CE NPSD-550

RISK EVALUATION
of
REMOVAL OF SHUTDOWN COOLING SYSTEM AUTOCLOSURE INTERLOCK

Prepared for the C-E OWNERS GROUP
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RISK EVALUATION OF REMOVAL OF SHUTDOWN COOLING SYSTEM AUTOCLOSURE INTERLOCK

1.0 PURPOSE

The purpose of this report is to document the results of an analysis of the impact of removing the autoclosure interlock (ACI) from the shutdown cooling system (SDCS). The analysis was performed to determine the change in interfacing system loss of coolant accident (LOCA) frequency, the change in SDCS unavailability, and the impact on mitigating low temperature over-pressure events due to removal of ACI. The analysis is intended to provide input to the decision to remove the ACI from the SDCS.

The analysis addresses three configurations of the SDCS. The first configuration considers SDCS suction valves with ACI only. The second configuration considers SDCS suction valves with ACI and valve position alarm. The first and second configurations are currently utilized at C-E supplied NSSS units considered in this analysis. For those units which have valve position alarm currently installed, the alarm is considered to be not well focused because the pressure at which it annunciates if the associated valve is not closed is also the setpoint pressure of the open permissive interlock (OPI). Therefore, the operator may misdiagnose or ignore the warning of the alarm. The third configuration considers SDCS suction valves with ACI removed and incorporation of a well focused valve position alarm in the control room. This configuration is regarded as the proposed or modified configuration.

Interfacing system LOCA frequency and SDCS unavailability are determined for the configurations addressed.

2.0 BACKGROUND

The shutdown cooling system is designed to provide core decay heat removal and reactor coolant system (RCS) residual heat removal once the RCS is below SDCS cooling entry conditions. The SDCS continues to operate throughout refueling operations.

All Combustion Engineering NSSS units are designed with a SDCS which is a low pressure system relative to normal RCS pressure. The majority of these units consists of SDCS with two suction lines. In order to protect the SDCS from RCS pressure and to maintain the RCS pressure boundary, each suction line flow path is isolated by two valves in series. Each valve has two RCS pressure interlocks associated with it. One of the interlocks is to prevent the valve from being opened unless RCS pressure is below shutdown cooling entry conditions. This is referred to as the open permissive interlock (OPI). The second interlock closes the valve automatically if RCS pressure increases above the design pressure of the SDCS. This interlock is referred to as the autoclosure interlock (ACI).

The purpose of the ACI is to ensure that the low pressure piping of the SDCS is properly isolated from the RCS pressure during startup operations. When RCS pressure rises above the setpoint pressure of the ACI, the SDCS suction valves inside the containment are signaled to close automatically if they have not been closed already. Failure to close the SDCS suction valves may result in inadvertent over-pressurization of the SDCS by the RCS and cause an interfacing system LOCA during startup operations. However, inadvertent actuation of ACI during shutdown cooling operations results in loss of decay heat removal from the RCS which may lead to core uncovery. Inadvertent actuation of ACI can also result in over-pressurization of the RCS at low temperature conditions.

EPRI and the NRC have analyzed loss of decay heat removal events at pressurized water reactors (References 1 and 2). Loss of decay heat removal events that occurred between 1976 and 1983 are analyzed. Those events that occurred between 1976 and 1981 are presented in Reference 1. Those that occurred in 1982 and 1983 are presented in Reference 2. The summary of events along with key findings are also presented in Reference 2. The reported results indicate that 130 loss of decay heat removal events were reported between 1976 and 1983. These results are presented in Table 2-1. The dominant contributor (28.5%) to loss of decay heat removal is inadvertent automatic closure of the SDCS suction isolation valves. Other important contributors include loss of inventory and component failures. The contributors to loss of decay heat removal are identified in Table 2-2.

Table 2-1 *

Frequency of DHR Losses
(1976 - 1983)

	1976	1977	1978	1979	1980	1981	1982	1983	Total
Davis-Besse			4	1	9	2			16
Beaver Valley - 1			1	1	4	2	1	1	10
Calvert Cliffs - 2			2	1		2	3	2	10
Salem - 2						2		8	10
Crystal River		1	2	2	3	2			10
Calvert Cliffs - 1			2		5		1	1	9
Trojan		1	5			1			7
North Anna - 1				1	2		2	2	7
North Anna - 2							3	3	6
Salem - 1	1			3			1		5
Farley - 1			2		2	1			5
McGuire - 1							2	1	3
Millsotne - 2				1		1	1		3
ANO - 2				2					2
Ginna								2	2
Maine Yankee						2			2
Palisades			1			1			2
Rancho Seco						1	1		2
St. Lucie - 1			1					1	2
Sequoyah - 1						1	1		2
Turkey Point - 3								2	2
Turkey Point - 4						2			2
Indian Point - 3	1								1
Fort Calhoun		1							1
San Onofre - 1					1				1
Oconee - 1						1			1
Oconee - 2						1			1
Zion - 1							1		1
Surry - 1								1	1
Sequoyah - 2								1	1
Farley - 2								1	1
McGuire - 2								1	1
Summer - 1								1	1
									130
Annaul Frequency of DHR Losses (# of events) / (# of Operating PWRs)	.06	.08	.5	.3	.6	.5	.35	.5	

* = This table is copied form Reference 2.

Table 2-2 *

Categories of Total DHR System Failures at U.S. PWRs 1976-1983 When Required to Oper; e (Loss of Function)

	No. of Events	(% of Events)
Automatic Closure of Suction/ Isolation Valves	37	(28.5)
Loss of Inventory		
o Inadequate RCS Inventory Resulting in Loss of DHR Pump Suction	26	(20.0)
o Loss of RCS Inventory Through DHR System Necessitating Shutdown of DHR System	10	(7.7)
Component Failures		
o Shutdown or Failure of DHR Pump	21	(16.2)
o Inability to Open Suction/ Isolation Valve	8	(6.1)
o Others	28	(21.5)
TOTAL	130	(100.0)

* = This table is copied from Reference 2.

Sandia Laboratories also assessed the impact of loss of decay heat removal using the Calvert Cliffs SDCS configuration. The results of their assessement are presented in Reference 3. In one of their conclusions they state that:

> " ... the best RHRS suction valve arrangement is to have a single suction line without primary system over-pressure interlocks on the valves."

With automatic closure of the SDCS suction isolation valves being such a large contributor to loss of decay heat, the NRC has indicated their willingness to consider removal of the ACI provided certain conditions are addressed. Pacific Gas and Electric Company has submitted (Reference 4) justifications to and received approval from the NRC for removal of ACI for the residual heat removal suction valves for Diablo Canyon Units. Members of Combustion Engineering Owners Group (CEOG) have made commitments to the NRC to pursue removal of the ACI function from their units.

"RCS/RHR Suction Line Interlocks on PWR's" is listed as generic issue No. 99 in NUREG-0933. To address this issue, NUREG/CR-5015 has been published. The following statement is made regarding the removal of the interlock circuitry:

> "With this design change, the frequency of spurious closure of an RHR suction valve would be significantly reduced. This design change reduces the frequency of loss-of-coolant events and reduces the calculated core damage frequency. Due to the large number of already experienced suprious isolation events, this event is an important contributor to the estimated frequency of loss-of-cooling events. The proposed design change results in a 60% reduction in the initiator frequency of loss-of-cooling events. The reduction in calculated core damage frequency based upon implementation of this possible upgrade is 8%."

The analysis presented in this report addresses the impact of removing the ACI function from the SDCS from C-E supplied NSSS. The analysis examines the impact of ACI removal on:

- o Interfacing system LOCA frequency
- o SDCS unavailability
- o Mitigating low temperature over-pressure events

The analysis also examines the impact of adding a valve position alarm circuitry to the SDCS suction isolation valves. This alarm will annunciate in the control room when any of the SDCS suction isolation valves is not fully closed when RCS pressure exceeds a certain limit. The Waterford Unit 3 plant configuration is used when plant specific information is required.

3.0 METHODOLOGY

As stated in Section 1.0, the purpose of this analysis is to determine the impact of removing the autoclosure interlock (ACI) function from the shutdown cooling system (SDCS). Inadvertent actuation of ACI is the dominant contributor to loss of SDCS which is used to remove decay heat from the RCS. The removal of ACI can be assessed by observing the change in SDCS unavailability, the change in interfacing system LOCA frequency, and the impact on mitigating low temperature over-pressure events.

Fault tree analysis is employed in determining the unavailability of the SDCS. The technique used is consistent with the methods outline in References 5 and 6. The technique involves the construction and evaluation of a fault tree model for the SDCS. In constructing the fault tree model, failures that can result in the top event of the model are considered. The top event is defined as failure of the SDCS to remove decay heat from the RCS. Failures are combined by using logical AND and OR gates to relate them to the top event. Refer to Figure 3-1 for a list of symbols used in fault tree models. Equipment failures, human errors, common cause faults, and unavailability due to testing or maintenance are included in the model. Once the fault tree model is constructed it is then evaluated to determine the minimal cut sets. These are combinations of failures that result in the top event. The evaluation also includes quantification of SDCS unavailability and determination of dominant contributors to unavailability.

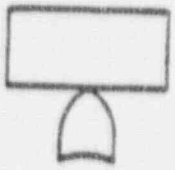
Construction and evaluation of the fault tree model are accomplished by using the IRRAS PC computer code (Reference 7).

In WASH-1400 (Reference 8) interfacing system LOCA is referred to as Event V. These events are defined as breaches of the RCS pressure boundary via an interfacing system which is designed to operate at a lower pressure than the RCS. Once the breach occurs RCS coolant is lost outside the containment. For plants with C-E supplied NSSS, the low pressure safety injection lines and shutdown cooling suction lines are potential locations for interfacing system LOCA. For this analysis, only the shutdown cooling suction lines are considered.

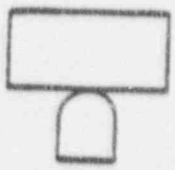
The shutdown cooling suction lines, as shown in Figure 3-2, each have a motor-operated valve and a hydraulic-operated valve in series inside the containment. A motor-operated valve, also in series, is located outside the containment. These valves are closed during power operations. When closed, the valves inside the containment provide redundant isolation for the low pressure piping of the SDCS from RCS pressure.

FIGURE 3-1

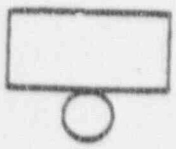
FAULT TREE SYMBOLOGY



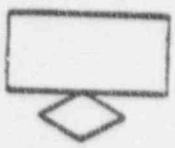
OR GATE — Output event occurs if one or more of the input events occurs.



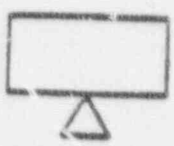
AND GATE — Output event occurs if and only if all input events occur.



BASIC EVENT — Basic fault event requiring no further development.

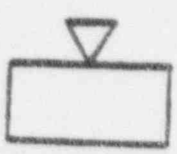


EXTERNAL INPUT — An eve[illegible]ch is described by a fa[illegible] model developed indepen[illegible]y - typically a support system failure.



TRANSFER IN

Used as method of conveniently segmenting the tree for drafting purposes and to avoid duplication of portions of the tree. Indicates continuation to other portions of the tree.



TRANSFER OUT

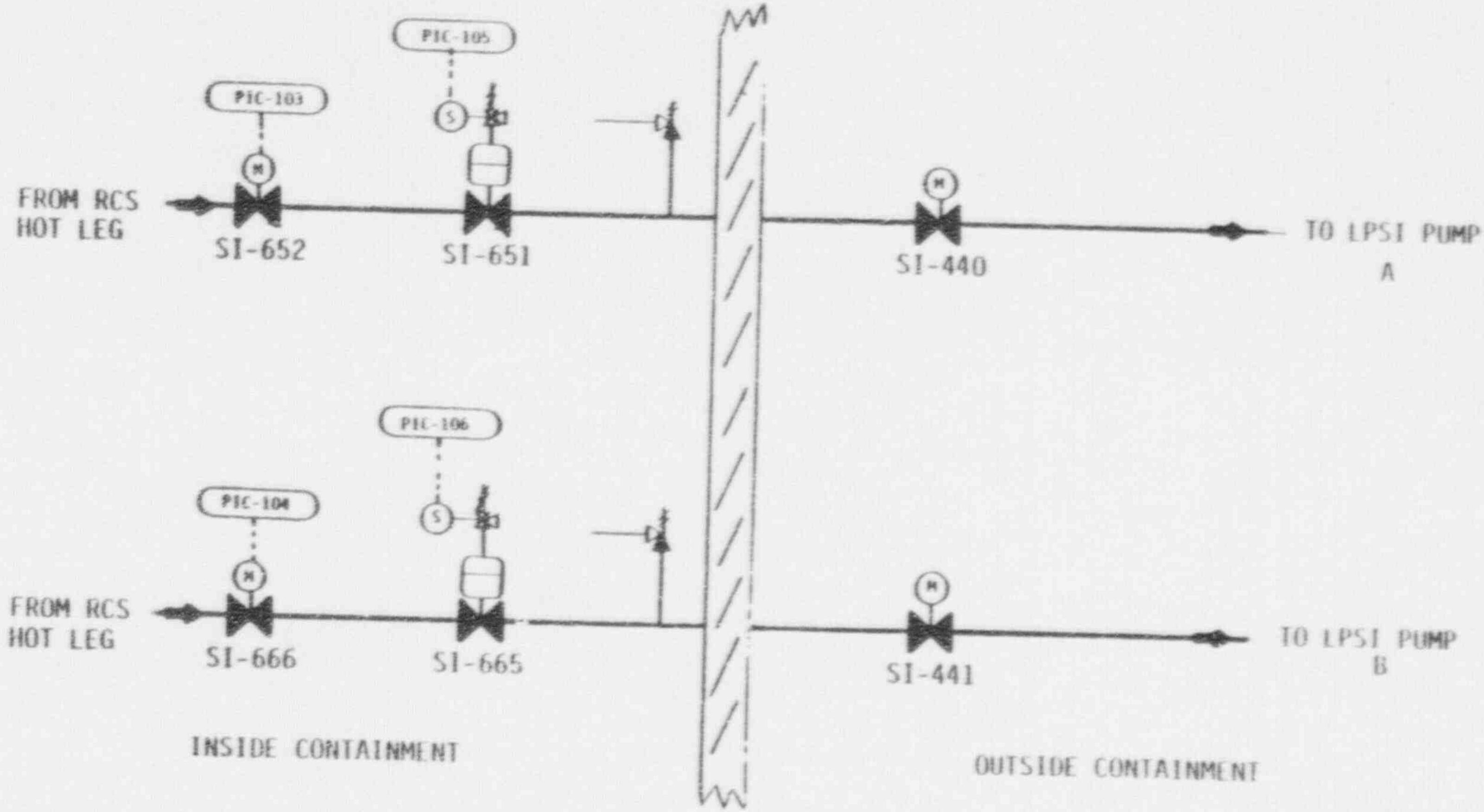


FIGURE 3-2
Shutdown Cooling System Suction Lines

There is also a six-inch relief valve which discharges to the containment sump. This relief valve is located inside the containment between the containment wall and the hydraulic-operated valve. Note that this relief valve has enough flow capacity to mitigate low temperature over-pressure events. The pressure setpoint for the relief valve is significanlty lower (approximately 450 PSIG) than the design pressure for the RCS piping. Figure 3-2 reflects the SDCS suction lines configuration for Waterford Unit 3.

The SDCS piping from the RCS up to and including the hydraulic-operated valve is rated for full RCS pressure. The piping downstream of the hydraulic-operated valve is designed to operate at pressures much lower than the RCS. Failure of the motor- and hydraulic-operated valves will expose the low pressure piping to RCS pressure. Given that the motor- and hydraulic- operated valves fail, a break is postulated to occur just outside the containment wall.

During power operation, an interfacing system LOCA via the shutdown cooling suction lines can occur if:

1. Both valves in series are left open,
2. Motor-operated valve is left open and hydraulic-operated valve in series ruptures,
3. Hydraulic-operated valve is left open and motor-operated valve in series ruptures, or
4. motor-operated and hydraulic-operated valves rupture.

During startup operations, failure of the motor- and hydraulic-operated valves inside the containment to close will suspend startup operations. Failure of these valves to close during startup operations will cause the six-inch relief valve to open and discharge reactor coolant into the containment sump. Events resulting from failure of these valves to close are:

- o Increasing containment sump level indications
- o Decreasing volume control tank level indications

These indications will inform the operator that the RCS pressure boundary is breached during startup. Startup operations will then be suspended until the breach is located and isolated. Therefore, item 1 above is considered to be a non-credible way for interfacing system LOCA to occur.

Because either the motor- or hydraulic-operated valve inside the containment is initially closed during power operation, the frequency for interfacing system LOCA via the shutdown cooling

lines can be estimated from the following expression:

$$F(ISL) = 2(\lambda Q_1 + \lambda Q_2 + \lambda Q_3) \quad [3.1]$$

where, $F(ISL)$ = frequency of interfacing system LOCA via SDCS suction lines

λ = catastrophic failure rate for motor- or hydraulic-operated valve

Q_1 = probability that motor-operated valve is not closed

Q_2 = probability that hydraulic-operated valve is not closed

Q_3 = probability that hydraulic-operated valve fails given that motor-operated valve has failed

The first term on the right represents the contribution due to the motor-operated valve is left open and the hydraulic-operated valve ruptures. The second term on the right represents the contribution due to the hydraulic-operated valve is left open and the motor-operated valve ruptures. The third term represents the contribution due to both valves rupturing.

Generic data is used in this analysis to quantify the frequency for interfacing system LOCA and SDCS unavailability. The primarily source of generic data is the Advanced Light Water Reactor (ALWR) Requirements Document data base (Reference 9). Other sources which include, NUREG/CR-4550 (Reference 10), WASH-1400 (Reference 8), IEEE-500 (Reference 11), and CEN-327 (Reference 13) are used when component data could not be obtained from Reference 9. The approach described by Swain and Guttmann (Reference 12) is used to determine human error probabilities.

4.0 ANALYSIS

The purpose of the SDCS autoclosure interlock (ACI) is to ensure that the low pressure piping of the SDCS is properly isolated from RCS pressure during startup operations. Although ACI protects the low pressure piping of the shutdown cooling system, spurious actuation will terminate decay heat removal during shutdown cooling operations. Several such events have occurred. One way of reducing inadvertent termination of decay heat removal is removal of ACI function from the SDCS.

Most but not all of the C-E supplied NSSS units considered in this analysis have position alarm installed for the SDCS suction valves. To account for the differences, three models for interfacing system LOCA were developed to reflect the current and proposed configurations of the SDCS suction valves.

The first configuration considers SDCS suction valves with ACI only. The second configuration considers SDCS suction valves with ACI and alarm. Although the operability of the installed alarm is not governed by the technical specification, plant specific information obtained from Louisiana Power and Light indicates that the alarm is tested every refueling. The first and second configurations currently exist at C-E supplied NSSS units considered in this analysis. A third configuration is being proposed. It considers SDCS suction valves with alarm only. This alarm will annunciate in the control room when RCS pressure increases above a certain setpoint while the associated valve is not fully closed.

For those units which have valve position alarms currently installed, the alarms may not be well focused. The alarm annunciates when RCS pressure increases above the setpoint of the OPI while the valve is not fully closed. For some of these units, the setpoint for OPI is significantly lower than the setpoint for ACI, while the OPI and ACI setpoints for the other units are approximately the same. Because the existing alarm and OPI provide different functions, the operator may misdiagnose or ignore the warning of the current installed alarm. To make the alarm well focused, the proposed configuration for these units will require setpoint or procedural changes.

This analysis determines what impact removal of ACI will have on the frequency of interfacing system LOCA, the unavailability of SDCS, and the mitigation of low temperature over-pressure events. The analysis quantifies the net changes in frequency and unreliability realized. The availability of the low temperature over-pressure relief valves is also assessed. The analysis

involves calculating the frequency of interfacing system LOCA for the following three cases:

- Case 1 - SDCS suction valves with ACI only,
- Case 2 - SDCS suction valves with ACI and alarm, and
- Case 3 - SDCS suction valves with alarm only.

The analysis also calculates SDCS unavailability for cases 1 and 3. The alarm has no impact on SDCS unvailability. Therefore for SDCS unavailability, case 2 above is the same as case 1. Case 3 considers a SDCS configuration which excludes ACI.

The quantification of the frequency of interfacing LOCA for the above configurations of the SDCS is discussed in Section 4.1. A recent precursor to interfacing system LOCA and its applicability to C-E supplied NSSS units are discussed in Section 4.2. A discussion on SDCS unavailability for the above configurations is contained in Section 4.3. Mitigating low temperature over-pressure events is summarized in Section 4.4.

4.1 Interfacing System LOCA Frequency

Interfacing system LOCA is a safety concern because it can provide a direct path to the environment for releasing radionuclides. For C-E NSSS supplied plants, the low pressure injection lines and shutdown cooling suction lines are potential locations for interfacing system LOCA. For this analysis, the frequency for interfacing system LOCA is calculated for SDCS suction lines only.

Interfacing system LOCA via the SDCS suction lines can occur due to failures of both suction isolation valves inside the containment. The failure combinations include:

- Catastrophic failures of motor- and hydraulic-operated valves,
- Catastrophic failure of motor-operated valve and hydraulic-operated valve not closed, and
- Catastrophic failure of hydraulic-operated valve and motor-operated valve not closed.

Therefore, the frequency of interfacing system LOCA via the SDCS suction lines can be estimated using the following expression:

$$F(ISL) = 2(\lambda Q_1 + \lambda Q_2 + \lambda Q_3) \qquad [4.1]$$

where, F(ISL) = frequency of interfacing system LOCA via SDCS suction lines

λ = catastrophic failure rate for motor- or hydraulic-operated valve

Q_1 = probability that motor-operated valve is not closed

Q_2 = probability that hydraulic-operated valve is not closed

Q_3 = probability that hydraulic-operated valve fails given that motor-operated valve has failed

From Appendix A of the EPRI ALWR requirements document (Reference 9), the mean failure rate for catastrophic internal leakage for a motor-operated valve is 3.1E-8 per hour. The variable Q_3 is determined by assuming that the hydraulic-operated valve is leak tested every refueling (18 months) and fails randomly in time. Therefore,

$$Q_3 = \tfrac{1}{2}\lambda T \qquad [4.2]$$

where, λ = catastrophic failure rate
T = fault exposure time (18 months)

substituting in equation [4.2] results in,

$$Q_3 = \tfrac{1}{2}\,(3.1E\text{-}8) \times 13140$$

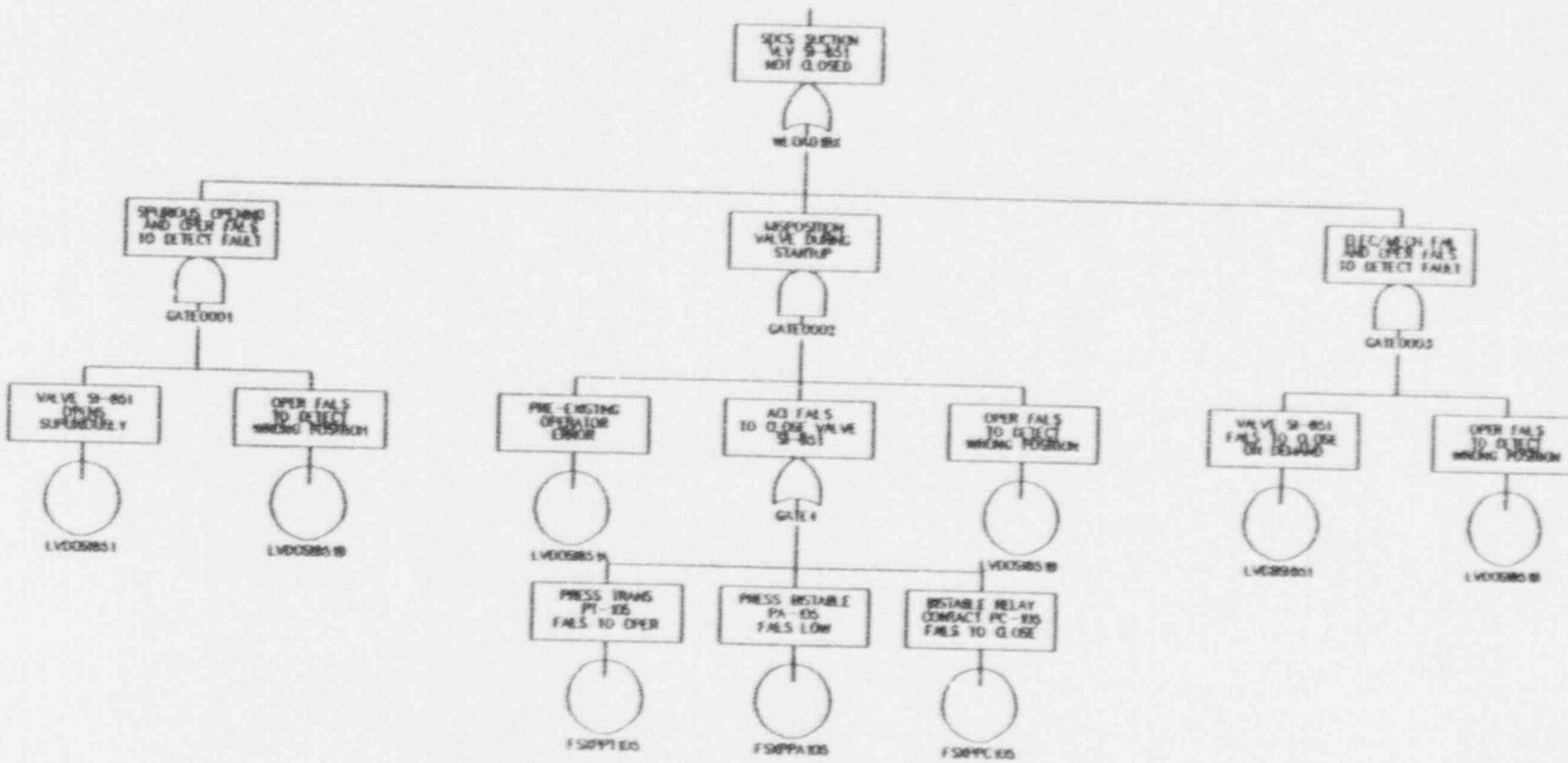
$$= 2.04E\text{-}4$$

Fault tree analysis is used to estimate the values for Q_1 and Q_2. The fault tree logic structures for motor- and hydraulic-operated valves not closed are similar. However, failure probabilities for these valves differ. The same fault tree model is used, with appropriate data, to estimate the probability that a motor- or hydraulic-operated valve is not closed.

A fault tree model was developed for each of the SDCS configurations considered. The fault tree models for cases 1 through 3 are presented in Figures 4-1, 4-2, and 4-3 respectively. The models presented in these Figures are applicable to motor- and hydraulic-operated valves.

In developing the fault tree models the following assumptions were made:

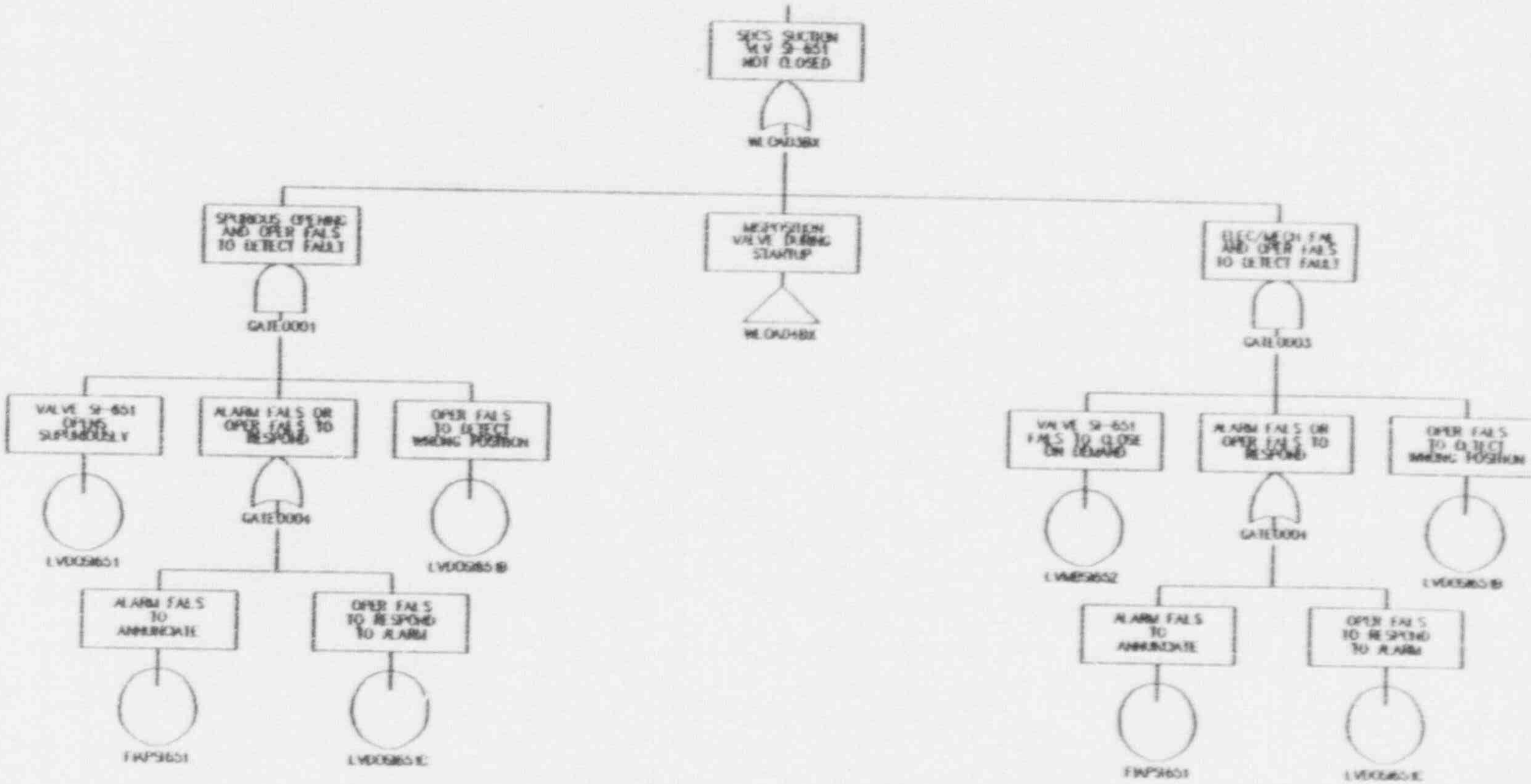
1. Startup operations will not proceed if it is observed that power required to close the SDCS suction isolation valves is lost. The SDCS motor-operated suction valves are fail-as-is valves. Loss of power to the valves during power operation will not cause the valves to be repositioned. Therefore,



WLOAO1BX

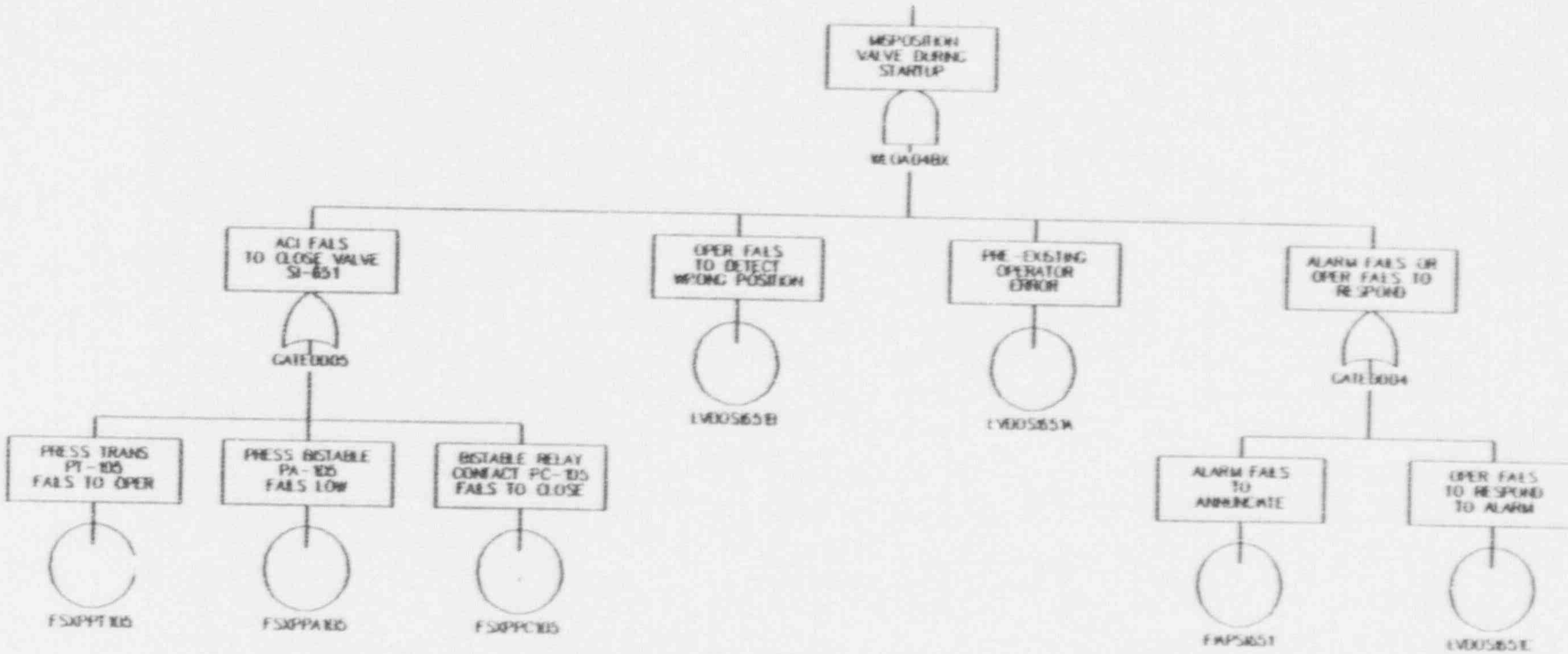
FIGURE 4-1

Fault Tree Model for
SDCS Suction Valve with ACI



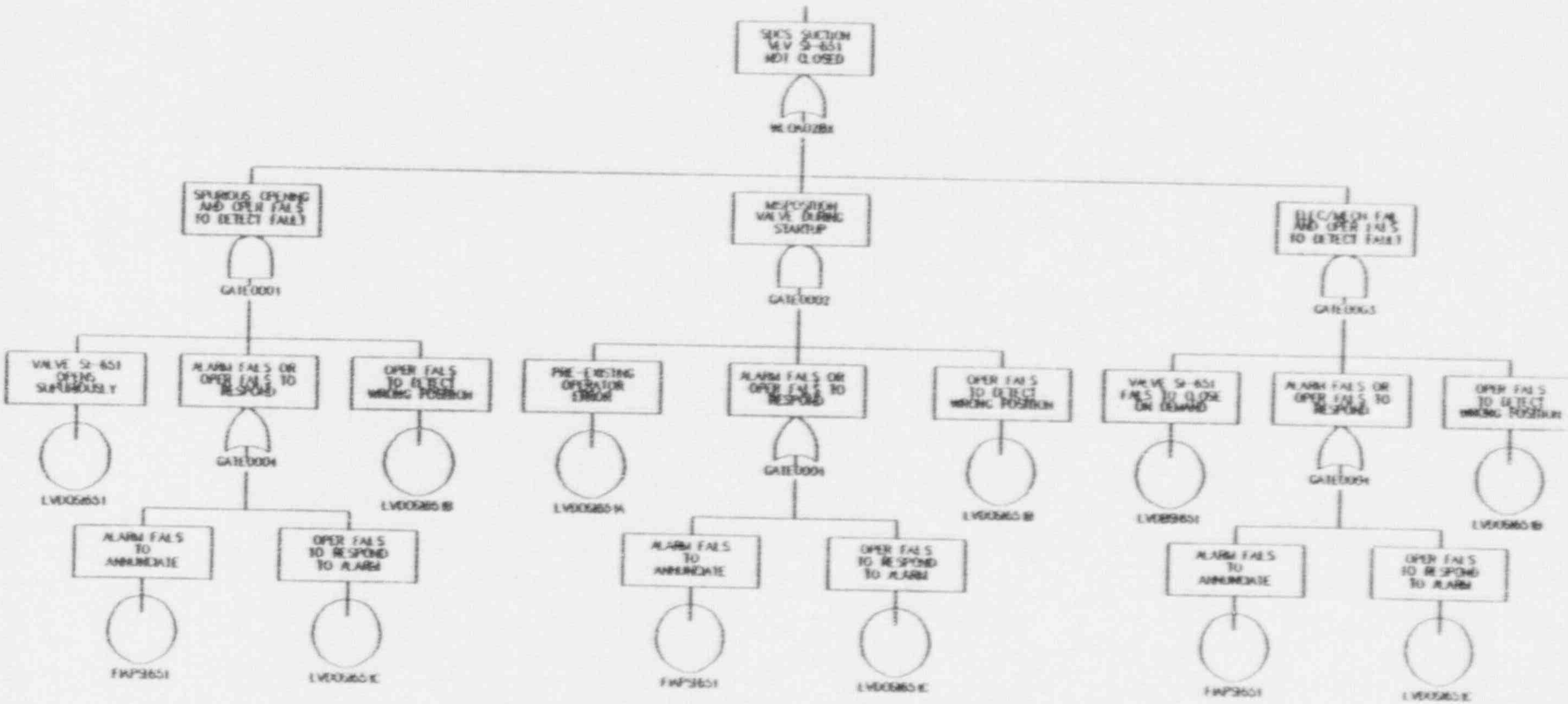
WLOA03BX

FIGURE 4-2 (Sheet 1 of 2)
Fault Tree Model for
SDCS Suction Valve with ACI
and Alarm



WLOA04BX

FIGURE 4-2 (Sheet 2 of 2)
Fault Tree Model for
SDCS Suction Valve with ACI
and Alarm



WLOA02BX

FIGURE 4-3
Fault Tree Model for
SDCS Suction Valve with Alarm

loss of power to the SDCS suction isolation valves is not included in the fault tree model.

2. SDCS suction isolation valves are leak tested every refueling. The refueling cycle is considered to be 18 months.

3. SDCS suction isolation valve positions are checked every shift during power operations. Therefore, a mispositioned SDCS suction isolation valve can be detected and corrected within one shift. One shift is regarded as twelve hours.

4. During power operations, each of the SDCS suction isolation valves closest to the RCS is exposed to RCS pressure and temperature. The other in series suction valve is exposed to significantly lower temperatures and pressures. Therefore, common cause failure associated with the SDCS suction isolation valves in series is not included in the fault tree model. Suction isolation valves in each train of the SDCS are exposed to different operating environments.

5. Failure of both SDCS suction isolation valves inside the containment, in any of the two lines, to close during startup operations will prohibit startup. Failure of the valves to close will result in the following events:

   - Increasing containment sump level indications
   - Decreasing volume control tank level indications

   These events will notify the oprator that the RCS pressure boundary is breached during startup operations. Therefore, the operator will elect to suspend startup operations until the breach in the RCS pressure boundary is located and isolated.

6. For units with valve position alarm currently installed, the alarm is not required to be maintained or tested on a periodic basis by the technical specification. For this analysis, it is assumed to be tested every refueling and is included in the model.

7. The SDCS ACI function is removed and replaced with a valve position alarm for units which do not have alarms currently installed. The alarm annunciates in the control room when RCS pressure increased above a certain setpoint while the associated SDCS suction isolation valves is not fully closed. The alarm circuitry is tested every refueling.

Component data used in the fault tree quantification are presented in Table 4-1. Human error probabilities also used in the fault tree quantification are presented in Table 4-2. Human error probabilities are based on the methodology presented in Reference 12.

The IRRAS personal computer code (Reference 7) is used to perform the fault tree quantification.

The probabilities obtained from the fault tree analysis are:

Case 1	Case 2	Case 3
Q_1 = 2.56E-05	Q_1 = 1.00E-06	Q_1 = 1.10E-06
Q_2 = 6.14E-06	Q_2 = 2.40E-07	Q_2 = 3.38E-07

Using these values along with the value for Q_3 and substituting into equation [4.1] yields the following frequencies for interfacing system LOCA:

	Case 1	Case 2	Case 2
F(ISL)	1.28E-7/year	1.12E-7/year	1.12E-7/year

The values presented above reflect a SDCS with two suction flow paths. Note that these values will decrease by a factor of two if a SDCS with only one suction path is considered. The change in interfacing system LOCA frequency will be the same for a SDCS with one or two suction flow paths.

4.2 Recent Precursors to Interfacing System LOCA

Interfacing system LOCA has been an out-standing issue of concern with the NRC. A recent event, which involves pressure isolation valves between the RCS and interfacing systems as reported in references 14 and 15, has renewed NRC concern on this issue. Because of this event, the NRC plans to implement a pilot inspection program of six PWRs to assess their vulnerability to interfacing system LOCA.

The recent event involving pressure isolation valves occurred at Biblis-A, a West German PWR. The event occurred December 16-17, 1987. The event began when operators restarted Biblis-A following an unplanned four-day outage. A pressure isolation valve between the RCS and the low pressure injection system was not reclosed as it should have been.

Table 4-1

Component Failure Probabilities
for
SDCS Suction Valve

Comp Name	Description	Probability
FSXPPA105	PRESSURE BISTABLE PA-105 FAILS LOW	2.560E-002
FSXPPC105	BISTABLE RELAY/CONTACT PC-105 FAILS TO CLOSE	8.100E-006
FSXPPT105	PRESSURE TRANSMITTER PT-105 FAILS TO OPERATE	2.760E-002
LVDBSI651	SDCS SUCTION VALVE SI-651 FAILS TO CLOSE ON DEMAND	1.000E-003
LVDQSI651	SDCS SUCTION VALVE OPENS SPURIOUSLY	2.000E-004
FIAPSI651	SDCS SUCTION VALVE SI-651 ALARM FAILS TO ANNUNCIATE	3.910E-002
LVMBSI652	SDCS SUCTION VALVE SI-652 FAILS TO CLOSE ON DEMAND	4.900E-003

Table 4-2*

Human Error Probabilities

1. LVDOSI651A - Operator fails to close hydraulic-operated valve after previous use

OMISSION ERROR : HEP = 0.01
Operator fails to close valve
Table 20-7 (Item # 4)

OR

COMMISSION ERROR: HEP = 0.0005
Operator turns handswitch in wrong direction
Table 20-12 (Item # 5)

AND

RECOVERY ERROR : HEP = 0.05
Checker fails to detect error made by others
Table 20-22 (Item # 3)

Therefore, the human error probability for failing to close valve after previous use is:

$$P = (0.01)(0.05) + (0.99)(0.0005)(0.05) = 5.25E-4$$

2. LVDOSI651B - Operator fails to detect hydraulic-operated valve in wrong position

OMISSION ERROR : HEP = 0.01
Operator fails to detect valve status light in wrong position
Table 20-26 (Item # 13)

AND

RECOVERY ERROR : HEP = 0.5
Checker fails to detect error made by others
Table 20-22 (Item #4)

* - Table and item number cited for each error are those presented in Reference 12.

Table 4-2* (Cont'd)

Human Error Probabilities

Therefore, the human error probability for failing to detect valve status light in wrong position is:

P = (0.01)(0.5)
  = 5.00E-3

3. LVDOSI651C - Operator fails to respond to alarm

OMISSION ERROR : HEP = 0.0001
Operator fails to respond to valve position alarm
Table 20-23 (Item # 1)

AND

RECOVERY ERROR : HEP = 0.5
Checker fails to detect error made by others
Table 20-22 (Item # 4)

Therefore, the human error probability for failing to respond to valve alarm is:

P = (0.0001)(0.5)
  = 5.00E-5

* - Table and item number cited for each error are those presented in Reference 12.

Operators who restarted the reactor on December 15 failed to observe a warning light indicating that the pressure isolation valve was not closed. Operators on the following shift did not notice the warning light or did not diagnose the warning light correctly. The problem was recognized by the third shift operators. Once the problem was recognized, the operator tried to close the valve by manipulating the pressure on it by slightly opening a second valve. According to the report, this is an acceptable means of closing the valve. However, this approach did not close the valve. The operator then decided to stop the startup and shutdown the reactor.

In opening the second valve, a path from the reactor coolant to outside of the containment was established. In doing so, a small amount of steam from the reactor coolant system was released into the annulus for a short period of 2-5 seconds and from there to the atmosphere via the reactor stack.

The SDCS suction isolation valve for all C-E supplied NSSS units are designed with two types of interlocks. During plant startup, the SDCS suction valves are closed by the operator. If plant startup continues and the SDCS suction valves(s) are not closed as they should, the autoclosure interlock (ACI) will close the valve(s). An open permissive interlock (OPI) is also associated with each SDCS suction valve. This interlock prevents the SDCS suction valves from being opened while the reactor coolant pressure is above shutdown cooling entry conditions.

In the Biblis-A event, the operator tried to close a mispositioned pressure isolation valve by opening a second valve to manipulate the pressure. For all SDCS of C-E supplied NSSS units the pressure isolation valves (SDCS suction valves) cannot be opened by the operator if RCS pressure is above shutdown cooling entry conditions. The OPI prevents such actions by the operator. These interlocks are not the subject of this analysis and will not be removed from the SDCS suction valves. The sequences of events involving operator actions that occurred at Biblis-A is precluded for C-E supplied NSSS units.

4.3 SDCS Unavailability

The primary function of the shutdown cooling system (SDCS) is to remove decay heat from the RCS during shutdown cooling operations. The SDCSs of C-E supplied NSSS plants are equipped with autoclosure interlocks (ACI). The main purpose of the ACI is to ensure that the low pressure piping of the SDCS is properly isolated from the RCS pressure during startup operations.

Operating experience has shown that several loss of decay heat removal events have occurred at pressurized water reactors. The dominant contributor to loss of decay heat removal is inadvertent closure of the SDCS suction isolation valves during shutdown cooling operations. Some of these valve closings are linked to spurious operation of ACI during shutdown cooling operations. One way of reducing loss of decay heat events is to remove the ACI function from the SDCS valves.

Removal of ACI function from the SDCS suction valves is analyzed in this section. The analysis involves determining the unavailability of SDCS to remove deacy heat for the following two cases:

- Case 1 - SDCS suction valve with ACI only, and
- Case 3 - ACI removed and inclusion of valve position alarm for the SDCS suction isolation valves.

As discussed in Section 4.0, Case 2 is similar to Case 1 for SDCS unavailability.

Fault tree analysis was used to determine the unavailability for the above cases. For each of the above cases, a fault tree model for SDCS was developed and quantified. In order to simplify the quantification several steps were taken to minimize the size of the fault tree model. These steps include:

- Treatment of support systems

  Because the focal point of this analysis is to determine the impact of ACI removal on SDCS unavailability, support systems for the SDCS were treated as developed events. These support systems include component cooling water and electrical distribution systems.

- Treatment of pipe failures

  SDCS piping failures are not included in the fault tree model. The contribution of piping failure to system unavailability is insignificant when compared with the contributions from other components.

- Potential flow diversion paths

  Potential flow diversion paths of the SDCS that are isolated from the main flow path by two or more normally closed valves are not considered as faults of the SDCS. Potential flow diversion paths with piping significantly smaller (10% or less) than the piping for the main flow path is also not included in the fault tree model.

o Control Circuits

Control circuits for major components (e.g. motor operated valves and pumps) are treated as part of the component. Therefore, they are not modeled as separate events in the fault tree model for SDCS.

Figure 4-4 is a schematic of the SDCS. It was used to construct the fault tree model for SDCS which is included in Appendix A. In constructing the model the following assumptions were made:

1. Successful operation of the SDCS involves the removal of RCS decay heat via one of the two shutdown cooling heat exchangers.

2. Because the purpose of this analysis is to determine the change in SDCS unavailability due to ACI removal, support systems for SDCS are assumed to be available.

3. Failure of the SDCS warmup valve to open will not result in SDCS becoming unavailable. The SDCS is designed to with stand a limited number of thermal shock while entering shutdown cooling operations. The SDCS warmup valves are not included in the fault tree model.

4. The contribution of spurious recirculation actuation signal (RAS) to SDCS unavailability is considered to be insignificant when compared with other component failures. Therefore, spurious actuation of RAS in not included in the fault tree model for SDCS.

5. If the low pressure safety injection (LPSI) pumps become unavailable, the containment spray pumps cannot be used as backup.

6. Operating procedures do not allow components in both trains of the SDCS to be in maintenance at the same time. As a result, the SDCS heat exchanger and the pump in train A are modeled as components which may be unavailable due to maintenance.

7. The LPSI pump suction isolation valves are normally open and are used to isolate the pump for maintenance. The pump is tested after maintenance before it is returned to service. This implies that the suction isolation valve must be re-open. Therefore, mispositioned LPSI suction isolation valves are considered unlikely and are not included in the fault tree model.

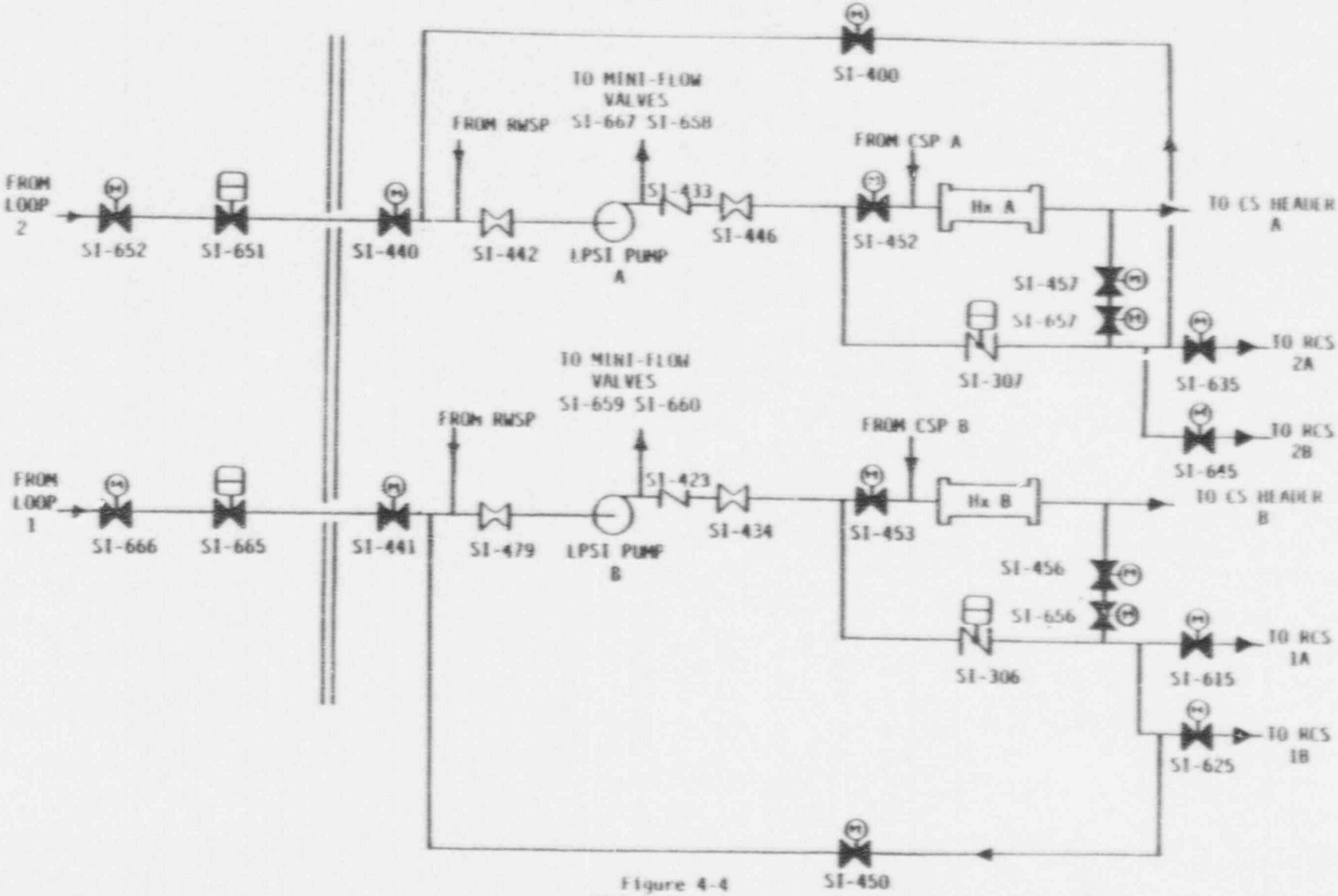


Figure 4-4
SDCS Schematic

Component data used to quantify SDCS unavailabilities for the cases considered are presented in Table 4-3. The IRRAS personal computer code is used to perform the qauntifications.

In addition to component hardware failures and unavailability due to maintenance, operator error that results in closure of SDCS suction isolation valves is explicitly modeled. It is estimated based on the following expression:

$$P(SDCS * OPER) = P(SDCS/OPER) * P(OPER) \qquad [4-3]$$

where, P(SDCS * OPER) = probability of operator error and loss of SDCS

P(SDCS/OPER) = probability of losing SDCS given that an operator error has occurred

P(OPER) = probability of operator error while performing test or maintenance

Based on a review of the actual events reported in References 1 and 2, 28 events involving opertor errors that resulted in automatic closure of all SDCS suction valves are identified. One hundred and thirty events resulting in loss of SDCS were reported. Therefore, the conditional probability of losing SDCS given that an operator error occurs is:

$$P(SDCS/OPER) = 28 \div 130$$
$$= 0.22$$

The probability of an operator erring while performing maintenance or test is obtained using the method described in Reference 12.

OMISSION ERROR : HEP = 0.001
Operator errs in using written procedures
Table 20-7 (Item # 1)

Because of insufficient time, no recovery action is assumed. Substituting in equation [4-3] yeilds a mean value of 2.15E-4. An error factor of 3.0 is assumed.

Table 4-3

Component Failure Probabilites for SDCS fault tree

Comp Name	Description	Probability
FSXHPA103	PRESSURE BISTABLE PA-103 FAILS HIGH	2.560E-002
FSXHPA103-1	PRESSURE BISTABLE PA-103-1 FAILS HIGH	2.560E-002
FSXHPA104	PRESSURE BISTABLE PA-104 FAILS HIGH	2.560E-002
FSXHPA104-1	PRESSURE BISTABLE PA-104-1 FAILS HIGH	2.560E-002
FSXHPA105	PRESSURE BISTABLE PA-105 FAILS HIGH	2.560E-002
FSXHPA105-1	PRESSURE BISTABLE PA-105-1 FAILS HIGH	2.560E-002
FSXHPA106	PRESSURE BISTABLE PA-106 FAILS HIGH	2.560E-002
FSXHPA106-1	PRESSURE BISTABLE PA-106-1 FAILS HIGH	2.560E-002
FSXHPT103	PRESSURE TRANSMITTER PT-103 FAILS HIGH	4.000E-003
FSXHPT104	PRESSURE TRANSMITTER PT-104 FAILS HIGH	4.000E-003
FSXHPT105	PRESSURE TRANSMITTER PT-105 FAILS HIGH	4.000E-003
FSXHPT106	PRESSURE TRANSMITTER PT-106 FAILS HIGH	4.000E-003
FSXOACI	OPERATOR ERR DURING MAINTENANCE OR TEST	2.150E-004
FSXQPC103-1	RELAY/CONTACT PC-103-1 CLOSES SPURIOUSLY	1.263E-004
FSXQPC104-1	RELAY/CONTACT PC-104-1 CLOSES SPURIOUSLY	1.263E-004
FSXQPC105-1	RELAY/CONTACT PC-105-1 CLOSES SPURIOULSY	1.263E-004
FSXQPC106-1	RELAY/CONTACT PC-106-1 CLOSES SPURIOUSLY	1.263E-004
FSXRPC103	RELAY/CONTACT PC-103 FAILS TO CLOSE	8.100E-006
FSXRPC104	RELAY/CONTACT PC-104 FAILS TO CLOSE	8.100E-006
FSXRPC105	RELAY/CONTACT PC-105 FAILS TO CLOSE	8.100E-006
FSXRPC106	RELAY/CONTACT PC-106 FAILS TO CLOSE	8.100E-006
FSXXOPI	COMMON CAUSE FAILURE OF OPEN PERMISSIVE INTERLOCK	8.790E-005
GHRCHXA	DEFECTIVE SHUTDOWN COOLING HEAT EXCHANGER A	3.000E-003
GHRCHXB	DEFECTIVE SHUTDOWN COOLING HEAT EXCHANGER B	3.000E-003
GHRVHXA	SDCS HX A UNAVAILABLE DUE TO MAINTENANCE	1.010E-003
GHRXSDCS	COMMON CAUSE FAILURE OF SHUTDOWN COOLING HEAT EXCHANGERS	1.587E-004
GVMOSI671	DIVERSION OF FLOW TO CCS DUE TO MISPOSITIONED VLV SI-671	5.000E-005
GVMOSI672	DIVERSION OF FLOW TO CCS DUE TO MISPOSITIONED VLV SI-672	5.000E-005
GVNOHXA	SDCS HX A INLET/OUTLET VALVE NOT OPEN	2.500E-004
GVNOHXB	SDCS HEAT EXCHANGER B CCW INLET/OUTLET VALVE NOT OPEN	2.500E-004
HVCASI217	INJECTION CHECK VALVE SI-217 FAILS TO OPEN	1.300E-004
HVCASI227	INJECTION CHECK VALVE SI-227 FAILS TO OPEN	1.300E-004
HVCASI237	INJECTION CHECK VALVE SI-237 FAILS TO OPEN	1.300E-004
HVCASI247	INJECTION CHECK VALVE SI-247 FAILS TO OPEN	1.300E-004
HVMBSI659	MINI-FLOW VALVE SI-659 FAILS TO CLOSE	4.900E-003
HVMBSI660	MINI-FLOW VALVE SI-660 FAILS TO CLOSE	4.900E-003
HVMBSI667	MINI-FLOW VALVE SI-667 FAILS TO CLOSE	4.900E-003
HVMBSI668	MINI-FLOW VALVE SI-668 FAILS TO CLOSE	4.900E-003
HVMXMINI	COMMON CAUSE FAILURE OF MINI-FLOW VALVES	1.540E-005
LBCBLPSIPA	LPSI PUMP A BREAKER FAILS TO CLOSE	3.400E-004
LBLBLPSIPB	LPSI PUMP B BREAKER FAILS TO CLOSE	3.400E-004
LPMJLPSIPA	LPSI PUMP A FAILS TO START	1.250E-003
LPMJLPSIPB	LPSI PUMP B FAILS TO START	1.250E-003
LPMKLPSIPA	LPSI PUMP A FAILS TO OPERATE	8.086E-002
LPMKLPSIPB	LPSI PUMP B FAILS TO OPERATE	8.086E-002
LPMVLPSIPA	LPSI PUMP A UNAVAILABLE DUE TO MAINTENANCE	2.010E-003

Table 4-3 (Cont'd)

Component Failure Probabilites for SDCS Fault tree

Comp Name	Description	Probability
LPMXLPSIP	COMMON CAUSE FAILURE OF LPSI PUMPS	3.880E-004
LVCASI114	INJECTION CHECK VALVE SI-114 FAILS TO OPEN	1.300E-004
LVCASI124	INJECTION CHECK VALVE SI-124 FAILS TO OPEN	1.300E-004
LVCASI134	INJECTION CHECK VALVE SI-134 FAILS TO OPEN	1.300E-004
LVCASI144	INJECTION CHECK VALVE SI-144 FAILS TO OPEN	1.300E-004
LVCASI433	LPSI PUMP A CHECK VALVE SI-433 FAILS TO OPEN	1.300E-004
LVCASI434	LPSI PUMP B CHECK VALVE SI-434 FAILS TO OPEN	1.300E-004
LVDASI651	SDCS SUCTION VALVE SI-651 FAILS TO OPEN	1.000E-003
LVDASI665	SDCS SUCTION VALVE SI-665 FAILS TO OPEN	1.000E-003
LVDXSDC3	COMMON CAUSE FAILURE OF SDCS SUCTION VLVS (SI-651 & 665)	8.300E-005
LVMASI440	SDCS SUCTION VALVE SI-440 FAILS TO OPEN	3.800E-003
LVMASI441	SDCS SUCTION VALVE SI-441 FAILS TO OPEN	3.800E-003
LVMASI452	SDCS CROSSOVER VALVE SI-452 FAILS TO OPEN	3.800E-003
LVMASI453	SDCS CROSSOVER VALVE SI-453 FAILS TO OPEN	3.800E-003
LVMASI456	SDCS CROSSOVER VALVE SI-456 FAILS TO OPEN	3.800E-003
LVMASI457	SDCS CROSSOVER VALVE SI-457 FAILS TO OPEN	3.800E-003
LVMASI615	LOW PRESSURE INJECTION HEADER VALVE SI-615 FAILS TO OPEN	3.800E-003
LVMASI625	LOW PRESSURE INJECTION HEADER VALVE SI-625 FAILS TO OPEN	3.800E-003
LVMASI635	LOW PRESSURE INJECTION HEADER VALVE SI-635 FAILS TO OPEN	3.800E-003
LVMASI645	LOW PRESSURE INJECTION HEADER VALVE SI-645 FAILS TO OPEN	3.800E-003
LVMASI652	SDCS SUCTION VALVE SI-652 FAILS TO OPEN	3.800E-003
LVMASI666	SDCS SUCTION VALVE SI-666 FAILS TO OPEN	3.800E-003
LVMCSI306	SDCS HX B BYPASS VALVE SI-306 FAILS TO OPERATE	4.900E-003
LVMCSI307	SDCS HX A BYPASS VALVE SI-307 FAILS TO OPERATE	4.900E-003
LVMCSI656	SDCS THROTTLE VALVE SI-656 FAILS TO OPERATE	4.900E-003
LVMCSI657	SDCS THROTTLE VALVE SI-657 FAILS TO OPERATE	4.900E-003
LVMOSDCS	OPERATOR FAILS TO INITIATE SHUTDOWN COOLING	1.700E-006
LVMOTHROT	OPERATOR FAILS TO THROTTLE SDCS BYPASS VALVE	1.000E-006
LVMXBYPSS	COMMON CAUSE FAILURE OF SDCS BYPASS VALVES	8.300E-005
LVMXHDR	COMMON CAUSE FAILURE OF LOW PRESSURE INJECTION HDR VLVS	1.540E-005
LVMXRTN	COMMON CAUSE FAILURE OF SDCS CROSSOVER VALVES	8.300E-005
LVMXSDCS1	COMMON CAUSE FAILURE OF SDCS SUCTION VLVS (SI-441 & 440)	8.300E-005
LVMXSDCS2	COMMON CAUSE FAILURE OF SDCS SUCTION VLVS (SI-652 & 666)	8.300E-005
LVMXTHROT	COMMON CAUSE FAILURE OF SDCS THROTTLE VALVES	8.300E-005
LVNOSI424	LPSI PUMP B MANUAL VALVE SI-424 NOT OPEN	1.250E-004
LVNOSI446	LPSI PUMP A MANUAL VALVE SI-446 NOT OPEN	1.250E-004

The SDCS unavailabilities obtained from the fault tree analysis are 5.05E-02 and 3.08E-02 for case 1 and case 3 respectively. These values include failure of the SDCS to actuate and failure to operate during refueling given that it has actuated.

4.4 Mitigating Low Temperature Over-pressure Events

During low RCS temperature (e.g. shutdown cooling) operations the reactor vessel material is more brittle than during normal operations. Because of the brittleness of the vessel material at low temperatures, over-pressurization of the RCS during low temperature operations is of concern. For the design considered in this analysis, relief valves are installed in the SDCS suction lines for plants which use this approach to mitigate low temperature over-pressure events.

The six-inch relief valves shown in Figure 3-2 have enough flow capacity to mitigate low temperature over-pressure events that may occur during shutdown cooling operations. These valves are located downstream of the inside containment SDCS suction valves. Because of their locations, inadvertent closure of the SDCS suction valves by ACI will isolate the relief valves and eliminate protection of the RCS piping if a low temperature over-pressure event occurs.

As shown in Section 4.2, removal of ACI from the SDCS suction valves decreases the unavailability of the SDCS. The number of inadvertent closures of SDCS suction valves also decreases. By removing the ACI from the SDCS suction valves the availability of the relief valves increases.

5.0 RESULTS

In order to determine the impact of removing the autoclosure interlocks (ACI) from the SDCS suction valves for C-E supplied NSSS units, three configurations of the SDCS were analyzed. The first configuration considers SDCS suction valves with ACI function only. The second configuration considers SDCS suction valves with ACI and valve position alarm. The third configuration considers SDCS suction valves with alarm only. The first and second configurations are currently utilized at C-E supplied NSSS units. The third configuration is regarded as a modified or proposed configuration. The analysis examined the net change in interfacing system LOCA frequency and and the net change in SDCS unavailability due to ACI removal.

5.1 Interfacing System LOCA Frequency

The analysis results for interfacing system LOCA frequency are presented below:

SDCS Configuration	Inter LOCA Frequency
Case 1: SDCS suction valves with ACI only	1.28E-7/year
Case 2: SDCS suction valves with ACI and alarm	1.12E-7/year
Case 3: SDCS suction valves with alarm only	1.12E-7/year

The dominant cut sets for SDCS isolation valve unavailability used to determine interfacing system LOCA frequency for the above cases are presented in Tables 5-1 through 5-6 respectively.

For units without an alarm currently installed, the results presented above show that the frequency of interfacing system LOCA via the SDCS suction paths decreases by approximately 13% if ACI is removed and replaced with a valve position alarm. For units which do have valve position alarm installed, there is a slight increase of 0.09% in the frequency of interfacing system LOCA. The values presented above reflect a SDCS with two suction flow paths. Note that these values will decrease by a factor of two if a SDCS with only one suction flow path is considered. The change in interfacing system LOCA frequency will be the same for a SDCS with one or two suction flow paths.

Table 5-1

SDCS Hydraulic Valve with ACI Fault Tree Cut Sets

Fault Tree: WLOA01BX
Mincut Upper Bound 6.140E-006

Cut No.	% Total	% Cut Set	Freq.	Cut Sets *
1	81.4	81.4	5.0E-006	LVDBSI651, LVDOSI651B
2	97.7	16.3	1.0E-006	LVDOSI651B, LVDQSI651
3	98.9	1.2	7.2E-008	FSXPPT105, LVDOSI651A, LVDOSI651B
4	100.0	1.1	6.7E-008	FSXPPA105, LVDOSI651A, LVDOSI651B
5	100.0	.0	2.1E-011	FSXPPC105, LVDOSI651A, LVDOSI651B

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

Table 5-2

SDCS Hydraulic Valve w/o ACI Fault Tree Cut Sets

Fault Tree: WLOA02BX
Mincut Upper Bound 3.377E-007

Cut No.	% Total	% Cut Set	Freq.	Cut Sets *
1	57.9	57.9	2.0E-007	FIAPSI651, LVDBSI651, LVDOSI651B
2	88.3	30.4	1.0E-007	FIAPSI651, LVDOSI651A, LVDOSI651B
3	99.9	11.6	3.9E-008	FIAPSI651, LVDOSI651B, LVDQSI651
4	99.9	.1	2.5E-010	LVDBSI651, LVDOSI651B, LVDOSI651C
5	100.0	.0	1.3E-010	LVDOSI651A, LVDOSI651B, LVDOSI651C
6	100.0	.0	5.0E-011	LVDOSI651B, LVDOSI651C, LVDQSI651

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

Table 5-3

SDCS HYDRAULIC VLV WITH ACI & ALARM FAULT TREE CUT SETS

Fault Tree: WLOA03BX
Mincut Upper Bound 2.404E-007

Cut No.	% Total	% Cut Set	Freq.	Cut Sets *
1	81.3	81.3	2.0E-007	FIAPSI651, LVDBSI651, LVDOSI651B
2	97.6	16.3	3.9E-008	FIAPSI651, LVDOSI651B, LVDQSI651
3	98.8	1.2	2.8E-009	FIAPSI651, FSXPPT105, LVDOSI651A, LVDOSI651B
4	99.9	1.1	2.6E-009	FIAPSI651, FSXPPA105, LVDOSI651A, LVDOSI651B
5	100.0	.1	2.5E-010	LVDBSI651, LVDOSI651B, LVDOSI651C
6	100.0	.0	5.0E-011	LVDOSI651B, LVDOSI651C, LVDQSI651
7	100.0	.0	3.6E-012	FSXPPT105, LVDOSI651A, LVDOSI651B, LVDOSI651C
8	100.0	.0	3.4E-012	FSXPPA105, LVDOSI651A, LVDOSI651B, LVDOSI651C
9	100.0	.0	8.3E-013	FIAPSI651, FSXPPC105, LVDOSI651A, LVDOSI651B
10	100.0	.0	1.1E-015	FSXPPC105, LVDOSI651A, LVDOSI651B, LVDOSI651C

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

Table 5-4

SDCS MOV with ACI Fault Tree Cut Sets

Fault Tree: WLOA01BX
Mincut Upper Bound 2.564E-005

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	95.6	95.6	2.5E-005	LVDOSI652B, LVMBSI652
2	99.5	3.9	1.0E-006	LVDOSI652B, LVDQSI652
3	99.7	.3	7.2E-008	FSXPPT103, LVDOSI652A, LVDOSI652B
4	100.0	.3	6.7E-008	FSXPPA103, LVDOSI652A, LVDOSI652B
5	100.0	.0	2.1E-011	FSXPPC103, LVDOSI652A, LVDOSI652B

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

Table 5-5

SDCS MOV w/o ACI FAULT TREE CUT SETS

Fault Tree: WLOA02BX
Mincut Upper Bound 1.101E-006

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	87.0	87.0	1.0E-006	FIAPSI652, LVDOSI652B, LVMBSI652
2	96.3	9.3	1.0E-007	FIAPSI652, LVDOSI652A, LVDOSI652B
3	99.9	3.6	3.9E-008	FIAPSI652, LVDOSI652B, LVDQSI652
4	100.0	.1	1.2E-009	LVDOSI652B, LVDOSI652C, LVMBSI652
5	100.0	.0	1.3E-010	LVDOSI652A, LVDOSI652B, LVDOSI652C
6	100.0	.0	5.0E-011	LVDOSI652B, LVDOSI652C, LVDQSI652

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

Table 5-6

SDCS MOV WITH ACI & ALARM FAULT TREE CUT SETS

Fault Tree: WLOA03BX
Mincut Upper Bound 1.004E-006

Cut No.	% Total	% Cut Set	Freq.	Cut Sets *
1	95.4	95.4	1.0E-006	FIAPSI651, LVDOSI651B, LVMBSI652
2	99.3	3.9	3.9E-008	FIAPSI651, LVDOSI651B, LVDQSI651
3	99.6	.3	2.8E-009	FIAPSI651, FSXPPT105, LVDOSI651A, LVDOSI651B
4	99.9	.3	2.6E-009	FIAPSI651, FSXPPA105, LVDOSI651A, LVDOSI651B
5	100.0	.1	1.2E-009	LVDOSI651B, LVDOSI651C, LVMBSI652
6	100.0	.0	5.0E-011	LVDOSI651B, LVDOSI651C, LVDQSI651
7	100.0	.0	3.6E-012	FSXPPT105, LVDOSI651A, LVDOSI651B, LVDOSI651C
8	100.0	.0	3.4E-012	FSXPPA105, LVDOSI651A, LVDOSI651B, LVDOSI651C
9	100.0	.0	8.3E-013	FIAPSI651, FSXPPC105, LVDOSI651A, LVDOSI651B
10	100.0	.0	1.1E-015	FSXPPC105, LVDOSI651A, LVDOSI651B, LVDOSI651C

* Refer to Tables 4-1 and 4-2 for cut set component descriptions

5.2 Interfacing System LOCA Frequency Uncertainty and Sensitivity

Because of the importance of interfacing system LOCA, uncertianty and sensitivity analyses were performed to determine the impact of assumptions regarding operator error on the LOCA frequency. The uncertainty analysis involves propagating the uncertainty of each fault included in the models to determine the upper and lower bounds for the frequency of interfacing system LOCA. Monte Carlo sampling of failure rates is performed to determine the uncertainty. The failure rates are assumed to be log-normally distributed. The results of the uncertainty analysis are presented below for each of the three cases discussed in Section 4.0.

		Case 1	Case 2	Case 3
point estimate	-	1.28E-07	1.12E-07	1.12E-07
mean	-	1.04E-07	1.07E-07	9.50E-08
standard deviation	-	3.91E-07	4.74E-07	5.18E-07
lower bound (5%)	-	4.95E-10	1.81E-10	1.58E-10
median	-	1.21E-08	7.50E-09	6.23E-09
upper bound (95%)	-	4.20E-07	4.07E-07	3.35E-07

Three types of operator errors are included in the fault tree models for interfacing system LOCA. To determine the potential impact of our assumptions about the likelihood of these operator errors, a sensitivity analysis was performed. This analysis involves systematically varying base case values for the following types of operator errors:

Code	Description	Base Case Probability
LVDOSI651A	Operator fails to close valve after previous use	5.25E-04
LVDOSI651B	Operator fails to detect valve in wrong position	5.00E-03
LVDOSI651C	Operator fails to respond to alarm	5.00E-05

Base case operator error probabilities were varied by fixed factors of 0.1, 0.2, 0.5, 2.0, 5.0, and 10.0. Upon varying the operator error probabilities, one at a time, the frequency of interfacing system LOCA was requantified and the impact observed. Additionally, the impact was also determined for the very conservative case of all three types of operator errors being varied together. According to Swain and Guttmann (Reference 12), variability of operator performance (or error) is restricted

during normal operating conditions due to the extensive training the operator receives.

For those units which have an alarm currently installed, it is assumed that the alarm is tested at each refueling. A sensitivity analysis was also performed to determine the potential impact of this assumption on the frequency of interfacing system LOCA. Test intervals of 30 days, 6 months, 1 year, 1½ years, 2 years, 5 years, 10 years, and 20 years were used for the sensitivity analysis.

The results of the sensitivity evaluation are presented in Figures 5-1 through 5-5. Figure 5-1 shows the potential impact on the frequency when all three types of operator errors are varied together. (This is considered to be a very conservative case.) This figure shows that the change in frequency is slightly sensitive to variations of operator error probabilities for units with ACI only. For units with ACI and valve position alarm currently installed, and for units with alarm only, the change in frequency is insensitive to the variations of operator error probabilities.

Figures 5-2, 5-3, and 5-4 show the impact on the frequency when one type of operator error is varied while the others remain fixed. The potential impact due to:

- Operator fails to close valve after previous use,
- Operator fails to detect valve in wrong position, or
- Operator fails to respond to alarm

is shown in figure 5-2, 5-3, and 5-4 respectively. Figure 5-3 shows that the change in frequency is slightly sensitive to "operator fails to detect valve in wrong position" for units with ACI only. The other figures show the change in frequencies as being insensitive to variations of one type of operator error only.

For units with ACI and valve position alarm currently installed, the frequency of interfacing system LOCA is relatively insensitive to how often the alarm is tested. Small increase in the frequency is observed when the test interval is 5 years or more. This is shown in Figure 5-5.

5.3 SDCS Unavailability

The fault tree model presented in Appendix A is used to evaluate the unavailability of SDCS with ACI included. Those portions of the model that explicitly included ACI components are deleted and the model is then re-evaluated to determine the unavailability of

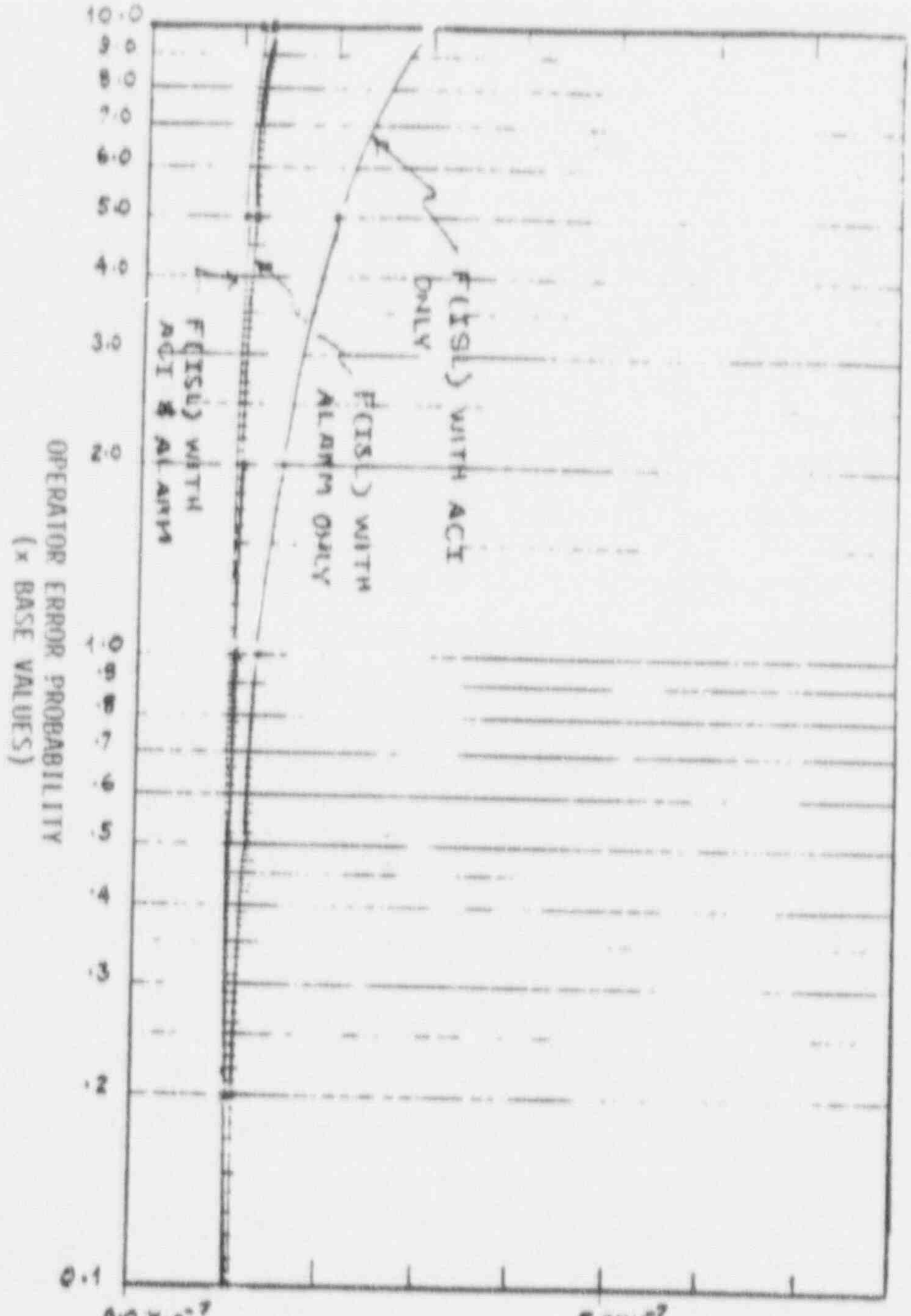


FIGURE 5-1
Impact of Varying All Operator Error Probabilities on Interfacing System LOCA Frequency

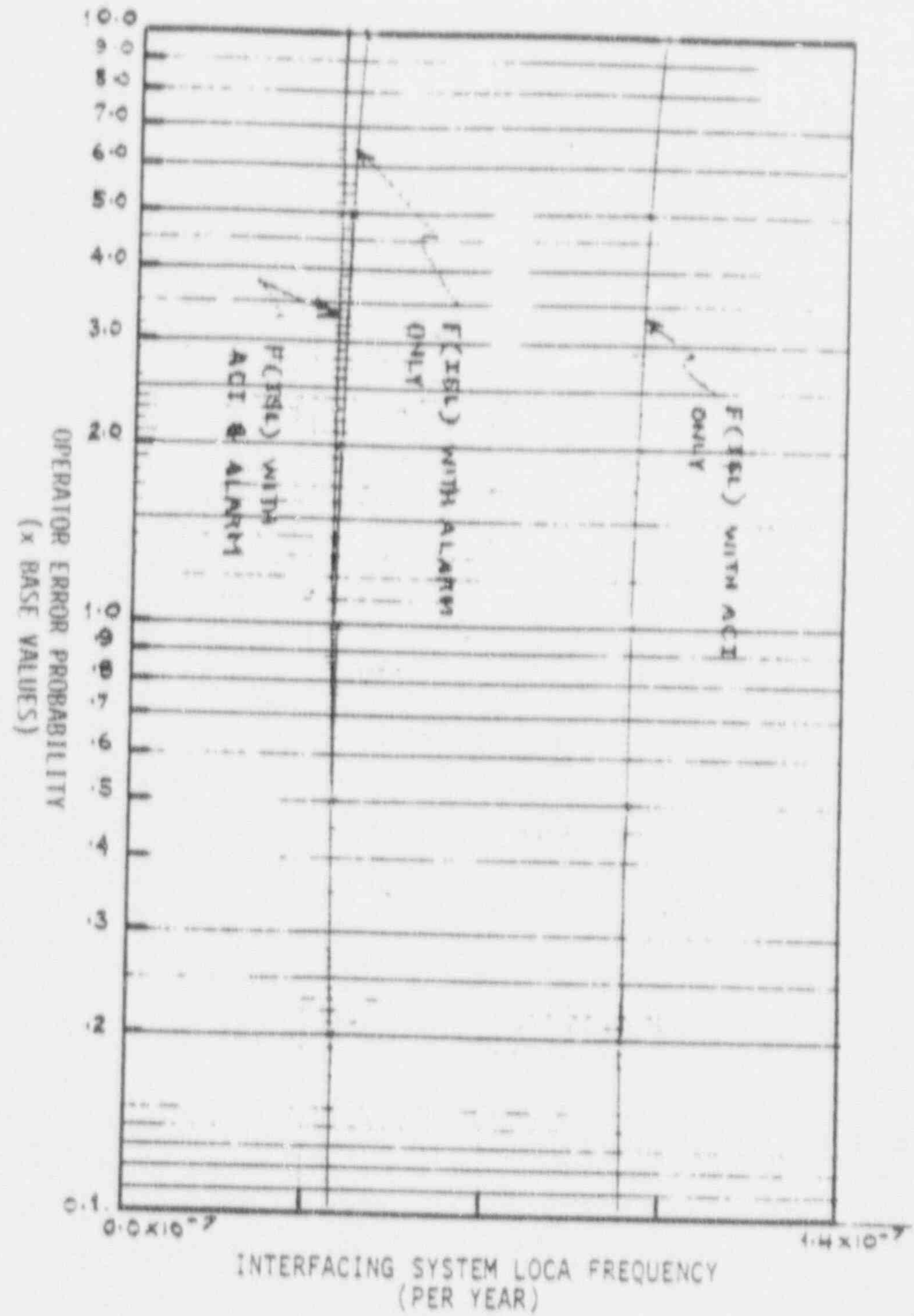


FIGURE 5-2
Impact of Varying Probability of Operator Fails to Close Valve After Previous Use on Interfacing System LOCA Frequency

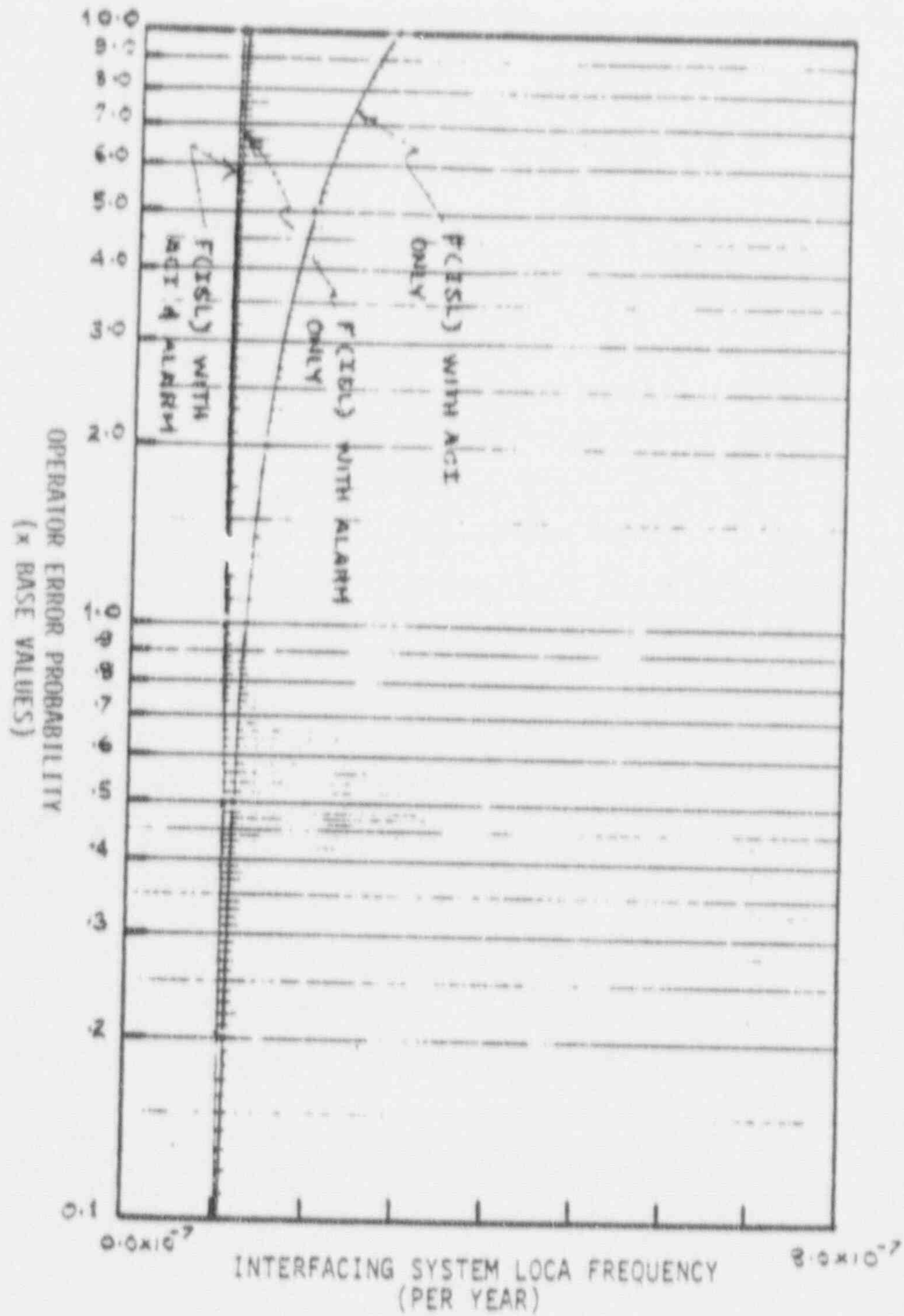


FIGURE 5-3
Impact of Varying Probability of Operator Fails to Detect Valve in Wrong Position on Interfacing System LOCA Frequency

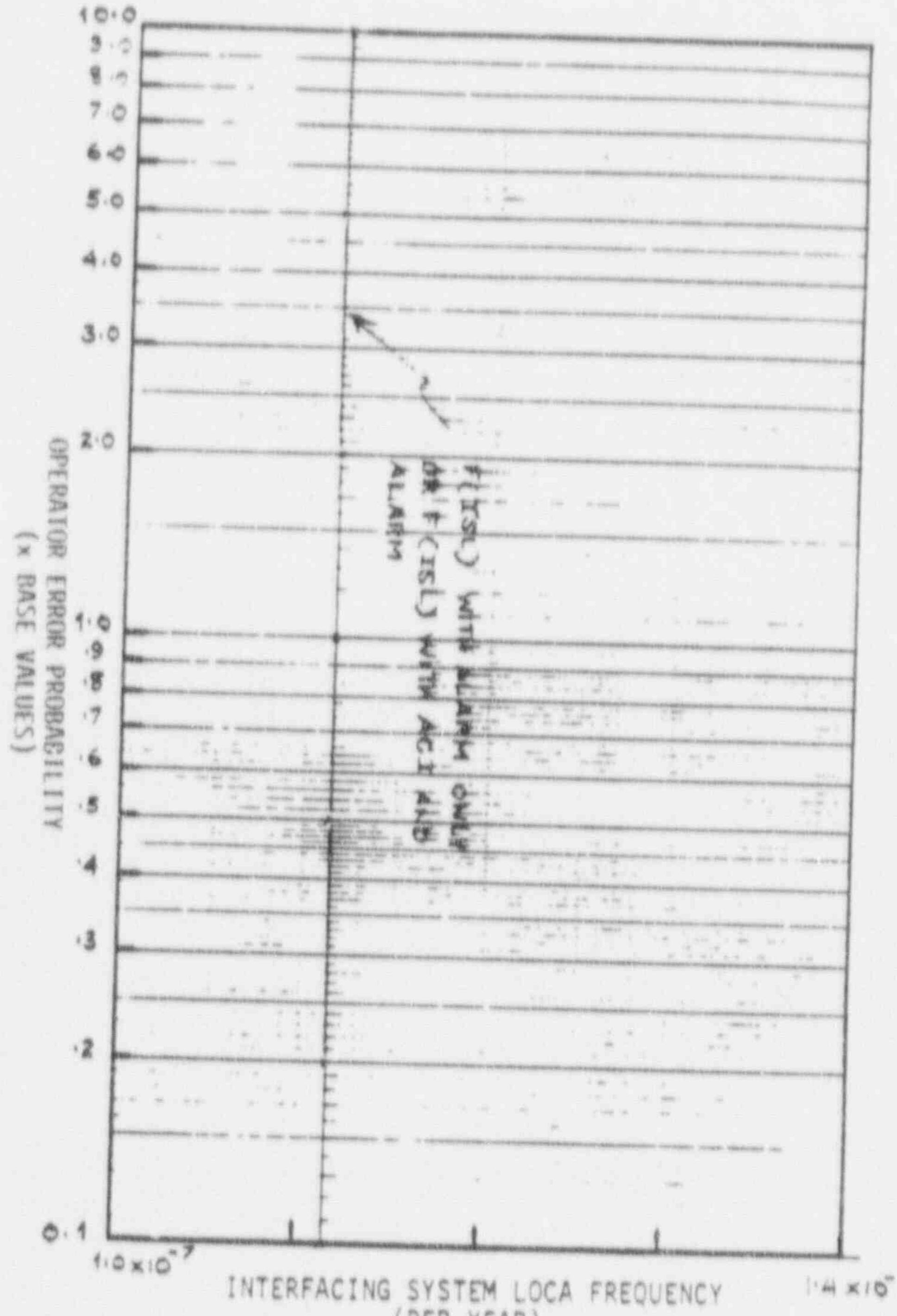


FIGURE 5-4
Impact of Varying Probability of Operator Fails to Respond to Alarm on Interfacing System LOCA Frequency

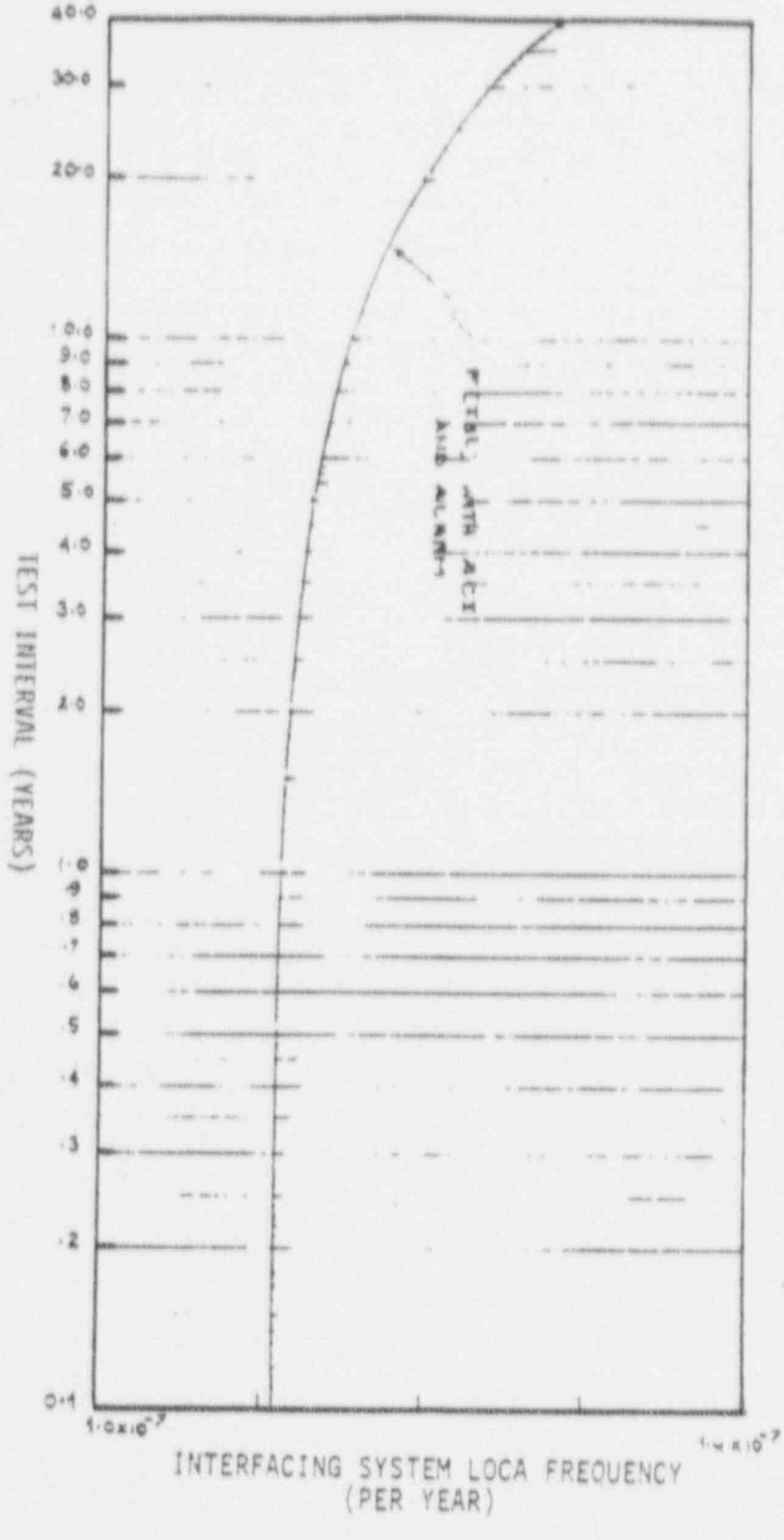


FIGURE 5-5
Impact of Varying Alarm Test Interval
on Interfacing System LOCA Frequency

SDCS with ACI removed. These two configurations of the SDCS are similar to the configurations of cases 1 and 3 considered for interfacing system LOCA.

For each configuration, SDCS unavailability is evaluated for failure to provide shutdown cooling during refueling operations. The refueling period is considered to be six weeks duration. The evaluation includes failure to actuate and failure to operate given that the system has actuated. The results are presented below:

SDCS Configuration	SDCS Unavailability
Case 1: SDCS suction valves with ACI only	5.05E-02
Case 3: SDCS suction valves with ACI removed	3.08E-02

SDCS unavailability changes from 5.05E-02 to 3.07E-02. This change represents 39% decrease in unavailability during refueling operations. The dominant contributors to SDCS unavailabilities are presented in Tables 5-7 and 5-8.

SDCS unavailabilities presented above reflect a SDCS with two suction flow paths. If a SDCS with one suction flow path is considered the unavailability for each configuration is expected to be greater than the above value. However, the percentage decrease in unavailability is expected to be the same as above.

Table 5-7

SDCS W/ACI FAULT TREE CUT SETS
(Case 1: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 5.051E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	13.0	13.0	6.6E-003	LPMKLPSIPA, LPMKLPSIPB
2	17.1	4.1	2.1E-003	FSXHPA105, LPMKLPSIPB
3	21.2	4.1	2.1E-003	FSXHPA104-1, LPMKLPSIPA
4	25.3	4.1	2.1E-003	FSXHPA103-1, LPMKLPSIPB
5	29.4	4.1	2.1E-003	FSXHPA105-1, LPMKLPSIPB
6	33.5	4.1	2.1E-003	FSXHPA106-1, LPMKLPSIPA
7	37.6	4.1	2.1E-003	FSXHPA104, LPMKLPSIPA
8	41.7	4.1	2.1E-003	FSXHPA103, LPMKLPSIPB
9	45.8	4.1	2.1E-003	FSXHPA106, LPMKLPSIPA
10	47.1	1.3	6.6E-004	FSXHPA105-1, FSXHPA106
11	48.4	1.3	6.6E-004	FSXHPA103, FSXHPA104-1
12	49.7	1.3	6.6E-004	FSXHPA105-1, FSXHPA106-1
13	51.0	1.3	6.6E-004	FSXHPA103, FSXHPA106
14	52.3	1.3	6.6E-004	FSXHPA103-1, FSXHPA106-1
15	53.6	1.3	6.6E-004	FSXHPA103-1, FSXHPA104-1
16	54.9	1.3	6.6E-004	FSXHPA103, FSXHPA106-1
17	56.2	1.3	6.6E-004	FSXHPA103-1, FSXHPA106
18	57.5	1.3	6.6E-004	FSXHPA103, FSXHPA104
19	58.8	1.3	6.6E-004	FSXHPA104-1, FSXHPA105
20	60.1	1.3	6.6E-004	FSXHPA105, FSXHPA106
21	61.4	1.3	6.6E-004	FSXHPA104-1, FSXHPA105-1
22	62.7	1.3	6.6E-004	FSXHPA105, FSXHPA106-1
23	64.0	1.3	6.6E-004	FSXHPA104, FSXHPA105
24	65.3	1.3	6.6E-004	FSXHPA103-1, FSXHPA104
25	66.6	1.3	6.6E-004	FSXHPA104, FSXHPA105-1
26	67.3	.8	4.0E-004	LPMKLPSIPA, LVMCSI306
27	68.1	.8	4.0E-004	LPMKLPSIPB, LVMCSI307
28	68.9	.8	4.0E-004	LPMKLPSIPA, LVMCSI656
29	69.7	.8	4.0E-004	LPMKLPSIPB, LVMCSI657
30	70.5	.8	3.9E-004	LPMXLPSIP
31	71.2	.7	3.4E-004	FSXHPT106, LPMKLPSIPA
32	71.8	.7	3.4E-004	FSXHPT104, LPMKLPSIPA
33	72.5	.7	3.4E-004	FSXHPT103, LPMKLPSIPB
34	73.2	.7	3.4E-004	FSXHPT105, LPMKLPSIPB
35	73.8	.6	3.1E-004	LPMKLPSIPB, LVMASI457
36	74.4	.6	3.1E-004	LPMKLPSIPB, LVMASI452
37	75.0	.6	3.1E-004	LPMKLPSIPA, LVMASI441
38	75.6	.6	3.1E-004	LPMKLPSIPA, LVMASI456
39	76.2	.6	3.1E-004	LPMKLPSIPA, LVMASI453
40	76.9	.6	3.1E-004	LPMKLPSIPB, LVMASI440
41	77.5	.6	3.1E-004	LPMKLPSIPB, LVMASI652
42	78.1	.6	3.1E-004	LPMKLPSIPA, LVMASI666
43	78.5	.4	2.2E-004	GHRCHXB, LPMKLPSIPA

Table 5-7 (Cont'd)

SDCS W/ACI FAULT TREE CUT SETS
(Case 1: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 5.051E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
44	78.9	.4	2.2E-004	GHRCHXA, LPMKLPSIPB
45	79.4	.4	2.1E-004	FSXOACI
46	79.7	.3	1.6E-004	LPMKLPSIPB, LPMVLPSIPA
47	80.0	.3	1.6E-004	GHRXSDCS
48	80.2	.2	1.3E-004	FSXHPA103, LVMCSI306
49	80.5	.2	1.3E-004	FSXHPA106, LVMCSI657
50	80.7	.2	1.3E-004	FSXHPA105-1, LVMCSI306
51	81.0	.2	1.3E-004	FSXHPA105, LVMCSI306
52	81.2	.2	1.3E-004	FSXHPA103, LVMCSI656
53	81.5	.2	1.3E-004	FSXHPA106-1, LVMCSI657
54	81.7	.2	1.3E-004	FSXHPA104, LVMCSI657
55	82.0	.2	1.3E-004	FSXHPA104-1, LVMCSI307
56	82.2	.2	1.3E-004	FSXHPA104-1, LVMCSI657
57	82.5	.2	1.3E-004	FSXHPA104, LVMCSI307
58	82.7	.2	1.3E-004	FSXHPA106, LVMCSI307
59	83.0	.2	1.3E-004	FSXHPA105-1, LVMCSI656
60	83.2	.2	1.3E-004	FSXHPA106-1, LVMCSI307
61	83.5	.2	1.3E-004	FSXHPA103-1, LVMCSI656
62	83.7	.2	1.3E-004	FSXHPA103-1, LVMCSI306
63	84.0	.2	1.3E-004	FSXHPA105, LVMCSI656
64	84.2	.2	1.1E-004	FSXHPA103-1, FSXHPT104
65	84.4	.2	1.1E-004	FSXHPA103-1, FSXHPT106
66	84.6	.2	1.1E-004	FSXHPA106-1, FSXHPT103
67	84.8	.2	1.1E-004	FSXHPA103, FSXHPT106
68	85.0	.2	1.1E-004	FSXHPA106, FSXHPT105
69	85.3	.2	1.1E-004	FSXHPA104, FSXHPT105
70	85.5	.2	1.1E-004	FSXHPA106-1, FSXHPT105
71	85.7	.2	1.1E-004	FSXHPA105-1, FSXHPT104
72	85.9	.2	1.1E-004	FSXHPA105, FSXHPT104
73	86.1	.2	1.1E-004	FSXHPA105, FSXHPT106
74	86.3	.2	1.1E-004	FSXHPA105-1, FSXHPT106
75	86.6	.2	1.1E-004	FSXHPA106, FSXHPT103
76	86.8	.2	1.1E-004	FSXHPA104-1, FSXHPT105
77	87.0	.2	1.1E-004	FSXHPA104-1, FSXHPT103
78	87.2	.2	1.1E-004	FSXHPA104, FSXHPT103
79	87.4	.2	1.1E-004	FSXHPA103, FSXHPT104
80	87.6	.2	1.0E-004	LPMJLPSIPA, LPMKLPSIPB
81	87.8	.2	1.0E-004	LPMJLPSIPB, LPMKLPSIPA
82	88.0	.2	1.0E-004	FSXHPA103-1, LVMASI441
83	88.2	.2	1.0E-004	FSXHPA105, LVMASI456
84	88.4	.2	1.0E-004	FSXHPA103, LVMASI456
85	88.6	.2	1.0E-004	FSXHPA106-1, LVMASI440
86	88.8	.2	1.0E-004	FSXHPA105, LVMASI453

Table 5-7 (Cont'd)

SDCS W/ACI FAULT TREE CUT SETS
(Case 1: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 5.051E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
87	89.0	.2	1.0E-004	FSXHPA103, LVMASI453
88	89.2	.2	1.0E-004	FSXHPA103-1, LVMASI453
89	89.4	.2	1.0E-004	FSXHPA103-1, LVMASI456
90	89.6	.2	1.0E-004	FSXHPA105-1, LVMASI453
91	89.7	.2	1.0E-004	FSXHPA105-1, LVMASI456
92	89.9	.2	1.0E-004	FSXHPA103, LVMASI441
93	90.1	.2	1.0E-004	FSXHPA106, LVMASI440
94	90.3	.2	1.0E-004	FSXHPA105-1, LVMASI441
95	90.5	.2	1.0E-004	FSXHPA105, LVMASI441
96	90.7	.2	1.0E-004	FSXHPA106-1, LVMASI452
97	90.9	.2	1.0E-004	FSXHPA104, LVMASI457
98	91.1	.2	1.0E-004	FSXHPA106, LVMASI452
99	91.3	.2	1.0E-004	FSXHPA104-1, LVMASI452
100	91.5	.2	1.0E-004	FSXHPA103, LVMASI666
101	91.7	.2	1.0E-004	FSXHPA104, LVMASI452
102	91.9	.2	1.0E-004	FSXHPA104, LVMASI652
103	92.1	.2	1.0E-004	FSXHPA104-1, LVMASI457
104	92.2	.2	1.0E-004	FSXHPA106-1, LVMASI457
105	92.4	.2	1.0E-004	FSXHPA106-1, LVMASI652
106	92.6	.2	1.0E-004	FSXHPA106, LVMASI457
107	92.8	.2	1.0E-004	FSXHPA104-1, LVMASI652
108	93.0	.2	1.0E-004	FSXHPA105-1, LVMASI666
109	93.2	.2	1.0E-004	FSXHPA105, LVMASI666
110	93.4	.2	1.0E-004	FSXHPA103-1, LVMASI666
111	93.6	.2	1.0E-004	FSXHPA106, LVMASI652
112	93.8	.2	1.0E-004	FSXHPA104-1, LVMASI440
113	94.0	.2	1.0E-004	FSXHPA104, LVMASI440
114	94.2	.2	8.8E-005	FSXXOPI
115	94.3	.2	8.3E-005	LVMXRTN
116	94.5	.2	8.3E-005	LVMXSDCS2
117	94.7	.2	8.3E-005	LVMXSDCS1
118	94.8	.2	8.3E-005	LVMXBYPSS
119	95.0	.2	8.3E-005	LVMXTHROT
120	95.1	.2	8.3E-005	LVDXSDCS3
121	95.3	.2	8.2E-005	GHRVHXA, LPMKLPSIPB
122	95.5	.2	8.1E-005	LPMKLPSIPB, LVDASI651
123	95.6	.2	8.1E-005	LPMKLPSIPA, LVDASI665
124	95.8	.1	6.9E-005	FSXHPA105, GHRCHXB
125	95.9	.1	6.9E-005	FSXHPA105-1, GHRCHXB
126	96.0	.1	6.9E-005	FSXHPA104-1, GHRCHXA
127	96.2	.1	6.9E-005	FSXHPA104, GHRCHXA
128	96.3	.1	6.9E-005	FSXHPA106, GHRCHXA
129	96.4	.1	6.9E-005	FSXHPA103-1, GHRCHXB

Table 5-7 (Cont'd)

SDCS W/ACI FAULT TREE CUT SETS
(Case 1: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 5.051E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
130	96.6	.1	6.9E-005	FSXHPA106-1, GHRCHXA
131	96.7	.1	6.9E-005	FSXHPA103, GHRCHXB
132	96.8	.1	5.1E-005	FSXHPA106, LPMVLPSIPA
133	96.9	.1	5.1E-005	FSXHPA104-1, LPMVLPSIPA
134	97.0	.1	5.1E-005	FSXHPA106-1, LPMVLPSIPA
135	97.1	.1	5.1E-005	FSXHPA104, LPMVLPSIPA
136	97.2	.1	3.2E-005	FSXHPA105-1, LPMJLPSIPB
137	97.3	.1	3.2E-005	FSXHPA104-1, LPMJLPSIPA
138	97.3	.1	3.2E-005	FSXHPA103, LPMJLPSIPB
139	97.4	.1	3.2E-005	FSXHPA105, LPMJLPSIPB
140	97.4	.1	3.2E-005	FSXHPA106-1, LPMJLPSIPA
141	97.5	.1	3.2E-005	FSXHPA106, LPMJLPSIPA
142	97.6	.1	3.2E-005	FSXHPA103-1, LPMJLPSIPB
143	97.6	.1	3.2E-005	FSXHPA104, LPMJLPSIPA
144	97.7	.1	2.8E-005	LBCBLPSIPA, LPMKLPSIPB
145	97.7	.1	2.8E-005	LBCBLPSIPB, LPMKLPSIPA
146	97.8	.1	2.6E-005	FSXHPA106, GHRVHXA
147	97.8	.1	2.6E-005	FSXHPA104-1, GHRVHXA
148	97.9	.1	2.6E-005	FSXHPA104, GHRVHXA
149	97.9	.1	2.6E-005	FSXHPA106-1, GHRVHXA
150	98.0	.1	2.6E-005	FSXHPA106, LVDASI651
151	98.1	.1	2.6E-005	FSXHPA104, LVDASI651
152	98.1	.1	2.6E-005	FSXHPA103, LVDASI665
153	98.2	.1	2.6E-005	FSXHPA104-1, LVDASI651
154	98.2	.1	2.6E-005	FSXHPA105-1, LVDASI665
155	98.3	.1	2.6E-005	FSXHPA105, LVDASI665
156	98.3	.1	2.6E-005	FSXHPA106-1, LVDASI651
157	98.4	.1	2.6E-005	FSXHPA103-1, LVDASI665
158	98.4	.0	2.4E-005	LVMCSI306, LVMCSI307
159	98.4	.0	2.4E-005	LVMCSI307, LVMCSI656
160	98.5	.0	2.4E-005	LVMCSI306, LVMCSI657
161	98.5	.0	2.4E-005	LVMCSI656, LVMCSI657
162	98.6	.0	2.1E-005	FSXHPT103, LVMCSI656
163	98.6	.0	2.1E-005	FSXHPT104, LVMCSI657
164	98.7	.0	2.1E-005	FSXHPT105, LVMCSI306
165	98.7	.0	2.1E-005	FSXHPT106, LVMCSI657
166	98.8	.0	2.1E-005	FSXHPT104, LVMCSI307
167	98.8	.0	2.1E-005	FSXHPT103, LVMCSI306
168	98.8	.0	2.1E-005	FSXHPT105, LVMCSI656
169	98.9	.0	2.1E-005	FSXHPT106, LVMCSI307
170	98.9	.0	2.0E-005	GVNOHXA, LPMKLPSIPB
171	99.0	.0	2.0E-005	GVNOHXB, LPMKLPSIPA
172	99.0	.0	1.9E-005	LVMASI441, LVMCSI657

Table 5-7 (Cont'd)

SDCS W/ACI FAULT TREE CUT SETS
(Case 1: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 5.051E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
173	99.0	.0	1.9E-005	LVMASI453, LVMCSI657
174	99.1	.0	1.9E-005	LVMASI457, LVMCSI656
175	99.1	.0	1.9E-005	LVMASI652, LVMCSI656
176	99.1	.0	1.9E-005	LVMASI452, LVMCSI656
177	99.2	.0	1.9E-005	LVMASI452, LVMCSI306
178	99.2	.0	1.9E-005	LVMASI666, LVMCSI307
179	99.2	.0	1.9E-005	LVMASI441, LVMCSI307
180	99.3	.0	1.9E-005	LVMASI666, LVMCSI657
181	99.3	.0	1.9E-005	LVMASI440, LVMCSI656
182	99.4	.0	1.9E-005	LVMASI456, LVMCSI657
183	99.4	.0	1.9E-005	LVMASI440, LVMCSI306
184	99.4	.0	1.9E-005	LVMASI457, LVMCSI306
185	99.5	.0	1.9E-005	LVMASI652, LVMCSI306
186	99.5	.0	1.9E-005	LVMASI453, LVMCSI307
187	99.5	.0	1.9E-005	LVMASI456, LVMCSI307
188	99.6	.0	1.8E-005	FSXHPT104, FSXHPT105
189	99.6	.0	1.8E-005	FSXHPT103, FSXHPT104
190	99.7	.0	1.8E-005	FSXHPT105, FSXHPT106
191	99.7	.0	1.8E-005	FSXHPT103, FSXHPT106
192	99.7	.0	1.6E-005	FSXHPT104, LVMASI440
193	99.8	.0	1.6E-005	FSXHPT105, LVMASI456
194	99.8	.0	1.6E-005	FSXHPT106, LVMASI440
195	99.8	.0	1.6E-005	FSXHPT104, LVMASI457
196	99.8	.0	1.6E-005	FSXHPT105, LVMASI453
197	99.9	.0	1.6E-005	FSXHPT103, LVMASI441
198	99.9	.0	1.6E-005	FSXHPT104, LVMASI452
199	99.9	.0	1.6E-005	FSXHPT103, LVMASI666
200	100.0	.0	1.6E-005	FSXHPT103, LVMASI453

Table 5-8

SDCS W/O ACI FAULT TREE CUT SETS
(Case 3: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 3.067E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
1	21.4	21.4	6.6E-003	LPMKLPSIPA, LPMKLPSIPB
2	28.1	6.8	2.1E-003	FSXHPA105, LPMKLPSIPB
3	34.9	6.8	2.1E-003	FSXHPA106, LPMKLPSIPA
4	41.6	6.8	2.1E-003	FSXHPA103, LPMKLPSIPB
5	48.4	6.8	2.1E-003	FSXHPA104, LPMKLPSIPA
6	50.5	2.1	6.6E-004	FSXHPA103, FSXHPA104
7	52.7	2.1	6.6E-004	FSXHPA103, FSXHPA106
8	54.8	2.1	6.6E-004	FSXHPA105, FSXHPA106
9	56.9	2.1	6.6E-004	FSXHPA104, FSXHPA105
10	58.2	1.3	4.0E-004	LPMKLPSIPA, LVMCSI306
11	59.5	1.3	4.0E-004	LPMKLPSIPA, LVMCSI656
12	60.8	1.3	4.0E-004	LPMKLPSIPB, LVMCSI657
13	62.1	1.3	4.0E-004	LPMKLPSIPB, LVMCSI307
14	63.4	1.3	3.9E-004	LPMXLPSI[illegible]
15	64.5	1.1	3.4E-004	FSXHPT105, LPMKLPSIPB
16	65.6	1.1	3.4E-004	FSXHPT103, LPMKLPSIPB
17	66.8	1.1	3.4E-004	FSXHPT106, LPMKLPSIPA
18	67.9	1.1	3.4E-004	FSXHPT104, LPMKLPSIPA
19	68.9	1.0	3.1E-004	LPMKLPSIPB, LVMASI652
20	69.9	1.0	3.1E-004	LPMKLPSIPA, LVMASI666
21	70.9	1.0	3.1E-004	LPMKLPSIPA, LVMASI441
22	71.9	1.0	3.1E-004	LPMKLPSIPB, LVMASI440
23	72.9	1.0	3.1E-004	LPMKLPSIPB, LVMASI452
24	73.9	1.0	3.1E-004	LPMKLPSIPB, LVMASI457
25	74.9	1.0	3.1E-004	LPMKLPSIPA, LVMASI456
26	75.9	1.0	3.1E-004	LPMKLPSIPA, LVMASI453
27	[illegible]	.7	2.2E-004	GHRCHXA, LPMKLPSIPB
28	77.3	.7	2.2E-004	GHRCHXB, LPMKLPSIPA
29	77.9	.5	1.6E-004	LPMKLPSIPB, LPMVLPSIPA
30	78.4	.5	1.6E-004	GHRXSDCS
31	78.8	.4	1.3E-004	FSXHPA105, LVMCSI656
32	79.2	.4	1.3E-004	FSXHPA106, LVMCSI657
33	79.6	.4	1.3E-004	FSXHPA1[illegible], LVMCSI306
34	80.0	.4	1.3E-004	FSXHPA[illegible] LVMCSI656
35	80.4	.4	1.3E-004	FSXHPA10[illegible], LVMCSI307
36	80.8	.4	1.3E-004	FSXHPA106, LVMCSI307
37	81.2	.4	1.3E-004	FSXHPA103, LVMCSI306
38	81.6	.4	1.3E-004	FSXHPA104, LVMCSI657
39	82.0	.4	1.1E-004	FSXHPA106, FSXHPT103
40	82.4	.4	1.1E-004	FSXHPA103, FSXHPT106
41	82.7	.4	1.1E-004	FSXHPA105, FSXHPT106
42	83.1	.4	1.1E-004	FSXHPA105, FSXHPT104
43	83.4	.4	1.1E-004	FSXHPA104, FSXHPT105

Table 5-8 (Cont'd)

SDCS W/O ACI FAULT TREE CUT SETS
(Case 3: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 3.067E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
44	83.8	.4	1.1E-004	FSXHPA106, FSXHPT105
45	84.1	.4	1.1E-004	FSXHPA103, FSXHPT104
46	84.5	.4	1.1E-004	FSXHPA104, FSXHPT103
47	84.8	.3	1.0E-004	LPMJLPSIPB, LPMKLPSIPA
48	85.1	.3	1.0E-004	LPMJLPSIPA, LPMKLPSIPB
49	85.5	.3	1.0E-004	FSXHPA104, LVMASI452
50	85.8	.3	1.0E-004	FSXHPA104, LVMASI457
51	86.1	.3	1.0E-004	FSXHPA106, LVMASI457
52	86.4	.3	1.0E-004	FSXHPA103, LVMASI453
53	86.7	.3	1.0E-004	FSXHPA105, LVMASI441
54	87.0	.3	1.0E-004	FSXHPA103, LVMASI456
55	87.4	.3	1.0E-004	FSXHPA103, LVMASI666
56	87.7	.3	1.0E-004	FSXHPA105, LVMASI666
57	88.0	.3	1.0E-004	FSXHPA104, LVMASI652
58	88.3	.3	1.0E-004	FSXHPA103, LVMASI441
59	88.6	.3	1.0E-004	FSXHPA104, LVMASI440
60	89.0	.3	1.0E-004	FSXHPA106, LVMASI452
61	89.3	.3	1.0E-004	FSXHPA106, LVMASI440
62	89.6	.3	1.0E-004	FSXHPA105, LVMASI453
63	89.9	.3	1.0E-004	FSXHPA106, LVMASI652
64	90.2	.3	1.0E-004	FSXHPA105, LVMASI456
65	90.5	.3	8.8E-005	FSXXOPI
66	90.8	.3	8.3E-005	LVMXSDCS1
67	91.0	.3	8.3E-005	LVMXRTN
68	91.3	.3	8.3E-005	LVMXSDCS2
69	91.6	.3	8.3E-005	LVDXSDCS3
70	91.9	.3	8.3E-005	LVMXTHROT
71	92.1	.3	8.3E-005	LVMXBYPSS
72	92.4	.3	8.2E-005	GHRVHXA, LPMKLPSIPB
73	92.7	.3	8.1E-005	LPMKLPSIPA, LVDASI665
74	92.9	.3	8.1E-005	LPMKLPSIPB, LVDASI651
75	93.2	.2	6.9E-005	FSXHPA106, GHRCHXA
76	93.4	.2	6.9E-005	FSXHPA103, GHRCHXB
77	93.6	.2	6.9E-005	FSXHPA104, GHRCHXA
78	93.8	.2	6.9E-005	FSXHPA105, GHRCHXB
79	94.0	.2	5.1E-005	FSXHPA106, LPMVLPSIPA
80	94.2	.2	5.1E-005	FSXHPA104, LPMVLPSIPA
81	94.3	.1	3.2E-005	FSXHPA105, LPMJLPSIPB
82	94.4	.1	3.2E-005	FSXHPA106, LPMJLPSIPA
83	94.5	.1	3.2E-005	FSXHPA104, LPMJLPSIPA
84	94.6	.1	3.2E-005	FSXHPA103, LPMJLPSIPB
85	94.7	.1	2.8E-005	LBCBLPSIPA, LPMKLPSIPB
86	94.8	.1	2.8E-005	LBCBLPSIPB, LPMKLPSIPA

Table 5-8 (Cont'd)

SDCS W/O ACI FAULT TREE CUT SETS
(Case 3: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 3.067E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
87	94.8	.1	2.6E-005	FSXHPA104, GHRVHXA
88	94.9	.1	2.6E-005	FSXHPA106, GHRVHXA
89	95.0	.1	2.6E-005	FSXHPA104, LVDASI651
90	95.1	.1	2.6E-005	FSXHPA103, LVDASI665
91	95.2	.1	2.6E-005	FSXHPA106, LVDASI651
92	95.3	.1	2.6E-005	FSXHPA105, LVDASI665
93	95.3	.1	2.4E-005	LVMCSI307, LVMCSI656
94	95.4	.1	2.4E-005	LVMCSI656, LVMCSI657
95	95.5	.1	2.4E-005	LVMCSI306, LVMCSI307
96	95.6	.1	2.4E-005	LVMCSI306, LVMCSI657
97	95.6	.1	2.1E-005	FSXHPT106, LVMCSI307
98	95.7	.1	2.1E-005	FSXHPT106, LVMCSI657
99	95.8	.1	2.1E-005	FSXHPT105, LVMCSI656
100	95.8	.1	2.1E-005	FSXHPT104, LVMCSI307
101	95.9	.1	2.1E-005	FSXHPT105, LVMCSI306
102	96.0	.1	2.1E-005	FSXHPT104, LVMCSI657
103	96.1	.1	2.1E-005	FSXHPT103, LVMCSI306
104	96.1	.1	2.1E-005	FSXHPT103, LVMCSI656
105	96.2	.1	2.0E-005	GVNOHXA, LPMKLPSIPB
106	96.3	.1	2.0E-005	GVNOHXB, LPMKLPSIPA
107	96.3	.1	1.9E-005	LVMASI440, LVMCSI306
108	96.4	.1	1.9E-005	LVMASI652, LVMCSI656
109	96.4	.1	1.9E-005	LVMASI456, LVMCSI657
110	96.5	.1	1.9E-005	LVMASI452, LVMCSI306
111	96.6	.1	1.9E-005	LVMASI452, LVMCSI656
112	96.6	.1	1.9E-005	LVMASI440, LVMCSI656
113	96.7	.1	1.9E-005	LVMASI457, LVMCSI306
114	96.7	.1	1.9E-005	LVMASI457, LVMCSI656
115	96.8	.1	1.9E-005	LVMASI441, LVMCSI657
116	96.9	.1	1.9E-005	LVMASI453, LVMCSI307
117	96.9	.1	1.9E-005	LVMASI453, LVMCSI657
118	97.0	.1	1.9E-005	LVMASI441, LVMCSI307
119	97.0	.1	1.9E-005	LVMASI666, LVMCSI657
120	97.1	.1	1.9E-005	LVMASI456, LVMCSI307
121	97.2	.1	1.9E-005	LVMASI652, LVMCSI306
122	97.2	.1	1.9E-005	LVMASI666, LVMCSI307
123	97.3	.1	1.8E-005	FSXHPT104, FSXHPT105
124	97.3	.1	1.8E-005	FSXHPT105, FSXHPT106
125	97.4	.1	1.8E-005	FSXHPT103, FSXHPT106
126	97.5	.1	1.8E-005	FSXHPT103, FSXHPT104
127	97.5	.1	1.6E-005	FSXHPT104, LVMASI652
128	97.6	.1	1.6E-005	FSXHPT106, LVMASI452
129	97.6	.1	1.6E-005	FSXHPT104, LVMASI440

Table 5-8 (Cont'd)

SDCS W/O ACI FAULT TREE CUT SETS
(Case 3: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 3.067E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
130	97.7	.1	1.6E-005	FSXHPT105, LVMASI666
131	97.7	.1	1.6E-005	FSXHPT106, LVMASI440
132	97.8	.1	1.6E-005	FSXHPT105, LVMASI441
133	97.8	.1	1.6E-005	FSXHPT104, LVMASI452
134	97.9	.1	1.6E-005	FSXHPT103, LVMASI441
135	97.9	.1	1.6E-005	FSXHPT103, LVMASI666
136	98.0	.1	1.6E-005	FSXHPT103, LVMASI453
137	98.0	.1	1.6E-005	FSXHPT105, LVMASI456
138	98.1	.1	1.6E-005	FSXHPT106, LVMASI457
139	98.1	.1	1.6E-005	FSXHPT105, LVMASI453
140	98.2	.1	1.6E-005	FSXHPT104, LVMASI457
141	98.2	.1	1.6E-005	FSXHPT106, LVMASI652
142	98.3	.1	1.6E-005	FSXHPT103, LVMASI456
143	98.4	.1	1.5E-005	LVMXHDR
144	98.4	.1	1.5E-005	HVMXMINI
145	98.4	.0	1.4E-005	LVMASI452, LVMASI666
146	98.5	.0	1.4E-005	LVMASI441, LVMASI457
147	98.5	.0	1.4E-005	LVMASI456, LVMASI652
148	98.6	.0	1.4E-005	LVMASI453, LVMASI457
149	98.6	.0	1.4E-005	LVMASI456, LVMASI457
150	98.7	.0	1.4E-005	LVMASI440, LVMASI666
151	98.7	.0	1.4E-005	LVMASI441, LVMASI452
152	98.8	.0	1.4E-005	LVMASI440, LVMASI441
153	98.8	.0	1.4E-005	LVMASI440, LVMASI456
154	98.9	.0	1.4E-005	LVMASI452, LVMASI456
155	98.9	.0	1.4E-005	LVMASI453, LVMASI652
156	99.0	.0	1.4E-005	LVMASI440, LVMASI453
157	99.0	.0	1.4E-005	LVMASI452, LVMASI453
158	99.1	.0	1.4E-005	LVMASI652, LVMASI666
159	99.1	.0	1.4E-005	LVMASI457, LVMASI666
160	99.2	.0	1.4E-005	LVMASI441, LVMASI652
161	99.2	.0	1.3E-005	GHRCHXB, LVMCSI307
162	99.2	.0	1.3E-005	GHRCHXB, LVMCSI657
163	99.3	.0	1.3E-005	GHRCHXA, LVMCSI656
164	99.3	.0	1.3E-005	GHRCHXA, LVMCSI306
165	99.4	.0	1.1E-005	FSXHPT104, GHRCHXA
166	99.4	.0	1.1E-005	FSXHPT106, GHRCHXA
167	99.4	.0	1.1E-005	FSXHPT103, GHRCHXB
168	99.5	.0	1.1E-005	FSXHPT105, GHRCHXB
169	99.5	.0	1.1E-005	LPMKLPSIPA, LVCASI434
170	99.5	.0	1.1E-005	LPMKLPSIPB, LVCASI433
171	99.6	.0	1.0E-005	GHRCHXB, LVMASI457
172	99.6	.0	1.0E-005	GHRCHXA, LVMASI666

Table 5-8 (Cont'd)

SDCS W/O ACI FAULT TREE CUT SETS
(Case 3: During Refueling)

Fault Tree: WLOB01BX
Mincut Upper Bound 3.067E-002

Cut No.	% Total	% Cut Set	Freq.	Cut Sets
173	99.6	.0	1.0E-005	GHRCHXA, LVMASI441
174	99.7	.0	1.0E-005	GHRCHXA, LVMASI456
175	99.7	.0	1.0E-005	GHRCHXA, LVMASI453
176	99.7	.0	1.0E-005	GHRCHXB, LVMASI440
177	99.8	.0	1.0E-005	GHRCHXB, LVMASI452
178	99.8	.0	1.0E-005	GHRCHXB, LVMASI652
179	99.8	.0	1.0E-005	LPMKLPSIPA, LVNOSI424
180	99.9	.0	1.0E-005	LPMKLPSIPB, LVNOSI446
181	99.9	.0	1.0E-005	LPMVLPSIPA, LVMCSI306
182	99.9	.0	1.0E-005	LPMVLPSIPA, LVMCSI656
183	100.0	.0	8.7E-006	FSXHPA105, LBCBLPSIPB

6.0 CONCLUSIONS

The removal of autoclosure interlocks from the shutdown cooling system and replacement with a valve position alarm or modification of the existing alarm was evaluated to determine the impact of such a change on Interfacing System LOCA frequency, SDCS unavailability, and low temperature over-pressure event mitigation.

The evaluation presented in this report assesses the impact of removing ACI from two existing configurations of SDCS suction valves at C-E supplied NSSS units. The evaluation addressed the two existing configurations in addition to a proposed configuration of the SDCS suction valves. The configurations addressed in this report are as follows:

- Case 1 - SDCS suction valves with ACI only,
- Case 2 - SDCS suction valves with ACI and alarm, and
- Case 3 - SDCS suction valves with alarm only.

The evaluation shows that for those units with ACI only, the removal of the ACI from the SDCS and replacement with a valve position alarm will reduce the frequency of interfacing system LOCA by approximately 13%. The evaluation also shows that for those units with ACI and valve position alarm, the removal of ACI and incorporation of certain changes to the existing alarm will result in negligible increase (0.09%) in the frequency of interfacing system LOCA.

These results are not particularly sensitive to assumptions made regarding opertor error porbabilities. Varying all types of operator error probabilities together results in only a slight increase in the frequency of interfacing system LOCA for units with ACI only. The frequency for the other type of units remain virtually constant. Of the three types of operator error evaluated, only "operator fails to detect valve in wrong position" shows any significant impact. When the probabilities for the other types of operator error are varied individually there is no noticable change in Interfacing System LOCA frequency.

The frequency of Interfacing System LOCA tends to increase as longer test intervals for the alarm are assumed. Noticable changes are observed when test intervals of 5 years or more are assumed. Therefore, since the proposed configuration includes an alarm that is tested at each refueling, units with ACI and alarm will realize a reduction in their interfacing system LOCA frequency if the existing alarm is tested less frequent than every

refueling. A test interval of every refueling is assumed in all analyses, except the sensitivity analyses.

A review of the recent interfacing system LOCA precursor event that occurred at Biblis-A PWR shows that the operator tried to close a mispositioned pressure isolation valve that should have been closed prior to startup. The operator tried to manipulate the pressure on the mispositioned valve by opening a second valve. In doing so, a path from the RCS to the atmosphere was established. As a result, a small amount of release occurred for a short time.

For all SDCS of C-E supplied NSSS units, the pressure isolation valves (SDCS suction valves) cannot be opened by the operator while RCS pressure is above shutdown cooling entry conditions. The open permissive interlocks prevent such actions by the operator. These interlocks are not the subject of this analysis. They will remain as an integral part of the SDCS suction valves. Therefore, the sequence of events involving operator actions that occurred at Biblis-A is not expected to occur in the SDCS of any C-E supplied NSSS unit.

The evaluation shows that by removing ACI and replacing it with a valve position alarm, SDCS unavailability will decrease by 39% during refueling operations. Therefore, removal of ACI from the SDCS will reduce the number of spurious closures of suction valves and thus increase the availability of SDCS. By increasing SDCS availability, the availability of the relief valves to mitigate low temperature over-pressure events also increases.

The results of the evaluation show that removal of ACI will decrease interfacing system LOCA frequency via SDCS suction lines at units with ACI only and will increase the frequency by an extremely small amount at units with ACI and alarm. The results also show that removal of ACI will increase SDCS reliability, and increase the availability of the low temperature over-pressure relief valves. Therefore, removal of ACI and replacement with a valve position alarm or modifications to existing alarm will result in safety improvements at plants with the configurations considered in this analysis.

7.0 REFERENCES

1. G. Vine, et al, "Residual Heat Removal Experience Review and Safety Analysis - Pressurized Water Reactors", NSAC-52, January 1983.

2. U.S. Nuclear Regulatory Commission, Office for Analysis and Evaluation of Operational Data, "Decay Heat Removal Problems at U.S. Pressurized Water Reactors", Case Study Report AEOD/C503, December 1985.

3. D.R. Gallup, et al, "Potential Benefits Obtained by Requiring Safety-Grade Cold Shutdown Systems", NUREG/CR-4335, November 1985.

4. Pacific Gas and Electric Company Letter, James D. Shiffer to NRC, "Diablo Canyon Units 1 and 2 Removal of RHR System Autoclosure Interlock Function", DCL-87-187, August 4, 1987.

5. I.A. Papazoglou and R.A. Buri, "Probabilistic Safety Analysis Procedures Guide", NUREG/CR-2815, January 1984.

6. "PRA Procedures Guide", NUREG/CR-2300, April 1982.

7. K.D. Russell and M.B. Sattison, "Integrated Reliability and Risk Analysis System (IRRAS) User's Guide - Version 2.0 (Draft)," NUREG/CR-5111, March 1988.

8. "Reactor Safety Study, An Assessment of Accident Risks in U.S. Commerical Nuclear Power Plants", WASH-1400/NUREG-75/014, October 1975.

9. "Advanced Light Water Reactor Requirements Document, Appendix A: PRA Key Assumptions and Groundrules", (Draft), July 1987.

10. M.T. Drouin, et al, "Analysis of Core Damage Frequency from Internal Events: Methodology Guidelines", Volume 1, NUREG/CR-4550, September 1987.

11. "IEEE Guide to the Collection and Presentation of Electrical, Electronic, and Sensing Component Reliability for Nuclear Power Generating Stations", IEEE-STD500-1984.

12. A.D. Swain and H.E. Guttmann, "Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications", NUREG/CR-1278, August 1983.

13. "RPS/ESFAS Extended Test Interval Evaluation", CEN-327, May 1986.

14. "NRC Looks for Generic Implications of HPIS Back flow at AP&L's ANO-1", INSIDE N.R.C., February 13, 1989.

15. "German Officals Defend Biblis Accident Precursor Handling", NUCLEONICS WEEK, December 8, 1988.

The following drawings were used to develop the fault tree model for SDCS:

1. Louisiana Power & Light Company Waterford S.E.S. Unit No. 3 - Flow Diagram, Safety Injection System, LOU-1564-G-167, sheet 1 of 2, Rev. 27.

2. Louisiana Power & Light Company Waterford S.E.S. Unit No. 3 - Flow Diagram, Safety Injection System, LOU-1564-G-167, sheet 2 of 2, Rev. 23.

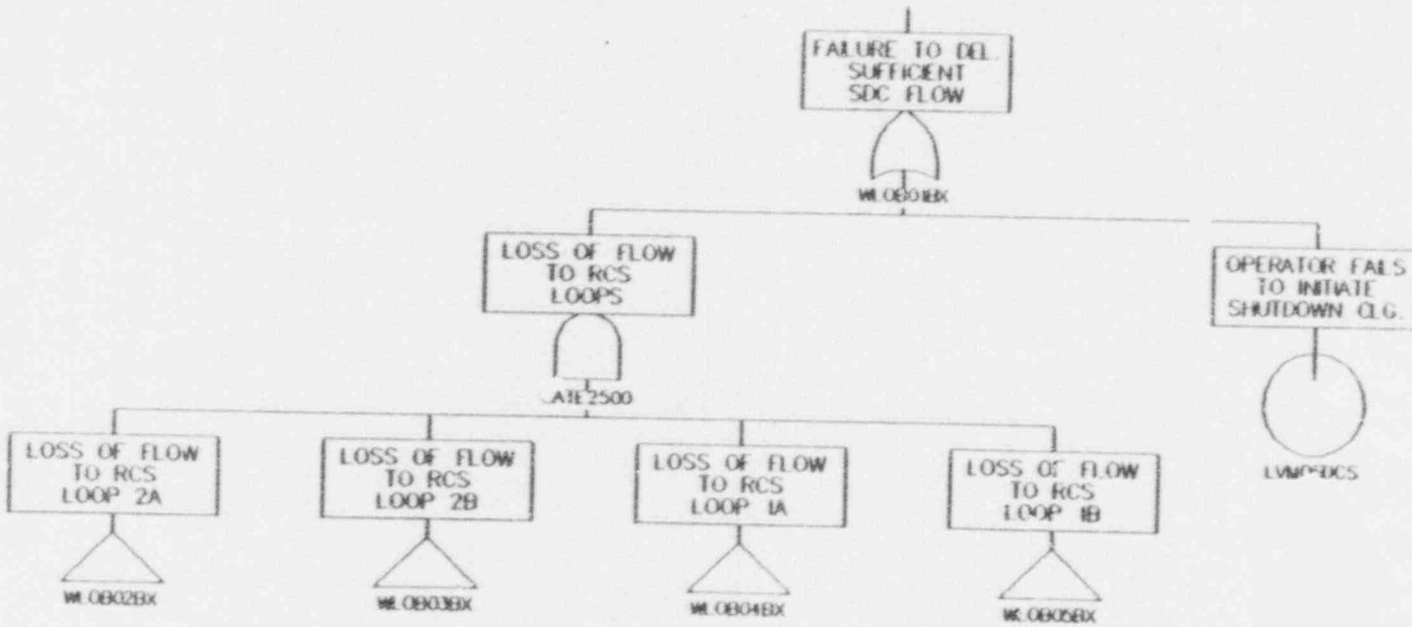
3. Combustion Engineering, Pressurizer Pressure (Low Range) CH. P-1103 & 1105 Interconnection Diagram, D-13172-416113, Rev. 05.

4. Combustion Engineering, Pressurizer Pressure (Low Range) CH. P-1104 & 1106 Interconnection Diagram, D-13172-416113, Rev. 05.

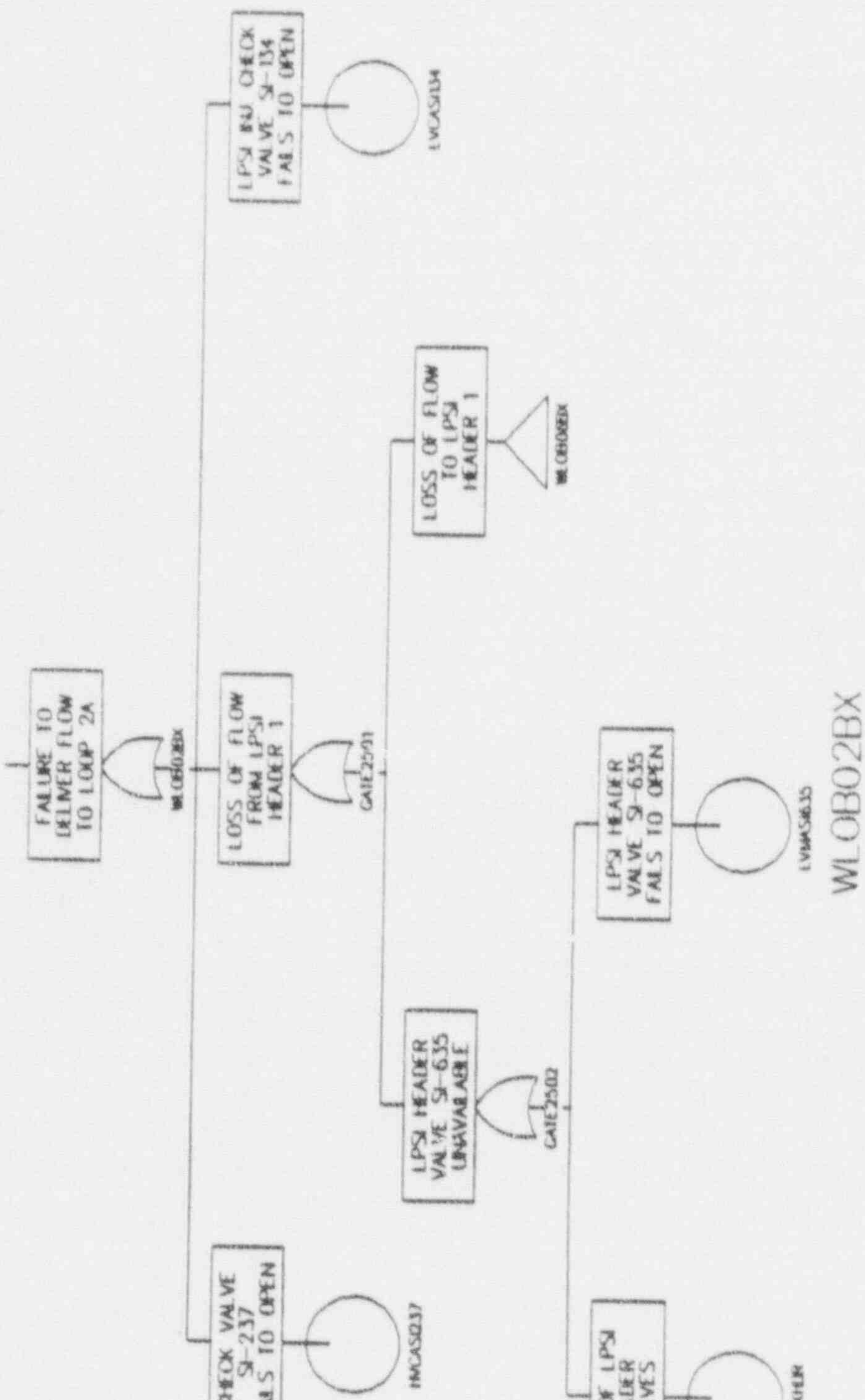
5. Elementary Wiring Diagram - Motor Operated Valves, B-13172-414-350, sheet 4 of 10, Rev. 01.

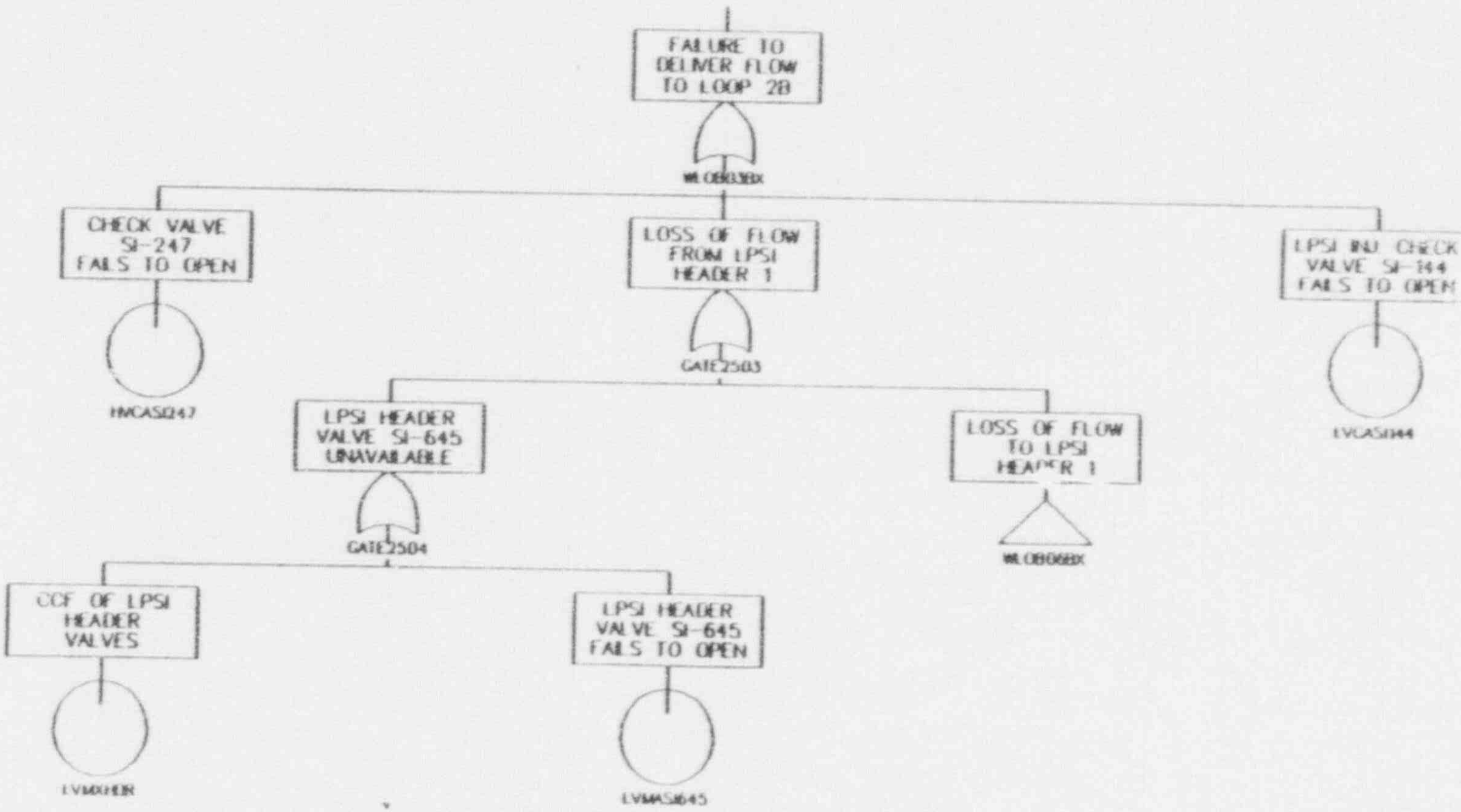
APPENDIX A

Fault Tree Model for SDCS

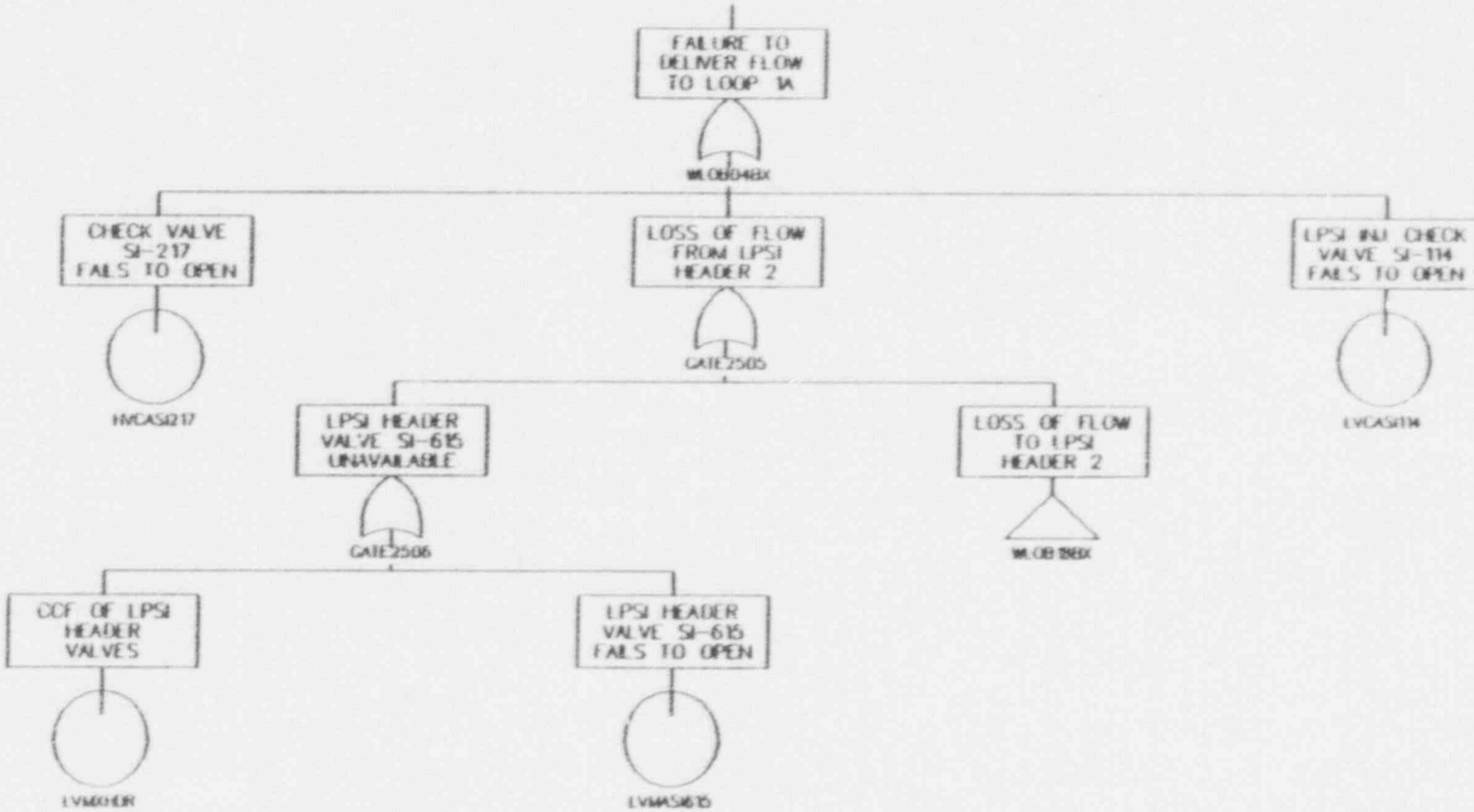

FAILURE TO DEL. SUFFICIENT SDC FLOW
WLOB01BX
LOSS OF FLOW TO RCS LOOPS
ATE2500
OPERATOR FAILS TO INITIATE SHUTDOWN CLG.
LOSS OF FLOW TO RCS LOOP 2A
WLOB02BX
LOSS OF FLOW TO RCS LOOP 2B
WLOB03BX
LOSS OF FLOW TO RCS LOOP 1A
WLOB04BX
LOSS OF FLOW TO RCS LOOP 1B
WLOB05BX

WLOB01BX

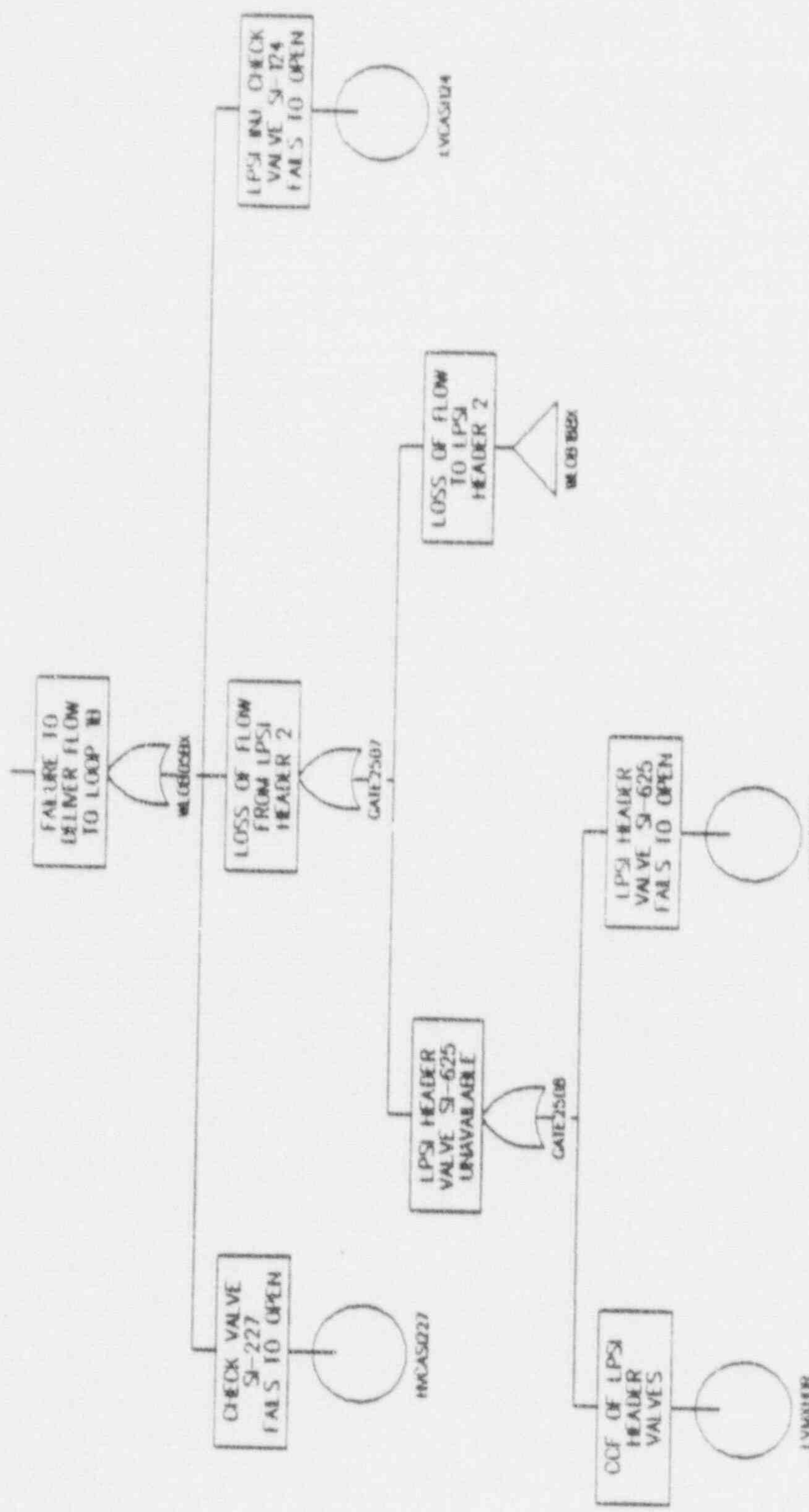

FAILURE TO DELIVER FLOW TO LOOP 2A
WLOB02BX
LOSS OF FLOW FROM LPSI HEADER 1
GATE2501
LPSI INJ CHECK VALVE SI-134 FAILS TO OPEN
LOSS OF FLOW TO LPSI HEADER 1
CHECK VALVE SI-237 FAILS TO OPEN
LPSI HEADER VALVE SI-635 UNAVAILABLE
GATE2502
LPSI HEADER VALVE SI-635 FAILS TO OPEN
CCF OF LPSI HEADER VALVES
WLOB02BX


FAILURE TO DELIVER FLOW TO LOOP 2B
WLOB03BX
CHECK VALVE SI-247 FAILS TO OPEN
LOSS OF FLOW FROM LPSI HEADER 1
LPSI INJ. CHECK VALVE SI-144 FAILS TO OPEN
GATE2503
LPSI HEADER VALVE SI-645 UNAVAILABLE
LOSS OF FLOW TO LPSI HEADER 1
GATE2504
WLOB06BX
CCF OF LPSI HEADER VALVES
LPSI HEADER VALVE SI-645 FAILS TO OPEN

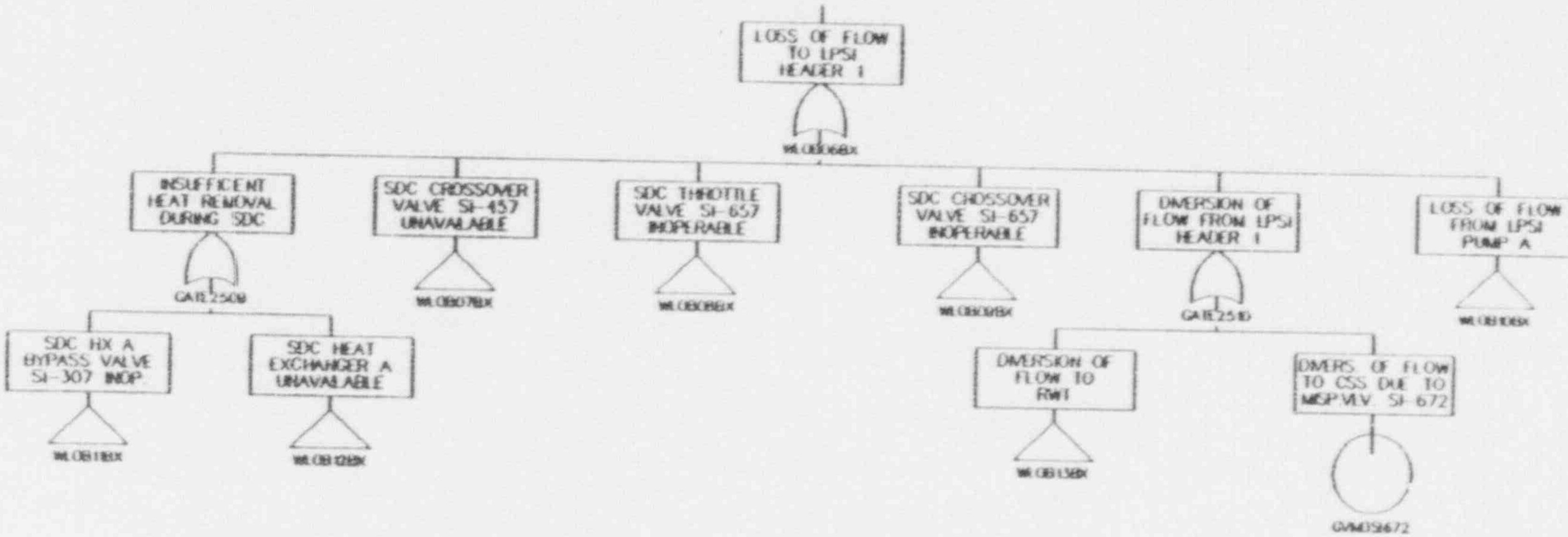
WLOB03BX


FAILURE TO DELIVER FLOW TO LOOP 1A
WLOB04BX
CHECK VALVE SI-217 FAILS TO OPEN
HVCASI217
LOSS OF FLOW FROM LPSI HEADER 2
GATE2505
LPSI INJ CHECK VALVE SI-114 FAILS TO OPEN
LVCASI114
LPSI HEADER VALVE SI-615 UNAVAILABLE
GATE2506
LOSS OF FLOW TO LPSI HEADER 2
CCF OF LPSI HEADER VALVES
LVMXHDR
LPSI HEADER VALVE SI-615 FAILS TO OPEN
LVMASI615

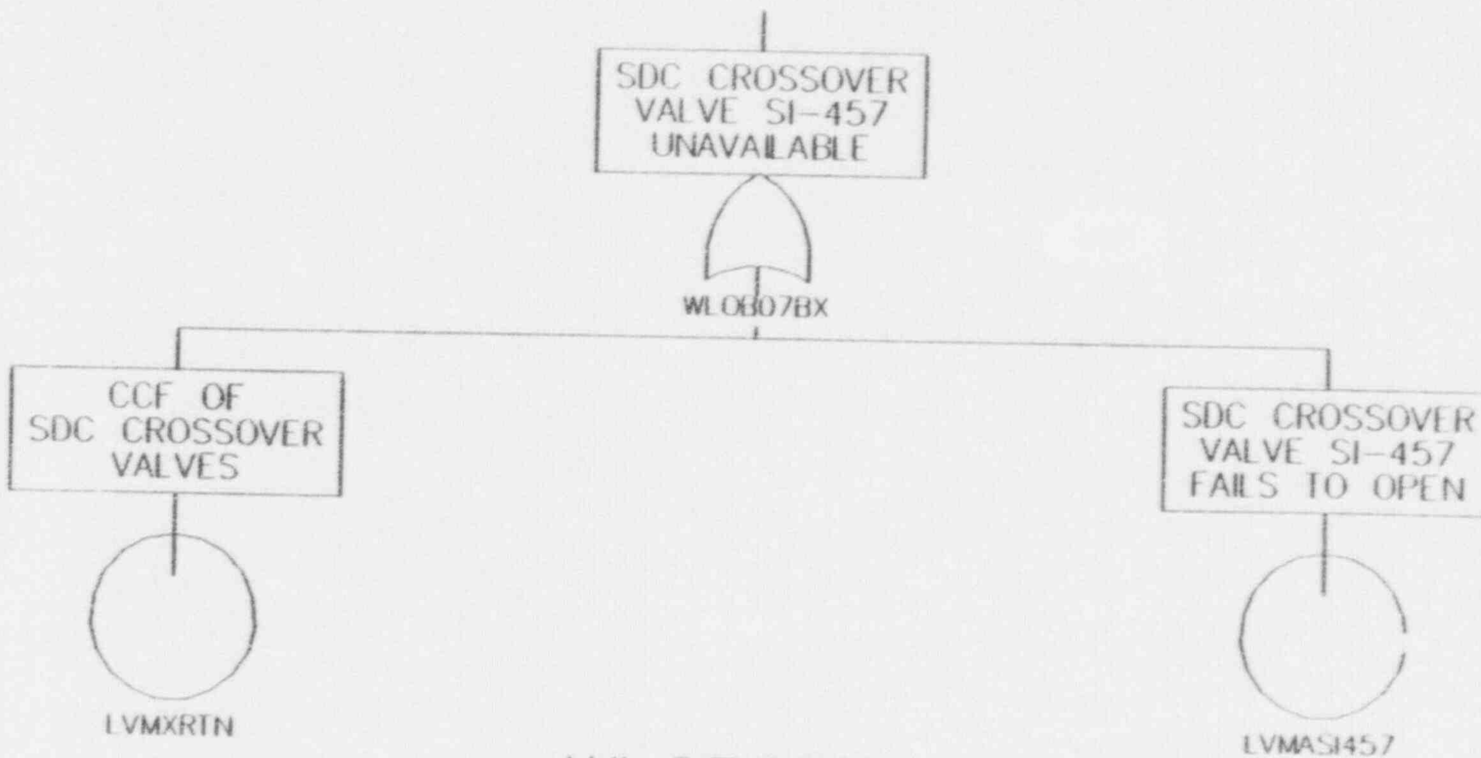
WLOB04BX


FAILURE TO DELIVER FLOW TO LOOP 1B
WLOB05BX
CHECK VALVE SI-227 FAILS TO OPEN
HVCASI227
LOSS OF FLOW FROM LPSI HEADER 2
GATE2507
LPSI INJ CHECK VALVE SI-124 FAILS TO OPEN
LVCASI124
LPSI HEADER VALVE SI-625 UNAVAILABLE
GATE2508
LOSS OF FLOW TO LPSI HEADER 2
WLOB1B2X
CCF OF LPSI HEADER VALVES
LVMXHDR
LPSI HEADER VALVE SI-625 FAILS TO OPEN
LVMASI625

WLOB05BX

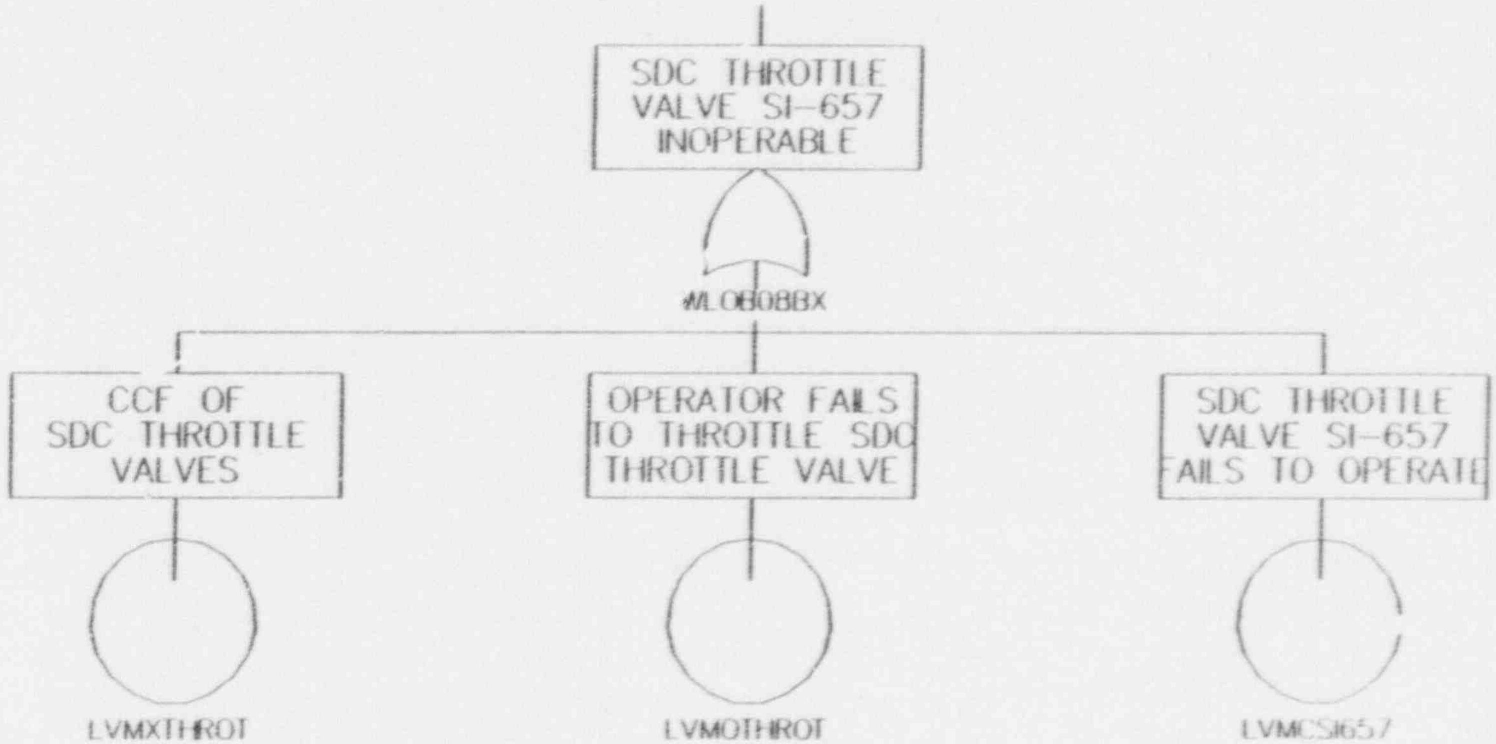

LOSS OF FLOW TO LPSI HEADER 1
WLOB06BX
INSUFFICENT HEAT REMOVAL DURING SDC
GATE2509
SDC HX A BYPASS VALVE SI-307 INOP.
WLOB11BX
SDC HEAT EXCHANGER A UNAVAILABLE
WLOB12BX
SDC CROSSOVER VALVE SI-457 UNAVAILABLE
WLOB07BX
SDC THROTTLE VALVE SI-657 INOPERABLE
WLOB08BX
SDC CROSSOVER VALVE SI-657 INOPERABLE
WLOB09BX
DIVERSION OF FLOW FROM LPSI HEADER 1
GATE2510
DIVERSION OF FLOW TO RWT
WLOB13BX
DIVERS. OF FLOW TO CSS DUE TO MISP.VLV. SI-672
GVMOSI672
LOSS OF FLOW FROM LPSI PUMP A
WLOB10BX

WLOB06BX

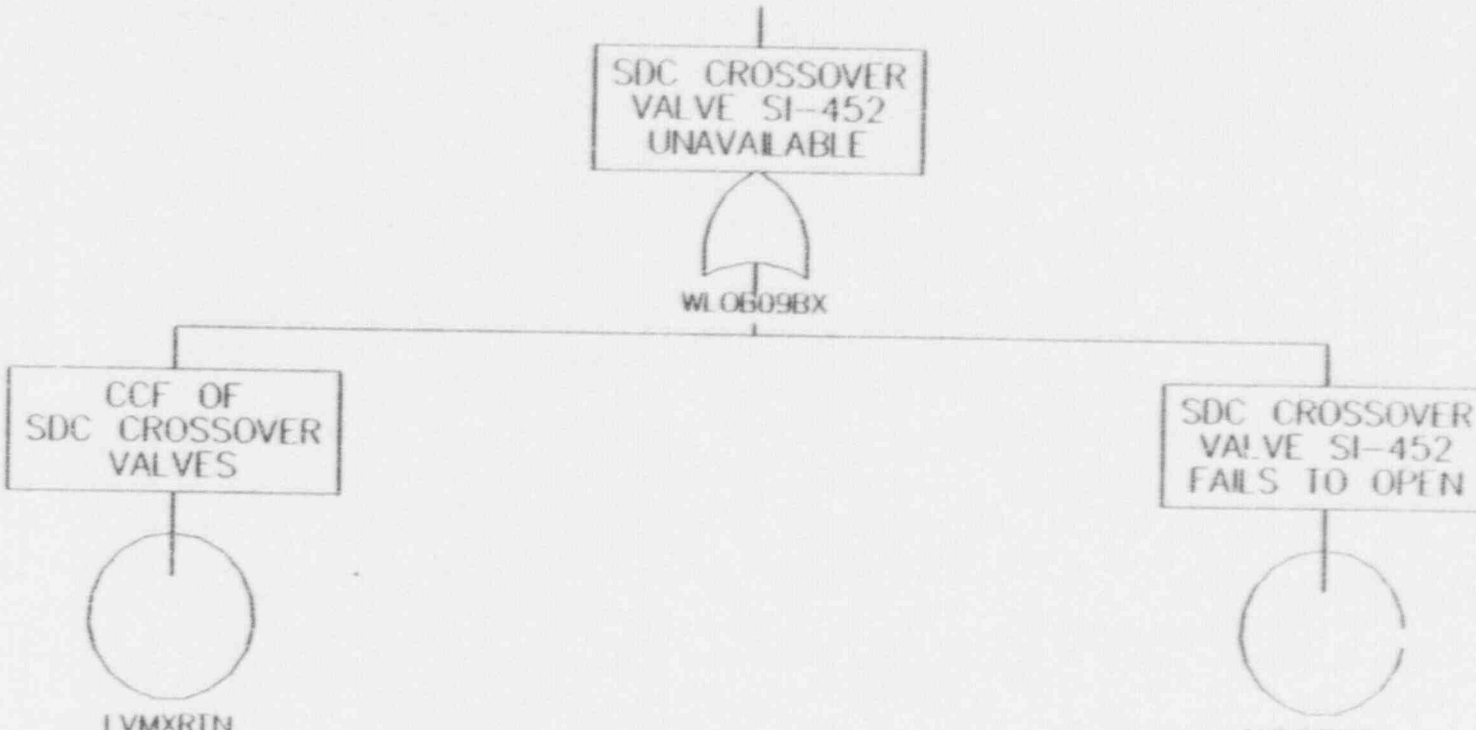


SDC CROSSOVER VALVE SI-457 UNAVAILABLE
WLOB07BX
CCF OF SDC CROSSOVER VALVES
SDC CROSSOVER VALVE SI-457 FAILS TO OPEN
LVMXRTN
LVMASI457

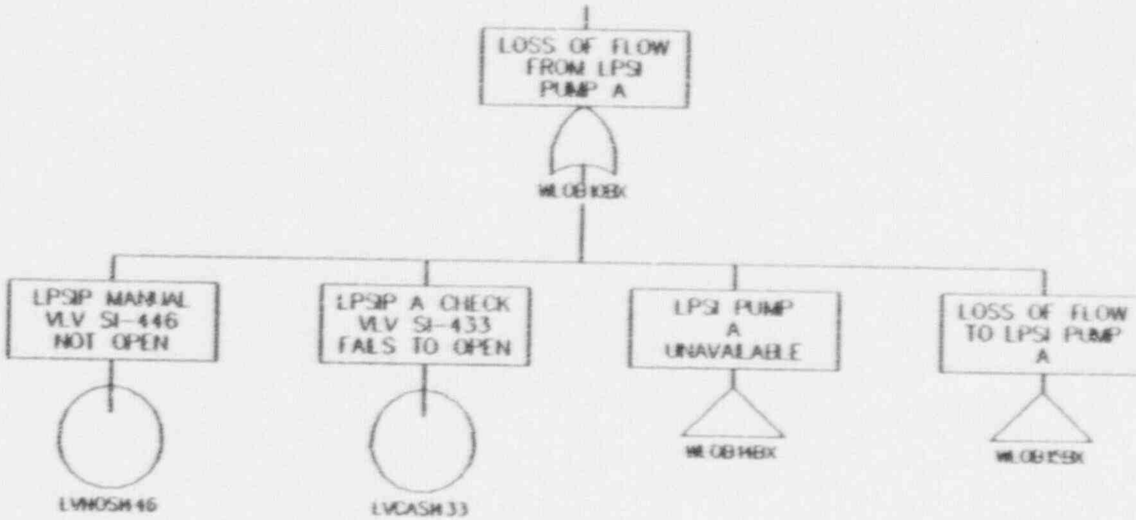
WLOB07BX


SDC THROTTLE VALVE SI-657 INOPERABLE
WLOB08BX
CCF OF SDC THROTTLE VALVES
OPERATOR FAILS TO THROTTLE SDC THROTTLE VALVE
SDC THROTTLE VALVE SI-657 FAILS TO OPERATE
LVMXTHROT
LVMOTHROT
LVMCSI657

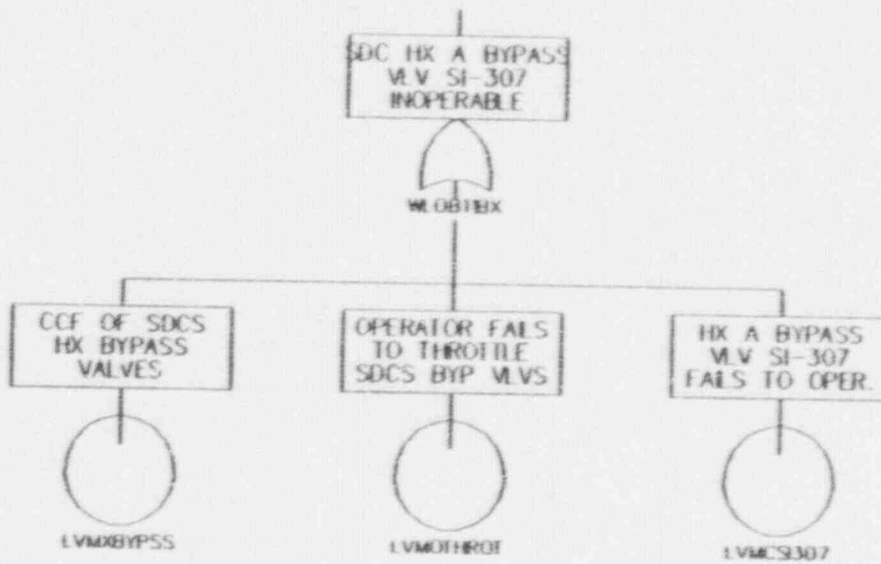
WLOB08BX


SDC CROSSOVER VALVE SI-452 UNAVAILABLE
WLOB09BX
CCF OF SDC CROSSOVER VALVES
SDC CROSSOVER VALVE SI-452 FAILS TO OPEN
LVMXRTN
LVMASI452

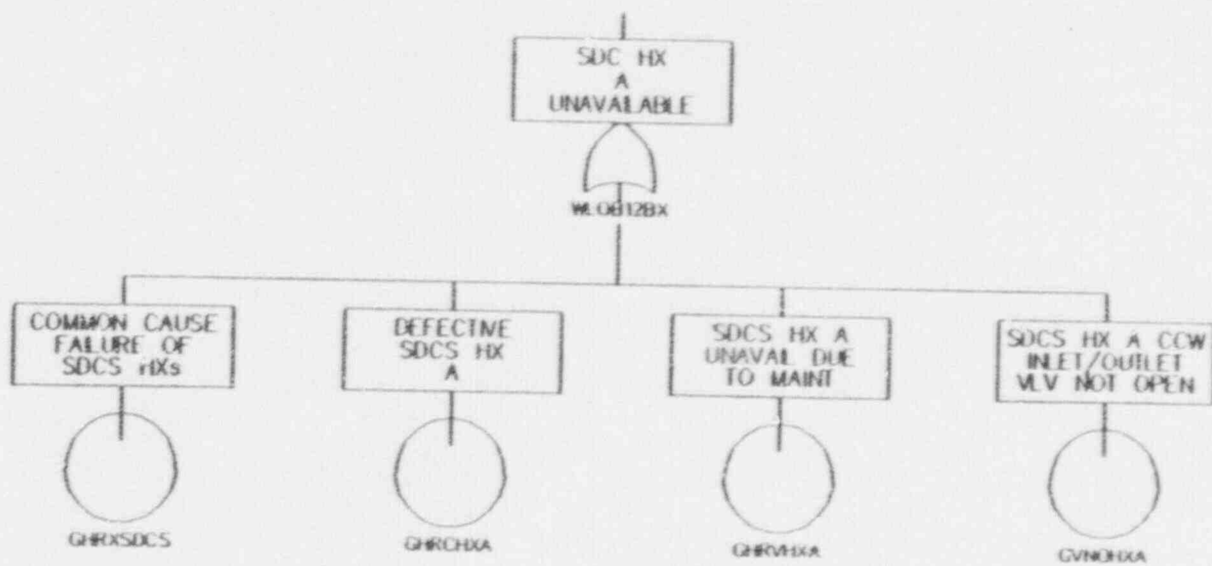
WLOB09BX


LOSS OF FLOW
FROM LPSI
PUMP A
WLOB10BX
LPSIP MANUAL
VLV SI-446
NOT OPEN
LVNOSI446
LPSIP A CHECK
VLV SI-433
FAILS TO OPEN
LVCASI433
LPSI PUMP
A
UNAVAILABLE
WLOB14BX
LOSS OF FLOW
TO LPSI PUMP
A
WLOB15BX

WLOB10BX


SDC HX A BYPASS
VLV SI-307
INOPERABLE
CCF OF SDCS
HX BYPASS
VALVES
OPERATOR FAILS
TO THROTTLE
SDCS BYP VLVS
HX A BYPASS
VLV SI-307
FAILS TO OPER.

WLOB11BX


SDC HX A UNAVAILABLE
WLOB12BX
COMMON CAUSE FAILURE OF SDCS rHXs
DEFECTIVE SDCS HX A
SDCS HX A UNAVAIL DUE TO MAINT
SDCS HX A CCW INLET/OUTLET VLV NOT OPEN
GHRXSDCS
GHRCHXA
GHRVHXA
GVNOHXA

WLOB12BX