

LOCA Evaluation of Safety Significance of Failure of
Emergency Sump Valve Linestarter
(LER 1998-003)

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SUMMARY

LER 1998-003 relates to an occurrence of an inoperable containment emergency sump outlet valve. To support an assessment of safety significance for LER 1998-003, Nuclear Fuel Management (NFM) performed an engineering evaluation of the postulated worst case accident scenario for this event, the Loss of Coolant Accident. The limiting LOCA scenario is the Large Break LOCA (LBLOCA). The consequences of the LBLOCA scenario bound all the postulated LOCA scenarios. However, based on input from the Probability Risk Assessment (PRA) group several different break size scenarios are evaluated as follows:

- I) The 2" break (approximately 0.025 ft² break area)
- II) All break sizes greater than the 2" break

Separate assessments for these two categories of LOCA break sizes are included in this evaluation. The purpose of this evaluation is to determine the minimum time to core damage after the actuation of Recirculation Actuation Signal (RAS).

Simplifying assumptions were used to minimize the time to core damage including:

- Starting of the swing HPSI pump on SIAS.
- Assuming only two charging pumps are available.
- Using a maximum constant containment spray pump flow.
- Assuming the minimum useable level in RWST is 5%.

No credit is taken for Operator action to secure any ECCS or Containment Spray pump after failure to enter the recirculation mode of operation (to extend the time to RWST depletion), or to initiate a plant cooldown via the atmospheric dump valves or the shutdown cooling system. This minimizes the time after RAS that is available for Operator action to mitigate the event.

The location of the break was assumed to be in the bottom of the RCS hot leg to minimize the RCS liquid volume available to cool the core after loss of ECCS. This evaluation conservatively assumed that core damage occurs when the RCS level drops below the top of the active core. However, there is additional time available between starting to uncover the core and the actual onset of core damage.

The 2" and 3" Break LOCA cases were evaluated by NFM using ABB's CENTS computer code. While CENTS is not approved for LOCA analyses, the numerical methods and nodal scheme are consistent with those utilized in CEFLASH, a computer code used for LOCA analyses. Therefore, CENTS is a reasonable computational tool for evaluating NSSS response characteristics for small RCS breaks. The CENTS input data base for these cases represents nominal 100% power operation.

The time for containment spray actuation was determined for the 2" Break LOCA case using Bachtel's computer code COPATTA, which is an approved code for these type of analyses. Initiation of containment spray was conservatively assumed to be coincident with SIAS for the 3" LOCA case.

For the Limiting LBLOCA, information from UFSAR Sections 6.3 and 15.6.3.3 and the Accident Analysis Design Basis Document, Section 4.3.11 was used to perform the evaluation. The limiting LBLOCA evaluation bounds all break sizes greater than 3". This event is dominated by the break size making the sequence of events essentially the same as the UFSAR case. Initiation of containment spray was conservatively assumed to be coincident with SIAS.

The following times to core uncover were determined:

- I) 144 minutes for the 2" break
- II) For breaks larger than 2":
 - 55 minutes for the 3" break
 - 31 minutes for the large break LOCA

2" RCS BREAK

INTRODUCTION - 2" RCS BREAK

An engineering evaluation was performed to determine the expected response of the plant to a postulated 2 inch diameter break in the reactor coolant system (break area of 0.025 ft²). The break was postulated to occur in the bottom of the hot leg. This evaluation included consideration of the actual plant configuration for the period between January 6, 1998 and January 24, 1998, when the Train A containment sump valve (HV-9305) line starter was jammed, but not known to be inoperable. Because of the unknown failure of the HV-9305 line starter, the Train B Component Cooling Water system was removed from service during this period for maintenance.

Containment Spray pump operation is the largest contributor to the depletion of the Refueling Water Storage Tank (RWST) during this event. A containment pressure analysis was performed using the COPATTA computer code to determine when the containment high-high pressure setpoint would be reached. This time was then used in the ECCS evaluation as the time at which the Containment Spray pump was initiated.

When the postulated hot leg LOCA has injected sufficient water from the RWST to reduce the RWST level to 18.5%, a Recirculation Actuation Signal (RAS) is generated. At this time, the failure of HV-9305 would become known to the operators. The failure of HV-9305, combined with the Train B maintenance activities, mean that only charging flow would enter the vessel once the RWST decreased below the ECCS suction lines (approximately 5% RWST level).

The charging pump suction is assumed to be aligned to the Boric Acid Makeup (BAMU) Tanks, and charging flow is injected to the RCS throughout the event.

This engineering evaluation determined the time needed generate the RAS signal, the time needed to reach the point at which no HPSI flow was available (approximately 5% RWST level), and determined the RCS and core response to the event.

To support this engineering evaluation, the ABB CENTS code was used. This code is not approved by the NRC for LOCA analyses, but was judged to be a reasonable evaluation tool for this type of small RCS break.

INPUTS - 2" RCS BREAK

1. HPSI flow is per the CENTS basedeck, and is consistent with RGR Table VII-1 (Reference 2). To minimize the time to RWST depletion, the flow from one HPSI pump was doubled to determine the 2 HPSI pump flow (neglecting the additional line losses that would occur).

2. The RWST volume (from 92% to 5%) is as follows per Reference 1, Figure 2.1-1:

$$RWST_{92\% \text{ to } 18.5\%} = \frac{92\% - 18.5\%}{100\%} \times 491,207 \text{ gallons} = 361,037 \text{ gallons}$$

$$RWST_{18.5\% \text{ to } 5\%} = \frac{18.5\% - 5\%}{100\%} \times 491,207 \text{ gallons} = 66,312 \text{ gallons}$$

3. Containment Spray nozzle flow is 2136 gpm per RGR Item IX.008 (Reference 2).
4. The Containment High Pressure setpoint used in the analysis is 5 psig per RGR Items VIB.015 and VIB.021 (Reference 2). This signal starts containment cooling.
5. The Containment High-High Pressure setpoint used in the analysis is 15 psig, which is conservative to the RGR Item VIB.017 analysis value. This signal starts flow through the containment spray nozzles.
6. The containment pressure analysis uses the following break flow rates and RCS pressures, per UFSAR Figures 15.6-115 and 15.6-116 (Reference 3). The associated enthalpies are taken from the ASME Steam Tables (Reference 4). The UFSAR Figures are for a 0.025 ft² cold leg break, but are also assumed to be representative of a hot leg break of the same size. The enthalpy values used are representative of a hot leg break.

Time (seconds)	Break flow (lb/hr)	Enthalpy (Btu/lb)	Comments
0 to 200	18.0E5	613	Water @ 600°F & 2300 psia
200 to 1200	9.0E5	613	Water @ 600°F & 2300 psia
1200 to 2400	2.52E5	1185	Sat Steam @ 1200 psia
2400 to 4800	2.16E5	1185	Sat Steam @ 1200 psia
4800 to end	1.44E5	1200	Sat Steam @ 800 psia

7. Two 44 gpm charging pumps, with suction from the BAMU Tanks, are available throughout the event. This is the minimum number of pumps required to be operable per Technical Specification 3.1.9. The charging pumps are not impacted by the Train B CCW maintenance. The total charging flow is 88 gpm, which is consistent with RGR Item III.025 (Reference 2). Over the 250 minute analysis interval, the total charging flow is:

$$\text{Total Charging Flow} = \frac{2 \times 44 \text{ gal}}{\text{min}} \times 250 \text{ min} = 22,000 \text{ gallons}$$

3. Per Licensee Controlled Specification 3.1.104, a minimum level of 5000 gallons is required in each BAMU Tank. Makeup to the BAMU Tanks is available from the 25,000 gallon Boric Acid Storage Tank (T-069). If necessary, additional boric acid can be prepared and added to the Boric Acid Storage Tank. Thus, sufficient boric acid is available to support the charging pumps.
9. The nominal Recirculation Actuation Signal setpoint of 18.5% level in the RWST is used. This is consistent with RGR Item VIB.020 (Reference 2).

ASSUMPTIONS - 2" RCS BREAK

1. Train B HPSI, LPSI, and Containment Spray are not available due to maintenance on the Train B Component Cooling Water system.
2. The swing HPSI pump will conservatively be assumed to be initiated concurrent with the autostart of the Train A HPSI pump, to maximize the rate of RWST depletion. This is consistent with the guidance provided in procedure SO23-12-3 (Reference 4).
3. For the purposes of the containment pressure analysis, one train of containment cooling and one train of containment spray are assumed to be available. This is consistent with the unavailability of CCW train 3.
4. Per procedure SO23-12-3 (Reference 5) the RCPs are assumed to be secured by operator action when the operational limits of 1430 psia (in the RCS) or 40°F subcooling are reached.
5. It is assumed that the HPSI and Containment Spray pumps will lose suction flow when the RWST level has decreased to 5%.
6. Conservatively, operator actions to cool down the plant using the Atmospheric Dump Valves are not credited.

REFERENCES - 2" RCS BREAK

1. Calculation J-BHB-029, Revision 0, CCN-1, "RWST Minimum Level to Maintain Safety Analysis Assumptions, Including Instrument Uncertainties"
2. RGR-U2-C9, Revision 0 (including Change Notes 1 and 2), "SONGS Unit 2 Cycle 9 Reload Ground Rules"
3. SONGS 2&3 Updated Final Safety Analysis Report, Revision 13.
4. ASME Steam Tables
5. Procedure SO23-12-3, Revision 14, "Loss of Coolant Accident"
6. CENPD 282-P-A, "Technical Manual for the CENTS Code", dated February 1991.
7. Letter # ST-98-203 from I.C. Rickard (ABB) to P.D. Myers (SCE), "Transmittal of Evaluation of 0.025 ft² and 0.05 ft² hot leg breaks with the CENTS code," April 6, 1998.

COMPUTER CODES - 2" RCS BREAK

1. The ECCS evaluation was performed using a developmental version of the ABB CENTS code (which has improved code stability). The CENTS code (Reference 6) is NRC approved only for use in non-LOCA transients. While CENTS is not approved for use in LOCA analyses, ABB determined it to be the most appropriate code to use for this evaluation. The SONGS code base deck used has not yet been formally approved, however ABB does not know of any discrepancies which would affect the results of this evaluation. The CENTS reactor kinetics best estimate decay heat model was used.
2. The containment pressure evaluation was performed using the Bechtel Corporation COPATTA code. The COPATTA code was derived by Bechtel from the CONTEMPT program and is described in section 6.2.1.1.3.1.C. of the SONGS Units 2&3 UFSAR. The COPATTA program was used by Bechtel during the design and licensing of SONGS Units 2 and 3, and is now used under license by SCE in support of continuing plant operations.

ANALYSIS - 2" RCS BREAK

Containment Pressure Response - 2" RCS Break

In order to determine when the Containment Spray pump would initiate, the containment pressure response to a 2" hot leg break event was determined using the COPATTA program. The basic containment model, including performance characteristics of the emergency air cooling units (ECUs) and containment spray (CS) system was the same as that used in current analyses of record for containment peak pressure analyses reported in section 6.2.1 of the SONGS Units 2&3 UFSAR.

The results of the containment pressure response to the 2" break event are shown in Figure 1. As indicated on the figure, the containment pressure reaches 15 psig at 1200 seconds (20 minutes), initiating spray flow from the one available train of containment spray. The analysis also showed that one train of ECUs would be operating by 170 seconds (about 3 minutes) following occurrence of the pipe break. The analysis assumed that RWST would decrease to a level of 5% in approximately 145 minutes, at which time the containment spray flow was discontinued. This time differs slightly from the 140 minute time subsequently determined by the ECCS analysis.

A small change in the timing of spray flow termination would not substantially change the shape of the subsequent pressure versus time curve. The general trend of containment pressure at 145 minutes is not affected by small changes in the time of spray flow termination. The discontinuities in the pressure curve at 200, 2400, and 4800 seconds are due to step changes in break flow and/or enthalpy used in the simplified input modeling of the break flow. The sharp change in slope of the curve at 1200 seconds is due to a combination of a change in break flow and the start of containment spray.

ECCS Evaluation - 2" RCS Break

Table 1 shows the sequence of events for this event. Figures 2 through 6 show the response of selected plant parameters during the event.

Table 1 - 2 Inch RCS Break - Sequence of Events				
Time After Break		Time After RAS (Min)	Action	Comments
sec	min			
0	0		Break occurs in 2 inch pipe (0.025 ft ² break area)	Plant status at event initiation: • Train B HPSI, LPSI, and Containment Spray not available due to Train B CCW maintenance
0	0		2 charging pumps inject to RCS from BAMU	• 2 charging pumps are the minimum required to be available per Technical Specification 3.1.9. The charging pumps are not impacted by the Train B CCW maintenance. • Makeup to the BAMU tanks is available from the boric acid storage tank.
107	1.8		Reactor trip occurs	
118	2		Operators secure all four RCPs	Per procedure SO23-12-3 the RCPs are assumed to be secured when the operational limits of 1430 psia and 40°F subcooling reached (both limits are reached at approximately 118 seconds).
138	2.3		2 HPSI pumps start	Conservatively assume the swing HPSI pump is initiated concurrently with the autostart of the Train A HPSI pump, to maximize the rate of RWST depletion.
170	2.8		Containment Emergency Cooler starts	Only one train credited, due to lack of second CCW train.
1200	20		Containment Spray flow from 1 pump starts, based on COPATTA analysis of containment pressure response to this event	CS nozzle flow is 2136 gpm for the ECCS analysis (for RWST depletion) which is conservative to the value used in the containment pressure analysis.
3400	57		SITs start to discharge	• RCS pressure 615 psia. • Pressurizer and upper head empty, loops essentially solid at 490°F. • RCS is cooling secondary side, which is bottled up at ~760 psia (reverse heat transfer). • Total SI flow spikes as SIT flow starts and stops as a function of SIT pressure and RCS pressure.
4800	80		Containment pressure reaches 20 psig	This is the maximum containment pressure that occurs while Containment Sprays are running.
7200	120	0	RAS setpoint reached. Operators discover that HV-9305 fails to open.	18.5% level on RWST.

Table 1 - 2 Inch RCS Break - Sequence of Events				
Time After Break		Time After RAS (Min)	Action	Comments
sec	min			
8400	140	20	RWST reaches 5%, ECCS analysis assumes that operators secure 2 HPSI and Containment Spray pumps. Only remaining flow into RCS is 2 charging pumps (suction from BAMU tanks, which are refilled as necessary from the Boric Acid Storage Tank)	<ul style="list-style-type: none"> RCS pressure ~280 psia. Voiding in pressurizer, upper head, and upper region of core (level above top of hot leg). Loops still solid, at ~320°F. RCS is cooling secondary side, SG side is bottled up at ~250 psia (reverse heat transfer).
9700	162	42	SIT discharge ends	<ul style="list-style-type: none"> RCS pressure 160 psia (minimum pressure for event). System at saturation conditions. System begins to repressurize. Break flow 70 lb/sec. SG Pressure ~200 psia
10,140	169	49	System has heated up to saturation conditions, break flow becomes saturated break flow	Break flow has dropped from 230 lbm/sec (at 8400 seconds) to 42 lbm/sec (at 10,140 sec)
10,500	175	55	SG tubes draining begins	
13,500	225	105	System has repressurized to 470 psia	<ul style="list-style-type: none"> Break flow has increased to ~80 lb/sec due to the increase in pressure. Core remains covered. SG Pressure 450 psia
13,700	228	108	Break uncovers	<ul style="list-style-type: none"> Break mass flow rate decreases ~25 lb/sec as break is now passing steam rather than liquid. Flow spikes back to 80 lb/sec when break passes liquid. Core remains covered.
15,870	264	144	Active core uncovers	<ul style="list-style-type: none"> RCS pressure 550 psia. Break flow 27 lb/sec. Charging flow 12 lb/sec. System at saturation conditions. Secondary side (at 530 psia) is cooling RCS (forward heat transfer). Containment at 33 psig and 272°F.

CONCLUSION - 2" PIPE BREAK

The core remains covered for at least 144 minutes after receipt of the RAS signal.

Figure 1

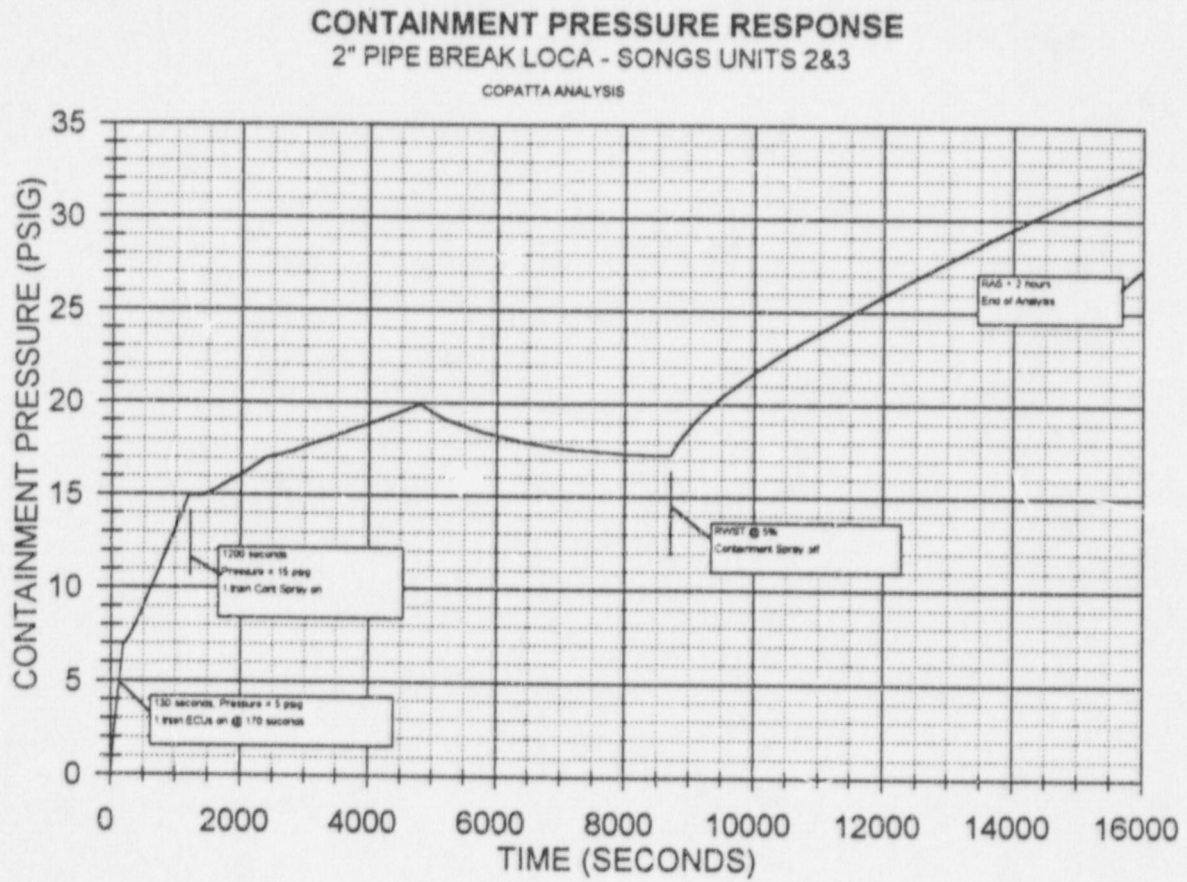


Figure 2

2 INCH RCS BREAK - BREAK FLOW RATE

Time (sec)	Event
0-139	Break occurs, Reactor trips, RCPs are manually tripped, 2 HPSI pumps are started. Break flow decreases with decreasing RCS pressure.
900 - 8400	HPSI flow into the RCS promotes increase in break flow.
8400	5% RWST level is reached, HPSI and Containment Spray pumps are secured
9700	SITs discharge ends, RCS begins to repressurize, break flow is increased
13700	Break flow changes from liquid to steam as level drops below the bottom of the hot leg
>13700	Spiking in break flow due to covering and uncovering break location

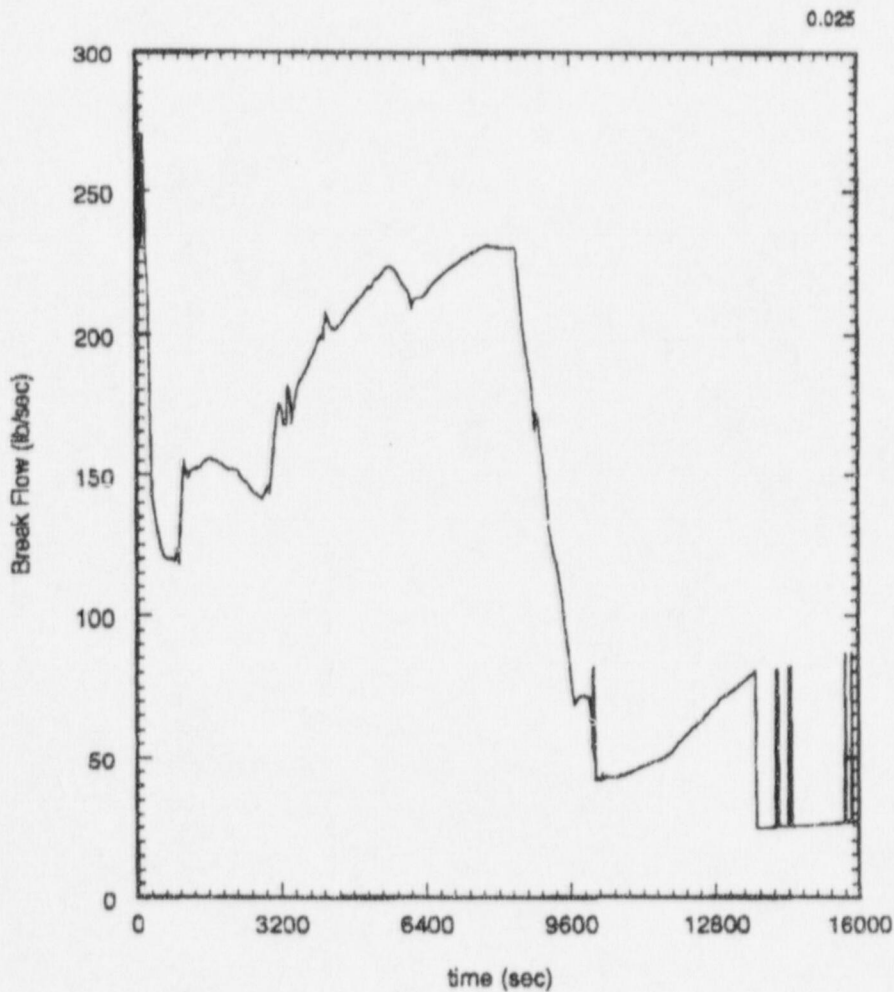


Figure 3

2 INCH RCS BREAK - SAFETY INJECTION FLOW RATE
(From HPSI and Safety Injection Tank)

<u>Time (sec)</u>	<u>Event</u>
138	2 HPSI pumps are started
3400	SITs start to discharge
8400	RWST level reaches 5%, HPSI pumps are secured, SIT flow maintains level
9700	SITs discharge ends

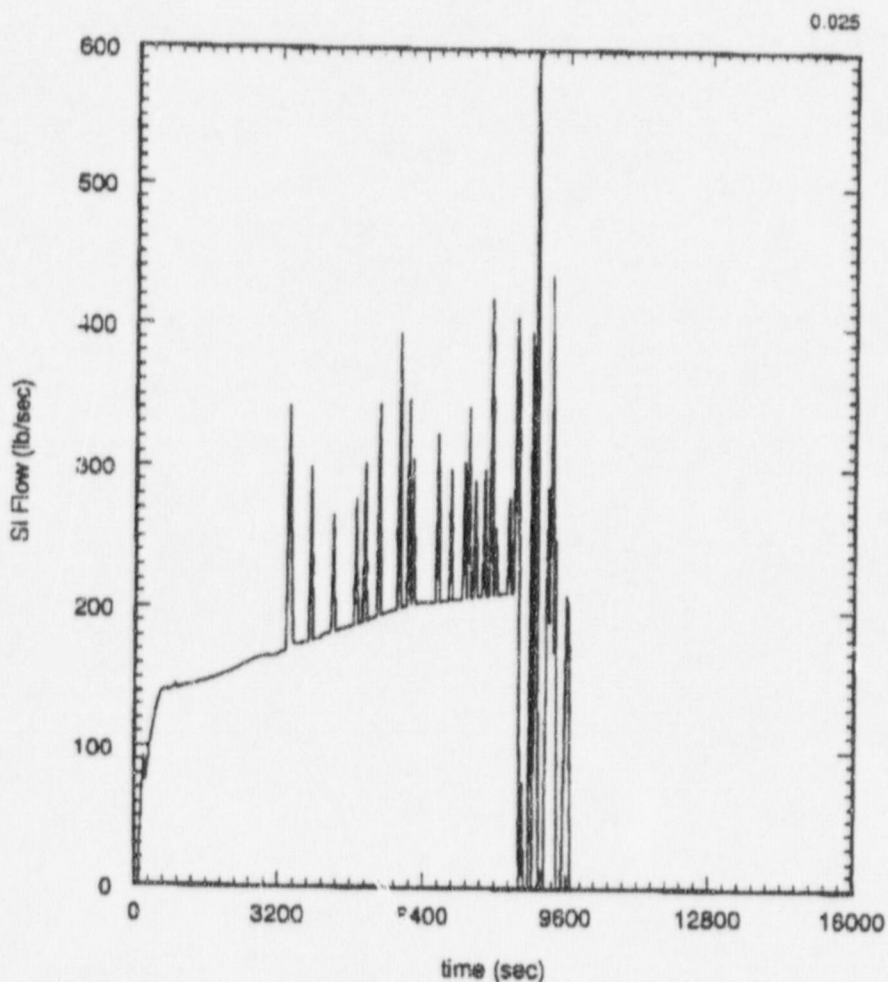


Figure 4

2 INCH RCS BREAK - PRESSURIZER PRESSURE

<u>Time (sec)</u>	<u>Event</u>
0	Break Occurs
107	Reactor trips
138 - 8400	2 HPSI pumps start, reducing rate of RCS depressurization
8400	5% RWST level is reached, HPSI pumps are secured
9700	SITs discharge ends, RCS begins to repressurize

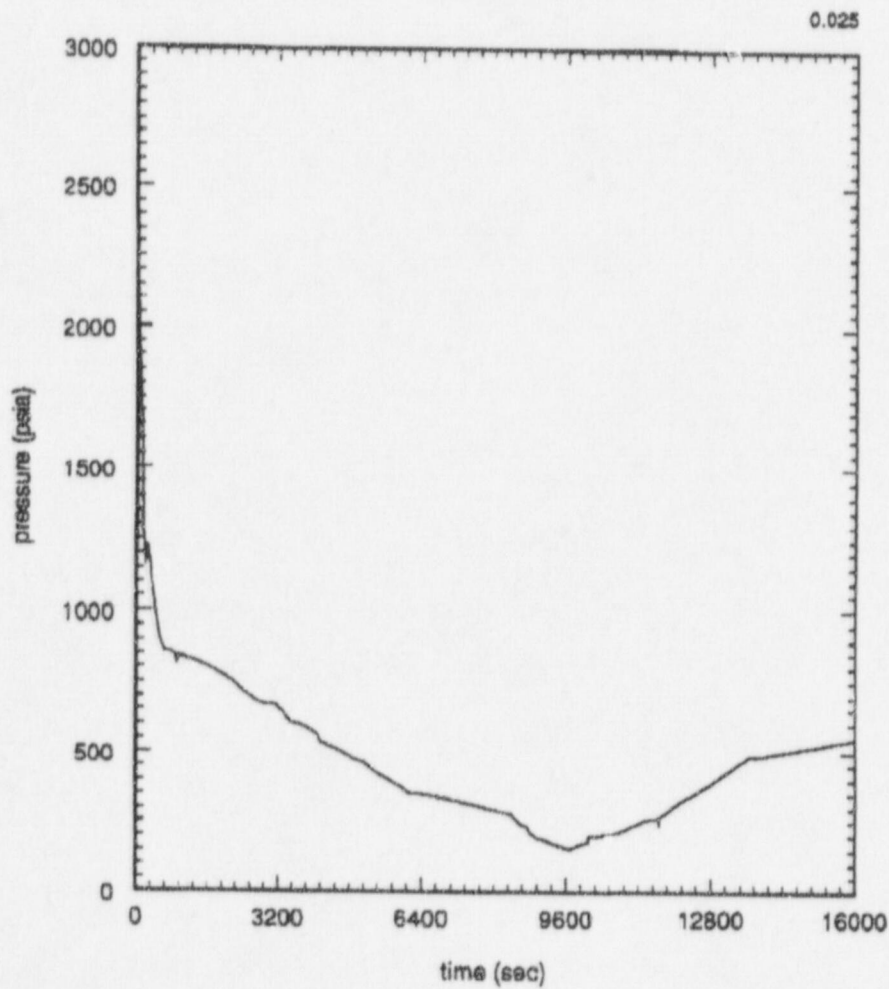
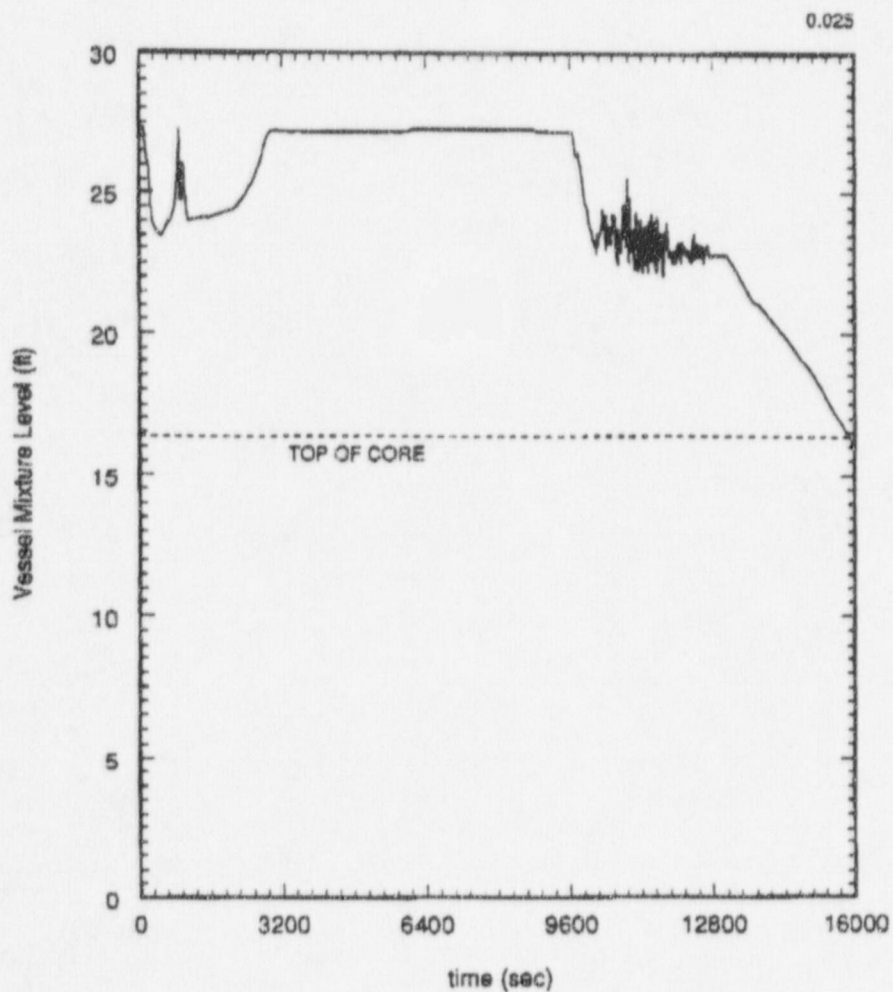


Figure 5

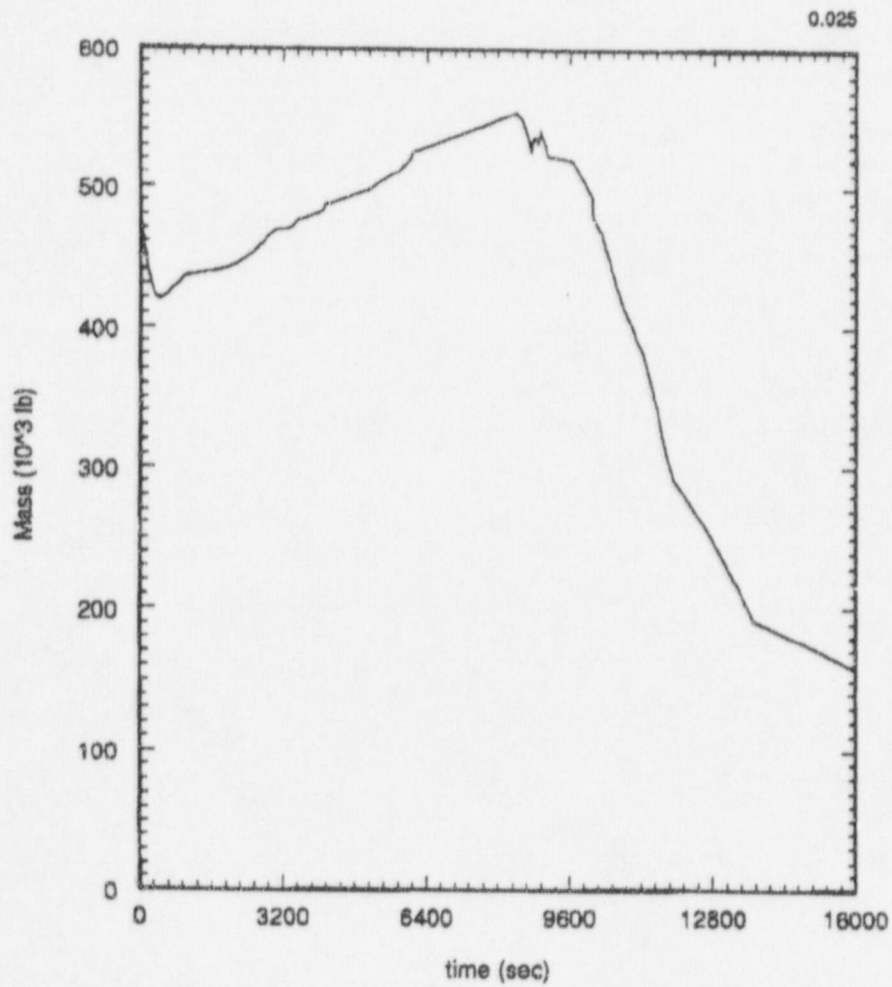
2 INCH RCS BREAK - REACTOR VESSEL MIXTURE LEVEL

Time (sec)	Event
0 - 118	Break Occurs, Reactor trips, RCPs secured, all of which drop level
138	2 HPSI pumps are started
600	Level begins to turn around as a result of HPSI
3400	SITs start to discharge, break flow increases
8400	RWST level reaches 5%, HPSI pumps are secured, SIT flow maintains level
9700	SITs discharge ends, level begins to drop
10,000 - 12,900	Oscillations in level due to interaction between cold water in downcomer and charging and boiling conditions in core, and due to reflux condensation in Steam Generators
15,870	Core uncovers

Figure 6



2 INCH RCS BREAK - TOTAL REACTOR COOLANT SYSTEM MASS



3" RCS BREAK

INTRODUCTION - 3" RCS BREAK

An engineering evaluation was performed to determine the expected response of the plant to a postulated 3 inch diameter break in the reactor coolant system (break area of 0.05 ft²). The break was postulated to occur in the bottom of the hot leg. This evaluation included consideration of the actual plant configuration for the period between January 6, 1998 and January 24, 1998, when the Train A containment sump valve (HV-9305) line starter was jammed, but not known to be inoperable. Because of the unknown failure of the HV-9305 line starter, the Train B Component Cooling Water system was removed from service during this period for maintenance.

When the postulated hot leg LOCA has injected sufficient water from the RWST to reduce the RWST level to 18.5%, a Recirculation Actuation Signal (RAS) is generated. At this time, the failure of HV-9305 would become known to the operators. The failure of HV-9305, combined with the Train B maintenance activities, mean that only charging flow would enter the vessel once the RWST decreased below the ECCS suction lines (approximately 5% RWST level).

The charging pump suction is assumed to be aligned to the Boric Acid Makeup (BAMU) Tanks, and charging flow is injected to the RCS throughout the event.

This engineering evaluation determined the time needed generate the RAS signal, the time needed to reach the point at which no HPSI flow was available (approximately 5% RWST level), and determined the RCS and core response to the event.

To support this engineering evaluation, the ABB CENTS code was used. This code is not approved by the NRC for LOCA analyses, but was judged to be a reasonable evaluation tool for this type of small RCS break.

INPUTS - 3"PIPE BREAK

1. HPSI flow is per the CENTS basedeck, and is consistent with RGR Table VII-1 (Reference 2). To minimize the time to RWST depletion, the flow from one HPSI pump was doubled to determine the 2 HPSI pump flow (neglecting the additional line losses that would occur).

2. The RWST volume (from 92% to 5%) is as follows per Reference 1, Figure 2.1-1:

$$RWST_{92\% \text{ to } 18.5\%} = \frac{92\% - 18.5\%}{100\%} \times 491,207 \text{ gallons} = 361,037 \text{ gallons}$$

$$RWST_{18.5\% \text{ to } 5\%} = \frac{18.5\% - 5\%}{100\%} \times 491,207 \text{ gallons} = 66,312 \text{ gallons}$$

3. Containment Spray flow is 2136 gpm per RGR Item IX.008 (Reference 2). A value of 2200 gpm will conservatively be used.
4. Two 44 gpm charging pumps, with suction from the BAMU Tanks, are available throughout the event. This is the minimum number of pumps required to be operable per Technical Specification 3.1.9. The charging pumps are not impacted by the Train B CCW maintenance. The total charging flow is 88 gpm, which is consistent with RGR Item III.025 (Reference 2). Over the 250 minute analysis interval, the total charging flow is:

$$\text{Total Charging Flow} = \frac{2 \times 44 \text{ gal}}{\text{min}} \times 250 \text{ min} = 22,000 \text{ gallons}$$

5. Per Licensee Controlled Specification 3.1.104, a minimum level of 5000 gallons is required in each BAMU Tank. Makeup to the BAMU Tanks is available from the 25,000 gallon Boric Acid Storage Tank (T-069). If necessary, additional boric acid can be prepared and added to the Boric Acid Storage Tank. Thus, sufficient boric acid is available to support the charging pumps.
6. The nominal Recirculation Actuation Signal setpoint of 18.5% level in the RWST is used. This is consistent with RGR Item VIB.020 (Reference 2).

ASSUMPTIONS - 3" RCS BREAK

1. Train B HPSI, LPSI, and Containment Spray are not available due to maintenance on the Train B Component Cooling Water system.
2. The swing HPSI pump will conservatively be assumed to be initiated concurrent with the autostart of the Train A HPSI pump, to maximize the rate of RWST depletion. This is consistent with the guidance provided in procedure SO23-12-3 (Reference 4).

3. Conservatively assume that the Containment Spray pump initiates when the SIAS is generated (a detailed containment pressure analysis was not performed for this break size).
4. Per procedure SO23-12-3 (Reference 4) the RCPs are assumed to be secured by operator action when the operational limits of 1430 psia (in the RCS) or 40°F subcooling are reached.
5. It is assumed that the HPSI and Containment Spray pumps will lose suction flow when the RWST level has decreased to 5%.
6. Conservatively, operator actions to cooldown the plant using the Atmospheric Dump Valves are not credited.

REFERENCES - 3" RCS BREAK

1. Calculation J-BHB-029, Revision 0, CCN-1, "RWST Minimum Level to Maintain Safety Analysis Assumptions, Including Instrument Uncertainties"
2. RGR-U2-C9, Revision 0 (including Change Notes 1 and 2), "SONGS Unit 2 Cycle 9 Reload Ground Rules"
3. SONGS 2&3 Updated Final Safety Analysis Report, Revision 13.
4. Procedure SO23-12-3, Revision 14, "Loss of Coolant Accident"
5. CENPD 282-P-A, "Technical Manual for the CENTS Code", dated February 1991.
6. Letter # ST-98-203 from I.C. Rickard (ABB) to P.D. Myers (SCE), "Transmittal of Evaluation of 0.025 ft² and 0.05 ft² hot leg breaks with the CENTS code," April 6, 1998.

COMPUTER CODES - 3" RCS BREAK

1. The ECCS evaluation was performed using a developmental version of the ABB CENTS code (which has improved code stability). The CENTS code (Reference 6) is NRC approved only for use in non-LOCA transients. While CENTS is not approved for use in LOCA analyses, ABB determined it to be the most appropriate code to use for this evaluation. The SONGS code base deck used has not yet been formally approved, however ABB does not know of any discrepancies which would affect the results of this evaluation. The CENTS reactor kinetics best estimate decay heat model was used.

ANALYSIS - 3" RCS BREAK

Table 2 shows the sequence of events for this event. Figures 7 through 11 show the response of selected plant parameters during the event.

Table 2 - 3 inch RCS Break - Sequence of Events				
Time After Break		Time After RAS (Min)	Action	Comments
sec	min			
0	0		Break occurs in 3 inch pipe (0.05 ft ² break area)	Plant status at event initiation: <ul style="list-style-type: none"> • Train B HPSI, LPSI, and Containment Spray not available due to Train B CCW maintenance.
0	0		2 Charging pumps inject to RCS from BAMU	<ul style="list-style-type: none"> • 2 charging pumps are the minimum required to be available per Technical Specification 3.1.9. The charging pumps are not impacted by the Train B CCW maintenance. • Makeup to the BAMU tanks is available from the boric acid storage tank.
40	0.7		Reactor trip occurs	
65	1.1		Operators secure all four RCPs	Per procedure SO23-12-3 the RCPs are assumed to be secured when the operational limits of 1430 psia and 40°F subcooling reached (both limits are reached at approximately 65 seconds).
100	1.7		2 HPSI pumps start Containment Spray pump starts	<ul style="list-style-type: none"> • Conservatively assume the swing HPSI pump is initiated concurrently with the autostart of the Train A HPSI pump, to maximize the rate of RWST depletion. • Conservatively assume 1 Containment Spray pump is initiated concurrently with HPSI, to maximize the rate of RWST depletion.
280	4.7		SG tubes start to drain	
300	5		RCS reaches plateau pressure	<ul style="list-style-type: none"> • RCS at ~850 psia. • Secondary at ~830 psia. • Secondary side is cooling the RCS (forward heat transfer).
2200	37		SG tubes empty	
2460	41		Level reaches bottom of hot leg	<ul style="list-style-type: none"> • Two phase conditions at break. • System depressurizes.
2760	46		SITs start to discharge	<ul style="list-style-type: none"> • RCS pressure 615 psia. • Pressurizer and upper head empty. • SG empty. • Hot legs essentially empty. • Total SI flow spikes as SIT flow starts and stops as a function of SIT pressure and RCS pressure. • SG Pressure ~860 psia.

Table 2 - 3 Inch RCS Break - Sequence of Events				
Time After Break		Time After RAS (Min)	Action	Comments
sec	min			
2800	47		Break is covered again	<ul style="list-style-type: none"> RCS is cooling secondary system (reverse heat transfer).
3620	60		SIT injection terminates, minimum RCS Pressure reached	<ul style="list-style-type: none"> RCS Pressure ~195 psia.
4050	68		Hot leg is full	<ul style="list-style-type: none"> RCS Pressure ~450 psia.
6250	104	0	RAS setpoint reached. Operators discover that HV-9305 fails to open.	18.5% level on RWST.
7000	117	13	RWST reaches 5%, ECCS analysis assumes that operators secure 2 HPSI and Containment Spray pumps. Only remaining flow into RCS is 2 charging pumps (suction from BAMU tanks, which are refilled as necessary from the Boric Acid Storage Tank)	<ul style="list-style-type: none"> RCS pressure ~380 psia. RCS is cooling secondary side, which is bottled up at ~610 psia (reverse heat transfer).
>7000	>117	>13	System heats up and depressurizes to saturation, draining of hot legs begin	<ul style="list-style-type: none"> RCS depressurizes.
7120	119	15	System reaches saturation	<ul style="list-style-type: none"> RCS pressure ~260 psia, begins to repressurize. SG Pressure ~600 psia.
8300	138	34	Break uncovers	<ul style="list-style-type: none"> Break flow reduces from 160 lb/sec to 48 lb/sec. RCS Pressure ~480 psia, begins to depressurize. SG Pressure ~540 psia.
9540	159	55	Active core uncovers	<ul style="list-style-type: none"> RCS Pressure ~375 psia. SG Pressure ~500 psia.

CONCLUSION - 3" RCS BREAK

The core remains covered for 55 minutes after receipt of the RAS signal.

Figure 7

3 INCH RCS BREAK - BREAK FLOW RATE

<u>Time (sec)</u>	<u>Event</u>
0-100	Break occurs, Reactor trips, RCPs are manually tripped, 2 HPSI pumps are started. Break flow decrease with decreasing RCS pressure.
300	RCS reaches plateau pressure, break flow begins to increase
2460	Level reaches bottom of hot leg, steam replaces liquid flow at break location, therefore break flow decreases
2800	Break is covered, liquid replaces steam flow at break location, therefore break flow increases
7000	5% RWST level is reached, 2 HPSI and Containment Spray pumps are secured
8300	Break flow changes from liquid to steam as level drops below the bottom of the hot leg

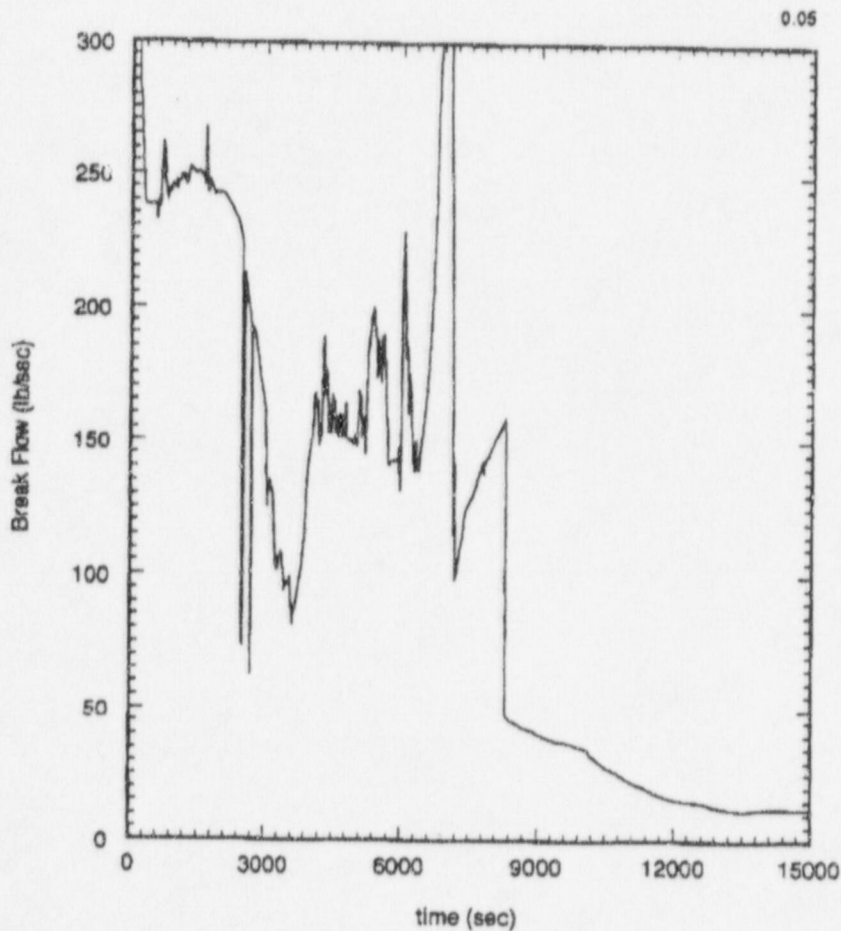


Figure 8

3 INCH RCS BREAK - SAFETY INJECTION FLOW RATE
(From HPSI and Safety Injection Tank)

<u>Time (sec)</u>	<u>Event</u>
100	2 HPSI pumps start
2760	SITs begin to discharge
3620	SITs discharge ends
7000	RWST reaches 5% level, operators secure both HPSI pumps

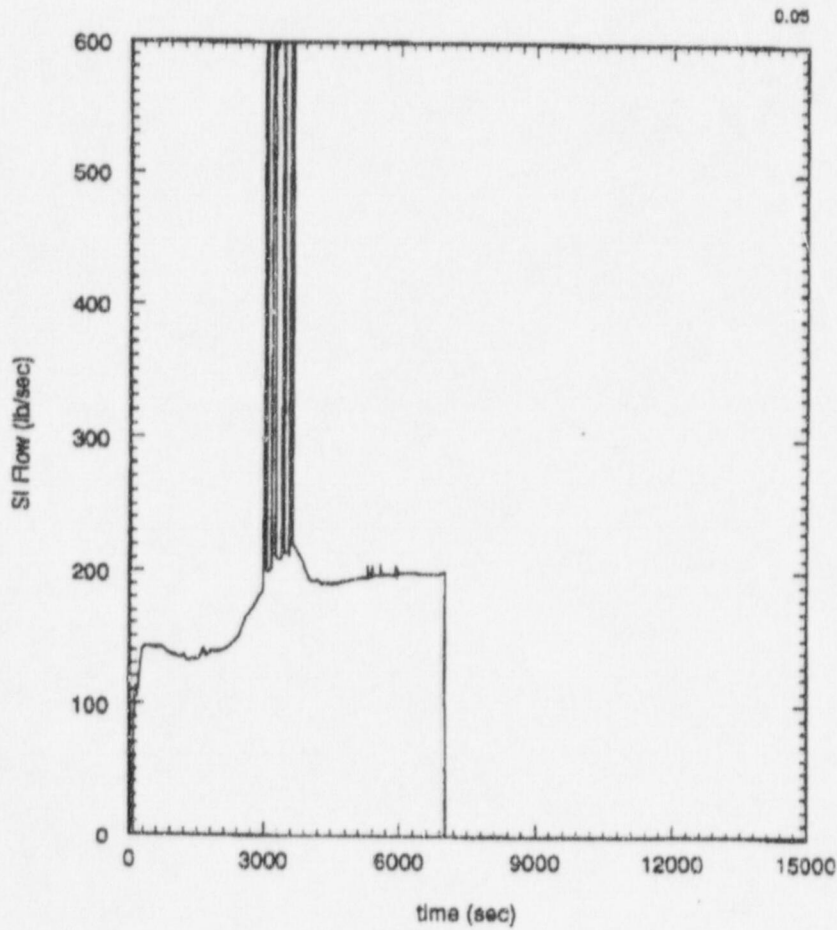


Figure 9

3 INCH RCS BREAK - PRESSURIZER PRESSURE

<u>Time (sec)</u>	<u>Event</u>
0	Break occurs
40	Reactor trips
100	2 HPSI pumps start
2460	Level at the bottom of hot leg, steam replaces liquid flow, RCS begins to depressurize
2800	Break is covered again
3620	SITs discharge ends
7000	RWST level reaches 5%, HPSI is terminated
8300	Break uncovers, pressure begins to drop

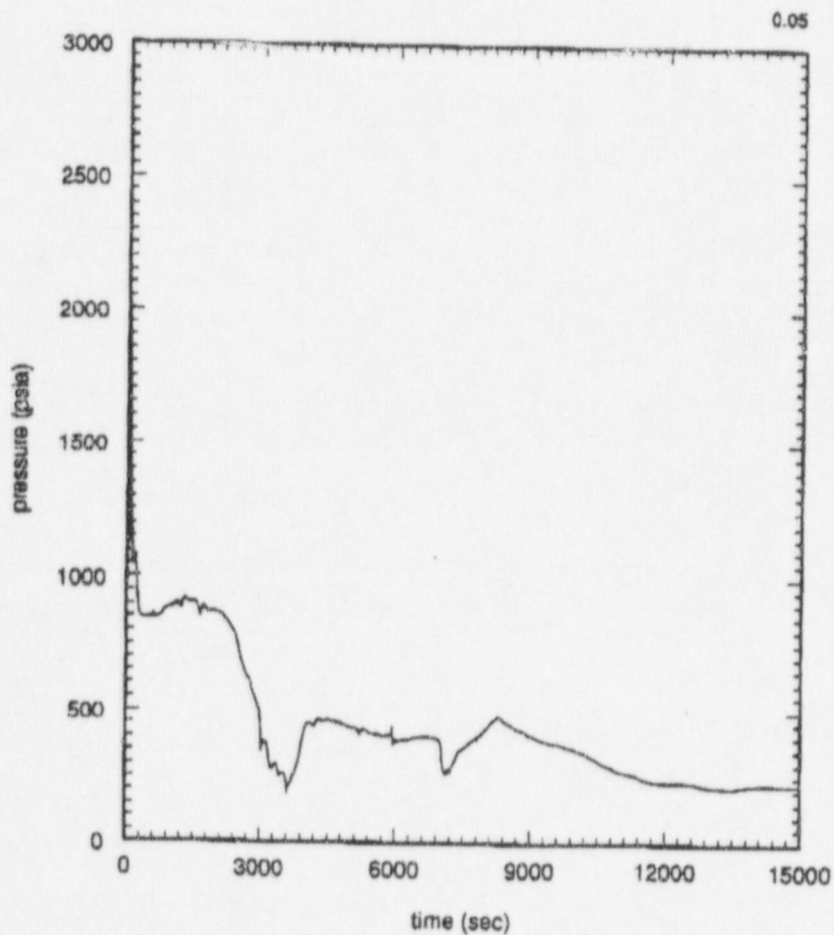


Figure 10

3 INCH RCS BREAK - REACTOR VESSEL MIXTURE LEVEL

<u>Time (sec)</u>	<u>Event</u>
100	2 HPSI pumps start
2760	SITs begin to discharge
3620	SITs discharge end
7000	5% RWST level is reached, HPSI is terminated
9540	Core is uncovered and remains uncovered

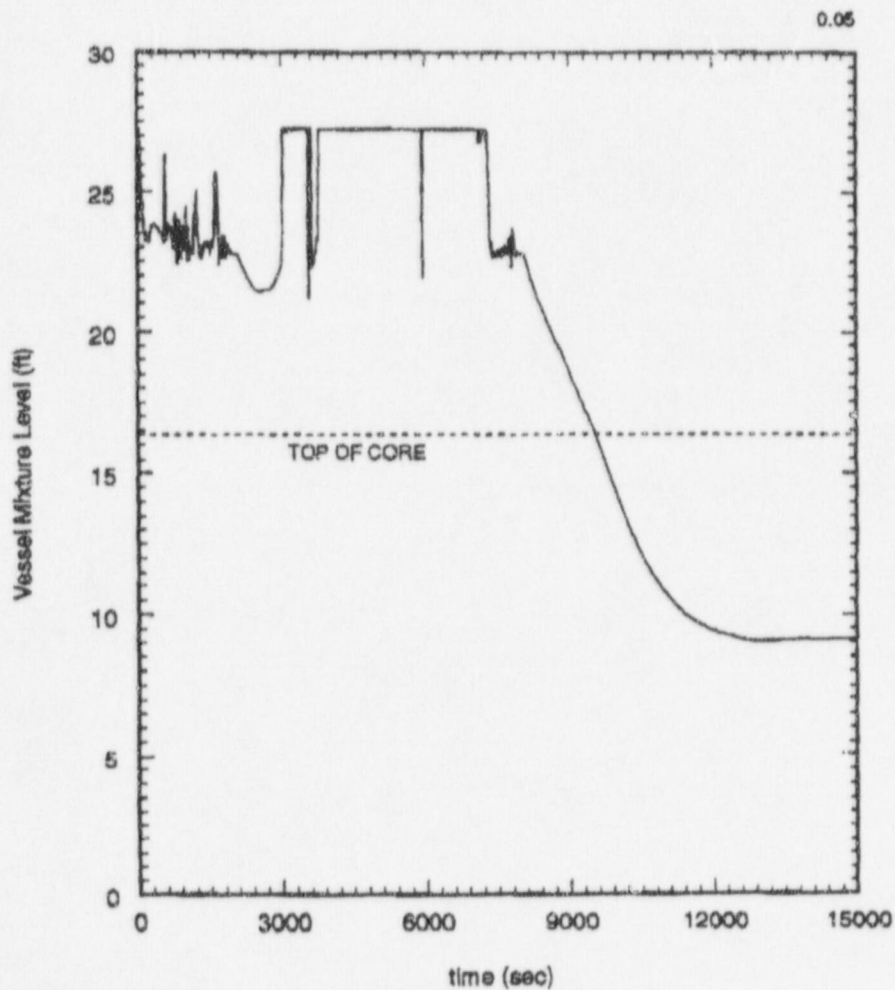
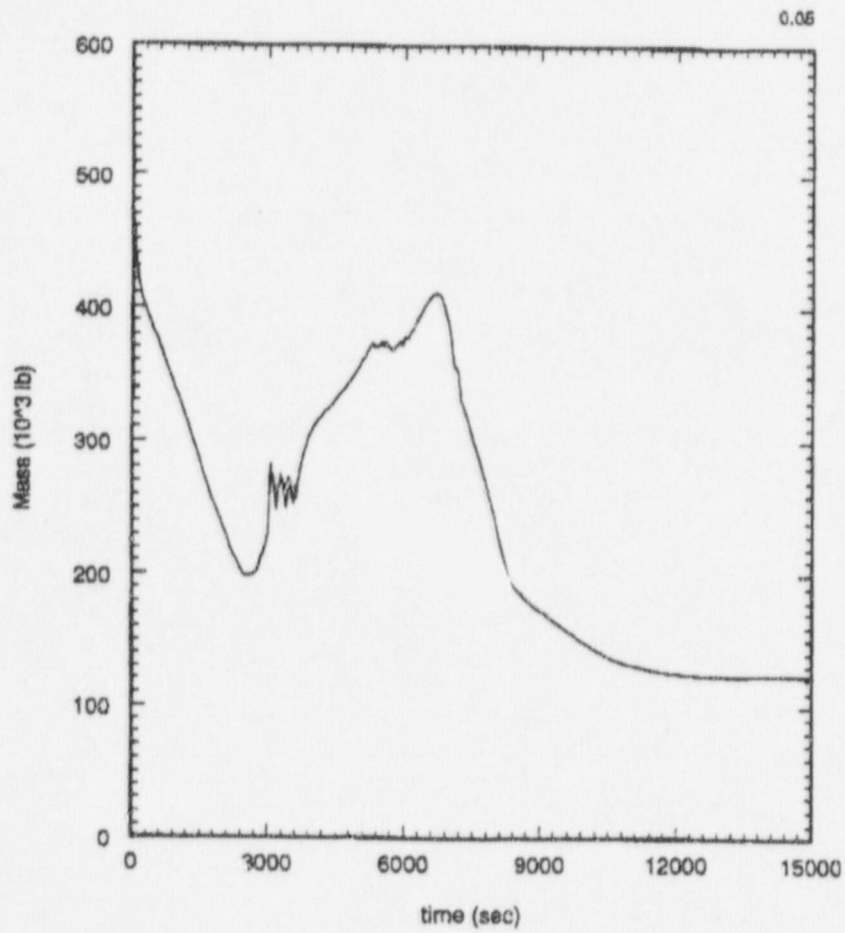


Figure 11

3 INCH RCS BREAK - TOTAL REACTOR COOLANT SYSTEM MASS



LARGE BREAK LOSS OF COOLANT ACCIDENT

INTRODUCTION - LBLOCA

An evaluation of Large Break Loss of Cooling Accident (LBLOCA) was performed during plant operation from January 6, 1998 to January 24, 1998 when Train A containment sump outlet valve 2HV9305 was inoperable. During this period, the Train B CCW was out of service for maintenance. Hence, Train B ECCS was inoperable.

With Train A containment sump outlet valve inoperable and Train B ECCS inoperable, recirculation flow from the sump to the core would not be available post-LOCA unless the Train A sump valve was restored to operability, Train B ECCS was restored to operability, or Train A HPSI was cross-connected to Train B sump valve to provide flow. Following Recirculation Actuation Signal (RAS), ECCS flow would be available for a short time by depleting the RWST below the RAS setpoint.

The evaluation is limited to the LBLOCA recirculation mode, since the injection mode is not affected by the failure of the containment sump outlet valve. The evaluation determines the minimum time to RAS following LBLOCA for the plant conditions and equipment operable during the affected period. Then, the time post-RAS to reach 5% RWST level is determined. Finally, the time to core uncovering assuming no HPSI flow is calculated assuming SI flow from 2 charging pumps.

The minimum time to RAS, time to 5% RWST level, and time to core uncovering are hand calculations (see Section 3.0) assuming no HPSI pump flow to the core. Long term core cooling following LBLOCA is normally assured by operation of one HPSI pump during the recirculation mode.

INPUTS - LBLOCA

Time To RAS and Time To 5% RWST Level

1. HPSI pump flow = 850 gpm @ 50 psia Ref. 2, Table VII-1A
2. LPSI pump flow = 3805 gpm @ 50 psia Ref. 2, Table VII-3
3. Containment spray pump flow = 2136 gpm @ spray nozzle Ref. 2, IX.008
4. RWST Volume To RAS (92 - 18.5%) = 361,037 gal Ref. 3, Figure 2.1-1
5. RWST Volume To RAS (18.5 - 5%) = 66,312 gal Ref. 3, Figure 2.1-1

Time To Core Uncovery

1. Water volume above core (bottom of hot leg to top of core)
= 603 ft³ (extrapolated from midloop volumes) Ref. 5, Table 7
2. Water density = (1/.017482) lbm/ft³ @ 70 psia Ref. 4
3. Charging pump flow rate = 83 gpm Ref. 2, III.025
4. Decay Heat = 167 x 10⁶ Btu/hr @ 1 hr after reactor trip Ref. 6, pg. 5
5. Heat of vaporization = 907.8 Btu/lbm @ 70 psia Ref. 4

ASSUMPTIONS - LBLOCA

1. Actual RWST level during the period was 92% per Operations.
2. The swing HPSI pump will conservatively be assumed to be initiated concurrent with the autostart of the Train A HPSI pump, to maximize the rate of RWST depletion. This is consistent with the guidance provided in procedure SO23-12-3 (Reference 7).
3. Train B HPSI, LPSI, and Containment Spray pumps are inoperable. This is the plant condition described in LER 1998-003.
4. Two charging pumps are automatically started on SIAS. This is normal system operation on SIAS. The third swing charging pump would be started by the operators, but its flow is conservatively neglected to minimize the time to core uncovery. Since the charging pumps take suction from the BAMU tanks, and not the RWST, they do not deplete the RWST.
5. The suction source for the charging pumps is assumed to be the BAMU tanks, backed up with the BAST.

REFERENCES - LBLOCA

1. UFSAR SONGS Units 2&3, Revision 13
2. RGR-U2-C9, Revision 0 (including Change Notes 1 and 2), "SONGS Unit 2 Cycle 9 Reload Ground Rules"
3. RWST Minimum Level To Maintain Safety Analysis Assumptions, Including Instrument Uncertainties, J-BHB-029, Rev. 0 CCN-1

4. 1967 ASME Steam Tables
5. RCS Heatup Following Loss of SDC, N-0220-029, Rev. 0
6. SONGS 2/3 Single Fuel Assembly Decay Heat, N-1020-043, Rev. 0
7. Procedure SO23-12-3, Revision 14, "Loss of Coolant Accident"

COMPUTER CODES - LBLOCA

No codes were used to perform this evaluation.

ANALYSIS - LBLOCA

Injection Mode

Following a LBLOCA, Train A HPSI pump, LPSI pump, and containment spray pump are actuated on SIAS and CSAS. Train B HPSI pump, LPSI pump, and containment spray pump are not available due to Train B CCW out of service. The operator is assumed to start the swing HPSI pump which is aligned to Train A immediately after SIAS. This will minimize the time to deplete the RWST. The HPSI pump, LPSI pump, and containment spray pump take suction from the RWST.

Train A and Train B charging pumps are actuated on SIAS and take suction from the BAMU tanks. Letdown is isolated on the SIAS. It is assumed that the third swing charging pump is conservatively not started by the operators to minimize time to core uncover.

Since one Train of ECCS is operable during the injection mode, the UFSAR LBLOCA safety analysis is valid for the injection mode. The LBLOCA injection mode (includes blowdown, refill, and reflood) is not affected by the failure of the Train A containment sump outlet valve 2HV9305. The Peak Clad Temperature (PCT) for LBLOCA occurs during the injection mode at approximately 270 seconds (UFSAR Figure 15.6-106). Hence, the PCT for LBLOCA is not affected by the failure of 2HV9305.

Recirculation Mode

The post-LOCA recirculation mode is initiated automatically when the RAS is reached. The RAS initiation setpoint is at 18.5% RWST level. When RAS is reached, the Train A LPSI pump trips and the Train A containment sump outlet valve 2HV9305 is supposed to open. In the case being evaluated, it is assumed the sump outlet valve 2HV9305 fails to open. The Train B sump outlet valve 2HV9304 opens but the Train B HPSI pump, LPSI pump, and containment spray pump are inoperable due to the Train B CCW being out of service.

On RAS, Train A LPSI pump trips, but Train A HPSI pump, the swing HPSI pump, and the containment spray pump continue to run and take suction from the RWST because sump suction is unavailable for Train A (failure of 2HV9305).

Time To RAS

The minimum time to RAS (18.5% RWST level) is calculated by depleting the RWST volume from 92% (actual initial RWST level during the period) to 18.5% (RAS setpoint) by 2 HPSI pumps, 1 LPSI pump, and 1 containment spray pump.

Safety analysis values are assumed for HPSI pump, LPSI pump, and containment spray pump flow rates. The flow for 2 HPSI pumps is conservatively assumed to be twice the safety analysis flow of 1 HPSI pump.

$$\text{Time to RAS} = \text{RWST Volume To RAS} /$$
$$[2 \times \text{HPSI pump flow} + \text{LPSI pump flow} + \text{spray pump flow}]$$

Using values from Design Input,

$$\text{Time To RAS} = 361,037 \text{ gal} / [2 \times 850 \text{ gpm} + 3805 \text{ gpm} + 2136 \text{ gpm}]$$
$$= 47.2 \text{ min}$$

Time From RAS To 5% RWST Level

The minimum additional time to 5% RWST level is calculated by depleting the RWST from 18.5% RWST level (RAS setpoint) to 5% RWST level assuming 2 HPSI pumps and 1 containment spray pump running. The operator is assumed to trip the HPSI pump and spray pump when RWST level reaches 5% to prevent vortexing and pump damage.

Using the values from Design Input,

$$\begin{aligned} \text{Time From RAS To 5\% RWST Level} &= 66,312 \text{ gal} / [2 \times 850 \text{ gpm} + 2136 \text{ gpm}] \\ &= \mathbf{17.3 \text{ min}} \end{aligned}$$

Time To Core Uncovery

After the operator trips the HPSI pumps at 5% RWST level, the only SI flow remaining to the core is from 2 charging pumps. The time to core uncovery (TTCU) is calculated by assuming the minimum mass above the core is depleted by the boiloff rate minus the charging pump flow rate.

The mass above the core conservatively assumes that the RCS level is at the bottom of the hot leg when the HPSI pumps are stopped. The decay heat used is at the time HPSI flow is terminated (approximately 1 hour after event). The boiloff rate is conservatively assumed at 70 psia (maximum containment backpressure of 55 psia) without credit for charging subcooling.

$$\text{Time To Core Uncovery (TTCU)} = \text{Mass Above Core} / [\text{Boiloff Rate} - \text{Charging Rate}]$$

Using values from Design Input,

$$\text{Mass Above Core} = (603 \text{ ft}^3) \times (11.017482 \text{ lbm/ft}^3) = 34,492 \text{ lbm}$$

$$\begin{aligned} \text{Charging Flow Rate} &= (88 \text{ gpm})(1/7.48 \text{ ft}^3/\text{gal})(1/60 \text{ min/sec})(11.017482 \text{ lbm/ft}^3) \\ &= 11.2 \text{ lbm/sec} \end{aligned}$$

$$\text{Boiloff Rate} = 1.67 \times 10^8 \text{ Btu/hr} / 907 \text{ Btu/lbm} = 1.84 \times 10^5 \text{ lbm/hr} = 51.1 \text{ lbm/sec}$$

$$\text{Time To Core Uncovery (TTCU)} = 34,492 / (51.1 - 11.2) = 864.5 \text{ sec} = \mathbf{14.4 \text{ min}}$$

Table 3 - Large Break LOCA - Sequence of Events			
Time After Break (Min)	Time After RAS (Min)	Action	Comments
0		Break Occurs	
0		2 HPSI pumps and 1 LPSI pump start injection to RCS and 1 Containment Spray (CS) pump starts spraying to containment from RWST. SITs initiate injection. 2 Charging pumps inject to RCS from BAMU	Assume swing HPSI is initiated early. HPSI flow to same line for given pressure in UFSAR case. LPSI flow for given pressure in UFSAR case. CS at 2136 gpm nozzle flow per Reload Groundrules.
1		SITs discharge ends	
47	0	RAS setpoint reached, LPSI trip	18.5% level on RWST
47	0	Operators discover that HV-9305 fails to open	
64	17	2 HPSI and CS secured	Reached 5% level on RWST and pumps secured to prevent damage
78	31	Top of core uncovered	Assumes two charging pumps operating

CONCLUSION - LBLOCA

The results for the LBLOCA evaluation are:

Time To RAS = 47.2 min

Time To 5% RWST Level = 17.3 min

Time To Core Uncovery = 14.4 min

The total time from RAS to core uncovery is the sum of the latter two times, or 17.3 + 14.4 = 31.7 minutes. This represents the time required for operator action to establish HPSI flow to augment the charging flow and prevent top of core uncovery.

ATTACHMENT 3

**Small Break Loss-of-Coolant Accident (SBLOCA)
with Incomplete Recirculation Actuation Signal
(RAS) - A Simulator Case Study**

SMALL BREAK LOSS-OF-COOLANT ACCIDENT (SBLOCA) WITH INCOMPLETE RECIRCULATION ACTUATION SIGNAL (RAS) - A SIMULATOR CASE STUDY

PURPOSE

To validate assumptions made with regards to operator actions on a SBLOCA with incomplete RAS, a simulator scenario was prepared to simulate the conditions that existed on Unit 2 on January 13-14, 1998 (i.e., inoperable Train A containment emergency sump outlet valve, 2HV9305, and a Train B Salt Water Cooling Heat Exchanger tube leak repair outage).

The scenario was run on April 2, 1998, with two crew groups who were in their third day of simulator training. One crew group performed the scenario in the morning and one in the afternoon. Neither crew group was aware this day's training had any unique purpose, even after the scenario was run. Based on feedback after completion of the scenario, both crews felt this scenario was new and quite interesting.

The simulator setup was as follows: Train B Saltwater Cooling (SWC) Heat Exchanger 2E002 cleared for tube leak repair. Train B Emergency Core Cooling System (ECCS) pumps had the direct current (DC) control power open (to preclude inadvertent start when SWC was not available). High Pressure Safety Injection (HPSI) pump 2P018 and Component Cooling Water (CCW) pump 2P025 were both aligned to Train A. The Unit was simulated to be at full power.

TIMELINE LAYOUT

The timelines that follow are shown with Time=0 as time of RAS actuation. Times are in minutes. The first timeline is Crew 1 and the second timeline is Crew 2.

SUMMARY OF ACTIONS PRIOR TO RAS

The scenario was initiated by triggering a SBLOCA, causing multiple alarms related to loss of inventory and radiation release in containment. Both crews manually tripped the reactor before an automatic trip setpoint was reached. Shortly after the manual trip an automatic Safety Injection Actuation Signal (SIAS)/Containment Cooling Actuation Signal (CCAS) and Containment Isolation Actuation Signal (CIAS) occurred (in addition to the usual Emergency Feedwater Actuation Signal [EFAS] 1 & 2 actuations). Both crews performed the Standard Post-Trip Actions (SPTAs) although, due to having only one train of ECCS, both crew Shift Supervisors (SS's) directed manually starting the second HPSI pump (2P017) to maximize safety injection flow (this is in accordance with the LOCA Emergency Operating Instruction (EOI)).

Both crews promptly completed the SPTA's, diagnosed a LOCA in containment, and transitioned to the LOCA EOI, SO23-12-3. In addition, both crew SS's declared a Site Area Emergency about 10 minutes after the reactor trip, per EPIP SO123-VIII-1,

"Recognition and Classification of Emergencies," Table B3. The rest of Emergency Plan response was simulated for this scenario. The Nuclear Operations Assistant (NOA) would at this time initiate offsite notification and recall. The break size was sufficient to depressurize the RCS to about 900 psia initially, and caused the RCS loops to cool below Steam Generator saturation temperature quite rapidly.

Containment Spray was actuated automatically about 10 minutes after the trip. One crew SS dispatched operators to turn control power back on for CCW pump 2P026, and HPSI pump 2P019 to make them available. [This action was not well thought out as CCW pump 2P026 auto-started and the CCW Hi Temp alarm immediately came in due to the Emergency Cooling Units (ECUs) pumping heat back into the CCW system]. The SS then directed CCW pump 2P026 be stopped, and rescinded his direction to turn control power on for HPSI 2P019.

At this point, both crews had Train A containment spray, plus HPSI 2P017 and 2P018 running, feeding from the Refueling Water Storage Tanks (RWSTs). Approximately 25 minutes into the event, the Safety Injection Tanks (SITs) began to inject. After most actions were completed, the crews took a break and debriefed their actions up to this point [this allowed the simulator to continue to run and lower RWST level to closer to the RAS setpoint at a time when there was little operator action required]. After the critique, the crew took over again with RWST level about 30%, and SIT's empty. The containment pressure had peaked at about 15 psi and was now trending down to about 11 psi (low enough to be secured per EOI procedure). One crew considered securing Containment Spray prior to RAS, but decided against it.

TIMELINE OF ACTIONS AFTER RAS

Note: The simulator could not model 2HV9305 failure, so a redundant Train A isolation valve 2HV9303 was modeled to not open.

CREW #1

- T=0 RAS Train A and B actuation occurred. Control Board operator directed to verify proper RAS actuation, and identified 2HV9303 Emergency Sump outlet did not open. Crew attempted to manually open 2HV9303 (from Control Room (CR)).
- T=1 Crew recognizes 2HV9303 is outside containment and requests operator be dispatched to locally open the valve [simulator instructor did not allow this success path, as it would not work for 2HV9305]
- T=3 Verified still had a flowpath from the RWST for HPSI 2P017/018, and elected to continue to run all Train A ECCS pumps [did not consider Containment Spray termination]. Crew problem solving began using P&ID's and simplified drawings.

- T=12 Crew recognizes that HPSI 2P018 can have its suction aligned to Train B Emergency Sump and still remain aligned to Train A for CCW pump/motor cooling.
- T=16 SS calls Operations Support Center (OSC) to dispatch operator to open HPSI suction Train A/ Train B cross-tie, S21204MU011 (after reviewing flowpath on prints with RO).
- T=21 HPSI throttle-stop criteria met and direction given to throttle HPSI flow.
- T=23 Crew noted loss of flow on Containment Spray pump 2P012, gave direction to override SIAS and stop 2P012.
- T=26 Crew noted loss of flow on HPSI 2P017 and 2P018, gave direction to override SIAS and stop 2P017 and 2P018. Crew now recognizes there is only 132 gpm charging flow from Boric Acid Makeup (BAMU) tanks.
- T=29 ARO prompts starting HPSI 2P019 after isolating ECUs and restarting CCW 2P026. SS concurs and action is initiated.
- T=33 Crew restarts HPSI 2P018 after receiving word that MU011 is open. Verifies proper HPSI flow. Abandons effort to turn control power back on HPSI 2P019.
- T=35 Crew discusses long term need for cooling, need to get SWC B back or 2HV9303 open to allow Containment Spray to cool emergency sump.

End of Crew #1 Scenario Critique

CREW #2

- T=0 RAS Train A and B actuation occurred. Board operator directed to verify proper RAS actuation and identifies 2HV-9303 did not open. Crew attempted to manually (from CR) open HV-9303.
- T=1 Problem solving starts. CO recommends stopping Containment Spray. Shift Technical Advisor (STA) recommends stopping one HPSI pump to extend RWST drawdown time. SS sends operator to breaker for 2HV9303 to investigate and cycle. SS/Control Room Supervisor (CRS)/STA agree on plan to stop Containment Spray and one HPSI pump.
- T=5 Crew overrode and stopped Containment Spray, after verifying all EOI termination criteria met. Crew overrode and stopped HPSI 2P018 and verified Safety Injection flow still satisfactory. Team dispatched to locally open 2HV9303.

- T=9 ARO recommends opening HPSI 2P018 suction cross-tie, S21204MU011, while pointing to simplified ECCS drawing on CR-57. SS/STA/CRS discuss and agree to leave 2P017 running, shut 2S21204MU010 and open S21204MU011 (isolating 2P017 to Train A and 2P018 to Train B suction).
- T=11 Operator dispatched to close 2S21204MU010 and open 2S21204MU011. SS gets Technical Support Center (TSC) concurrence with plan, and declares and logs 50.54X entry.
- T=29 HPSI 2P018 started on Train B suction, crew verified proper SI flow and then stopped 2P017. RWST level still at about 14%.
- T=35 Crew discusses long term cooling plan, Shutdown Cooling (SDC) entry criteria met, so plan is to align LPSI 2P015 to SDC for cooling and continue to use HPSI 2P018 suction from emergency sump to keep RCS inventory up (combination of RAS and SDC). This combination does not require E002 RTS or 2HV9303 opened.

End of Crew #2 Scenario Critique

SUMMARY

Both crews immediately recognized an improper RAS actuation, and promptly came to same solution to align HPSI 2P018 suction to Train B sump and leave the rest of HPSI 2P018 aligned to Train A. Fifteen minutes was allotted for travel and alignment of the valve, resulting in restoration of the Safety Injection flow in 33, and 29 minutes respectfully. Neither crew pursued the maintenance repair aspects of 2HV9303 or 2E002 RTS. In non-EPIP training scenarios, it is the crews problem-solving skills alone that are being evaluated, and they tend to pursue options they have control of first. In full-blown EPIP scenarios, the SS will promptly call for restoration of any OOS equipment at the onset of the accident (drill), and immediately refer any failures during the scenario to the TSC and OSC for support. It is believed that in a real event, the crew would aggressively pursue restoration of OOS equipment anytime an accident occurred.

ATTACHMENT 4

**Probabilistic Risk Assessment - 2HV9305
Linestarter Failure**

PROBABILISTIC RISK ASSESSMENT 2HV9305 Linestarter Failure

PURPOSE

The purpose of this study is to determine the increase in core damage and large early release risk from inoperability of valve 2HV9305 from January 5, 1998 to January 24, 1998.

BACKGROUND

LER-98-003 documents an event where valve 2HV9305 was determined to be inoperable from 1142 hours on January 6, 1998 to 1133 hours on January 24, 1998. The valve was inoperable due to a failure of the mechanical interlock on valve's reversing linestarter.

Valve 2HV9305 is located inside containment in the containment sump post-LOCA recirculation flow path (see Figure 1). This valve is normally closed and receives a signal to open on a recirculation actuation signal (RAS). Failure of the valve to open would have prevented the success of the Train A post-LOCA recirculation flow path.

The San Onofre Living PRA model assumes that post-LOCA recirculation flow is required in small (3/8" to 2" diameter breaks), medium (2" to 6" diameter breaks), and large (6" diameter to double-ended break) LOCAs. The bases for this assumption are plant specific MAAP analyses which assume the most likely plant response (e.g., both trains of ECCS injecting) and worst case break location.

METHODOLOGY

The increase in core damage and large early release risk from inoperability of valve 2HV9305 was evaluated using the San Onofre Living PRA model contained in the Safety Monitor. Actual plant configurations during the period January 6, 1998 to January 24, 1998 including the unavailability and alignment of key plant components important to risk were considered in the assessment. During the period January 6, 1998 to January 24, 1998, three events contributed significantly to the risk increase from inoperability of 2HV9305: Train B CCW heat exchanger E002 out of service for a tube repair for 27.08 hours on 1/13/98, heat treatment of the Train B SWC/CCW for 6.6 hours on 1/16/98 and 7.0 hours on 1/24/98.

The Safety Monitor risk model contains the following conservatisms which impact the assessment of the risk increase from the 2HV9305 inoperability:

1. Recovery from the heat treat events prior to core damage is not modeled.
2. Recovery of 2HV9305 prior to core damage is not modeled.
3. Recovery of CCW heat exchanger 2E002 prior to core damage is not modeled.
4. Cross-tie of post-LOCA HP3I suction injection paths prior to core damage is not modeled.

These recovery actions were not modeled either because engineering analysis to support their success were not available or the actions required to perform the recoveries were not described in written plant procedures. Based on guidance in NUREG-1335, "Individual Plant Examination: Submittal Guidance", "The [NRC] staff, however, expects that all assumed or modeled recovery actions will have written procedures. Most often the [NRC] staff has received justifications for the assumptions of success for non-proceduralized actions based solely on time available for such actions. The [NRC] staff does not believe this type of argument to be correct."

However, since these recovery actions are likely and at least one was utilized in two simulator exercises modeling this event, a sensitivity analysis was performed to determine the risk impact of success of each and combinations of these recovery actions. The failure probability for each recovery action is calculated assuming the action was proceduralized or within the skill of plant personnel. This best estimate failure probabilities are then determined based on engineering judgement and available plant data including simulator runs. Given that different plant personnel would be performing the recoveries after event diagnosis by control room operators, all the actions are assumed to be independent and will not individually impact the likelihood of other recovery actions.

ANALYSIS

The actual plant configurations during the period January 6, 1998 to January 24, 1998 were analyzed in the Safety Monitor for two cases: (1) assuming availability of 2HV9305 and (2) assuming unavailability of 2HV9305. The difference in the risk results between the two cases represents the increase in risk due to unavailability of 2HV9305.

The Safety Monitor model was then modified to include the four recovery actions identified above. Since these recovery actions are not proceduralized, sensitivity analyses were performed for each and combinations of these recovery actions to determine the risk impact of the recoveries on plant risk.

The failure probability of each recovery action was determined using the ASEP human reliability analysis method documented in NUREG/CR-4772 (Ref. 1). It was assumed for the purposes of this analysis that the recovery actions were proceduralized or within

the skill of the plant operating staff. The results of the human reliability analysis are provided in Table 1.

Plant management reviewed the human reliability analysis for each recovery action and selected a more conservative value to account for some or all the action not being proceduralized (see Table 2). Also, simulator runs modeling the failure of 2HV9305 and unavailability of CCW heat exchanger 2E002 provided additional information on timing and the likely recovery action which the operators would select (a summary of the simulator runs are provided in another attachment).

Since these recovery actions have varying likelihoods of success depending on the event timing, the recovery actions were credited only in small LOCAs (3/8" to 2" diameter LOCAs). Large and medium LOCAs were conservatively assumed to lead to core damage prior to the success of any of the recovery actions based on the limited time available for recovery from deterministic thermal-hydraulic analyses.

The recovery actions were not credited for time periods other than those where the Train B post-LOCA recirculation train redundant to 2HV9305 was known to be unavailable (i.e. during the repair of CCW heat exchanger 2E002). The recovery of random failures in other time periods is very difficult and time-consuming since some of the random failures in the other time periods cannot be recovered by these recovery actions. This represents a significant conservatism in the analysis.

ASSUMPTIONS

The following key assumptions were used in the risk assessment:

1. Based on input from operations, recovery from the CCW/SWC heat treatments prior to core damage was assumed. The time available to recover the inoperable CCW/SWC train in heat treat prior to core damage for a small LOCA is approximately 250 minutes. The operators would be expected to exit the heat treat configuration soon after the LOCA initiation and restore CCW/SWC capability within 20 minutes. Based on the large margin between the time available and time required, this recovery action was assumed to occur.

When heat treating a SWC train the Inop flag alarms are actuated by procedure as a reminder of high temp on the SWC system. Usually the CCW train is off so as to not heat up the entire CCW system to 103°F. Upon the SIAS the CCW pump would start and actuate the CCW Hi Temp alarm, a further prompt to take action.

For the unit under heat treat, the LOCA will cause an auto reactor and turbine trip. If there is not a loss of all offsite power, the loss of turbine heat and the circ flow will rapidly cool the intake back down with no operator action required.

For the heat treat on the other unit, the above alarms would prompt the crew to secure the heat treat on the other unit and initiate swapping the SWC pump breaker to the opposite unit intake. To do this the operators would first need to secure the ECCS pumps and CCW train (override and stop from CR). Then override and stop the SWC pump, go to 50' electrical, rack out one breaker, rack in the other, start the SWC pump, and restart the CCW pump and the ECCS pumps.

2. The recovery actions considered are assumed to be independent and do not individually impact the likelihood of other recovery actions. The plant personnel performing each of recovery action would be different, thus concerns about staff manning and miscommunication are not applicable. The diagnosis error rate for each of these recovery actions is negligible compared to the action error rate for these actions. Therefore, it can be conservatively assumed that the control room staff performs the diagnosis for each of these recovery actions sequentially. Once the diagnosis occurs and plant personnel are implementing the actions, the actions are assumed to occur in parallel since each involves a different organization (i.e., maintenance mechanics would restore the CCW heat exchanger, maintenance electricians would troubleshoot and open 2HV9305, and an auxiliary operator would realign the HPSI suction flow path).

RESULTS

The increase in core damage risk from inoperability of valve 2HV9305 from January 6, 1998 to January 24, 1998 without crediting any recovery actions is estimated to be $2E-5$. Crediting each of the recovery actions independent of the others results in the core damage risks graphs provided in Figures 2, 3, and 4. When all the recovery actions are credited with the best estimate values selected in Table 2, the core damage risk increase is estimated to be $6E-6$. The likelihood that at least one recovery action will succeed is 96%.

The increase in large early release risk from inoperability of valve 2HV9305 was estimated to be $3E-8$ assuming recovery of the heat treat and $3.3E-8$ assuming no recovery of the heat treat events. However, based on the large redundancy in containment cooling systems (4 emergency fan coolers as well 2 trains of containment spray), this event would not have significantly impacted containment cooling capability. Any one emergency containment fan cooler or train of containment spray would have been capable of preventing containment failure based on MAAP analyses performed for the IPE. The inoperability of 2HV9305 would only have impacted the availability of

a single containment spray train. Therefore the increase in large early release risk from this event is assumed negligible.

CONCLUSIONS

The increase in core damage release risk from inoperability of valve 2HV9305 from January 6, 1998 to January 24, 1998 was small. The increase in large early release risk from inoperability of valve 2HV9305 was insignificant.

REFERENCES

1. Swain, A., "Accident Sequence Evaluation Program Human Reliability Analysis Procedure", NUREG/CR-4772, February 1987.

TABLE 1
Recovery Actions Human Reliability Analysis (HRA) Summary

Operator Action	Time to Core Damage (T _w)	Indication Time (T _i)	Time to Perform Action (T _A)	Time Available to Perform Diagnosis (T _D) #	Diagnosis Human Error Probability (HEP _D) (Figure 8-1, Ref. 1)	Post-Diagnosis Action Human Error Probability (HEP _A) (Table 8-5, Ref. 1)	Total Human Error Probability (HEP = HEP _D + HEP _A)
Recovery of 2HV9305 (SLOCA)	250 minutes	118 minutes (RAS)	40 minutes (+)	250-118-40 = 92 minutes	0.002 (Upper Bound Curve Used)	0.25 (HEP, Item 5) x 2 (PSF Outside CR Task) x 0.5 (RF, Item 8) = 0.25 (*)	0.25
CCW Recovery (SLOCA)	250 minutes	0 minutes (IE)	200 minutes (++)	250-200 = 50 minutes	0.004 (Upper Bound Curve Used)	0.05 (HEP, Item 4) x 2 (PSF Outside CR Task) = 0.1 (**)	0.1
HPSI Cross-Connect (SLOCA)	250 minutes	118 minutes (RAS)	20 minutes (+++)	250-118-20 = 112 minutes	0.002 (Upper Bound Curve Used)	0.25 (HEP, Item 5) x 2 (PSF Outside CR Task) x 0.5 (RF, Item 8) x 0.5 (2nd RF by STA or OSC/TSC, Item 8) = 0.13 (*)	0.13

Notes:

* The assumed Performance Shaping Factors (PSFs) for the Post-Diagnosis action are: 1) dynamic task, 2) extremely high stress, 3) outside CR task (a factor of 2 was assumed), and 4) skilled operating crew.

** The assumed Performance Shaping Factors (PSFs) for the Post-Diagnosis action are: 1) step-by-step task, 2) extremely high stress, 3) outside CR task (a factor of 2 was assumed), and 4) skilled operating crew.

Notes (cont.):

- + The specific tasks with their times are: 1) recognize failure of 2HV9305 to open and secure HPSI and CS pumps (1 min), 2) direct maintenance to troubleshoot 2HV9305 (5 min), 3) transit to MCC and perform troubleshooting (21 min), 4) perform work to open 2HV9305 (10 min), and 5) restart HPSI 2P018 (3 min) [$T_A = 1+5+21+10+3 = 40$ min].
- ++ The specific tasks with their times are: 1) Shift Supervisor (SS) declares LOCA event (10 min), 2) SS direct maintenance to restore Train B CCW (5 min), 3) reassemble SW side of CCW and notify CR (120 min), 4) restore Train B CCW and SW flow (60 min), 5) restore DC and start HPSI 2P019 (5 min) [$T_A = 10+5+120+60+5 = 200$ min].
- +++ The specific tasks with their times are: 1) recognize failure of 2HV9305 to open (1 min), dispatch PEO to open 2MU011 (1 min), PEO open 2MU011 and notify CR (15 min), restart HPSI 2P018 (3 min) [$T_A = 1+1+15+3 = 20$ min].

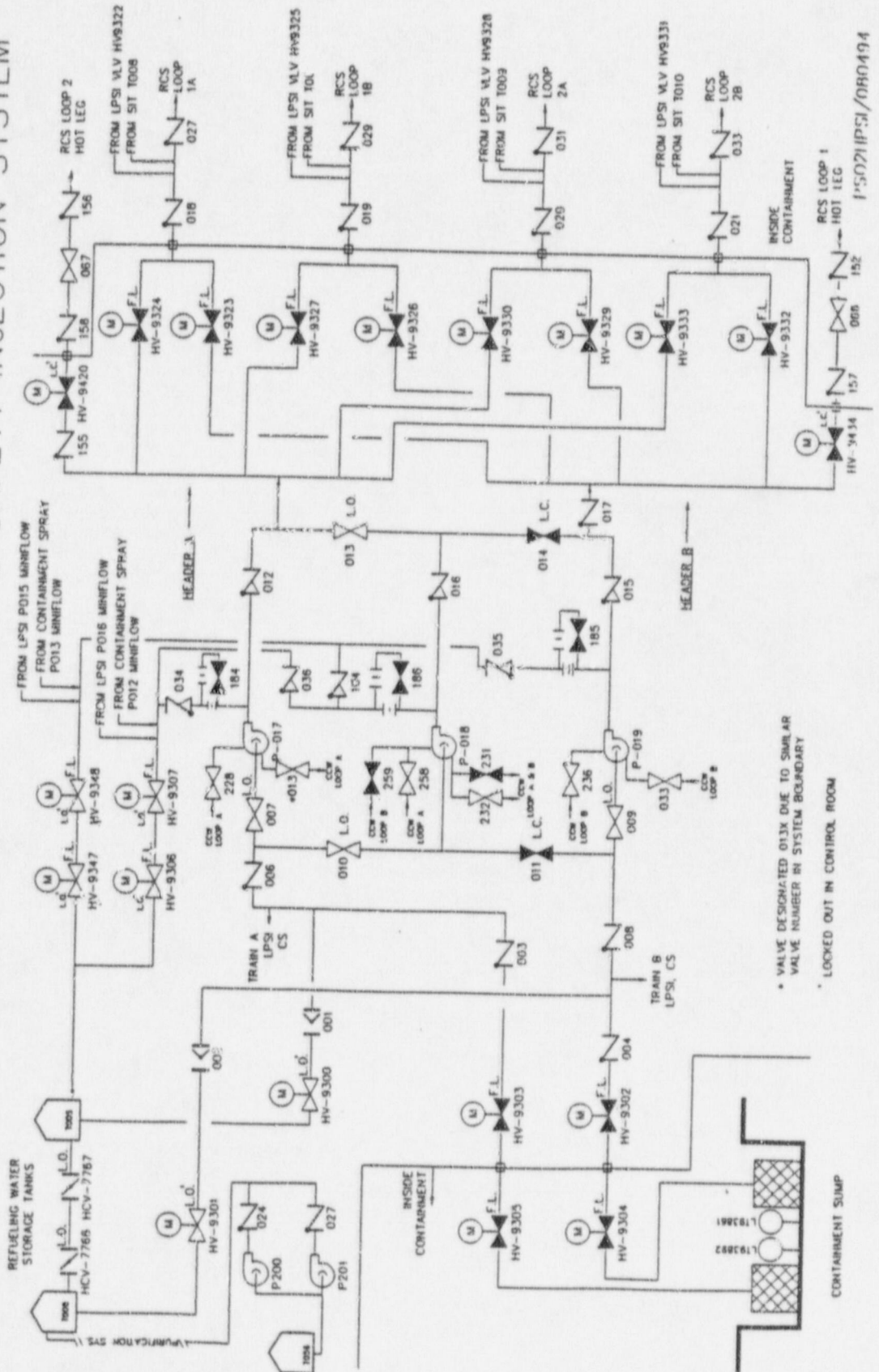
$$\# T_D = T_w - T_I - T_A$$

TABLE 2
Best Estimate Recovery Action Probabilities Selected Based on Engineering Judgement

Operator Action	Time to Core Damage (T_{CD})	Indication Time (T_I)	Time to Perform Action (T_A)	Time Available to Perform Diagnosis (T_D)	Human Error Probability assuming proceduralized (from Table 1)	Best Estimate Human Error Probability
Recovery of 2HV9305 (SLOCA)	250 minutes	118 minutes (RAS)	40 minutes	250-118-40 = 92 minutes	0.25	0.5
CCW Recovery (SLOCA)	250 minutes	0 minutes (IE)	200 minutes	250-200 = 50 minutes	0.1	0.4
HPSI Cross-Connect (SLOCA)	250 minutes	118 minutes (RAS)	20 minutes	250-118-20 = 112 minutes	0.13	0.2 (based on two simulator runs where operators completed action approximately 30 minutes from RAS)

FIGURE 1

SAN ONOFRE UNITS 2/3 HIGH PRESSURE SAFETY INJECTION SYSTEM

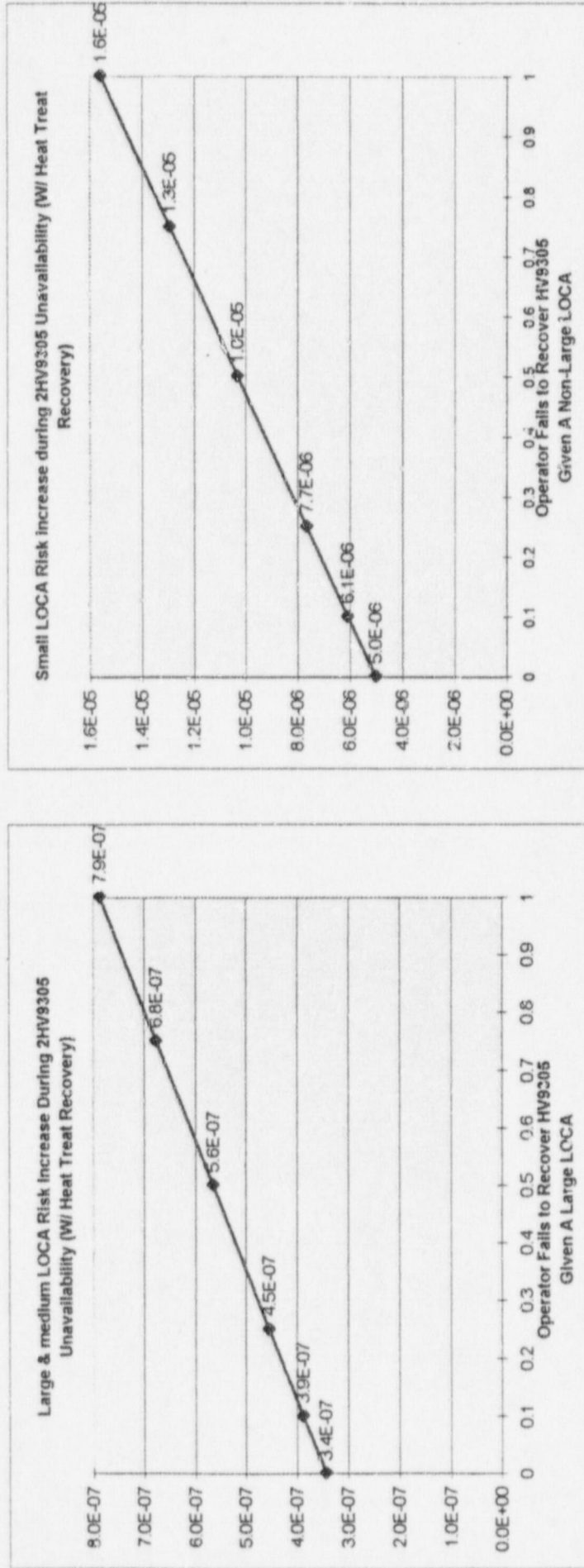


* VALVE DESIGNATED 013X DUE TO SIMILAR VALVE NUMBER IN SYSTEM BOUNDARY

* LOCKED OUT IN CONTROL ROOM

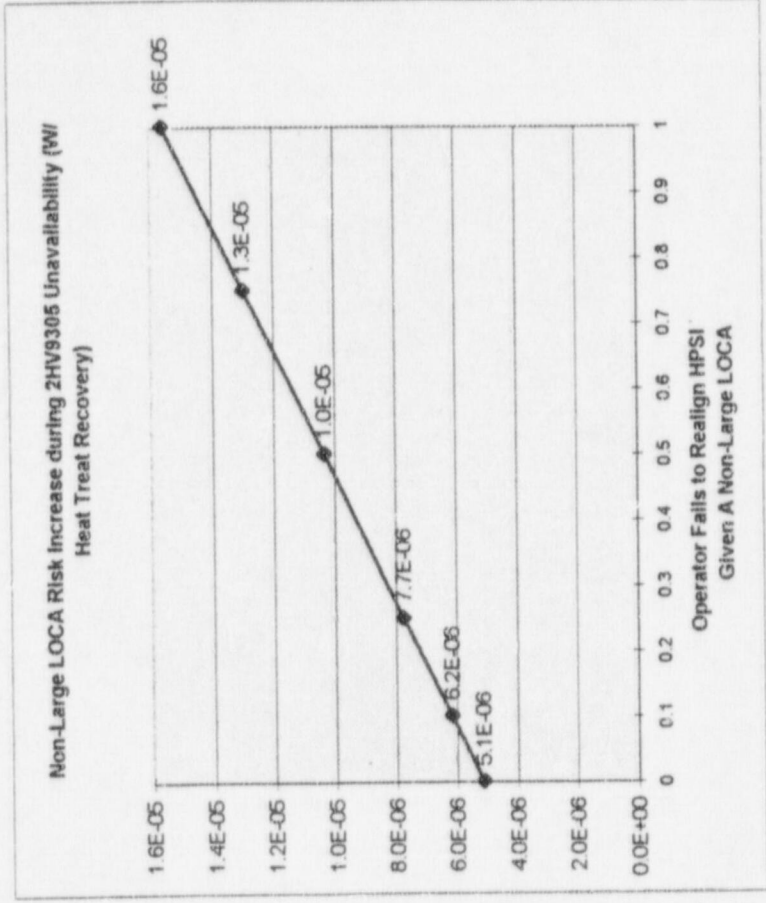
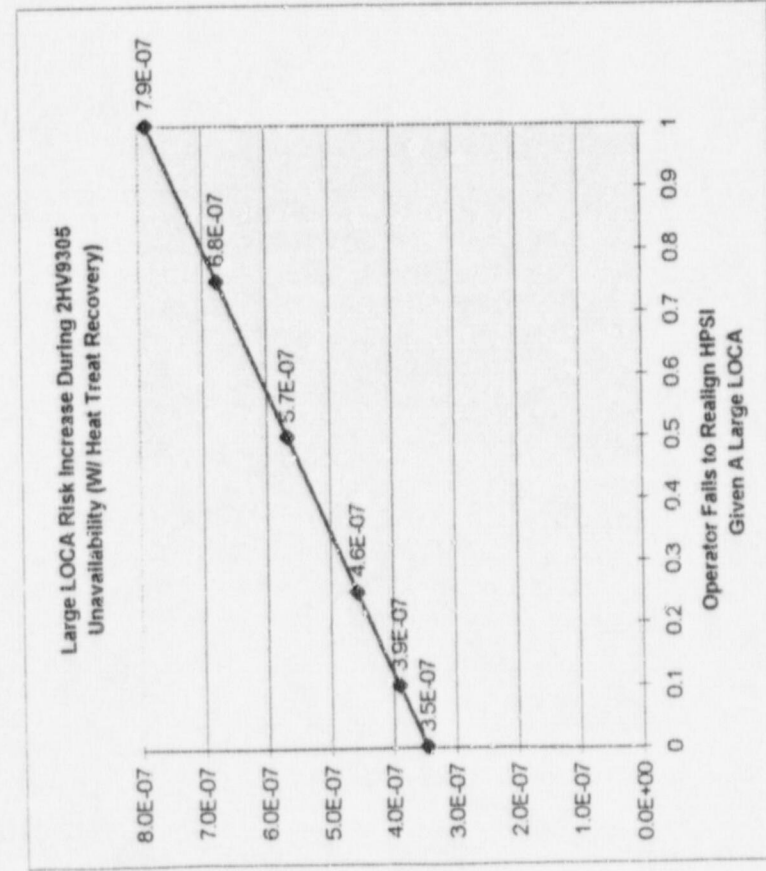
15021P51/DR0494

FIGURE 2
Core Damage Risk Increase with Recovery of 2HV9305



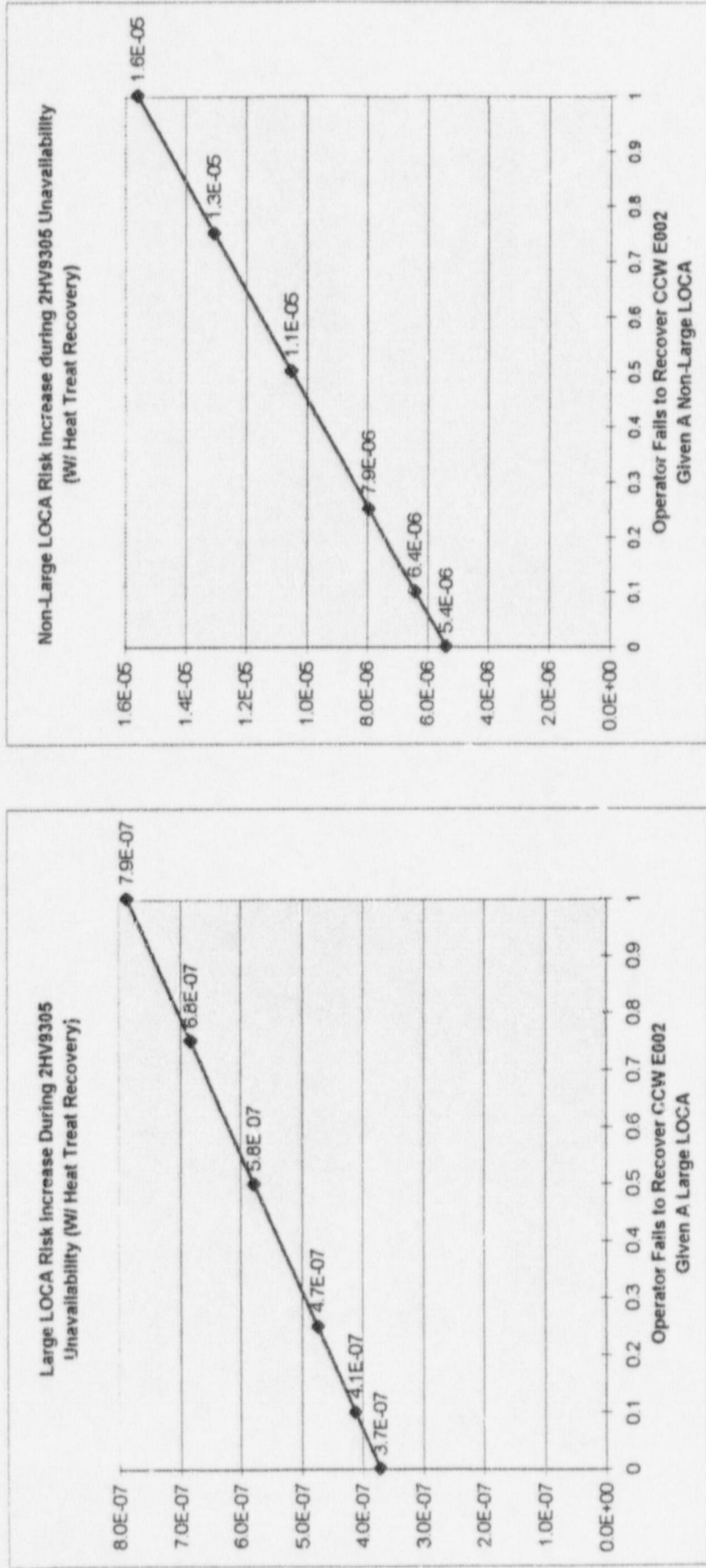
Assumptions 1) No credit for recovery of 2HV-9305 during configurations where CCW HX is initially available
 2) Heat Treatment of the SWC Train is assumed recovered prior to Core Damage.
 3) No credit for E002 recovery or HPSI cross-connect.

FIGURE 3
Core Damage Risk Increase with Recovery of HPSI Suction via Cross-Connect



- Assumptions
- 1) No credit for HPSI cross-connect during configurations where CCW HX (E002) is initially available
 - 2) Heat Treatment of the SWC Train is assumed recovered prior to Core Damage.
 - 3) No credit for 2HV9305 recovery or E002 recovery.

FIGURE 4
Core Damage Risk Increase with Recovery of CCW Heat Exchanger 2E002



Assumptions 1) No credit for recovery of E002 during configurations where CCW HX (E002) is initially available
 2) Heat Treatment of the SWC Train is assumed recovered prior to Core Damage
 3) No credit for 2HV9305 recovery or HPSI Cross-connect.

ATTACHMENT 5

**Failure Analysis Report 98-005, Failure Analysis
of the 2HV9305 Motor Starter**