B.8 LER Number 254/92-004 and 254/92-002

Event Description: Reactor Trip With HPCI and One Safety Relief Valve Unavailable

Date of Event: February 7, 1992

Plant: Quad Cities 1

B.8.1 Summary

Quad Cities 1 was at 100% power when a spurious Group 1 isolation signal resulted in main steam isolation valve (MSIV) closure and a reactor trip. One safety-relief valve (SRV) failed to open for pressure control. Feedwater (FW) was manually isolated and reactor core isolation cooling (RCIC) was used for makeup. High-pressure coolant injection (HPCI) was out of service for maintenance and unavailable during the event. The conditional probability of subsequent core damage estimated for the event is 6.9×10^{-6}. The relative significance of the event, compared to other postulated events at Quad Cities 1, is shown in Fig. B.9.

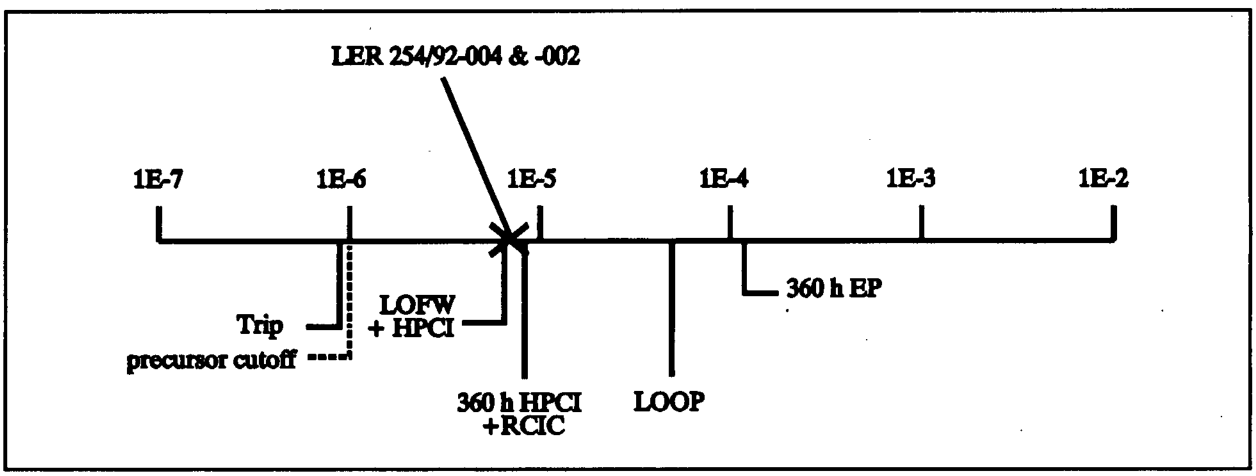

Fig. B.9. Relative event significance of LER 254/92-004 and -002 compared with other potential events at Qaud Cities 1.

B.8.2 Event Description

With the plant at 100% power on February 7, 1992, a spurious signal in the main steam line high flow circuitry resulted in the generation of a Group 1 isolation signal which closed the MSIVs. The reactor feed pumps did not auto-trip as expected at +48 inches, so FW was isolated by closing valves in the A

feedwater line and manually tripping the B feedwater pump. The investigation following the event indicated that the failure-to-isolate was caused by calibration errors, and that FW would have isolated had reactor vessel (RV) level continued to increase. Level and pressure were controlled by manually initiating RCIC and manually opening the B safety-relief valve. Following the initial use of the B valve, an attempt was made to use the C valve; however, this valve failed to open.

On the day preceding this event (February 6, 1992, 10CFR50.72 Report No. 22754), while testing the remote HPCI trip function, HPCI stop valve H01-2317 had failed in the open position. HPCI had been declared inoperable, the stop valve had been isolated, and was disassembled at the time of the reactor trip (LER 254/92-002).

B.8.3 Additional Event-Related Information

In addition to HPCI and RCIC, Quad Cities can utilize a Safe Shutdown Makeup Pump (SSMP) to provide high pressure makeup in the event of a loss of feedwater (FW). The pump is motor driven and is capable of supplying 400 gpm at essentially all reactor pressures. The pump and associated valves can be operated from the control room. Utilization of the SSMP requires opening a test return valve, starting the pump, opening the injection valve, and closing the test return valve. The SSMP would be used if both HPCI and RCIC were to fail.

Four electromatic and one Target Rock relief valve are available for depressurization at Quad Cities 1. The test history for these valves is shown in Table B.6. Based on maintenance demands, and assuming for the purposes of this analysis that the results for the five valves can be grouped, a failure-to-open probability of 0.056 and a failure-to-close probability of 0.013 is estimated.

Table B.6. Quad Cities 1 Safety Relief Valve Demand History for LER 254/92-004

		Valve				
Date[2]	Type	A	B	C	D	E
020073	Initial Startup	s	s	s	s	s
080073	Routine	s	s	s	s	s
020074	Routine	s	s	s	s	s
070074	Post Maint	s	s	s	s	s
010075	Routine	s	s	s	s	s
070075	Routine	s	s	s	s	s
010376	Routine	s	s	s	s	s
050076	Post Maint	s	s	s	s	s
110776	Post Maint			s		s
032077	Routine	s	s	fto	s	s
051077	Post Maint	s	s	s	s	s
102977	Routine	s	s	s	s	s
111677	Scram		fto			
111677(?)	Post Maint		s		s	

Table B.6. Quad Cities 1 Safety Relief Valve Demand History for LER 254/92-004

		Valve				
Date[2]	Type	A	B	C	D	E
020578	Routine(?)		s	s	s	fto
021378	Post Maint					s
042478	Routine(?)	s	s	fto	s	s
042678	Post Maint			s		
102678	Routine	s	s	s	s	s
022779	Post Maint	s	s	s	s	s
051179	Routine	s	s	s	s	s
091479	Routine(?)	s	s	s	s	s
092079	Post Maint					s
122079	Routine(?)	s	s	s	s	s
051180	Routine	s	fto	s	s	s
051180(?)	Post Maint		s			
083180	?	s	ftc			
083180(?)	Post Maint	s	s	s	s	s
122080	Post Maint	s	s	s	s	s
030381	?	s	s	s	s	s
052281	?	s				
052581	Post Maint		s	s	s	s
112081	Routine	s	s	s	s	s
052882	Routine	s	s	s	s	s
122282	Post Maint	s	s	s	s	s
031183	?	s				
031583	?		s	s	s	s
092283	Routine	s	s	s	s	s
030584	Routine	s	s	s	s	fto
081784	Post Maint	s	s	s	s	s
021685	Routine	s	s	s	s	s
091385	Routine	s	s	s	s	s
010786	Post Maint	s	s	s	s	s
040586	Post Maint	s	fto	s	s	s
111686	?					s
030287	Routine	s	s	s	s	s
122387	Post Maint	s	s	s	s	s
122887	HPCI Inop	s	s	s	s	s
060088	Routine	s	s	s	s	s
120088	Routine	s	s	s	s	s
041789	?	s	s	s	ftc	

Table B.6. Quad Cities 1 Safety Relief Valve Demand History for LER 254/92-004

		Valve				
Date[2]	Type	A	B[1]	C	D	E
041889	Post Maint		s		s	s
090989	?	s	s	s	s	s
031390	Post Maint	s	s	s	s	s
081190	?	s	s	fto	s	s
081790	Post Maint			s		
042691	Post Maint	s	s	s	s	s
102791	Routine	s	fto	s	s	s
112491	Post Maint		s			s
020792	Scram		s	fto		
021992	Post Maint	s	s	s	s	s
Non post-maint fto		0	3	4	0	2
Non post-maint ftc		0	1	0	1	0
Non post-maint demands		32	34	32	31	31

p(fto) = 9/160 = 0.056
p(ftc) = 2/160 = 0.013

s: successful operation
fto: failed to open
ftc: failed to close

1. Taking credit for a stuck-open relief valve for ADS would be optimistic for situations in which the valve is partially open.

2. Only months and years were provided by the utility for dates indicated as MM00YY.

Based on the Quad Cities final safety analysis report (FSAR), operability of three of the five safety relief valves is required for automatic depressurization system (ADS) success. In the event of a stuck-open relief valve, two of the remaining four valves must operate. Thermal-hydraulic analyses performed in support of the Individual Plant Examination (IPE) indicate that RCIC or the SSMP, in addition to HPCI and FW, can provide sufficient makeup to prevent core damage in the event of a single stuck-open relief valve (the potential use of RCIC for this function has been confirmed at other plants).

B.8.4 Modeling Assumptions

The event has been modeled as a reactor trip with MSIV closure (loss of power conversion systems [PCS]). Because of the way that feedwater was isolated, it was assumed to be nominally available (the

failure probability for FW was not modified in the analysis). HPCI was modeled as unavailable and nonrecoverable.

The probability of a stuck-open relief valve was estimated to be 0.013. At Quad Cities, normal practice appears to involve the manual opening of one relief valve to control pressure following a scram. Therefore, only one valve could fail to close during most transients.

The failure probability for ADS was estimated based on the single relief valve failure-to-open probability (0.056) discussed above and the common cause β-factors listed in NUREG/CR-4550, *Analysis of Core Damage Frequency: Internal Events Methodology*, Vol. 1, Rev. 1, January 1990, pp 6-13 and 6-14. These β-factors are 0.22 (two relief valves fail to open), 0.15 (three valves), and 0.12 (four valves). The three-out-of-five success criteria described above was utilized for ADS. This criteria is consistent with that utilized in the NUREG 1150 ananlysis of Peach Bottom (NUREG/CR-4550, *Analysis of Core Damage Frequency: Peach Bottom, Unit 2, Internal Events*, Vol. 4, Rev. 1, August 1989). For sequences in which three of five valves must operate for success (three of five valves must fail to fail ADS), the ADS failure probability is estimated as p(ADS) = p(independent failures) + p(dependent failures) + p(incorrect operator actions associated with depressurization) $\approx$ C(5,3) $\times$ $P_I^3 + P_I\beta_3$ + p(opr) $\approx$ 10 $\times$ $(0.056)^3$ + (0.056) $\times$ 0.15 + 0.01 $\approx$ 0.020.

For sequences in which two of four valves must open (sequences involving a stuck open relief valve, three of four valves must fail in order to fail ADS), p(ADS) $\approx$ C(4,3) $\times$ $P_I^3 + P_I\beta_3$ + p(opr) $\approx$ 4 $\times$ $(0.056)^3$ + 0.056 $\times$ 0.15 + 0.01 $\approx$ 0.019.

For this event, the C relief valve failed to open. The ADS failure probability is estimated to be

p(ADS | 3 valves required and one failed) $\approx$ C(4,2) $\times$ $P_I^2 + P_I\beta_2$ + p(opr) $\approx$ 0.041, and

p(ADS | 2 valves required and one failed) $\approx$ C(4,3) $\times$ $P_I^3 + P_I\beta_3$ + p(opr) $\approx$ 0.019.

The calculations were performed using a branch probability for ADS of 0.041. Probabilities for sequences involving a stuck-open relief valve and ADS challenge were modified to reflect an ADS failure probability of 0.019.

The SSMP was considered the primary backup for HPCI and RCIC in the analysis. Since the pump can be operated from the control room, it was assumed that no effort would be made to recover RCIC before using the SSMP (HPCI was unavailable during the event). Two motor-operated valves plus the pump itself must be remote-manually operated for SSMP success. A failure probability of 0.04 was estimated, based on the nominal failure probabilities used in the ASP program (0.01 for pumps and motor-operated valves) and an assumed operator error probability of 0.01. This operator error probability is typically used for failure to utilize the CRD pumps for reactor pressure vessel makeup following HPCI and RCIC failure (see Appendix A, Sect. A.3.2, BWR Nonspecific Reactor Trip, and Table A.14). At Quad Cities, however, the operators are directed to use the CRD pumps only if HPCI, RCIC and the SSMP all fail. The probability assumed in the analysis for failure to use the CRD system following failure of HPCI, RCIC and the SSMP was 0.12 (see Appendix A, Sect. A.1).

To address the potential use of RCIC or the SSMP to provide core cooling in the event of a single stuck-open relief valve, the conditional probabilities for sequences involving a stuck-open relief valve with FW and HPCI failure (sequences 23 - 28) were muliplied by

p(2 or more RVs open | one RV open) + p(RCIC) * P(SSMP).

Since only one RV is manually opened at Quad Cities for most transients, p(2 or more RVs open | one RV open) ~ 0. Sequences with successful relief valve closure and FW, HPCI and RCIC failure (sequences 14 - 20 and 32 - 38) were similarly modified to include failure of the SSMP by multiplying their failure probabilities by p(SSMP).

Modifications to the sequence conditional probabilities indicated on the Conditional Core Damage Probability Calculation sheets to reflect the above considerations follow:

Sequence	p(RCIC)	p(SSMP)	p(ADS)
14 - 20	included	0.04	
23 - 28	0.042	0.04	0.019
32 - 38	included	0.04	

For the dominant sequences shown on the calculation sheets, the above modifications result in the following revised conditional probabilities:

	calculation sheet probability	revised probability
sequence 28	5.2×10^{-5}	4.1×10^{-8}
sequence 20	2.1×10^{-5}	8.4×10^{-7}
sequence 11	4.9×10^{-6}	4.9×10^{-6}

The overall conditional probability estimated for the event is 6.9×10^{-6}.

B.8.5 Analysis Results

The estimated conditional probability calculated for this event is 6.9×10^{-6}. The dominant sequence associated with the event, shown on the event tree in Fig. B.10, involves failure of long-term core cooling following successful scram and failure of continued PCS operation, SRV challenge and successful reseat, and successful FW. Note that the core damage probabilities shown on the calculation sheets have been revised as described above.

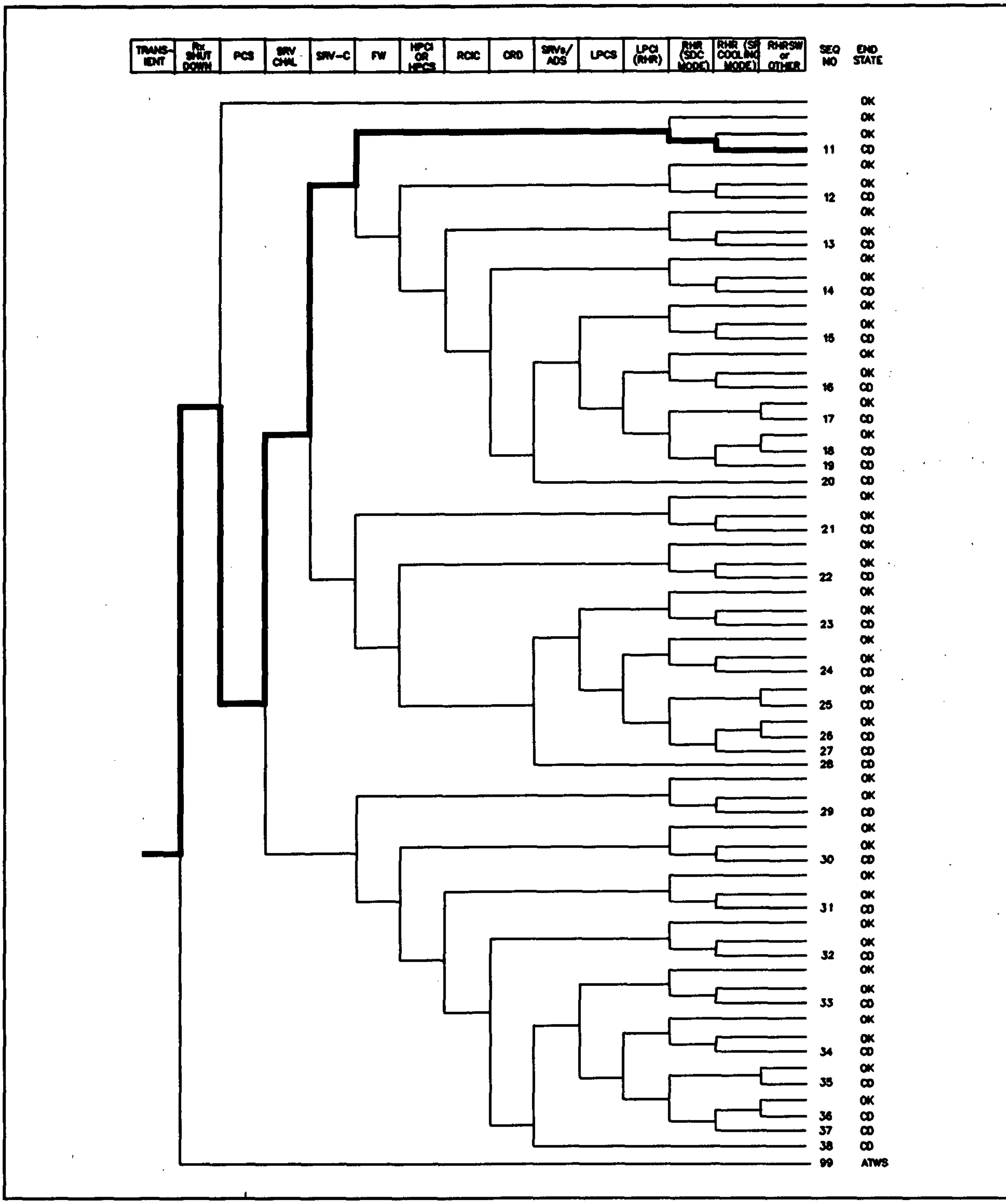

Fig. B.10. Dominant core damage sequence for LER 254/92-004.

CONDITIONAL CORE DAMAGE PROBABILITY CALCULATIONS

Event Identifier: 254/92-004
Event Description: Trip and FW isolation with HPCI and one SRV unavailable
Event Date: 02/07/92
Plant: Quad Cities 1

INITIATING EVENT

NON-RECOVERABLE INITIATING EVENT PROBABILITIES

TRANS	1.0E+00

SEQUENCE CONDITIONAL PROBABILITY SUMS

End State/Initiator	Probability
CD	
TRANS	7.9E-05 (1)
Total	7.9E-05 (1)
ATWS	
TRANS	3.0E-05
Total	3.0E-05

SEQUENCE CONDITIONAL PROBABILITIES (PROBABILITY ORDER)

	Sequence	End State	Prob	N Rec**
28	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram SRV.CLOSE fw/pcs.trans HPCI SRV.ADS	CD	5.2E-05[1]	3.4E-01
20	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -SRV.CLOSE fw/pcs.trans HPCI rcic CRD SRV.ADS	CD	2.1E-05[1]	2.4E-01
11	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -SRV.CLOSE -fw/pcs.trans rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.9E-06	1.1E-01
99	trans rx.shutdown	ATWS	3.0E-05	1.0E+00

** non-recovery credit for edited case

SEQUENCE CONDITIONAL PROBABILITIES (SEQUENCE ORDER)

	Sequence	End State	Prob	N Rec**
11	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -SRV.CLOSE -fw/pcs.trans rhr(sdc) rhr(spcool)/rhr(sdc)	CD	4.9E-06[1]	1.1E-01
20	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram -SRV.CLOSE fw/pcs.trans HPCI rcic CRD SRV.ADS	CD	2.1E-05[1]	2.4E-01
28	trans -rx.shutdown PCS/TRANS srv.chall/trans.-scram SRV.CLOSE fw/pcs.trans HPCI SRV.ADS	CD	5.2E-05[1]	3.4E-01
99	trans rx.shutdown	ATWS	3.0E-05	1.0E+00

** non-recovery credit for edited case

Event Identifier: 254/92-004

SEQUENCE MODEL: c:\asp\1989\bwrcseal.cmp
BRANCH MODEL: c:\asp\1989\quadcit1.si1
PROBABILITY FILE: c:\asp\1989\bwr_csi1.pro

No Recovery Limit

BRANCH FREQUENCIES/PROBABILITIES

Branch	System	Non-Recov	Opr Fail
trans	1.4E-04	1.0E+00	
loop	1.6E-05	5.3E-01	
loca	3.3E-06	5.0E-01	
rx.shutdown	3.0E-05	1.0E+00	
rx.shutdown/ep	3.5E-04	1.0E+00	
PCS/TRANS	1.7E-01 > 1.0E+00	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	1.7E-01 > Unavailable[2]		
srv.chall/trans.-scram	1.0E+00	1.0E+00	
srv.chall/loop.-scram	1.0E+00	1.0E+00	
SRV.CLOSE	1.0E-02 > 1.3E-02	1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	1.0E-02 > 1.3E-02[3]		
emerg.power	2.9E-03	8.0E-01	
ep.rec	4.9E-02	1.0E+00	
fw/pcs.trans	2.9E-01	3.4E-01	
fw/pcs.loca	4.0E-02	3.4E-01	
HPCI	2.9E-02 > 1.0E+00	7.0E-01 > 1.0E+00	
Branch Model: 1.OF.1			
Train 1 Cond Prob:	2.9E-02 > Unavailable[4]		
rcic	6.0E-02	7.0E-01	
CRD	1.0E-02 > 1.0E-02	1.0E+00	1.0E-02 > 1.2E-01[5]
Branch Model: 1.OF.1+opr			
Train 1 Cond Prob:	1.0E-02		
SRV.ADS	3.7E-03 > 3.1E-02[3]	7.1E-01 > 1.0E+00[3]	1.0E-02
Branch Model: 1.OF.1+opr			
Train 1 Cond Prob:	3.7E-03 > 3.1E-02		
lpcs	3.0E-03	3.4E-01	
lpci(rhr)/lpcs	1.0E-03	7.1E-01	
rhr(sdc)	2.1E-02	3.4E-01	1.0E-03
rhr(sdc)/-lpci	2.0E-02	3.4E-01	1.0E-03
rhr(sdc)/lpci	1.0E+00	1.0E+00	1.0E-03
rhr(spcool)/rhr(sdc)	2.0E-03	3.4E-01	
rhr(spcool)/-lpci.rhr(sdc)	2.0E-03	3.4E-01	
rhr(spcool)/lpci.rhr(sdc)	9.3E-02	1.0E+00	
rhrsw	2.0E-02	3.4E-01	2.0E-03

* branch model file
** forced

Notes:
[1] See Modeling Assumptions for modifications to this sequence conditional probability value.
[2] The MSIVs were closed during the event; this resulted in PCS unavailability.
[3] See Modeling Assumptions for development of this probability value.
[4] The HPCI stop valve was disassembled during the event; this resulted in HPCI unavailability.
[5] The probability of failing to initiate CRD injection for core cooling was modified based on consideration of the SSMP in the analysis. See Modeling Assumptions.

Event Identifier: 254/92-004