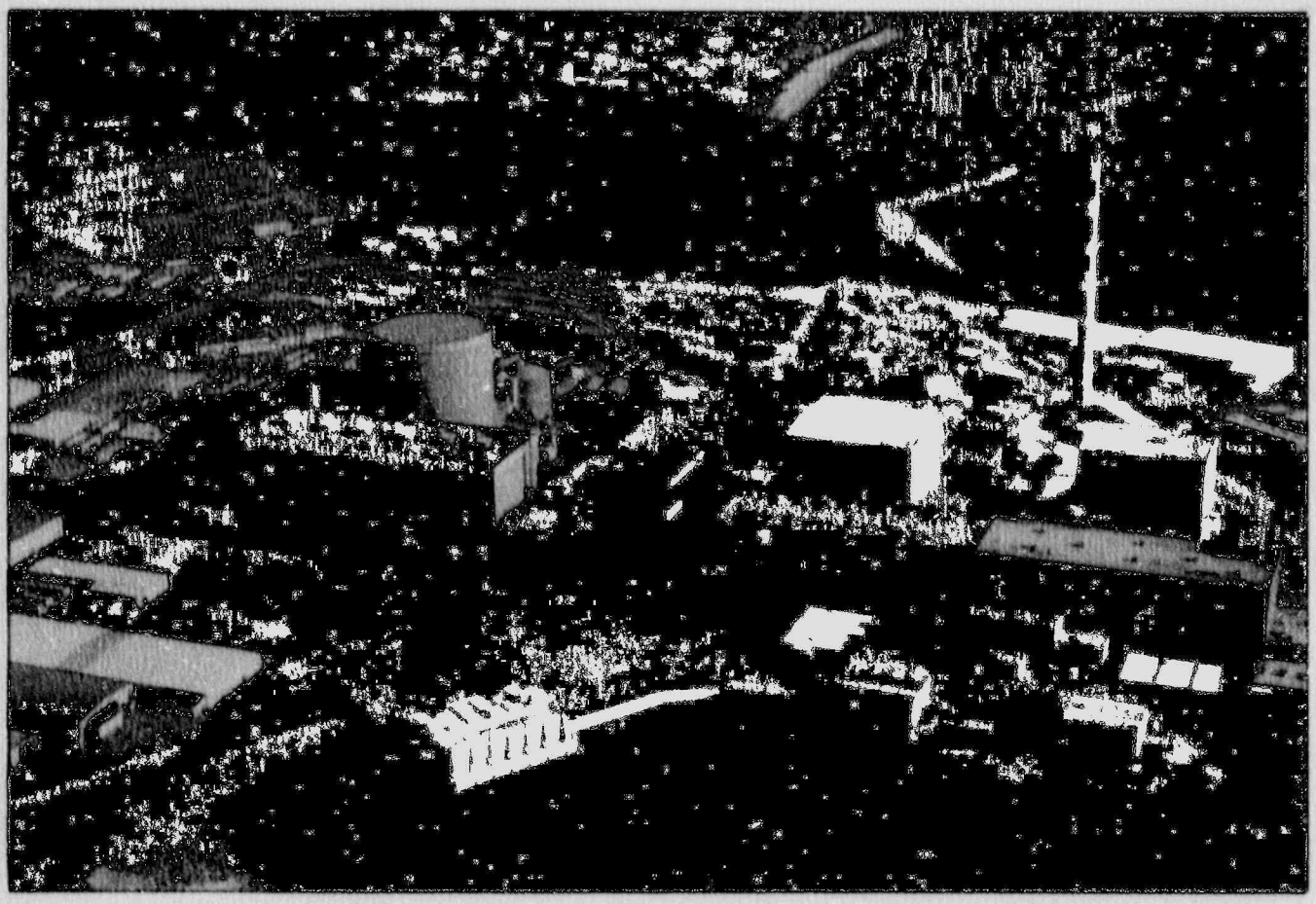
NUSCO 170

Millstone Unit 3

RHR Autoclosure Interlock Removal at Millstone Unit 3



PREPARED BY

Probabilistic Risk Assessment Section

Northeast Utilities Service Co.

April 1990

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Prepared by: _____ 5/7/90
Sunil Weerakoddy
PRA Section, NUSCo Reactor Engineering

Reviewed by: David B. Owens 5/7/90
David Owens
PRA Section, NUSCo Reactor Engineering

Approved by: Donald A. Dube 5/7/90
Donald A. Dube
PRA Section, NUSCo Reactor Engineering

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

The purpose of this analysis is to investigate the risk impact of removing the autoclosure interlock (ACI) from the residual heat removal system (RHRs) suction valves 3RHS*MV8701A&B and 3RHS*MV8702A&B at Millstone Unit 3 (MP3). In place of this automatic feature, an alarm will be added to indicate to the operators that the valve is open while the reactor coolant system pressure is high. This report summarizes the probabilistic risk assessment (PRA) performed in support of the RHR ACI removal. The detailed supporting analysis is found in Reference 1.

The RHRS is aligned to the reactor coolant system (RCS) for shutdown cooling after RCS temperature is lowered to less than 350°F and the RCS pressure is less than 390 psia.[2] After the RHRS is aligned, the RCS pressure should be maintained below this pressure. If the RCS pressure exceeds 765 psia while the RHRS is in service, then the ACI will send a signal to close the RHR suction valves 8701A&B and 8702A&B.[3] The purpose of the ACI is to prevent the RHRS, whose design pressure is approximately 600 psi, from being exposed to high pressures. The proposed project, when implemented, will delete this ACI feature. Instead, an alarm will be added in the control room to warn the operators if the isolation MOVs are open while the RCS pressure is high.

2 BACKGROUND

Loss of RHR during shutdown operations has been a concern to the regulators and the industry for a considerable period of time. These events have continued to occur at a rate of several per year, in spite of the increased attention given.[4,5] A major contributor to the loss of RHR events has been the spurious actuation of the ACI. Spurious closure of the RHR suction valves attributed to the failure of the ACI circuitry, not only causes a loss of RHR and an overpressure transient, but also isolates the RHR relief valve, which can mitigate overpressure transients. In its backfit analysis in support of the Generic Letter 88-17, "Loss of Decay Heat Removal"[5], under programmed enhancements, the NRC stated the following:

> "...We are asking licensees to consider evaluation of the ACI for the DHR system, and we encourage its removal. Experience shows that spurious closure of these valves (RHR suction path isolation valves) has caused approximately 60% of the loss of DHR events. Since the ACI aids in preventing LOCAs outside containment (Event V), this should be evaluated on a plant specific basis.[6]"

Removal of the ACI has several impacts on risk. As pointed out in the previous section, removal of the ACI affects the frequency of interfacing systems LOCAs which may occur when the RHRS is subjected to pressures exceeding its design pressure. Removal of the automatic isolation feature is expected to increase the Event V frequency. However, the installation of the new alarms which would warn the operators of already open RHR

suction motor operated valves (MOVs) is expected to counter the risk increase due to ACI removal. When the ACI is removed, a high percentage of loss of DHR events will be prevented. That is, the risk attributed to the loss of RHR during shutdown is reduced. Finally, the response of the plant to overpressure transients during non-power operation will also be affected. This report provides a summary of the PRA analysis performed using the method established by WCAP-11736-A[7] to address the above mentioned issue.

3 SCOPE

This PRA analysis will address the following three concerns:

- Means Available to Minimize Event V Concerns

  The PRA analysis will examine the change in Event V frequency through the RHR suction path due to removal of RHR ACI and replacing it with the new Alarm "RX PRESSURE HIGH, RHR SUCTION ISOLATION MOV OPEN."

- The RHRS Relief Capacity

  As a part of examining the success criteria for mitigating inadvertent safety injection (SI) events, the RHR suction path relief valve capacity will be investigated.

- The RHRS Reliability, as well as Low Temperature Overpressure (LTOP) Concerns

  The effect of RHR ACI removal on the RHRS unavailability will be examined. Further, the effect of RHR ACI removal on the capability to mitigate or initiate LTOP transients will be examined.

4 PRA ANALYSIS

4.1 Interfacing System LOCA (Event V) Analysis

An interfacing systems LOCA outside the containment is a breach of the RCS when the RCS is at high pressure at an interface with the low pressure piping system. Such a breach has the potential to cause a LOCA outside the containment in which radionuclides are transported directly from the RCS to the environment.

This section provides the summary of calculations of the interfacing systems LOCA frequency for the RHRS-RCS system interface for the two cases: 1) with the present autoclosure interlock (ACI) feature, and 2) without the ACI feature and with the proposed alarm to be installed. Reference 7 (WCAP-11736-A) performed the Event V analysis for four reference plants. None of these analyses are directly applicable to Millstone Unit 3 due to the following key differences:

- There are three RHR suction path isolation valves in MP3 compared to two valves in Callaway.

- The relative positioning of the relief valve in Callaway with respect to isolation MOVs is different from MP3.

- In MP3, power is removed from MOV8701C and MOV8702C only, during power operation. In Callaway, power is removed from all four RHR isolation valves.

Figure 1 is a simplified diagram for RHR suction valves illustrating parameters and components significant for the Event V analysis. For each of the three valves, MV8701A, MV8701B, and MV8701C in RHR train A, the following failure modes were considered. Since the two RHR trains are identical, the discussion and the analysis are applicable to the motor operated valves in RHR train B as well.

- Left open during startup.
- Spurious opening during normal operation.
- Catastrophic rupture.

Treating valve stem separation failure was also considered. However, it was determined that it is unnecessary to treat this as a separate failure mode.

The combinations of failure modes of the valves that could lead to an Event V were examined. Credible failure modes of valve MV8701A depend upon the failure mode of MV8701C. For example, if MV8701C was left open during startup, then rupture is a credible failure mode for MV8701A since this gate valve is exposed to the high reactor pressure. However, if MV8701C was not left open, then rupture of MOV8701A is not a credible initiator since it is not exposed to a high pressure. However, if MOV8701C ruptures, then MOV8701A gets exposed to the reactor pressure for a maximum duration of 1.5 years.

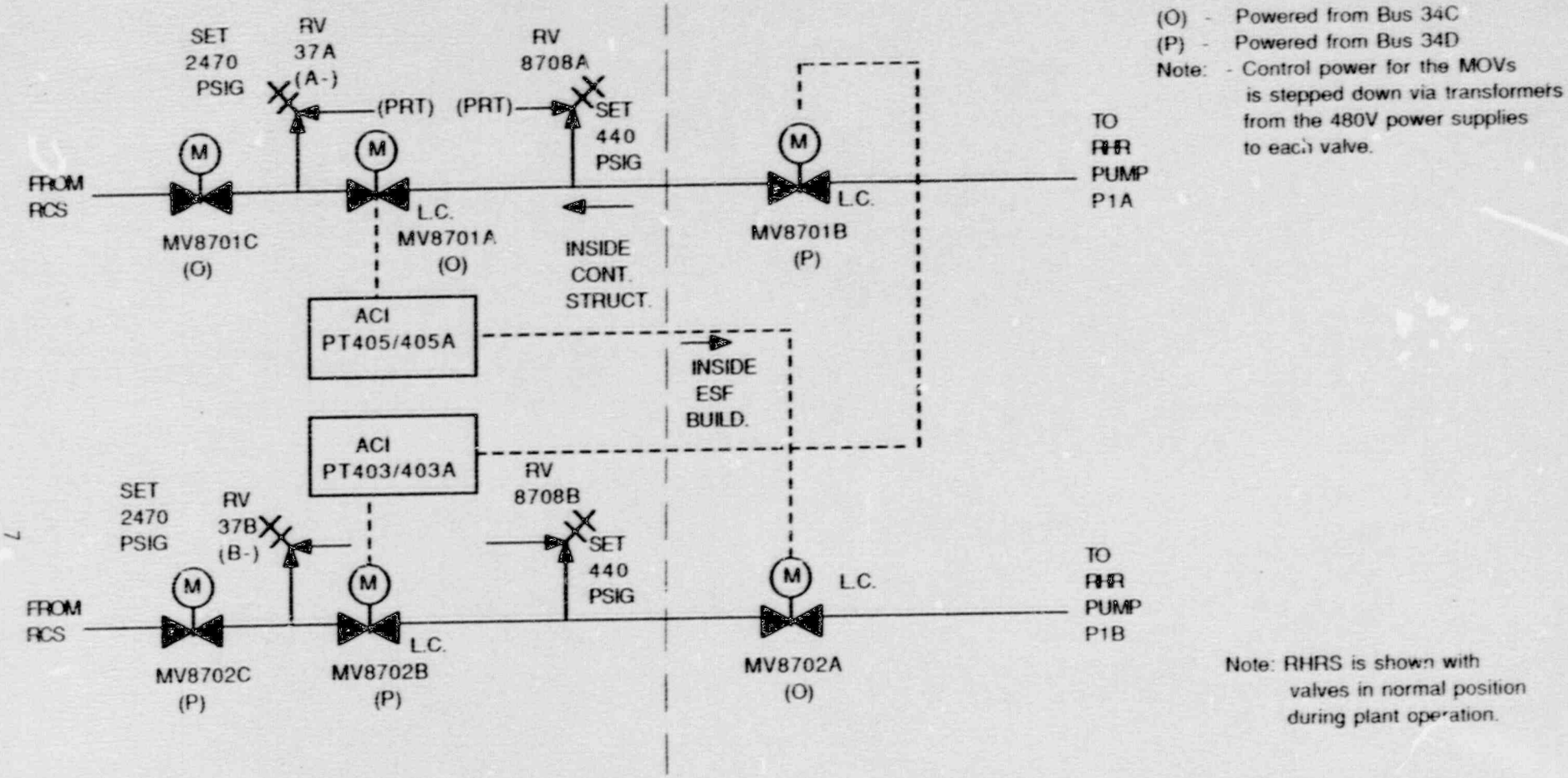


FIGURE 1: SIMPLIFED P&ID OF RHR SUCTION ISOLATION VALVES

4.1.1 Base Case Analysis

In order to model the dependency of failure modes among RHR suction valves that may lead to interfacing system LOCAs and consider all potential Event V scenarios, two event trees were constructed. Figures 2 and 3 are the event trees for the two cases "with ACI" and "without ACI." It is important to note that MOV8701B is not included in the event tree. Credit was not taken for MOV8701B (and MOV8702A) for Event V analysis. These two valves are 12" 600# class RHR valves. The two valves installed at MP3 have a maximum allowable working pressure as per ANSI standard of 1235 psig and a ceiling pressure of 1795 for the RCS operating temperature.[1] Therefore, these valves were assumed to fail as soon as they get exposed to the high RCS pressure. However, given the design margins provided in the ANSI standard, this valve will have a moderate likelihood of surviving a one-time, short duration application of RCS pressure.

The failure mode in which both MV8701C and 8701A are left open during startup is not considered due to a) leak rate testing requirements of these valves, and b) lifting of relief valves that will be noticed in the control room. At MP3, when the relief valves lift, the RCS coolant discharges to the pressurizer relief tank (PRT) which alarms.

The probabilities of some failure modes change when the RHR ACI feature is deleted. Therefore, the frequency of an interfacing systems LOCA event through the RHR suction path changes. Table 1 summarizes failure probabilities of different failure modes of the two valves MV8701C and MV8701A, with and without the RHR ACI feature. The fault trees and the

Table 1: Probabilities of Failure of Components with and without ACI

COMPONENT AND FAILURE MODE	FAILURE PROBABILITY WITH ACI	FAILURE PROBABILITY WITHOUT ACI
MOV8701C		
Rupture	8.76E-04	8.76E-04
Left Open During Startup	3.25E-03	3.25E-03
Spuriously Opens	3.84E-10	3.84E-10
MOV8701A		
Rupture (Given 8701C Left Open)	8.76E-04	8.76E-04
Rupture (Given 8701C Ruptures)	6.57E-04	6.57E-04
Left Open During Startup	9.83E-05	2.02E-06
Spurious Opering	2.40E-07	2.40E-07

other supporting calculations used to compute the failure probabilities are found in Reference 1.

These probabilities were calculated using fault trees which are based on the elementary diagrams of RHR system inlet isolation valves 3RHS*MV8701A and 3RHS*MV8701C.[8,9] Component failure rate data used in the fault tree analysis were derived primarily from two documents (NUREG/CR-2815 Rev. 1 and IEEE-500) and appear in Table 7-1 of WCAP-11736-A. The basic event probabilities used for the fault trees were derived from Table B-5 of WCAP-11736-A. The following boundary conditions and assumptions were applied in the fault tree construction and analysis. Some of these assumptions were derived from WCAP-11736-A and are applicable to MP3 for comparing merits/demerits of RHR ACI removal.

- Plant is in mode 1, 2, or 3.

- Valve MV8701A will be exposed to RCS pressure if and only if MV8701C is open or ruptures.

- Valve MV8701B ruptures if exposed to the RCS pressure.

- No common cause rupture of valves is considered.

- The failure rate is the same for MV8701A and MV8701C valves given that the valve is exposed to RCS pressure.

- All electric power to the control circuitry is assumed to be available.

- A refueling outage occurs every 18 months.

- The rupture rate for valves is 1 X 10^{-7}/hr.

- The term "valve rupture" is defined as catastrophic internal leakage. Leakage past the valve does not lead to failure since the time frame of events allow appropriate remedial action.

At MP3, per plant operating procedure OP3310A[3], the MCC breakers that supply power to valves 3RHS*8701C and 8702C are open (i.e., MOV de-energized) when the RHRS is aligned during plant heat up. Therefore, spurious opening of MOV8701C during modes 1, 2, or 3 can occur if and only if the operator omits to perform this step. Therefore,

Prob (MOV8701C Spurious Opens) = 2.40 X 10^{-7} X 1.6 X 10^{-3}
= 3.84 X 10^{-10}

Here, 1.6 X 10^{-3} is the probability of operator failure to de-energize power to MOV8701C with the valve in the closed position. This probability is derived from WCAP-11736-A. The probability 2.40 X 10^{-7} is the probability of spurious opening of MOV8701A (or MOV8701C) given that power was available at the circuit breaker and is derived by solving a fault tree.[1]

The probability of operator failing to close valve 8701A during startup changes from 9.83E-05 (with ACI) to 2.02E-06 (without ACI). The key factor that lowers the probability when ACI is removed is the relatively low probability of failure to detect an open MOV using an alarm annunciation (P (failure to detect via annunciator) = 2.66E-04) compared to failure to

detect an open MOV via mainboard light (P (failure to detect via MB light) = 0.98). These human error probabilities were derived from WCAP 11736-A. Reference 3 was reviewed to examine the applicability of these failure probabilities to MP3. The sensitivity of the probability 0.98 (human error) on the results was examined. When this probability is lowered, the difference between Prob (valve left open) between the "with ACI" and the "without ACI" cases is reduced. Therefore, lower values for this human error probability results in a reduction of the impact of ACI deletion on the V sequence frequency.

A fault tree (Figure C-3, Reference 1) was used to quantify the probability of leaving valve MV8701C in the open position during startup as 3.25E-03. This probability is higher than the corresponding value for MV8701A since ACI feature is not associated with the valve MV8701C and since the new alarms will not be installed on it. This probability is unaffected by the proposed change.

WCAP-11736-A uses a valve rupture rate of 1 X 10^{-7} per hour. Although the industry experience indicates a lower rupture rate (between 10^{-7} and 10^{-8}), this conservative rupture rate (10^{-7} per hour) was used to calculate valve rupture probabilities.

For valve MV8701C and for valve MV8701A when MV8701C is left open during startup, the probability of a rupture in a year (8760 hours), based upon a rupture rate of 1 X 10^{-7} per hour, is 8.76 X 10^{-4} (10^{-7} X 8760).

For valve MV8701A, if MV8701C ruptures, the probability of a rupture is the product of the rupture rate and the average exposure time. Based upon an

average exposure time of half of a refuel cycle (nine months), the probability of rupture of MV8701A, given that MV8701C fails due to rupture, is 6.57 X 10^{-4} (10^{-7} X 8760 X 0.75).

Figures 2 and 3, event trees for the case "with ACI" and "without ACI," illustrate the V-sequences through the RHR suction paths and the frequency of each path.

By summation of the sequences, the following frequencies result:

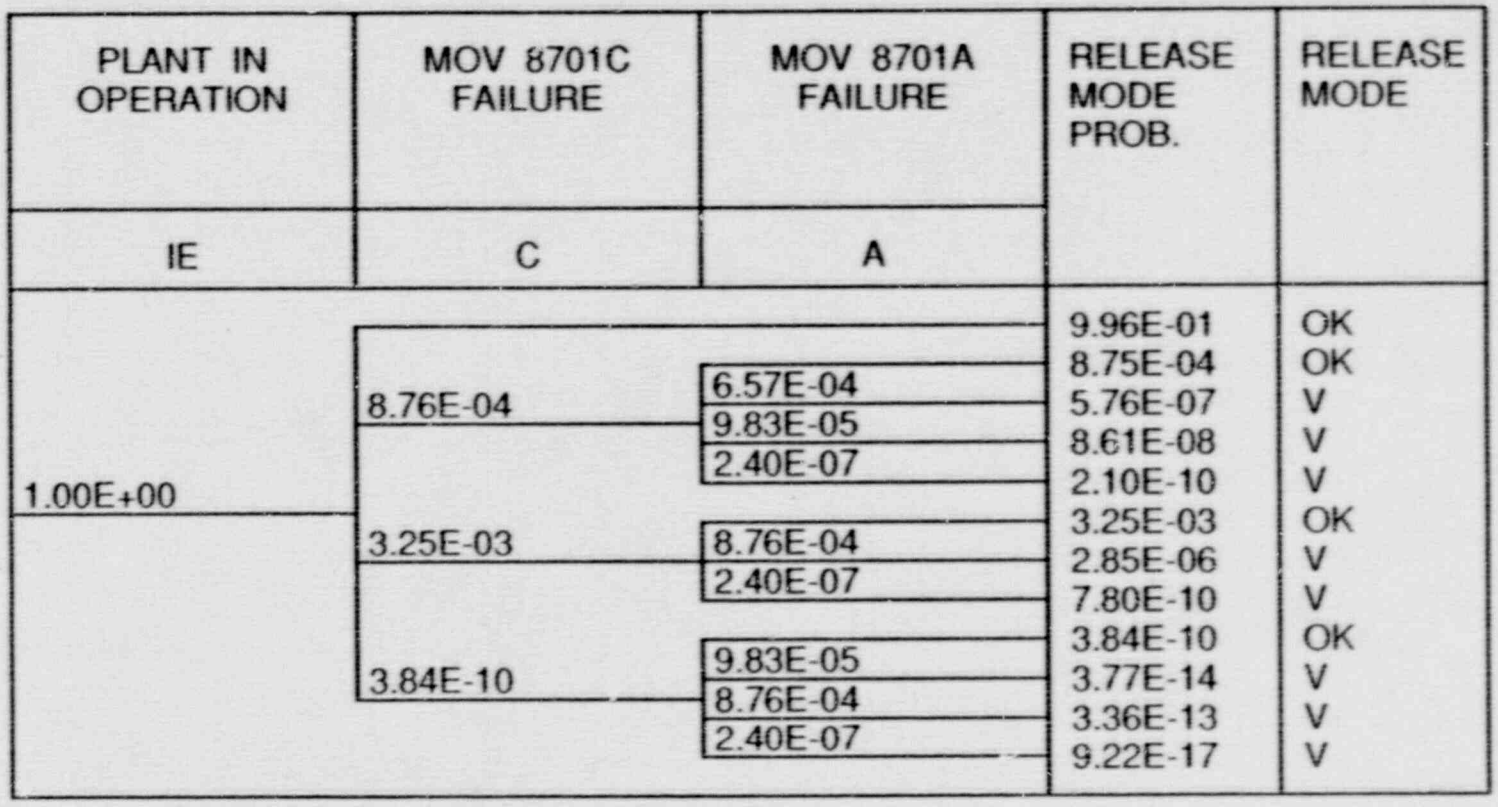
Event V frequency (with ACI) = 3.51 X 10^{-6} per year/RHR A Train
Event V frequency (without ACI) = 3.43 X 10^{-6} per year/RHR A Train

Since two RHR suction paths exist, these frequencies become 7.02 X 10^{-6} and 6.86 X 10^{-6} per year for the with ACI and the without ACI cases, respectively.

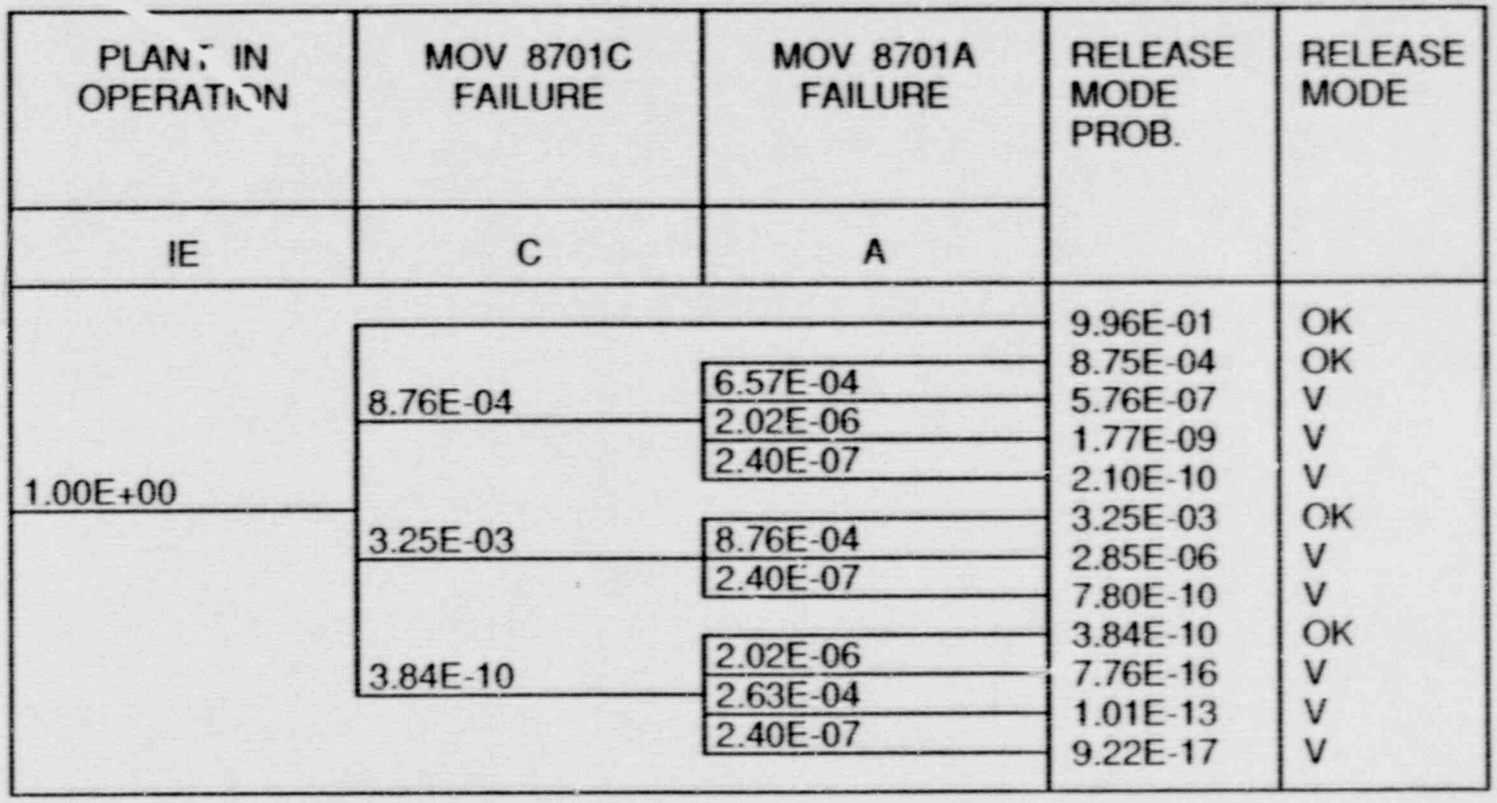
Therefore, removal of the ACI and installation of the alarms lower the Event V frequency by approximately 2.3%.

4.1.2 Comparison with Callaway

Table 2 summarizes the Event V frequency results for Callaway as reported in WCAP-11736-A and Millstone Unit 3. The results indicate a significant reduction (24%) in Event V frequency for Callaway as compared to a small reduction (2.3%) for Millstone Unit 3. This difference is accounted for as follows:



EVENT V SCENARIOS: RHR SUCTION PATH: WITH ACI FIGURE 2



EVENT V SCENARIOS: RHR SUCTION PATH: WITHOUT ACI FIGURE 3

Table 2: Event V Frequency Through RHR Suction Paths

	Callaway*	Millstone Point 3
With ACI	1.52E-06/year	7.02E-06/year
Without ACI	1.16E-06/year	6.86E-06/year
Percent Change	-24%	-2.3%

*Source: Reference 7

- As illustrated in Figure 4 which compares the RHR nuclear path designs between Callaway and Millstone 3, MP3 has three isolation valves per RHR train A compared to only two for Callaway. However, since MV8701B (and 8702A) are assumed to withstand only 1800 psi, it was not credited in the Event V analysis. Therefore, out of the two valves MV8701A and MV8701B in which the ACI feature is replaced by an alarm, only one is credited in the MP3 analysis.

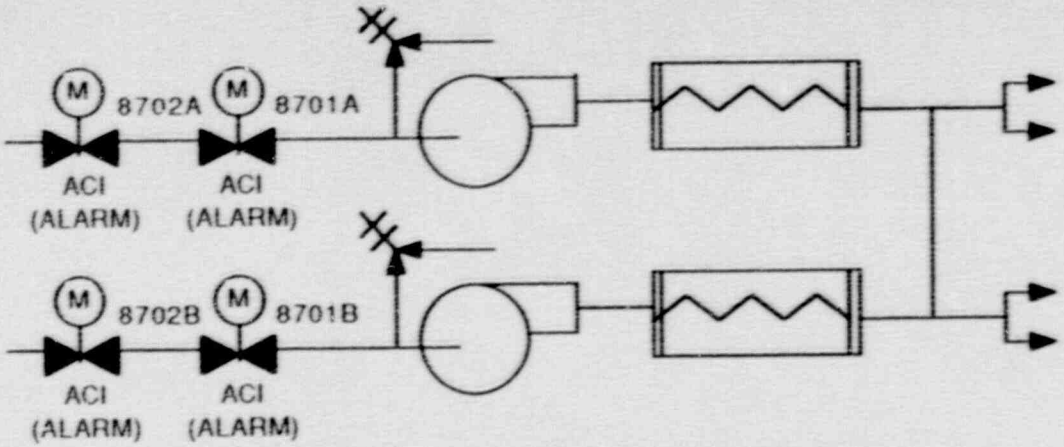
- Probability of leaving MV8701C open is 3.25×10^{-3} since this valve has no ACI interlock (before the modification) or alarm (after the modification). For Callaway, the corresponding probability is 1.04×10^{-4}. This accounts for the higher Event V frequency for MP3 compared to Callaway in spite of having three suction valves in series.

4.1.3 Sensitivity Analysis

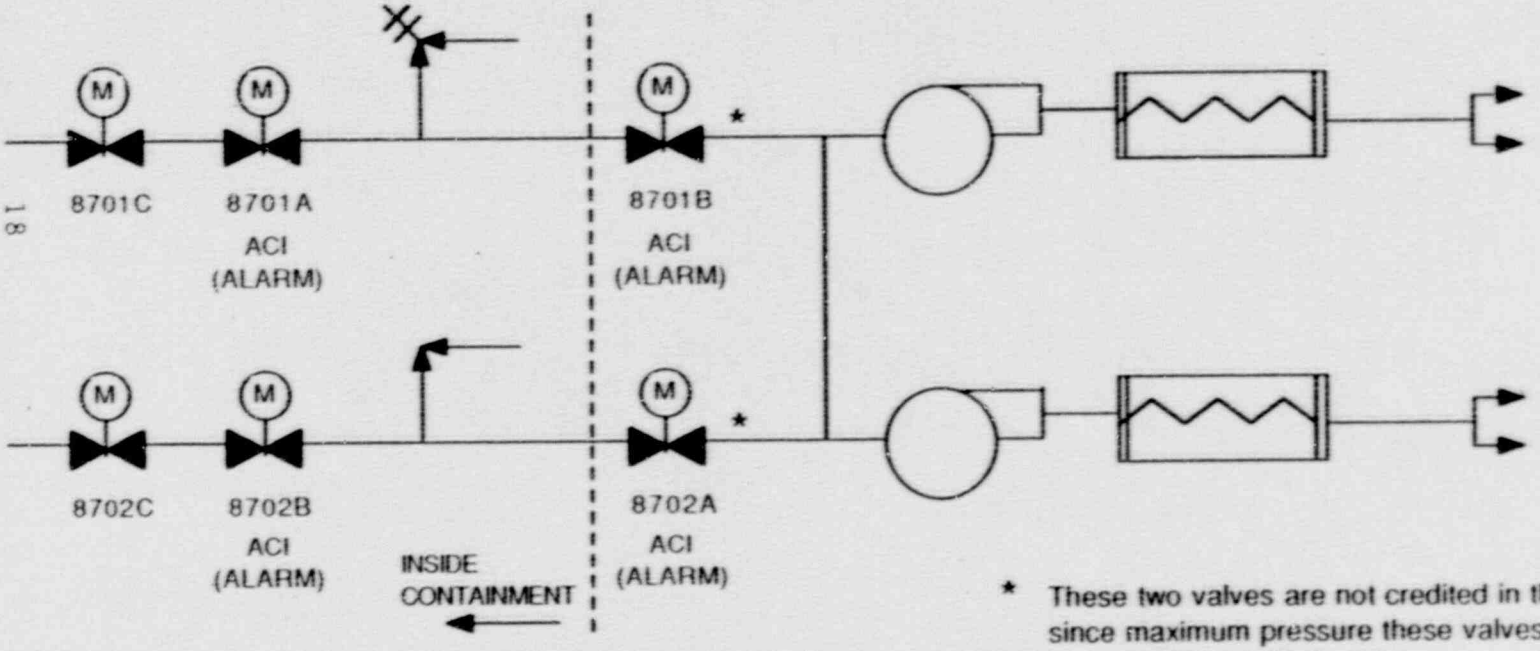
The Event V frequency via the RHR suction path of MP3 at present is estimated at 7.02E-06. While the above Event V frequency calculations are adequate to compare the impact of ACI removal and alarm installation, they are considered overly conservative due to the following:

- MOVs 8701B and 8702A in the RHR suction paths are not credited.

- Rupture rate of 10^{-7} is high and is inconsistent with industry experience.



WCAP-11736 GROUP 2 PLANTS (CALLAWAY) RHR DESIGN



MILLSTONE UNIT 3 RHR DESIGN

* These two valves are not credited in the MP3 event V analysis since maximum pressure these valves can withstand is assumed to be 1800 psi (Ref. 13).

FIGURE 4. COMPARISON OF RHR DESIGN BETWEEN GROUP 2 (WCAP-11736) PLANTS AND MILLSTONE UNIT 3.

Although MV8701B has an assumed maximum allowable pressure of 1800 psi, when exposed to 2200 psi RCS pressure, it most probably will not undergo catastrophic failure. If the P (MV8701B rupture when exposed to RCS pressure) is assumed to be 0.1, and a rupture rate of 3 X 10^{8}/hour is assumed, then the Event V frequency reduces to 1.86 X 10^{-7} per year for the "with ACI" case and to 1.81 X 10^{-7} for the "without ACI" case. These values are better approximations of the Event V frequency through RHR suction paths at MP3.

Discussions with operators at MP3 on the leak testing procedure of the RHR suction isolation valves, emphasizes why the relatively high Event V frequencies computed in this analysis may not be indicative of actual Event V frequency at MP3, although they may be adequate for comparing merits/demerits of RHR ACI removal.

The analysis in this report, following WCAP-11736-A uses:

P(Valve Left Open) = 9.83E-5 (for 8701A)

P(Valve Left Open) = 3.25E-3 (for 8701C)

However, the valve leak test procedures and the operator awareness indicate that these unavailabilities may be lower. If these probabilities are lowered, then Event V frequency reduces further.

4.2 RHR Unavailability Analysis

The availability of the RHRS for shutdown cooling is an issue of significant concern in the nuclear industry. Many events have occurred in which

the RHR function has been lost. Spurious actuation of the ACI while the reactor is shutdown has caused a large fraction of the loss of RHR events.

This section determines the impact of removing the ACI feature on the unavailability of RHR. To achieve this objective, RHR unavailability is calculated with and without the ACI feature.

4.2.1 RHR Initiation

The actions taken to initiate RHR are not affected by the removal of the ACI feature or installation of an alarm on 3RHS*8701A and 3RHS*8701B. Therefore, it was determined that failure probability does not change due to the proposed ACI circuitry removal and installation of an alarm.

4.2.2 RHR Short-Term Cooling Unavailability

Fault trees were constructed to quantify RHR short-term cooling unavailability with and without the ACI feature. Appendix D to Reference 1 contains these fault trees. The following boundary conditions and the assumptions used in the WCAP-11736-A analysis were reviewed for their applicability to MP3:

- Two trains of RHR are required for 72 hours following initiation of the RHRS.

- Injection into two cold legs is required for the initial RHR cooldown phase.

- No testing or maintenance operations are assumed to occur during the initial RHR cooldown phase.

- During the RHR initiation, both RHR pumps are started successfully.

- All electric power is assumed to be available.

- No common cause failure of components is considered.

These boundary conditions assumptions were found to be applicable for determining of merits/demerits of RHR ACI removal on RHR short-term unavailability.

The fault trees for MP3 were constructed using the fault trees already developed for Callaway in WCAP-11736-A. The following major differences between Callaway and MP3 were identified:

- MP3 has three suction isolation valves per suction path compared to only two in Callaway.

- MP3 has an additional check valve 8847A/B/C/D in each injection path.

The piping and instrumentation diagrams (P&IDs) and the elementary electrical diagrams which served as the basis for the fault trees are listed in Reference 1. The basic event probabilities were derived from Table C-10 of WCAP-11736-A. The cut-sets obtained by solving the fault trees are also given in Appendix D of Reference 1.

The short-term RHR unavailability (first 72 hours after the RHR cooling begins) for MP3 are listed and compared with the corresponding unavailabilities of Callaway in Table 3. The ACI removal reduces the short-term RHR unavailability at MP3 by approximately 12%, from 1.64 X 10^{-2} to 1.45 X 10^{-2}.

As illustrated by Table 3, the unavailabilities of Callaway and Millstone Point 3 compare well in spite of the additional isolation valve MV8701C (8702C in train B) in MP3. This is due to the RhR unavailability being dominated by the "RHR pumps failing to run" and "spurious actuation of ACI signal." These two failure modes are independant of the number of suction valves.

For the case "with ACI," approximately 88% of the total unavailability is attributed to RHR pumps failing to run for 72 hours. Approximately 12% of the total unavailability is attributed to the spurious ACI signal that isolates the RHR trains. This 12% is eliminated when the RHR ACI is deleted. For the case "without ACI," approximately 99% of the RHR unavailability is attributed to RHR pump failures.

4.2.3 RHR Long-Term Cooling Unavailability

RHR is required to cool the RCS throughout the shutdown. However, decay heat load continues to decrease during shutdown. MP3 plant operating procedure OP3208 notes the following:

"As the reactor coolant system heat load is reduced, adequate cooling may be obtained using only one RHR train. If desired and when possible, the

Table 3: RHR Short-Term Unavailability

	Callaway*	Millstone Point 3
With ACI	1.64E-02	1.64E-02
Without ACI	1.44E-02	1.45E-02
Percent Change	-12	-12

*Source: Reference 7

RHR system should be shifted from two train operation to one train operation in accordance with the plant operating procedure OP3310A."

Based on the above, the success criteria for RHR cooling in the long-term is the successful operation of a single RHR train. The mission time of six weeks (1008 hours) used in the WCAP-11736-A is applicable to MP3. Therefore, basic event data provided in Table C-10 of WCAP-11736-A was determined to be applicable to MP3. This basic event data was used to quantify the fault trees.

The assumptions and boundary conditions used in the fault tree analysis to determine RHR long-term cooling unavailability are as follows:

- One train of RHR is required for six weeks. Six weeks is representative of the time of a refueling outage.

- Injection into two cold legs is required for long-term RHR.

- Train A pump is operating, and the train B pump is in standby. No switching of trains is assumed.

- Human error contribution to RHR unavailability is not considered since the effect is independent of the ACI feature.

These assumptions are in addition to the six boundary conditions listed under RHR short-term cooling. When the applicability of the above assumptions to MP3 were investigated, it was found that the RHR trains are typically switched during shutdown to accommodate refuel work activities.

Since the probability of losing RHR due to RHR train switching is independent of the ACI feature, this assumption does not affect the comparison of results between the two cases.

The fault trees for Callaway for long-term RHR unavailability were examined to determine their applicability to MP3. Some changes to the Callaway trees were made to account for the following differences between the MP3 and Callaway RHR designs:

- MP3 has three isolation valves (MOVs) per suction path.

- MP3 has an additional check valve (8847A, B, C, and D) in each injection path to the cold legs.

The MP3 fault trees and the cut-sets for RHR long-term cooling for the cases "with ACI" and "without ACI" are included in the Appendix D of the analysis file.[1]

The long-term RHR unavailability for MP3 is listed and compared with the corresponding unavailabilities of Callaway in Table 4. The ACI removal reduces the long-term RHR unavailability at MP3 by approximately 70%, from 3.94×10^{-2} to 1.19×10^{-2}. As illustrated by Table 4, the unavailabilities of Callaway and MP3 compare well in spite of the additional isolation valves 3RHS*8701C and 3RHS*8702C at MP3. This is attributed to the RHR unavailability being dominated by spurious ACI signal (for the case of "with ACI" only) and the RHR pump failures.

Table 4: RHR Long-Term Unavailability

	Callaway*	Millstone Point 3
With ACI	3.91E-02	3.94E-02
Without ACI	1.17E-02	1.19E-02
Percent Change	-70	-70

*Source: Reference 7

4.3 Overpressure Transient Analysis

Equipment malfunctions, procedural deficiencies, and incorrect operator actions during startup or shutdown conditions can lead to pressure transients in the RCS while the RHRS is in operation. These pressure transients are of concern because the RHRS may be subjected to pressures exceeding its design pressure.

This section identifies events that would initiate overpressure transients and analyze the effect of ACI removal on those transients.

4.3.1 Initiating Events

Reference 7, having surveyed past reports that characterizes different types of transients possible at cold shutdown, lists the following overpressure transients:

- Premature opening of the RHRS.
- Rod withdrawal.
- Failure to isolate RHRS during startup.
- Pressurizer heaters actuation.
- Startup of inactive loop (startup of an RCP).
- Loss of RHRS cooling train.

- Opening of accumulator discharge isolation valves.

- Letdown isolation.

  - RHRS operable.

  - RHRS isolated.

- Charging/safety injection pump actuation.

In addition to the above generic events, the potential for plant specific overpressure transients was examined by screening the plant incident reports (PIRs) at MP3. This screen did not reveal any potential initiators outside of those listed above. The single significant observation made as a result of screening the PIRs is that MP3 has had several inadvertent safety injection actuation events during its relatively short operating history.

The RCS pressure can go up due to a) events that affect the heat input/heat removal balance (heat input transients), and b) events that affect the mass balance (mass input transients). The following sections address these two types of transients and the change in response to these transients due to ACI removal.

4.3.2 Heat Input Transients

4.3.2.1 Premature Opening of the RHRS

This type of event was not considered plausible and was not analyzed in detail, due to the following:

- The "prevent-open" interlock of the RHRS prevents the opening of the interlock valves MV8701A/B and MV8702A/B, unless the RCS hot leg pressure is less than 375 psig.[2]

- This type of event has not occurred to date.

4.3.2.2 Rod Withdrawal

The Westinghouse analysis[7] determined that the rod withdrawal accident produced one of the least severe transients of those analyzed and would not overpressurize the RHRS. It has been determined that pressure would not exceed 110% of the RHRS design pressure. Based upon 600 psi, RHRS design pressure, 660 psig is not exceeded. This is well below the ACI set point of 765 psig. Further, RHRS relief valves would also be available to mitigate this transient. Therefore, removal of ACI has negligible, if any, impact on this transient.

4.3.2.3 Failure to Isolate RHRS During Startup

Failure to close all three MOVs during startup is not considered as a credible transient since this condition would become apparent when the RHR

relief valves lift and discharge to the pressurizer relief tank (PRT). The unusually low pressure increase rate and the PRT alarms will warn operators that the RHR isolation valves are open.

If one or two of the three suction valves are left open, the RCS pressure may rise without exposing the RHRS to the high pressure and the relief valves may not lift. A loss-of-coolant accident can occur if the closed valve opens or ruptures. Removal of the ACI has an impact on the frequency of this interfacing system's LOCA scenario. This impact was assessed in Section 4.1 under Event V analysis.

4.3.2.4 Pressurizer Heaters Actuation

At MP3, according to the plant operating procedure OP3208, group A, B, D, and E pressurizer backup heaters are de-energized prior to aligning RHRS. If the operator decides to cool down with a bubble in the pressurizer to 140°F, the desired heaters are manually energized. Further, according to OP3201[10], during plant heat up (transition from Mode 5 cold shutdown to No-Load operating conditions), the heaters are energized prior to isolating RHRS. Therefore, a likelihood exists for overpressure transients due to pressurizer heater actuation, while the RHRS is lined up with the RCS. Removal of the ACI will remove one mitigating feature of this type of transients. In spite of the above, after discussions with MP3 operators, it was decided that this initiator does not warrant detailed analysis, due to the following:

- Since this transient is very slow, the operator should recognize and terminate the transient.

- RHRS relief valve limits the pressure increase.

- To date, Westinghouse plants have not experienced this type of transient.

4.3.2.5 Startup of an Inactive Loop

When the reactor coolant pumps (RCPs) have been stopped, the steam generator water may remain at a relatively constant temperature greater than the RCS temperature. At MP3, the operators are instructed to have at least one RCP running when the RCS temperature is above 160°F. Therefore, the non-uniform temperature condition will prevail only when the RCS temperature is below 160°F.

When there is a temperature difference between SG and RCS, if an RCS pump is inadvertently started, the sudden heat input will result in a rapid increase in RCS temperature. Westinghouse analysis estimates that the pressure change is approximately 1500 psi and occurs in roughly 90 seconds with no relief valve actuation.

The following reasons explain why ACI removal has a negligible impact upon the frequency or the response to this transient:

- The plant operating procedure OP3208 instructs the operator to stop all reactor coolant pumps and rack down and tag out all the RCP power supply breakers, when the pressurizer temperature in 160-170°F and the RCS temperature is 130-140°F. Therefore, the likelihood of an inadvertent actuation of an RCP is extremely low.

- In the event of an inadvertent actuation of an RCP, the rate of pressure rise is relatively rapid (1500 psi in 90 seconds) compared to the timeframe associated with closing of MOVs. Therefore, it is very likely that the RHRS will see the increased pressure for long enough in spite of the ACI feature. Hence, removal of the ACI has less of an impact.

- Two mitigating features: a) the RHR relief valves, and b) the cold overpressure protection system (COPPS) will reduce the impact of this accident on the RHRS. Note that, according to OP3208, COPPS is placed in service when the RCS temperature has been lowered to 425°F, before the RHRS is aligned to RCS.

4.3.2.6 Loss of RHRS Cooling Train

The continuous addition of decay heat into the reactor coolant with no heat removal by the RHRS cooling will result in a gradual rise in the RCS temperature and the RCS pressure. This overpressure transient does not warrant detailed analysis, due to the following:

- The rate of pressure increase due to continuous addition of decay heat is relatively slow compared to the timeframe in which mitigating actions and RHR isolation actions can be taken, with or without the ACI feature. With the ACI feature, if the pressure reaches the set point 765 psia, the suction isolation MOVs will isolate the RHR within approximately two minutes. Without the ACI, however, with the new alarms to be added, the operators will be warned of the

increasing pressure while the RHRs are lined up with RCS when the pressure reaches 440 psig (the set point of the new alarm). This pressure is low compared to the ACI set point 765 psi. Therefore, the operators have more time available to them to close the suction isolation MOVs than in the case with ACI.

- The operators can limit the RCS pressure by venting the pressurizer.

4.3.3 Mass Input Transients

4.3.3.1 Opening of Accumulator Discharge Valves

According to plant heatup and cooldown procedure[2,10] at MP3, the following actions are implemented. During plant cooldown, when the RCS pressure is lowered to 1015 psia, safety injection accumulator tanks are isolated by closing the valves: 3 SIL * MV8808A, MV8808B, MV8808C, and MV8808D. After these valves are closed, the valve power supply breakers are locked open. During the plant heatup, the above supply breakers are energized, valves MV8808A/B/C/D are opened, and power supplies are locked out, before RCS pressure reaches 1000 psia. However, the above is performed after isolating RHRS. Therefore, MV8808A/B/C/D, the safety injection accumulator tank outlet isolation valves, are kept closed with power off of the supply breaker during the whole duration when RHRS is aligned to RCS.

Following the above sequence of events, the likelihood of SI accumulator discharge to RCS while RHRS is aligned is considered a low probability event.

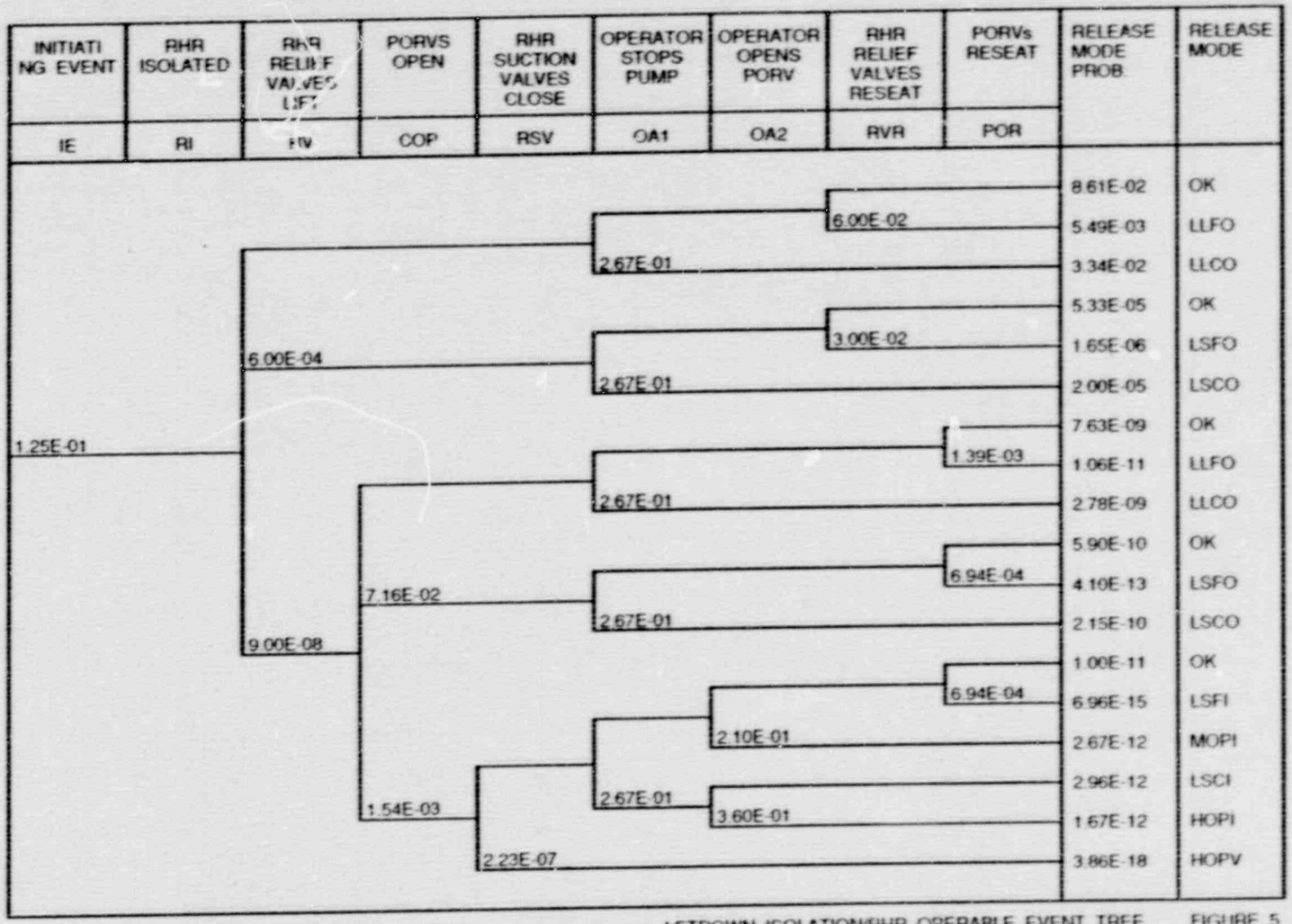
In the event the above transient occurs, the pressure rise in RCS is limited by the pressure of accumulators. At MP3, the accumulators are maintained at 650 psig under normal operation. Further, overpressure protection is provided to the accumulator by relief valves whose set pressure is 700 psig. Therefore, in the event the accumulator discharges to the RCS, the maximum pressure achieved will be less than 650 psig. Since the set point of ACI is 765 psia, the ACIs will not actuate during the above transient. That is, removal of ACI will have no impact on this transient.

4.3.3.2 Letdown Isolation; RHRS Operable

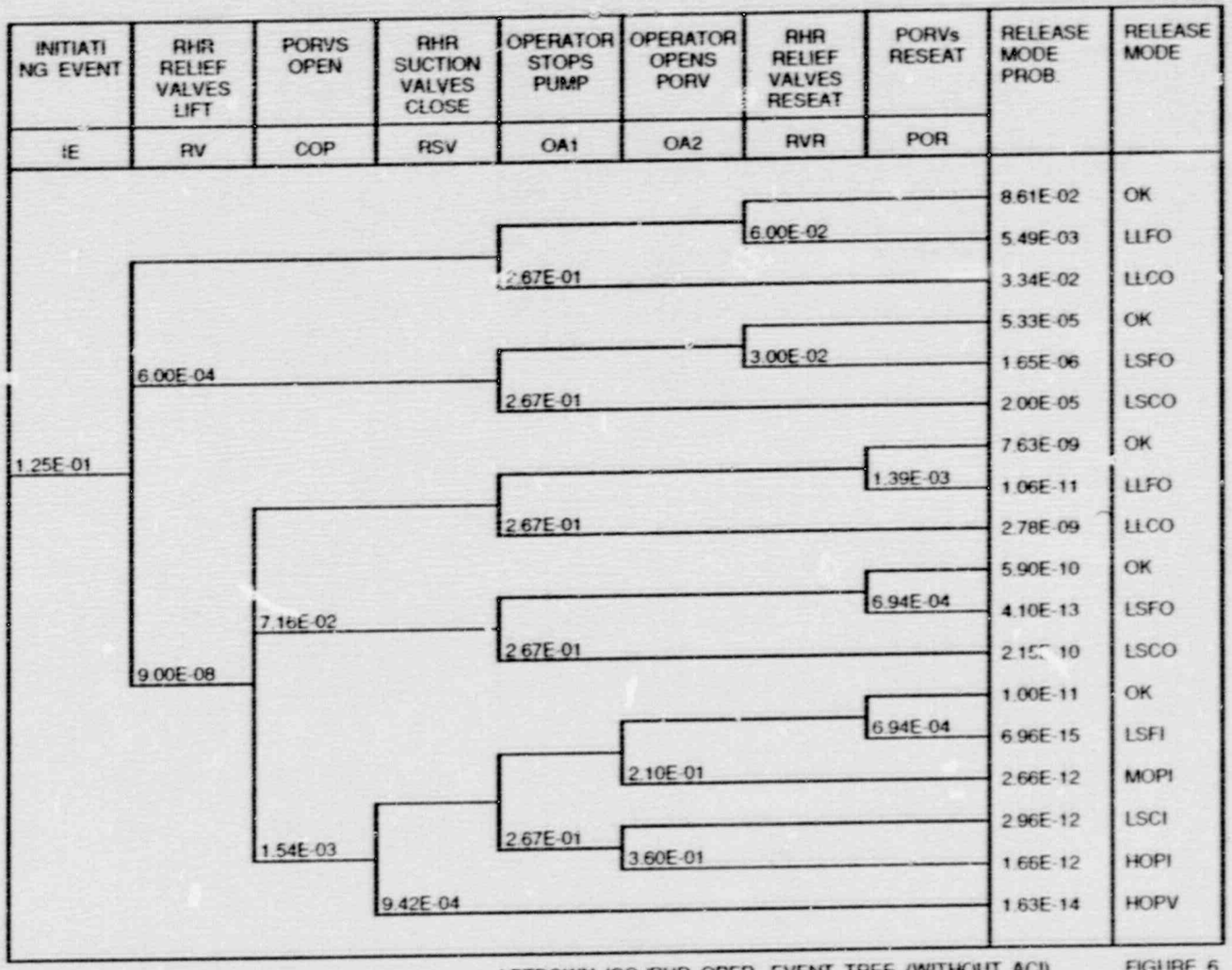
At MP3, plant cooldown procedure (OP3208) instructs the operator to establish a letdown path using RHRS by opening 3CHS-HC128 letdown flow control valve. If a failure occurs in the letdown path, a mass input transient can result with the RHRS operable. The following mitigating features may be challenged during this transient:

- RHRS relief valves.
- COPPS (PORVs and the Logic Circuits).
- ACI (or Manual isolation of RHRS).

Figures 5 and 6 show the event tree used to analyze this transient for the two cases with and without ACI.



LETDOWN ISOLATION/RHR OPERABLE EVENT TREE FIGURE 5



LETDOWN ISO./RHR OPER. EVENT TREE (WITHOUT ACI) FIGURE 6

Initiating Event

Based upon operating experience, the frequency of the initiating event is estimated at 1.25E-01.[7]

Event RV

The relief valve set point of the RHRS is 440 psig. The actual capacity of the two valves is 1060.9 gpm/valve. The maximum flowrate of a charging pump at MP3 is 560 gpm.[11] Therefore, if one of two RHR RVs open, the pressure rise due to letdown isolation can be arrested. Using the failure probability of 3.00E-4 for failure of an RV to open upon demand, the nodal probabilities are:

P (1/2 RHR relief valves fails to open) = 3.00E-4 + 3.00E-4

= 6.00E-4

P (2/2 RHR relief valves fail to open) = $(3.00E-4)^2$

= 9.00E-8

In the event both RVs fail to lift, the pressure surge will continue until the COPP system is challenged.

Event COP

COPPS (cold overpressure protection system) at MP3 consist of two pressurizer power operated relief valves (PORVs), and actuation logic to

continuously monitor RCS temperature and pressure conditions when armed by the operator.

According to OP3208, the operator should arm COPPS when the RCS pressure has been lowered to 425°F. That is, COPPS is armed prior to aligning the RHRS with RCS.

The probabilities of failure to open one or both PORVs were calculated using fault trees. These fault trees are included in Reference 1.

Event RSV

If one or both of the RHRS RVs open, the relief capacity is more than adequate to relieve mass input from the charging pump. However, if both PORVs fail to open, then the pressure will rise until the ACI is actuated and the RHRS is isolated. This occurs when the pressure reaches the ACI set point 765 psia.

At [redacted] MOVs 3RHS*8701A/B and 3RHS*8702A/B have the ACI feature. If the RCS pressure exceeds 765 psia, the ACI feature will automatically initiate the closing of these valves.

The probability of failure to close RHR suction valves with ACI is 2.23×10^{-7}. This number was derived from WCAP-11736-A after ensuring that the fault tree constructed for Callaway (Figure D-12, Reference 7) is applicable to MP3. The minor differences that exist between the Callaway and MP3 circuitry does not affect the above probability.

When the ACI feature is removed and replaced by an overpressure alarm, the nodal probabilities at event RSV will be different. Failure to close at least one MOV on each RHR train with the overpressure alarm is modeled using a fault tree in Figure D-13 of WCAP-11736-A. The failure probability at node RSV is dominated by the probability of operator error and is determined to be:

- 1.11E-05 (if a previously demanded mitigating system is successful)

- 9.42E-04 (if none of the previously demanded mitigating systems are successful)

The basis for these probabilities were examined, and it was determined that these probabilities are applicable to the MP3 analysis.

Events OA1, OA2, RVR

The basis for the nodal probabilities of these events were investigated. It was determined that the nodal probabilities used in the Westinghouse analysis for Callaway are applicable to MP3, as well.

Event POR

The probability of PORVs to re-seat were determined by quantifying a fault tree (Figure 11, Reference 1). These probabilities are:

P (1/1 PORV fail to re-seat) = 6.94E-4

P (1/2 PORV fails to re-seat) = 1.39E-3

Figures 5 and 6 show the event tree for the Letdown Isolation RHRS operable transient with and without ACI feature, respectively. Table 5 summarizes the frequency of consequence categories. These consequence categories are as defined in Table D-5 of WCAP-11736-A.

The only consequence category that is affected significantly is HOPV. The frequency of this category increases from 3.86E-18 to 1.63E-14. Although this is an increase by a factor of approximately 4200, the significance of the impact is considered trivial due to the absolute magnitude of frequencies.

It is concluded that ACI removal has no significant impact on the Letdown Isolation/RHR operable transients based on the low probability of failing to open both RHR RVs (9.00E-8) and the COPP system (1.54E-3).

Letdown Isolation - RHR Isolated

During a transient in which letdown and RHR isolates, the RHR ACIs are not available as a mitigating feature. Therefore, removal of the RHR ACI has no impact on the response to this transient. However, the frequency of the transient is significantly affected by the deletion of the ACI feature.

Table 5: Frequencies of Consequence Categories for Letdown Isolation - RHR Operable Event

Consequence Category [1]	With ACI	Without ACI
OK	8.62E-02	8.62E-02
LLFO	5.49E-03	5.49E-03
LLCO	3.34E-02	3.34E-02
LSFO	1.65E-06	1.65E-06
LSCO	2.00E-05	2.00E-05
LSFI	6.96E-15	6.96E-15
MOPI	2.67E-12	2.66E-12
LSCI	2.96E-12	2.96E-12
HOPI	1.67E-12	1.66E-12
HOPV[2]	3.86E-18	1.63E-14

(1) See Table D-5 of WCAP-11736-A for explanation of categories.

(2) Only category that changes frequency to any measure. The consequence category is an interfacing systems LOCA without opening of any relief valves.

Table D-2 of WCAP-11736 lists 50 loss of RHR events due to spurious closure of isolation MOVs at Westinghouse plants. Based on total shutdown years of 112.4, the frequency of this transient is 0.445 per shutdown year.

Based upon past experience, it can be conservatively assumed that 50% of these overpressure transients would be avoided by removing the ACI feature. Elimination of inadvertent isolation of RHRs is the major motivation to remove the ACI. Naturally, 50% reduction in the initiator frequency with no other changes to nodal probabilities brings down the frequency of each consequence category by 50%.

4.3.3.3 Inadvertent SI Actuations

This overpressure transient was analyzed in detail since MP3 has had ten inadvertent SI events during its relatively short operating history. The detailed analysis included:

- Examination of the ten SI events. Only three out of ten were found to have occurred during mode 5 and one event in mode 4. Therefore, six of the events were irrelevant to the RHR ACI removal study.

- Discussions with operators on the past SI events and on the general response of plant at mode 5 to inadvertent SI events.

- Examination of pump flow rates and the capacities of the relief valves and the PORVs.

- Examination of racking down and racking in procedures of the HPSI and charging pump motor breakers.

4.3.3.3.1 Review of Past Events at MP3

Since the Millstone Unit 3 began operation, ten SI actuation events have occurred. Only four of these events occurred when the plant was in either operating mode 4 or mode 5. In one of these events, no injection to the reactor pressure vessel (RPV) took place. During the other events, the charging pump injected into the core. In all the events the plant was stabilized by resetting the SI signal and stopping the pump prior to progression of the overpressure transient.

4.3.3.3.2 Discussion with Operators

The purpose of the discussion was to a) confirm the operating procedures that require racking down of SI and inoperable Charging Pump breakers, b) obtain insights of the operators, and to c) examine plant specific vulnerabilities. During the discussions, the capability of RVs, PORVs, and the availability of COPPS was discussed. As a response to the numerous inadvertent SI events, a new procedure that requires the operator to install safety tags to close on 3SIH*MV8801A and 8801B so that these valves will stay closed upon an SI signal, has been implemented. Therefore, injection into the RPV through the cold legs from the operable charging pump cannot occur during an inadvertent SI at MP3 (OP3208). Instead, an inadvertent SI signal will cause the operable charging pump to inject into the RWST.

4.3.3.3.3 Review of Operating Procedures

According to the plant cooldown procedure OP3208, the following actions are performed on the SI pump breakers prior to aligning RCS with RHRS.

- Rackdown the A and B SI pump breakers.
- Rackdown the inoperable charging pump breakers.

According to the plant heatup procedure, OP3201, the following actions are performed after aligning the RHR system to safety injection mode.

- Rack in the other charging pump motor breaker.
- Line up the high pressure safety injection for automatic operation.

The sequence of these steps indicate that when the procedures are followed, only one charging pump is powered with the RHRS aligned. Therefore, an inadvertent SI signal can cause only one pump (charging) to inject.

4.3.3.3.4 Relief Valve Capacity

The relief valves 3RHS*RV8708A and 3RHS*RV8708B are located inside the containment structure between the valves MV8701A and MV8701B for RHR train A and between the valves MV8702A and MV8702B for RHR train B. These relief valves lift when the RHR pressure exceeds the set point of 440 psi.[12]

As a part of the PRA analysis and in order to address an NRC concern, the relief valve capacities were examined in detail. Review of technical data sheets and calculation files revealed the actual capacity of each valve is rated at 1060.9 gpm at a back pressure of 3 psi. Since the maximum charging pump flow rates are 560 gpm for single pump operation and 740 gpm for two pump operation, it is concluded that the relief valves at MP3 are adequately sized to mitigate most overpressure transients.

WCAP-11736-A estimates the annual frequency of inadvertent SIs as 1.25E-1 based upon 112.4 shutdown years and 14 occurrences at Westinghouse plants. Based upon MP3 experience, four SI events have occurred in approximately 165 shutdown days, i.e., 165/365 shutdown years. Therefore, MP3 specific inadvertent SI occurrence frequency is 8.85 occurrences per shutdown year, assuming the frequency remains the same in the future.

Any one of the two relief valves is capable of mitigating an inadvertent SI. However, assuming conservatively that only one RHR is aligned to RCS, 1/1 relief valves is needed to mitigate the accident. The failure probability of this event is 3.00E-4 according to WCAP-11736-A.

In the event the RVs fail, the subsequent pressure increase will demand the COPP system to mitigate the transient. MP3 specific COPPS failure probability is 7.16E-02 for one out of 2 PORVs failing and 1.54E-03 for both PORVs failing. These probabilities were calculated using fault trees.[1] Opening of one out of two PORVs is considered as adequate to mitigate an overpressure transient due to an inadvertent SI. Since the water flow capacity through a single PORV exceeds 1000 gpm. Therefore, COPPS is considered failed only if both PORVs fail to open. The probability of this

event is 1.54E-03. This probability was calculated using fault trees constructed for the MP3 PORVs.[1]

Based upon the above discussion, the frequency of an inadvertent SI leading to a demand of the ACI is:

$(8.85) \times (3.00E\text{-}4) \times (1.54E\text{-}3) = 4.09 \times 10^{-6}$

Given the probability of RHR ACI failure as 1.24E-7 (WCAP-11736-A), and the probability of operator error to isolate RHR when the ACI is removed as 9.42E-4 (WCAP-11736-A), the frequency of undesirable consequence category resulting from an inadvertent SI increases from 5.07×10^{-13} ($4.09 \times 10^{-6} \times 1.24 \times 10^{-7}$) to 3.85×10^{-9} ($4.09 \times 10^{-6} \times 9.42 \times 10^{-4}$).

Although the frequency of the consequence category HOPV increases by a factor of approximately 7500, the impact of ACI removal is considered insignificant due to the extremely low absolute frequencies. This frequency will be even lower since a new operating procedure requires the two motor operated valves in the injection path to RCS from the charging pumps to be de-energized in the closed position. If the operator error probability to implement this step of the procedure is assumed to be 1.00E-2, now the frequency of the inadvertent SI initiated sequence drops from 3.85×10^{-9} to 3.85×10^{-11}.

5 SUMMARY AND CONCLUSIONS

5.1 Interfacing Systems LOCA Frequency

As illustrated in Table 1, the removal of the ACI feature and replacing it with an alarm that occurs when the reactor pressure exceeds a set point 440 psig while RHR suction MOVs are open, reduces the Event V frequency at Millstone Point 3 by approximately 2.3%. The lowering of the Event V frequency is driven by the reduced probability of operator error to recognize that an RHR suction MOV is open via the new alarm to be installed.

The reduction is Event V frequency was subjected to a sensitivity analysis after:

a) reducing valve rupture rate from 1.00E-07 to 3.00E-08, and

b) the change in (a) above combined with a reduction of the valve left open probability by a factor of 10.

For these two cases (a) and (b), the differences in Event V frequencies (with and without ACI) were 2.2% and 1.4%, respectively.

Based upon the above analysis, it is concluded that replacing the RHR ACI with the proposed alarm has no undesirable impact on the Event V frequency at MP3.

5.2 RHR Unavailability

According to Tables 3 and 4, the removal of ACI will reduce the RHR short-term unavailability by 12% from 1.64E-2 to 1.45E-2. Further, removal of the ACI feature significantly reduces the long-term RHR unavailability (approximately 70%) from 3.94E-2 to 1.19E-2. These results clearly convey the major advantage of removing the ACI feature.

5.3 Overpressure Transients

5.3.1 Heat Input Transients

Six initiators leading to overpressure transients during shutdown were examined. The removal of the RHR ACI does not affect risk attributed to heat input transients. In general, except the inadvertent start of an RCP, the pressure transient attributed to the other heat input transients develop relatively slowly. Therefore, the function of the RHR ACI can easily be accomplished by the new alarm to be installed.

The new alarm warns the operator of the high pressure condition in RCS when the pressure exceeds 440 psig. The set point for ACI which the alarm replaces is 765 psia. Therefore, the new alarm will increase the time available to respond to the high pressure condition. This additional time will compensate for the delay of several minutes which the operator needs to close the RHR suction isolation valves after the alarm sounds.

The inadvertent RCP startup frequency is low due to precautions taken such as racking down and tagging out all the RCP power supply breakers.

Furthermore, in the unlikely event of an inadvertent RCP startup, the pressure transient is too rapid for either the ACI feature or the alarm (to be installed) to accommodate. In addition, the RHR relief valves and the PORVs provide a relief path to mitigate this transient.

5.3.2 Mass Input Transients

Three different mass input transients were examined. The frequency of transients attributed to the opening of accumulator discharge valves are extremely low since the isolation MOVs are closed and power is removed from the breakers. Further, since the accumulators are maintained at 700 psi, this maximum pressure attributed to this transient is well within the capabilities of RHR RVs, and the RHR ACIs will not be challenged due to their 765 psia set point. "Letdown isolation; RHRS operable" transient analysis illustrate a major advantage of removing the RHR ACI. Specifically, when the ACI is removed the frequency of this transient will reduce significantly.

The inadvertent SI actuation transient was examined in detail since four events have occurred during the relatively short duration of the MP3 history. None of the above events progressed to an extent where the RHR ACI was demanded. It is concluded that the removal of the RHR ACI has no significant impact on this overpressure transient due to a) adequate capacity of RHR RVs, b) adequate capacity of PORVs, and c) modification to plant procedure that would direct the inadvertent SI actuated charging flow to the refueling water storage tank (RWST), rather than to the RCS.

6 RECOMMENDATIONS

At MP3, the RHR ACIs are associated with valves MV8701A and MV8701B in RHR Train A and valves MV8702A and MV8702B in RHR Train B. Therefore, when the RHR ACI is deleted, the new alarms will be associated with these valves, too. However, the pressure isolation valves (PIVs) of the two RHR suction paths are MV8701C and MV8701A for RHR Train A and MV8702C and MV8702B for RHR Train A. That is, two of the overpressure alarms will be associated with two non-PIVs MV8701B and MV8702A. These two valves are not designed to withstand the RCS pressure for extended durations.

If the new alarms are installed on the valves MV8701C and MV8702C instead of MV8701B and MV8702A, the interfacing systems LOCA frequency can be lowered. However, such a design change is not recommended due to the following:

- A cost benefit analysis performed using the MP3 ISAP procedure[13] indicate a relatively low benefit.

- Existence of alternative actions such as procedural changes that would compensate for not having the ACIs or the new alarms on two PIVs.

The probability of leaving the MV8701C and MV8702C in the open position is already very low due to existence of a leak rate test.[14] The sequence of activities performed during the leak rate test can be summarized as follows:

i. Close MOVs MV8701A and MV8701C.

ii. Leak test MV8701A (gradually opening MV8701C).

iii. Close MV8701C.

iv. Remove power from MV8701C.

v. Leak test MV8701C.

Since power is removed from the valves MV8701C and MV8702C, the probability of spurious opening is extremely low for these valves. Therefore, the probability of the "valve left open" event is dominated by the product of the probability of operator errors to close MV8701C and failure to leak test MV8701C. While the product of the two operator errors will be low, it can be further reduced by checking the valve position from the control after the leak test is completed, prior to entering mode 1. Such an action, and/or periodic checking of valve position indication of MV8701C and MV8702C, will compensate for not having the new alarm on valves MV8701C and MV8702C.

7 REFERENCES

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