION POOL TEMPERATURE TRIP AND CHANGE LOW REACTOR WATER LEVEL TRIP SETPOINT (OPTION 7)



*120 SECOND ACTUATION TIMER WILL RESET IF REACTOR WATER LEVEL RECOVERS ABOVE TRIP ELEVATION BEFORE IT TIMES OUT. THE TIMER WILL RESTART IF THE LOW REACTOR WATER LEVEL SIGNAL OCCURS AGAIN.

FIGURE 2-8: ADD A MANUAL INHIBIT SWITCH (OPTION 8)

3. TRANSIENT RESPONSE ASSESSMENT

This section analyzes each of the ADS logic options (1) for its effect on assurance of adequate core cooling for the two classes of isolation events previously identified in Section 1, (2) for its effect on LOCA analyses contained in Safety Analysis Reports, and (3) for its effect on ATWS mitigation (assuming Alternate 3A plant modifications).

3.1 ISOLATION TRANSIENTS

For these analyses it is assumed that isolation has occurrred and scram is successful but all high pressure injection systems fail to operate. In order to assure adequate core cooling for these events the RPV must be depressurized to allow the low pressure makeup systems to inject. The modeling used in the performance of these analyses is the same as that which was previously used in NEDO-24708A.

3.1.1 CURRENT DESIGN (OPTION 1)

The current logic design does not actuate the ADS automatically for the events considered. However, the operator has 30 to 40 minutes to depressurize the RPV to prevent inadequate core cooling under the worst case conditions. This is more than enough time to assess the situation and take the necessary corrective actions.

In addition to the time available for the operator to depressurize the RPV, automatic ADS actuation will occur for these events in plants which lose drywell cooling on a low RPV water level signal. Since the drywell is isolated, a loss of drywell cooling will cause drywell temperature and, consequently, drywell pressure to increase. Drywell pressure is expected to reach the setpoint required for ADS initiation 5 to 10 minutes after the loss of drywell cooling, resulting in ADS actuation if RPV water level has not been restored to above Level 1. The time required for the drywell to heat up and pressurize is relatively insensitive to the power level of the reactor or to the initial ambient conditions inside and outside the containment. Thus automatic ADS actuation would most likely occur without operator action within about 10 minutes after RPV water level decreases to Level 1 even for events which do not directly pressurize the drywell.

Analyses presented in NEDO-24708A (Figure Group 3.5.2.1-33) demonstrate that adequate core cooling is assured for isolation events when the ADS blowdown is delayed 10 minutes after RPV water level decreases to Level 1. Figures 3-1.1 through 3-1.8

show the same analysis for isolation events with an SORV. The results shown are typical of BWR/4-6. These results bound BWR/2-3 because of the latter's higher RPV water level trip setpoint for ADS. Because the BWR/2-3 RPV water level trip is at a higher elevation, the resulting core uncovery is shorter and the core heatup is less.

3.1.2 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 2)

Elimination of the high drywell pressure trip results in a reactor system response to the transients considered in this study similar to that for small break LOCA events where the break flow discharges into the primary containment.

For a pipe break inside the drywell, the high drywell pressure trip occurs before the low RPV water level trip. Since the current ADS initiation logic requires both signals, elimination of the high drywell pressure trip has no effect on ADS performance for events which pressurize the drywell.

The RPV water level response for isolation events is bounded by small break LOCA analyses where the majority of the inventory is lost not through the break but through the cycling of relief valves. The RPV water level response to a stuck open relief valve is essentially the same as that for a small recirculation line break. Thus the break spectrum analyses provided in existing Safety Analysis Reports demonstrate that adequate core cooling would be assured for this option.

In the earlier (BWR/2-3) plant designs, both the high and low pressure ECCS are actuated at one common RPV water level. The ADS timer allows the high pressure systems about two minutes to start and restore RPV water level to above the trip setpoint. If RPV water level is not restored to above the trip setpoint before the ADS timer times out, the RPV is depressurized. The RCIC and isolation condensers for these plants are sized to prevent core uncovery for isolations, but they do not have sufficient capacity to restore RPV water level to above the trip setpoint and reset the ADS initiation logic within the allotted two minutes. Thus with an isolation and loss of high-capacity, high-pressure makeup, the RCIC or isolation condenser could bring RPV water level under control and ADS actuation would not be needed. However, with the high drywell pressure trip eliminated, ADS actuation would occur unless manually defeated.

The addition of a manual inhibit switch to the ADS initiation logic has no effect on the automatic ADS response to isolation events.

3.1.3 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 3)

The reactor system response for this option is similar to that for Option 2. The only difference is that automatic ADS actuation will occur after RPV water level drops to TAF instead of Level 1. Adequate core cooling would still be assured for this option since the time required for RPV water level to decrease from Level 1 to TAF is less than 10 minutes. As discussed above, analyses presented in NEDO-24708A have demonstrated that adequate core cooling is assured for isolation events when the ADS blowdown is delayed 10 minutes after RPV water level decreases to Level 1.

3.1.4 BYPASS HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 4)

Addition of a timer (10 minutes or less) bypassing the high drywell pressure portion of the current ADS logic will result in ADS actuation occurring no more than ten minutes after the low RPV water reactor level trip setpoint (Level 1) is reached, irrespective of drywell pressure. As discussed above, analyses presented in NEDO-24708A have demonstrated that adequate core cooling is assured for isolation events when the ADS blowdown is delayed 10 minutes after RPV water level decreases to Level 1.

The addition of a manual inhibit switch to the ADS initiation logic has no effect on the automatic ADS response to isolation events.

3.1.5 BYPASS HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 5)

The reactor system response for this option is similar to that for Option 4. The only difference is that the bypass timer would begin running when RPV water level had decreased to TAF. To assure adequate core cooling for this option, the bypass timer setting would have to be less than that in Option 4 in order to result in ADS actuation at about the same time as with that option (i.e., approximately 10 minutes after Level 1 is reached).

3.1.6 ADD SUPPRESSION POOL TEMPERATURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 6)

The discussion and conclusions presented in Section 3.1.2 are applicable for this option provided that the temperature monitoring system is designed to reliably produce the high pool temperature trip within about 8 minutes after RPV water level decreases to Level 1 for the classes of events previously described. This would ensure ADS actuation within about 10 minutes after RPV water level had decreased to Level 1.

The addition of a manual inhibit switch to the ADS initiation logic has no effect on the automatic ADS response to isolation events.

3.1.7 ADD SUPPRESSION POOL TEMPERATURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 7)

The automatic ADS response for this option will be identical to that for Option 6 since the high suppression pool temperature trip is not expected to occur until after RPV water level drops to below TAF.

3.1.8 MANUAL INHIBIT SWITCH (OPTION 8)

Addition of a manual inhibit switch to the current ADS logic has no effect on the automatic ADS response to isolation events.

3.2 LOCA SAFETY ANALYSIS REPORT CALCULATIONS

Loss-of-coolant accident calculations performed to show compliance with 10CFR50.46 and Appendix K will be affected by ADS logic options which lower the RPV water level trip to TAF (Options 3, 5 and 7). This section discusses the effect of the lower RPV water level trip setpoint on those calculations. Options which do not change the RPV water level trip setpoint will affect only Appendix K LOCA calculations for breaks outside the containment, which are discussed in Section 3.1.

3.2.1 LARGE BREAKS

For large breaks (≥1.0 ft^2) in the recirculation line or steamline, the RPV depressurizes rapidly without ADS actuation. Consequently, lowering the low RPV water level trip setpoint to TAF has a negligible effect on large break LOCA calculations.

3.2.2 SMALL AND INTERMEDIATE BREAKS

Small and intermediate size breaks (<1.0 ft^2) may require ADS operation to depressurize the RPV in the event of HPCI/HPCS failure. Lowering the low RPV water level trip setpoint results in later ADS actuation, which keeps the core covered longer. However, it also prevents the low pressure pumps from injecting water into the RPV for a longer period of time. These two effects tend to offset each other resulting in small (on the order of $\pm$ 50^{o}F) changes in the peak cladding temperature (PCT).

For BWR/2-3 plants the low RPV water level trip setpoint is currently about five feet above TAF. These plants also have a relatively small number (3 to 5) of ADS valves. As a result, the peak cladding temperatures currently calculated for small breaks for these plants are very close to the PCT calculated for the limiting break. Consequently, options with the lower RPV water level trip setpoint for BWR/2-3 plants would require plant-specific calculations to ensure that the small break PCTs remain below the limiting break PCT.

The low RPV water level trip setpoint for BWR/4-6 plants is currently about one foot above TAF. These plants typically have more ADS valves of larger capacity than most BWR/2-3 plants. These features result in small break peak cladding temperatures which are several hundred degrees lower than the PCT for the limiting break. Since the impact on the small break PCT of changing the low RPV water level trip setpoint is small, the limiting break for BWR/4-6 plants would still be in the large break region of the break spectrum for options with the lower RPV water level trip setpoint.

In conclusion, changing the low RPV water level trip setpoint to TAF is acceptable with respect to LOCA analysis for BWR/4-6 plants. However, BWR/2-3 plants may require plant-specific LOCA calculations to accomodate this change.

3.3 ANTICIPATED TRANSIENTS WITHOUT SCRAM (ATWS)

This section discusses the impact of each option on design calculations for proposed modifications for ATWS.

Currently, a large range of modifications are being considered in response to the ATWS issue. These extend from implementation of the BWR Owners' Group EPGs and no equipment modifications to requiring Alternate 3A of NUREG-0460, Volume 4 (Draft). The proposed ADS logic modifications are compared in this Section by considering each in conjunction with the Alternate 3A design. The acceptability of Options 4 and 5 is believed to be independent of final resolution of the ATWS issue because no operator actions are required to prevent ADS actuation within 10 minutes of ATWS event initiation.

All BWR/4-6 ATWS Alternate 3A calculations referenced in this section are documented in NEDE-24222, Volume 2.

3.3.1 CURRENT DESIGN (OPTION 1)

During an ATWS event RPV water level will usually drop causing core power to decrease until an equilibrium between boiloff and the high pressure systems makeup capacity is reached. To prevent an ADS actuation with the current logic design RPV water level must be restored to above the RPV water level trip setpoint before a high drywell pressure signal is received and the ADS timer times out. Drywell pressurization is caused by the loss of drywell cooling on low RPV water level as discussed in Section 3.1.1. ATWS Alternate 3A design calculations show that for BWR/4-6 plants with HPCI/HPCS operable the current logic prevents an automatic ADS actuation for all postulated ATWS events. Calculations have not been performed for BWR/2-3 plants. However, because of the higher low RPV water level trip setpoint in these plants, manual operator action may be required to prevent ADS actuation for some ATWS events.

3.3.2 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 2)

Elimination of the high drywell pressure trip from the ADS initiation logic requires RPV water level to recover to above the low RPV water level trip setpoint (Level 1) before the ADS timer times out if an automatic ADS actuation is to be prevented during an ATWS event. ATWS Alternate 3A design calculations performed for BWR/4-6 plants show that RPV water level is restored to above Level 1 before the timer times out for only BWR/4 and BWR/5 plants. For other product lines, operator action within 10 minutes of ATWS event initiation is required to prevent actuation of ADS.

3.3.3 ELIMINATE HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 3)

The automatic ADS response for this option is similar to that for Option 2 except that RPV water level must recover to above TAF before the ADS timer times out if an ADS actuation is to be prevented. ATWS Alternate 3A design calculations show that this condition is met for only BWR/4 and BWR/5 plants. As with Option 2, operator action is required to prevent ADS actuation within 10 minutes of ATWS event initiation for other product lines.

3.3.4 BYPASS HIGH DRYWELL PRESSURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 4)

Addition of a bypass timer to the ADS logic allows ADS actuation to be prevented for an ATWS event. This is accomplished by setting the timer so that it will not time out until after RPV water level has been restored to above Level 1.

Plant-specific calculations will be required to determine the minimum timer setting for this option. The maximum allowable timer setting is determined from LOCA considerations.

3.3.5 BYPASS HIGH DRYWELL PRESSURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 5)

The automatic ADS response for this option is similar to that for Option 4 except that the minimum bypass timer setting will be based on the time required to restore RPV water level to above TAF.

3.3.6 ADD HIGH SUPPRESSION POOL TEMPERATURE TRIP AND ADD MANUAL INHIBIT SWITCH (OPTION 6)

To prevent automatic ADS actuation during an ATWS event the setpoint of the high suppression pool temperature trip must be sufficiently high that it is not reached before RPV water level is restored to above Level 1. However, for isolation and SORV events, the high suppression pool temperature trip must also be set sufficiently low to allow ADS actuation within about 10 minutes after RPV water level reaches Level 1. Additional plant-specific analyses will be required to determine if an acceptable setpoint for the high suppression pool trip exists which meets both of these criteria.

3.3.7 ADD HIGH SUPPRESSION POOL TEMPERATURE TRIP AND CHANGE LOW RPV WATER LEVEL TRIP SETPOINT (OPTION 7)

The automatic ADS response for this option is similar to that for Option 6. For this option the high suppression pool temperature trip setpoint must be sufficiently high that it is not reached before RPV water level is restored to above TAF during an ATWS event. As with Option 6, plant-specific analyses will be required to determine whether an acceptable trip setpoint exists.

3.3.8 MANUAL INHIBIT SWITCH (OPTION 8)

Addition of a manual inhibit switch to the current ADS logic does not affect the automatic reactor system response during any ATWS event. Consequently the discussion and conclusions presented in Section 3.3.1 are applicable.

3.4 SUMMARY

The current ADS logic meets all of the applicable design and licensing requirements. In addition, the current ADS logic assures adequate core cooling for isolation and SORV events when drywell pressurization results from the loss of drywell cooling on low RPV water level. Options 2 through 7 provide additional assurance of adequate core cooling by further automating RPV depressurization for isolations and SORV events. Options which lower the RPV water level trip setpoint for ADS to TAF (Options 3, 5 and 7) may adversely affect BWR/2-3 small break LOCA PCT calculations, and options which eliminate the high drywell pressure trip (Options 2 and 3) may not satisfy ATWS modification design concerns. Options which incorporate a high suppression pool temperature trip (Options 6 and 7) or a high drywell pressure bypass timer (Options 4 and 5) require additional plant specific calculations to determine acceptable trip setpoints. Options which incorporate a manual inhibit switch (Options 2, 4, 6 and 8) do not adversely affect automatic ADS system performance for ATWS or design basis transients and accidents.

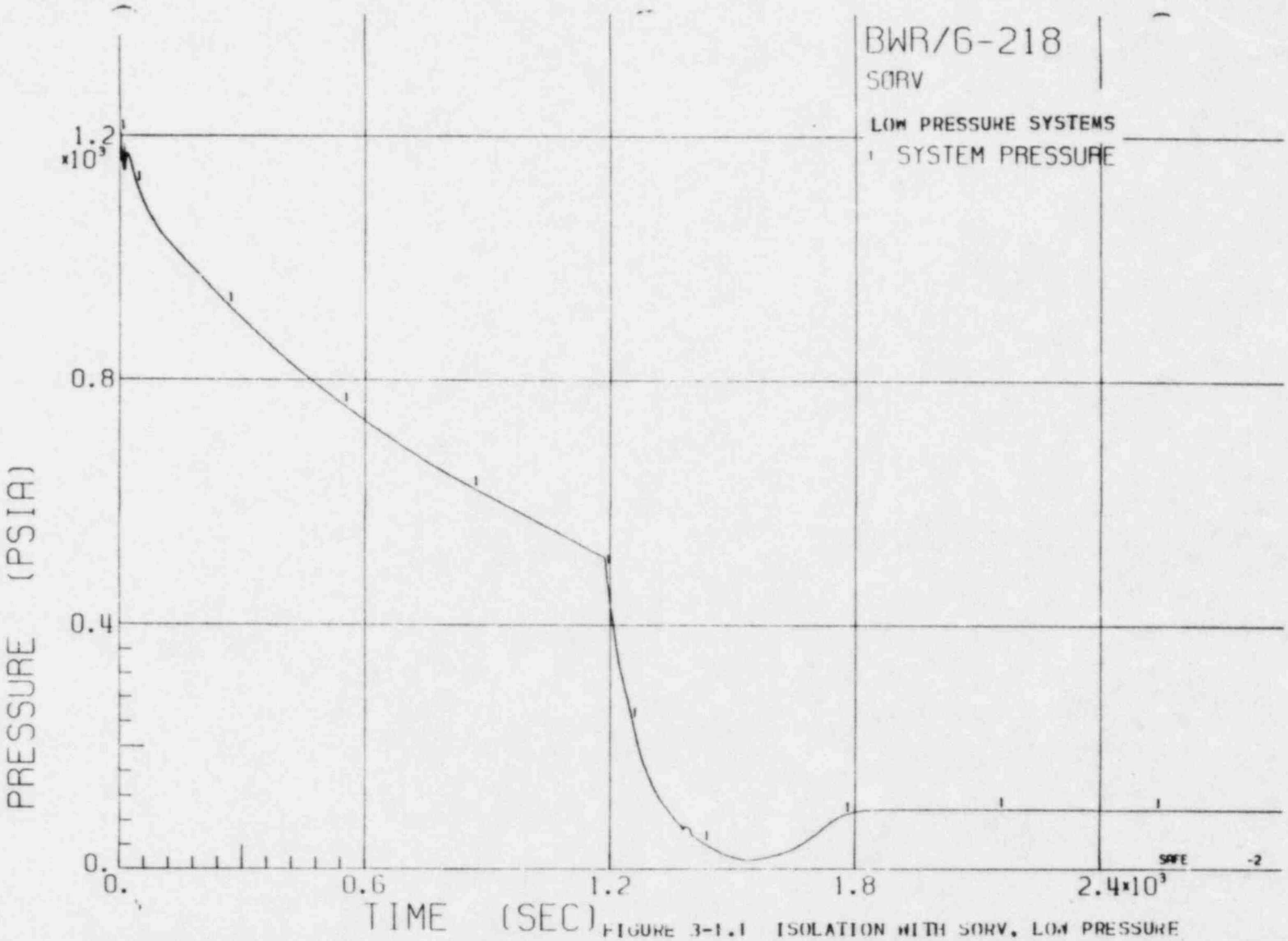


FIGURE 3-1.1 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

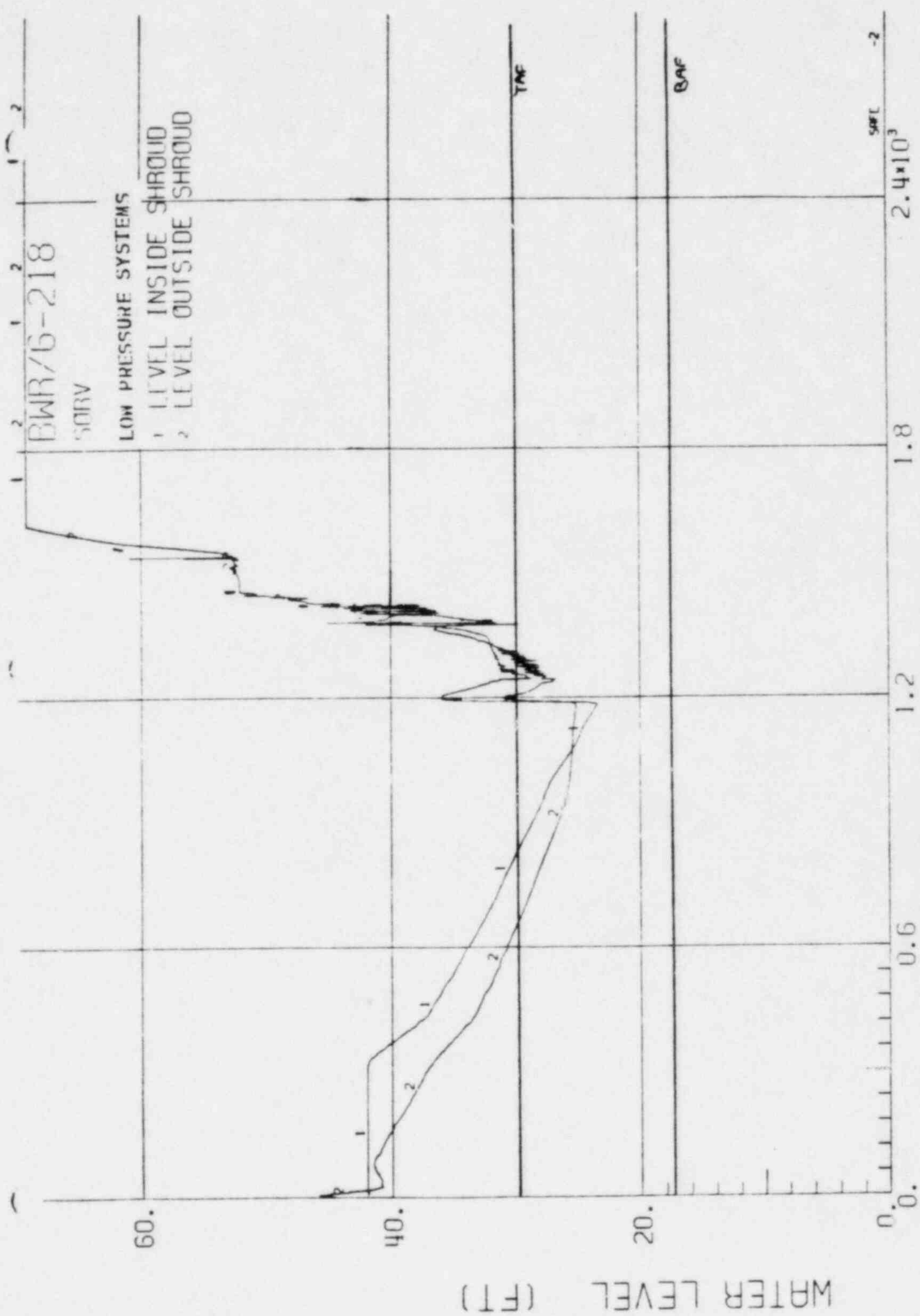


FIGURE 3-1 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

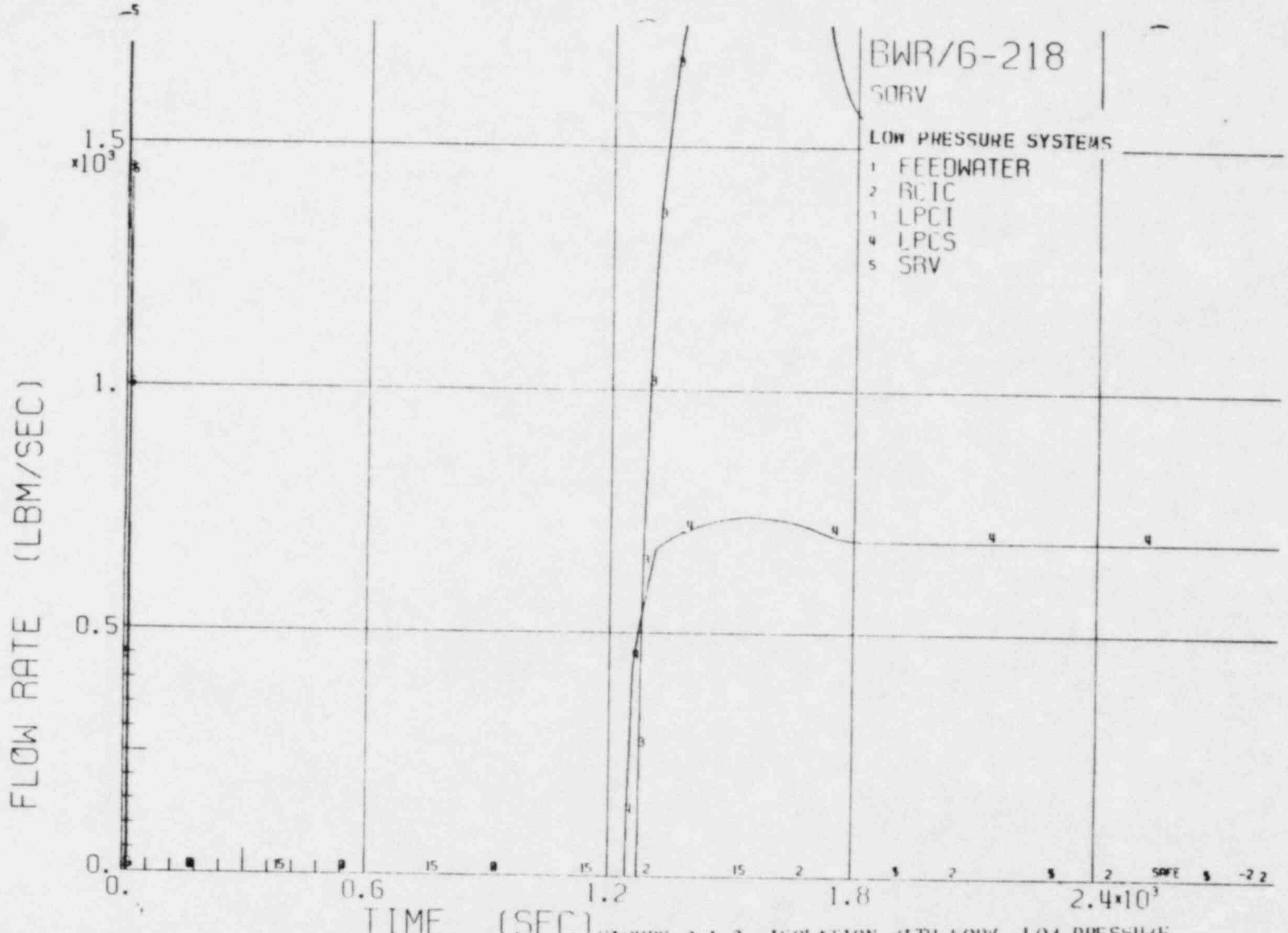


FIGURE 3-1.3 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

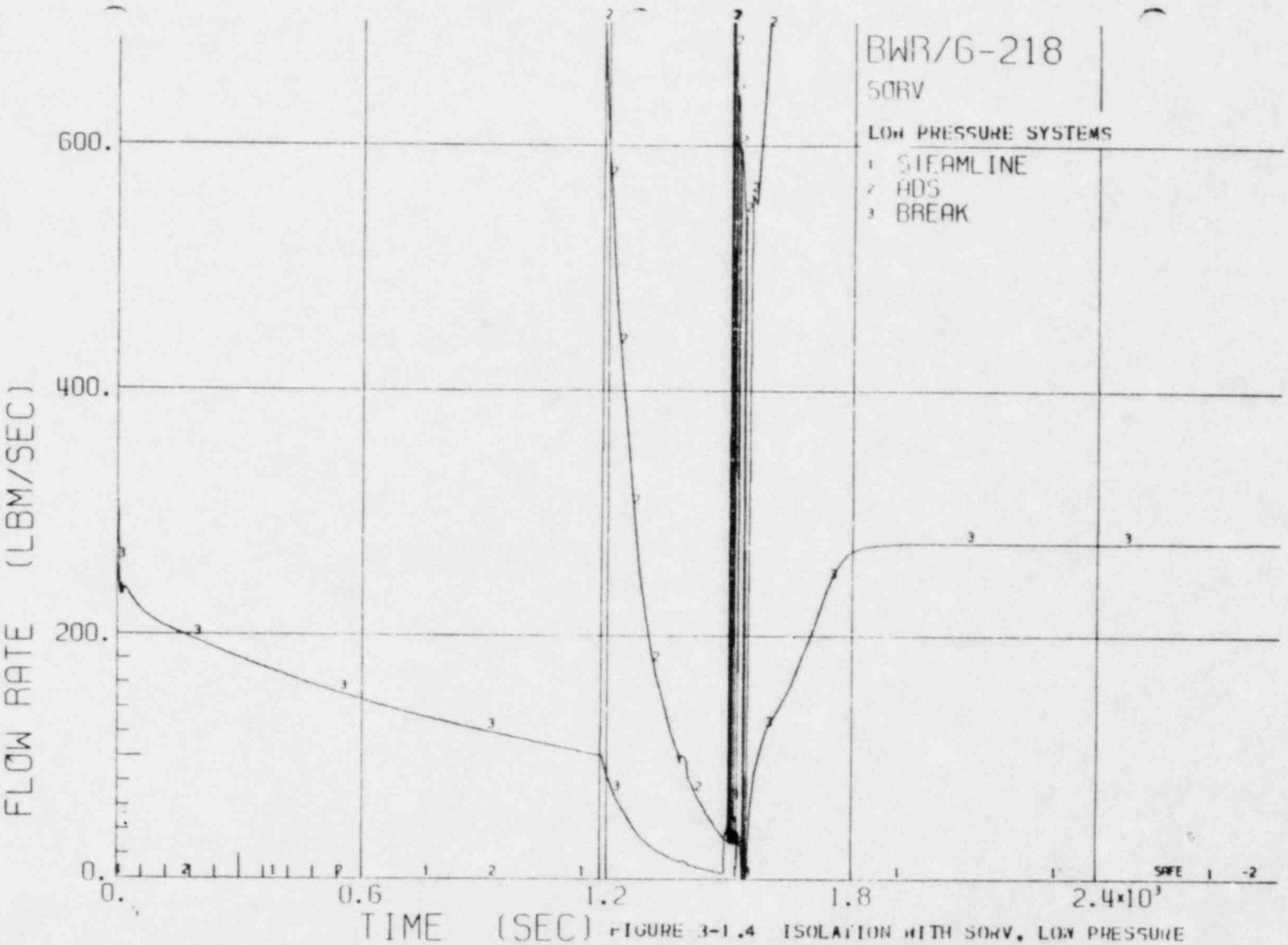


FIGURE 3-1.4 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

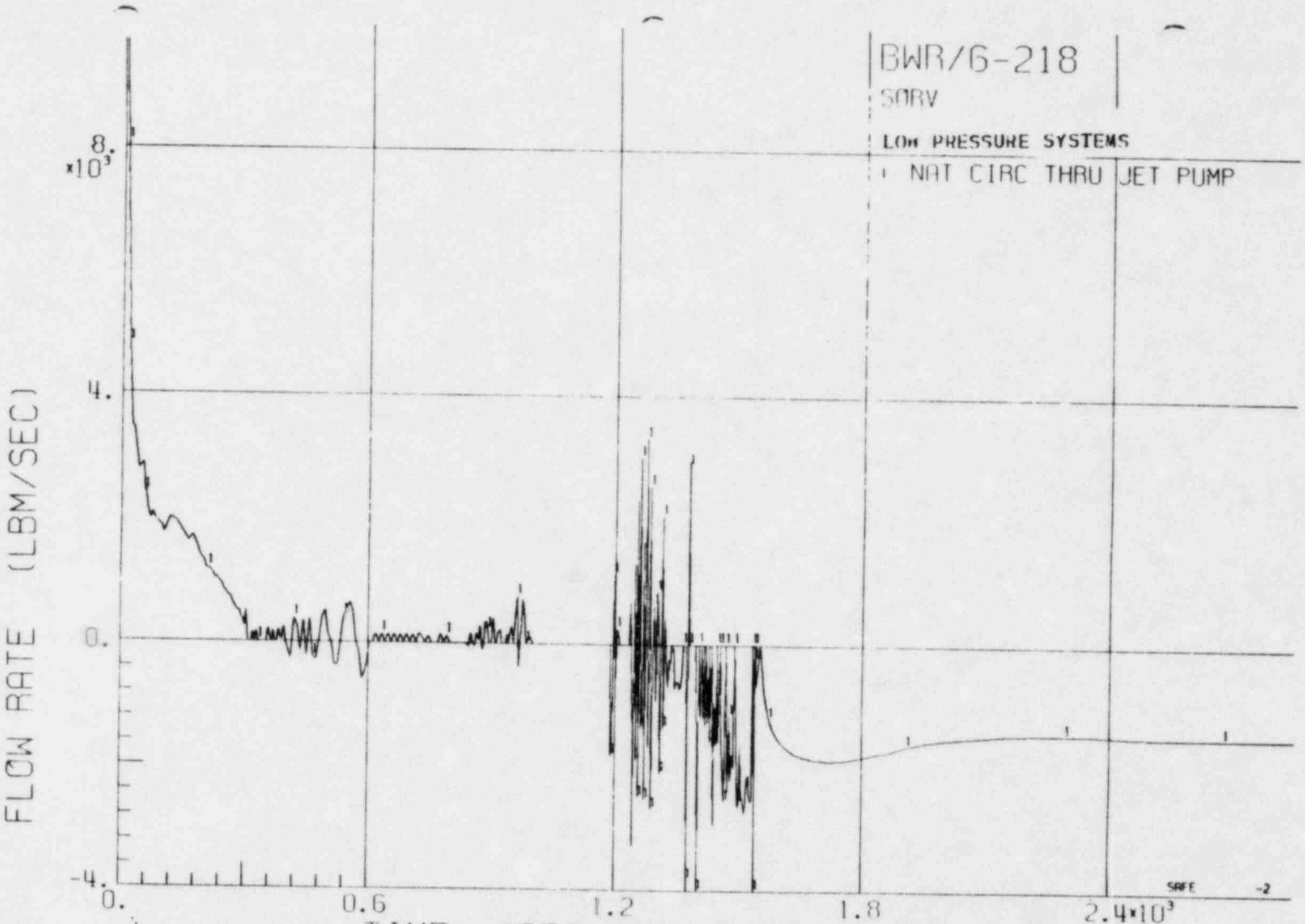


FIGURE 3-1.5 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

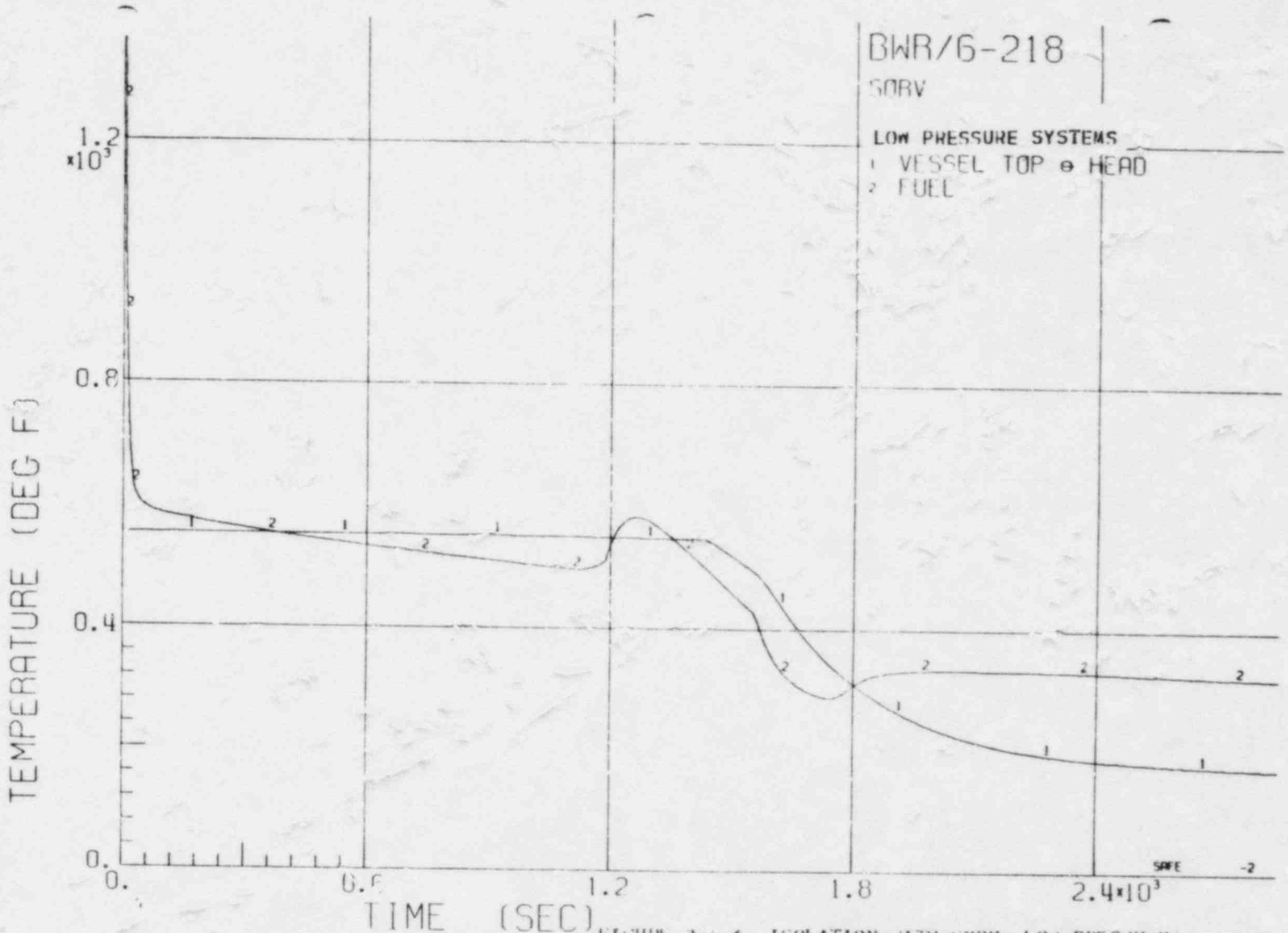


FIGURE 3-1.5 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

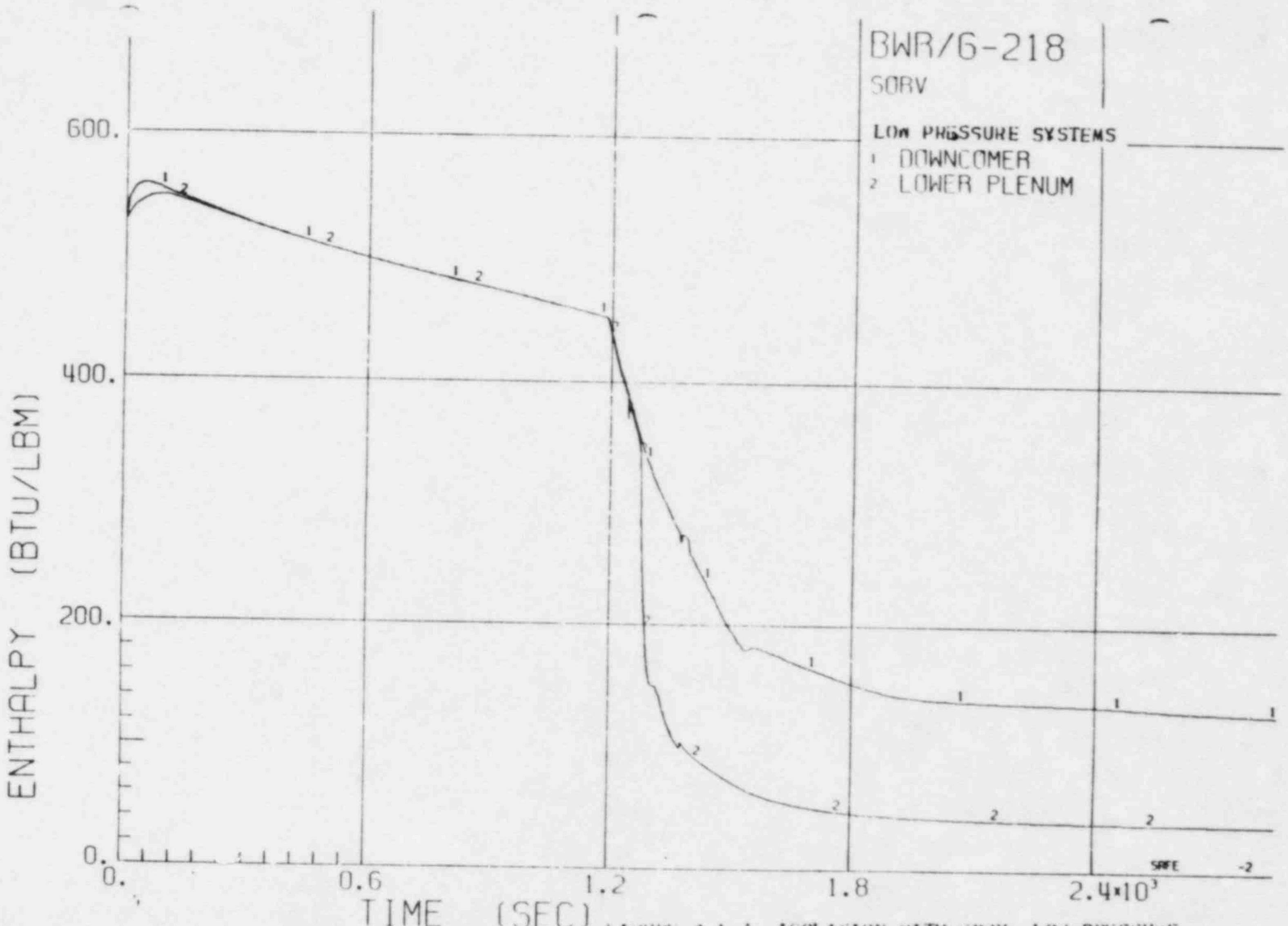


FIGURE 3-1.7 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

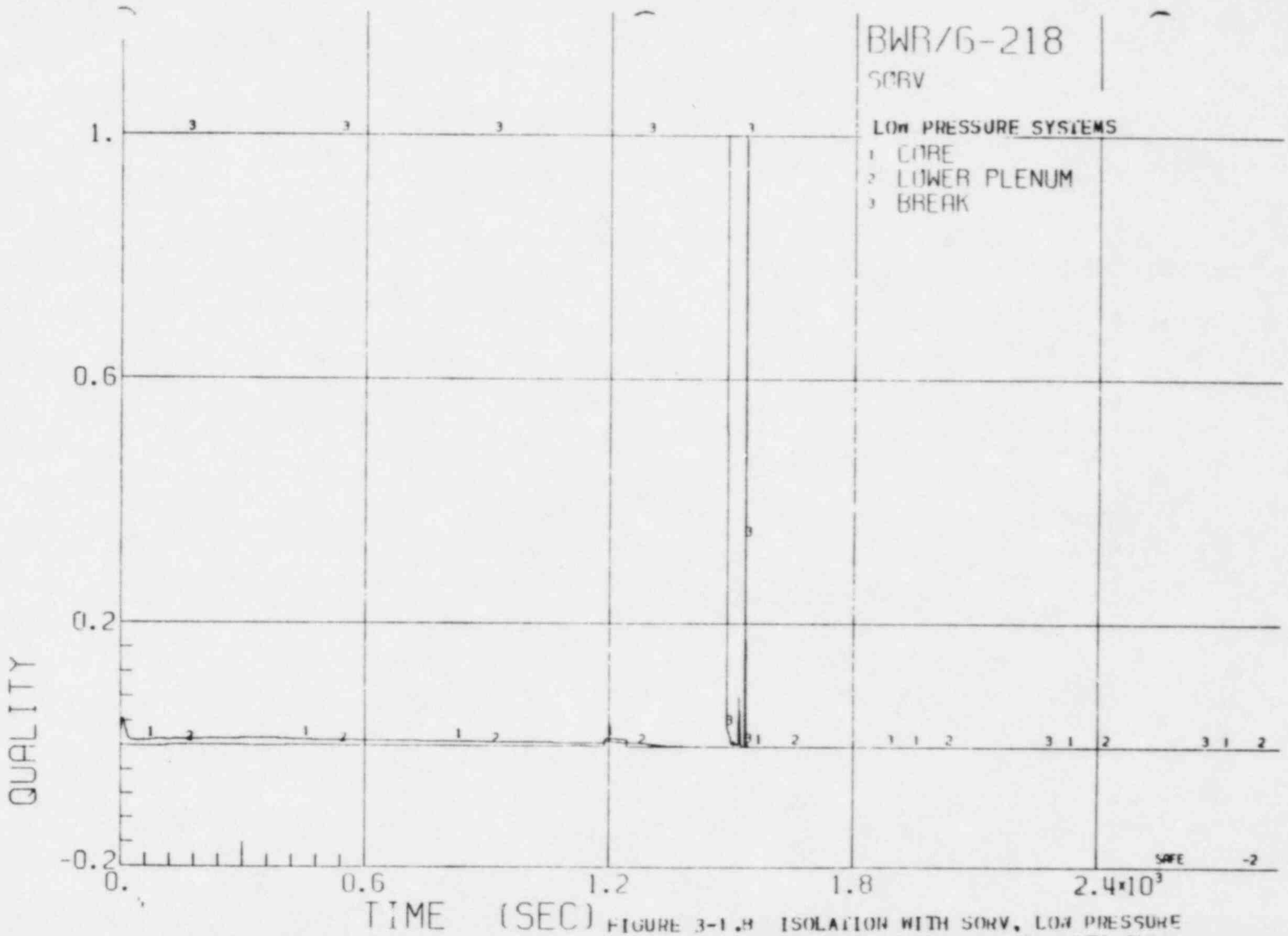


FIGURE 3-1.8 ISOLATION WITH SORV, LOW PRESSURE SYSTEMS AVAILABLE, ADS ACTUATION 10 MINUTES AFTER LEVEL ONE

4. EMERGENCY PROCEDURES ASSESSMENT

4.1 CURRENT DESIGN

The symptom-based Emergency Procedure Guidelines (EPGs) were developed for plants ''as built'' and therefore with the current ADS logic design. These guidelines specify operator actions which extend ADS operation to all events which require emergency RPV depressurization to assure adequate core cooling, including the classes of isolation events previously described. They also specify operator actions which utilize ADS operation to protect containment integrity. Therefore, the current ADS logic design together with the symptom-based EPGs satisfies the intent of NUREG-0737 Item II.K.3.18 in that this combination provides additional assurance of adequate core cooling for events which do not directly produce a high drywell pressure signal.

4.2 OPTIONS INCORPORATING A MANUAL INHIBIT SWITCH

Although the EPGs were developed for plants ''as built'', certain operator actions specified in the EPGs could be performed more reliably if the ADS initiation logic were modified. Principal among these is the action to prevent automatic initiation of ADS following commencement of boron injection or while restoring RPV water level manually.

The current ADS initiation logic design incorporates a timer reset feature which permits the operator to reset the ADS timer, thereby delaying automatic depressurization for up to two minutes. This feature does not disable the timer but merely resets it, so that repeated use of this feature at least once every two minutes is required to prevent automatic depressurization while the high drywell pressure and low RPV water level signals are present. (ADS initiation may also be prevented by locking out all low-pressure ECCS pumps, thereby removing the low-pressure-ECCS-pumps-running permissive, but this precludes the use of RHR pumps for suppression pool cooling.) Use of this feature to prevent automatic initiation of ADS for the extended periods of time required after boron injection has commenced is cumbersome at best and requires an operator to devote a significant portion of his time to this function alone. The addition of a manual inhibit switch in the ADS initiation logic simplifies performance of this operator action and increases the probability that it will be successfully accomplished.

Incorporation of other modifications to the ADS initiation logic in conjunction with the manual inhibit switch will not significantly impact the simplicity or probability of accomplishment of the operator actions specified in the EPGs. This is true so long as the ADS timer setting remains sufficiently long to permit operation of the manual inhibit switch when automatic initiation of ADS must be prevented.

4.3 OPTIONS INCORPORATING CHANGING THE LOW RPV WATER LEVEL TRIP SETPOINT TO THE TOP OF THE ACTIVE FUEL (TAF)

The EPGs specify operator actions for emergency RPV depressurization (manual initiation of ADS) for many different plant conditions, only one of which is low RPV water level. For this particular condition, emergency RPV depressurization is not required until RPV water level decreases to TAF (unless, as detailed in the EPGs, at least two independent low-pressure injection subsystems are lined up for injection with pumps running and boron has not been injected). When emergency RPV depressurization is not required until RPV water level decreases to TAF, automatic initiation of ADS must be prevented during the period of time that RPV water level is between TAF and Level 1 if the high drywell pressure signal is also present.

As discussed in Section 4.2, the current ADS initiation logic design incorporates a timer reset feature which may be utilized to prevent automatic initiation of ADS when RPV water level is between TAF and Level 1. However, use of this feature to prevent automatic initiation of ADS has the same drawbacks detailed in that Section. Changing the low RPV water level trip setpoint to TAF eliminates this problem in some situations. However, since automatic initiation of ADS must also be prevented for conditions when RPV water level has decreased to below TAF, this feature does not simplify performance of the operator actions specified in the EPGs to the same extent as does the manual inhibit switch feature.

5.0 RELIABILITY ASSESSMENT

This section assesses each of the eight options described in Section 2 as to their reliability in actuating the ADS for the classes of events previously described, and as to whether the probability of spurious or inadvertent ADS actuation would be increased by their incorporation in the logic design. Also included is a discussion of the expected improvement in operator reliability as a result of implementation of the EPGs.

5.1 RELIABILITY OF ADS INITIATION

5.1.1 CURRENT LOGIC

With the current logic, the operator may be required to manually initiate emergency RPV depressurization (manual ADS) to assure adequate core cooling for the classes of events previously described. These events are slow, uncomplicated, and well understood transients for which the operator is extensively trained and familiar with the equipment to be operated, the sequence of actions to be taken, and the overall plant response.

Following the TMI accident, reviews of emergency procedures and operator training indicated that operator reliability under degraded plant conditions could be improved by providing better procedures and training. The symptom-oriented EPGs were developed as a result of these reviews. The EPGs give the operator additional guidance beyond that previously provided for responding to degraded plant situations. Use of procedures developed from the EPGs in control room simulations using both newly qualified and experienced operators have shown a significant improvement in the reliability of operator performance under degraded conditions. Thus, implementation of the symptom-oriented EPGs and operator training in the use of the new procedures results in added assurance that the operator will properly respond to events which require manual operation to depressurize the RPV.

In addition, for plants where low RPV water level causes primary containment isolation and loss of drywell cooling with subsequent heatup and pressurization of the drywell, the current ADS logic provides an automatic backup to operator action for the classes of events previously described.

5.1.2 LOGIC MODIFICATIONS

The logic modifications considered either eliminate the high drywell pressure initiation signal or provide trips that serve as alternates to the high drywell pressure trip for events that do not pressurize the drywell. These logic modifications also incorporate either a lower RPV water level trip setpoint or a manual inhibit switch to aid the operator in execution of actions required by the EPGs. The added instrumentation necessary to implement any of these various logic modifications can be designed to be more reliable than the operation of the ADS valves themselves.

Eliminating the high drywell pressure trip and lowering the RPV water level trip setpoint are simple features that utilize hardware and instrumentation similar to that used in the current logic. Thus it can be concluded that these features have about the same reliability as the current logic.

The suppression pool temperature trip incorporated in Options 6 and 7 could be designed to provide roughly the same level of reliability as the other features in the logic.

Addition of a manual inhibit switch is expected to have a negligible impact on ADS reliability since it is already possible for the operator to inhibit ADS. However, this feature has several advantages over the current mechanisms for manually inhibiting ADS actuation as discussed in Section 4.

Thus, the reliability of ADS actuation occurring for plant conditions satisfying the logic design is approximately the same for all options.

5.2 SPURIOUS AND INADVERTENT ACTUATION

Fault tree analyses of the various options were performed in order to estimate the probability of unnecessary RPV depressurization. These analyses addressed inadvertent manual depressurization, false initiation signals, and testing and maintenance errors. The results of the studies show that the probability of an unnecessary RPV depressurization is not significantly affected by any of the modifications to the ADS initiation logic proposed in Options 2 through 8. This is basically because any increase in the probability of spurious actuation is approximately offset by a decrease in the probability of inadvertent manual depressurization.

The probability of inadvertent operator actuation of the ADS when RPV depressurization is not required is slightly lower if the system is further automated as proposed in Options 2 through 7. The probability of inadvertent manual ADS initiation is higher for the current ADS logic because the operator, knowing that for some events he is responsible for manual depressurization, may be more apt to err in what he believes is the conservative direction by depressurizing the RPV. However, this is offset to some degree by the detailed guidance on emergency RPV depressurization provided by the new emergency procedures developed from the EPGs.

The probability of spurious actuation due to equipment failure, testing or maintenance errors is slightly greater for Options 2 through 7 since the high drywell pressure initiation signal is bypassed or eliminated. This is because the logic modifications provide more paths to complete the automatic ADS initiation logic or require fewer signals to satisfy this logic.

Because these results are based on conceptual designs only, it is difficult to precisely quantify reliability. However, the decrease in probability of inadvertent manual depressurization should offset any increase in the probability of spurious actuation. The overall probability of unnecessary ADS actuation should be slightly lower.

Thus from the standpoint of probability of inadvertent ADS actuation, it is concluded that all options, including the current design (Option 1), are about the same.

5.3 SUMMARY

Each of the options considered reliably actuates the ADS for plant conditions satisfying the logic design. There is no significant difference between any of the options from the standpoint of probability of inadvertent ADS actuation caused by operator error, false signals, or testing and maintenance errors.

6.0 FEASIBILITY ASSESSMENT

This section compares the feasibility of each of the proposed design features incorporated in the proposed ADS logic modifications. The practicality of each concept and the resources required for implementation are discussed.

6.1 ELIMINATE HIGH DRYWELL PRESSURE TRIP (FEATURE 1)

Implementation of this feature requires only a few simple wiring changes with no hardware additions. Maintenance and testing is somewhat easier in that the resultant logic design has fewer components than the current design.

6.2 BYPASS HIGH DRYWELL PRESSURE TRIP (FEATURE 2)

The cost of hardware to implement this feature into the current ADS logic is relatively low compared to some of the other changes considered. Installation of the necessary hardware is easily performed. Any additional maintenance and surveillance testing for this feature would be minimal.

6.3 ADD HIGH SUPPRESSION POOL TEMPERATURE TRIP (FEATURE 3)

The hardware required for this feature is complex. The suppression pool temperature monitoring and averaging equipment must be precise enough to measure a relatively slow suppression pool heatup in order to initiate the ADS consistent with the need to assure adequate core cooling. Variations in suppression pool mixing (a function of SRV discharge location and RHR operation) requires installing a large number of temperature sensors and sophisticated averaging and recording equipment. Compared to other options, hardware for options incorporating this feature (Options 6 & 7) would be very expensive to purchase and install. Maintenance and surveillance testing for ths hardware would also be substantial.

The selection of an appropriate setpoint may not be feasible. In Section 2.6, two approaches were suggested: measuring the pool heatup rate or establishing a high pool temperature trip. Measuring the pool heatup rate requires additional hardware compared to the high temperature trip and is consequently somewhat less reliable and more expensive. A detailed plant-specific analysis would have to be performed to determine whether an acceptable temperature or heatup rate exists and if so, what it is.

The setpoint must allow the ADS to reliably actuate when needed to maintain adequate core cooling but prevent ADS actuation from occurring for other events.

6.4 MANUAL ADS INHIBIT SWITCH (FEATURE 4)

Implementation of this modification requires only minor hardware additions. The additional maintenance and surveillance testing required is minimal.

6.5 CHANGE LOW REACTOR WATER LEVEL TRIP SETPOINT TO TAF (FEATURE 5)

Implementation of this modification would be very expensive since installation of new water level instrumentation would be required for many plants. The additional maintenance and surveillance testing required would be substantial.

7. CONCLUSIONS

The intent of NUREG-0737 Item II.K.3.18 is to provide added assurance of adequate core cooling for the events which do not directly produce a high drywell pressure signal.

The intent has already been satisfied by preparation and implementation of the Emergency Procedure Guidelines. Based upon the assessments herein, further assurance of adequate core cooling for these events may be obtained by modification of the ADS initiation logic to include a manual inhibit switch in combination with either elimination of the high drywell pressure trip, timed bypass of the high drywell pressure trip or addition of a high suppression pool temperature trip. Plant-specific analyses may be required for some of these modifications.

APPENDIX A

PARTICIPATING UTILITIES

NUREG-0737 II.K.3.18

This report applies to the following plants, whose Owners participated in the report's development.

Utility	Plant
Boston Edison	Pilgrim 1
Carolina Power & Light	Brunswick 1 & 2
Commonwealth Edison	LaSalle 1 & 2, Dresden 2-3, Quad Cities 1 & 2
Georgia Power	Hatch 1 & 2
Iowa Electric Light & Power	Duane Arnold
Niagara Mohawk Power	Nine Mile Point 1 & 2
Nebraska Public Power District	Cooper
Northern States Power	Monticello
Philadelphia Electric	Peach Bottom 2 & 3, Limerick 1 & 2
Power Authority of the State of New York	FitzPatrick
Detroit Edison	Enrico Fermi 2
Long Island Lighting	Shoreham
Mississippi Power & Light	Grand Gulf 1 & 2
Pennsylvania Power & Light	Susquehanna 1 & 2
Washington Public Power Supply System	Hanford 2
Cleveland Electric Illuminating	Perry 1 & 2
Illinois Power	Clinton Station 1 & 2
Vermont Yankee Nuclear Power	Vermont Yankee
Jersey Central Power and Light	Oyster Creek 1
Tennessee Valley Authority	Browns Ferry 1-3, Hartsville 1 & 2
Gulf States Utilities	River Bend 1 & 2
Cincinnati Gas & Electric	Zimmer 1
Public Service Electric & Gas	Hope Creek 1 & 2
Northeast Energy Services	Skagit 1 & 2
Northeast Utilities	Millstone 1