Final Precursor Analysis

Accident Sequence Precursor Program -- Office of Nuclear Regulatory Research

Watts Bar Unit 1	Silt Accumulation in ERCW System		
Event Date 11/22/2004	LER IR 05000390/2004005	ΔCDP	7.5 x 10^{-6}

June 15, 2006

Event Summary

Description

On November 22, 2004, while performing a manual valve exercising procedure it was determined that the backup cooling line from the Essential Raw Cooling Water (ERCW) system to the lube oil cooler for the 1A-A Centrifugal Charging Pump (CCP) was completely blocked with silt. This line provides backup cooling to this CCP in the event of loss of the normal cooling from the Component Cooling System (CCS). This pump is the only high head pump provided with backup cooling. The blocked line was mechanically cleared with the unit remaining on line at 100% power during the process.

This condition placed the unit in a situation where, if the CCS is lost, all Reactor Coolant Pump (RCP) seal cooling and high pressure injection is lost. This results in a seal LOCA and core damage.

Cause

The unavailability of the ERCW backup cooling for the 1A-A CCP was due to the accumulation of silt and/or debris in this standby, not normally flowing, line. This was the latest in a series of observations of significant buildup of silt/debris in the ERCW lines beginning in early 2004. The inspection report (Reference 1) does not include a root cause for this increased occurrence of silt buildup.

Condition Duration

In early 2004, Watts Bar began to observe significant buildup of silt in the ERCW lines. Between 2/19/2004 and 10/4/2004 ten Problem Evaluation Reports (PERs) were prepared concerning silt/debris blockage of ERCW lines. None affected component operability since they involved only partial blockage or the blockage cleared when flow was initiated. The earliest recent report concerning blockage specifically attributed to silt/debris was a PER on 7/29/2003 involving a small (5-10%) buildup in the ERCW B train backup supply to the Turbine Driven Auxiliary Feed Water (TDAFW) pump. The condition duration is assumed to be 6024 hours (251 days) which is half of the time from the prior successful testing of the ERCW line to the 1A-A CCP until it was found plugged.

Other Related Conditions or Events During the Condition Period

A review of LERs and Inspection Reports from the beginning of 2004 until the present did not identify any Engineered Safety Feature operability issues.

Reference 1 identifies PERs in the time period from early 2004 until the complete blockage of the ERCW line to the 1A-A CCP associated with silt/debris blockage to the following components:

1. ERCW supply to A, B and C Station Air Compressors
2. ERCW A train backup supply to Turbine Driven Auxiliary Feed Water (TDAFW) pump (2 reports)
3. ERCW backup supply to the Train A CCS surge tank (2 reports)
4. ERCW backup supply to the Train B CCS surge tank (2 reports)
5. ERCW flood mode return line
6. ERCW B train backup supply to TDAFW pump
7. ERCW supply to the 1A containment spray heat exchanger

In each case component operability was not in question since each occurrence involved only partial blockage or the blockage cleared when flow was initiated. The number of events, and in particular the repeated events, indicates that the probability of inoperability due to blockage might be higher than the nominal values.

Analysis Results

- **Importance**

The point estimate importance of the described condition for the 6024 hour duration is

$$\Delta CDP = CCDP - CDP = (8.8 \times 10^{-5}) - (8.0 \times 10^{-5}) = 7.5 \times 10^{-6}$$

The GEM report for this assessment is provided in Appendix C.

The uncertainty distribution is compared to the point estimate for the conditional core damage probability and the revised base case core damage probability as follows.

	5%	Mean	Point Estimate	95%
CDP	7.9E-06	7.0E-05	8.0E-05	2.4E-04
CCDP	1.0E-05	1.5E-04	8.8E-05	5.7E-04
ΔCDP			**7.5E-06**	

- **Dominant Sequences**

The dominant accident sequences which collectively contribute to more than 98% of the ΔCDP are listed in Table 1 and are shown graphically in Figures A-1 through A-4 of Appendix A. All other sequences individually contribute less than 0.6% of the total.

The three dominant sequences are initiated by a total loss of Component Cooling Water, which with failure of the ERCW to the 1A-A Centrifugal Charging Pump due to the debris, leads to loss of RCP seal cooling, seal failure with no high pressure injection available and core damage. In sequence 3-02-06, the RCP stage 2 fails due to binding or popping. In sequence 3-03-06 the RCP stage 1 fails due to binding or popping. In sequence 3-04-3, both seal stages fail.

- **Results Tables**

  - The conditional probabilities for the dominant sequences are shown in Table 1.
  - The event tree sequence logic for the dominant sequences are presented in Table 2a.
  - Table 2b defines the nomenclature used in Table 2a.
  - The most important cut sets for the dominant sequences are listed in Table 3.
  - Definitions and probabilities for modified or dominant basic events are provided in Table 4.

- **Total Loss of Component Cooling Water Initiating Event**

The frequency of the total loss of component cooling water initiating event is an important contributor to the importance of the described condition. This frequency and its uncertainty distribution is

	Frequency (per year)				
	Point Estimate	**Mean**	**5%**	**Median**	**95%**
IE-LOCCW	1.04E-04	1.06E-04	1.85E-05	6.36E-05	3.25E-04

The important cut sets that contribute to the loss of CCW (CCS at Watts Bar) initiating event frequency are apparent in the dominant sequence cutsets in Table 3. Common cause plugging and fouling of the heat exchangers and of the CCW pumps seem to be the major causes of the initiator. A flow diagram of the Watts Bar CCW system is provided in Appendix E.

Modeling Assumptions

- **Analysis Type**

  This event is analyzed as a condition event assessment involving the unavailability of the backup ERCW supply to the 1A-A CCP. The initial evaluation was performed using the *Condition Assessment* feature of GEM 7.25 software package with event tree and fault tree modifications made using the SAPHIRE 7.25 software package. The final analysis was performed with SAPHIRE/GEM 7.26. The WBNP model utilized was a further modification to a revision by INEL of the Revision 3.11 WBNP SPAR model to include a complete loss of CCS (LOCCW) initiating event (Reference 3). This revision was prepared by INEL in order to perform the SDP Phase III analysis reported in Reference 2.

- **Unique Design Features**

  Only one high pressure injection source, CCP 1A-A, is available upon loss of the CCS and this availability depends on the ERCW system.

  WBNP was originally designed as a two unit plant. The CCS was to be shared between units. Although Unit 2 was not completed, the common portions of the CCS were completed consequently the Unit 1 CCS benefits from some added redundancy in CCS pumps.

- **Modeling Assumptions Summary**

  Key modeling assumptions. The key modeling assumptions are listed below and discussed in detail in the following sections. These assumptions are important contributors to the overall risk. Since the revised model which was the starting point for this analysis has not been released by INEL, the major changes in the INEL model as well as the current modifications made to analyze this condition are described below.

  – **Loss of Component Cooling System Initiating Event**

  The unavailability of the ERCW backup supply to the 1A-A CCP is most important for a complete loss of the CCS. This backup is utilized if Train A of the CCS is unavailable. If Train B of the CCS is also unavailable, either as a result of an initiating event or during the mission time of another initiating event, then all high head injection pumps are lost. This results in loss of seal cooling and the potential for a seal LOCA which then leads to core damage.

  The Revision 3.11 SPAR model for WBNP includes a loss of Train A of the CCS (LOCCW-A) initiating event but does not include the loss of both trains as an initiating event. An event tree for the total loss of CCS (LOCCW) has been added by INEL for the Phase III SDP assessment. The event tree is identical to the LOCCW-A event tree. The initiating event frequency is obtained from a fault tree model that assumes that the

failure of the running pump in Train A is followed within a 3 day time period by failure of the other Train A pump and Train B failure. The only common cause failures in the LOCCW initiating event frequency assessment are failure of four of four CCS pumps to run and failure of two of two standby CCS pumps to start. No recovery of any of the failed running CCS pumps is considered in the model.

Common cause failure of both of the CCS heat exchangers (one in each train) is not modeled in the INEL LOCCW initiating event model but is included in the models for loss of CCS following the other initiating events. SPAR database values for heat exchanger failures indicates that these failures could be important contributors to loss of CCS events.

Information on heat exchanger failure rates (Reference 4) implies two failure modes or causes, fouling and plugging, both with rates significantly less than that given in the SPAR database. It is assumed that fouling is a degradation of the ability of the surfaces to transfer heat and occurs more gradually over a period of time which is measured in days. Plugging is assumed to be a blockage of the flow through the heat exchanger and could occur over a very short time span.

Fouling and plugging of the heat exchangers were therefore added to all of the Watts Bar SPAR models associated with loss of CCS. It was assumed that the approach to fouling failure could be detected by the normal monitoring of CCS temperatures and the spare CCS heat exchanger (normally being used for fuel pool cooling) valved into service. Plugging, on the other hand, is assumed to be sufficiently rapid that the spare heat exchanger cannot be used. Since the spare heat exchanger is in normal use and therefore subject to the same conditions as the CCS Train A and B heat exchangers, all the CCS heat exchangers are included in the same common cause group for failure due to fouling.

– **Plugging of ERCW line to 1A-A CCP**

Plugging of the relatively large normally flowing portions of the ERCW side of the CCS heat exchangers would be expected to require a significant amount of material. Given this, it is considered highly likely that the relatively small, not normally flowing ERCW line to the 1A-A CCP oil cooler would be plugged when ever there is a complete loss of CCS due to common cause plugging of the CCS heat exchangers. This assumption is incorporated in the base case model.

– **Condition Duration**

The condition duration is assumed to be 6024 hours (251 days) which is half of the time from the prior successful testing of the ERCW line to the 1A-A CCP until it was found plugged.

Reference 1 notes that this line was found blocked in April 1999 but the cause was not known. Subsequently, 4 successful flushes were performed with the last being in July

2003 (about July 10 - Reference 2) or approximately 17 months (501 days) prior to the discovery of the blocked line on 10/22/2004. The required frequency of silt accumulation tests on this line was once every 18 months.

Since the exact time the blockage occurred is unknown, half of the actual last test interval will be used as the duration or 251 days. This corresponds to approximately the middle of March 2004 which is after the first report of significant blockage in other ERCW lines. The date of previous tests of any other ERCW line without blockage is not known and it is therefore possible that the ERCW line to the 1A-A CCP could have been blocked for one year or more. A duration of one year will be evaluated in a sensitivity analysis.

– **Plugging of Other ERCW Lines**

As discussed above, in the nine months prior to the discovery of the blocked ERCW line, debris and or silt accumulation was found in seven other ERCW lines. However, no instances of loss of function were found. All but one of these lines were standby lines with no flow under normal conditions. The single instance of silt/debris accumulation in a line with flow during normal conditions is that for the three station air compressors aftercoolers. The related PER does not indicate that performance was degraded. The lines to the aftercoolers are much smaller than those for the CCS heat exchangers and therefore the lines to the aftercoolers are considered to be more prone to silt accumulation than the lines to the CCS heat exchangers.

All but one of the standby lines found with the silt debris accumulation are utilized only for seismic or external flooding initiating events. In these instances the normal function is degraded by the initiating event and reliance is made on the ERCW system. Complete blockage and unavailability of these lines would therefore not impact the risk for internal initiating events.

The single instance of partial silt/debris blockage in a ERCW standby line to safety system required after a design basis accident was the line to the 1A containment spray heat exchanger. While the accumulation was not cleared by flow through the small drain line, it would have been cleared by the very much higher flow through the heat exchanger if it would have been initiated. Further, containment spray heat removal is not needed after an accident and it is not included in the SPAR Watts Bar model.

Based on the above assessments, it is assumed that the only ERCW line unavailable is the line to the 1A-A CCP and the nominal frequency of fouling and plugging are applicable to the conditions found.

– **Recovery Opportunities**

Diagnosing the cause of the failure of backup cooling to the 1A-A CCP and clearing the blockage is not considered an option under the circumstances associated with the demand for this cooling which is a complete loss of CCS.

The failure of the ERCW backup cooling to the 1A-A CCP is only important for failure of the CCS Train A as part of an initiating event or during the mission time following another initiator. Recovery of the CCS is therefore a possible recovery opportunity that would prevent core damage.

Other assumptions. Other assumptions that have a negligible impact on the results due to relatively low importance include the following:

The spare CCS heat exchanger is assumed to be available only if the Train A heat exchanger is found to be subject to a fouling failure. While the spare heat exchanger would also be available if the Train B heat exchanger were found to be subject to fouling, the Train B heat exchanger is less important and this option is not included in the model.

- **Event Tree Modifications**

  An event tree for the total loss of the CCS was added for the Phase III SDP analysis and, except for the initiating event, is identical to the event tree for the partial loss of CCS (LOCCW-A). These two trees were modified for this analysis by adding a new initiating event in front of the existing initiating event. The new initiating events (IE-D-LOCCW and IE-D-LOCCW-A) have values of 1.0 and are inserted to enable SAPHIRE/GEM to treat the loss of CCS initiating events (IE-LOCCW and IE-LOCCW-A) as any other top event in the event tree. Sequence cut sets therefore include the basic events that cause the initiating event. (See Figures A-1 and A-2)

- **Fault Tree Modifications**

  LOCCW Initiating Event - A new fault tree (IE-LOCCW) for determining the frequency of the total loss of the CCS was created for the Phase III SDP (References 2 and 3). This fault tree required failure of CCS Train A (IE-LOCCW-A) and CCS Train B (IE-LOCCW-B) and effectively included only failure of the CCS pumps. These fault trees (IE-LOCCW-A and IE-LOCCW-B) were revised for this analysis to include both fouling and plugging failure of the heat exchangers. Loss of CCS Train A occurs due to fouling if its normally in use heat exchanger (HTX A) fouls and either, the spare heat exchanger (HTX B) fouls or is not utilized. Loss of CCS Train B occurs if the Train B heat exchanger (HTX C) fouls. For either train, failure occurs if the trains heat exchanger plugs either as an independent event or as a common cause event. The revised fault trees are shown in Figures A-5, A-6 and A-7.

  Common cause failure of the heat exchangers due to fouling is modeled by adding new recovery rules for the LOCCW sequences as shown in Table A-1. If independent failure of all 3 heat exchangers occur in a cut set then a new cut set is created which includes the common cause failure of 3 in a group of 3 given that one has failed. Similarly, if only 2 fouling failures appear in a cut set (which occurs when the spare heat exchanger is

not utilized) a new cut set is created which includes the common cause failure of 2 in a group of 2 given that one has failed.

The above method of incorporating CCFs using recovery rules can be very sensitive to truncation value selected for solving the sequences. If the truncation value is too high, cut sets involving the independent failures will not be included in the solution prior to applying the recovery rules. A truncation value of 1E-16 was selected based on consideration of the independent failure cut sets expected. The adequacy of this was demonstrated by a sensitivity study that shows convergence when the truncation limit is lowered by an order of magnitude.

LOCCW-A Initiating Event - The frequency of the loss of CCS Train A is obtained from the IE-LOCCW-A fault tree described above. The recovery rules for sequences from this initiator are however different in that they involve only common cause failure of the Train A components and are shown in Table A-1.

CCW-A, CCW-B, and CCW-A-RECIRC - These fault trees which model the CCS support function to mitigating systems after other initiating events were revised in a similar fashion as the initiating event fault trees described above (See Figures A-8, A-9 and A-10).

CVC-MDPA and CVC-MDPS-SEAL - In these fault trees which model the failure of the charging pumps were revised to add failure of the ERCW backup cooling to CCP-1AA whenever both CCS heat exchangers fail due to common cause plugging. (See Figures A-11 and A-12).

- **Basic Event Probability Changes**

Table 4 provides all the basic events that were added or revised in the fault tree models described above, were modified to reflect the best estimate of the conditions during the event, or are in the important cut sets in the dominant sequences. The basis for these changes are provided below:

Heat Exchanger Plugging - The probability of heat exchanger plugging was taken to be 3E-08 per hour (Reference 4) with the mission time being either 8760 hours for an initiating event, 72 hours as the time associated with the LCO of a heat exchanger being out of service or 24 hours for the mission time following another initiating event.

Heat Exchanger Fouling - The probability of heat exchanger fouling was taken to be 1E-07 per hour (Reference 4) with the mission time being as described above.

Common Cause Failure Rates - The common cause failures due to plugging or fouling were utilized the SPAR template alpha factor values for plugging.

Spare Heat Exchanger Not Utilized - These human errors were obtained from application of the SPAR-H methodology (Reference 5). The work sheets are provided in Appendix B.

- **Sensitivity Analyses**

Sensitivity analyses were performed to determine the effects of model uncertainties on results based on best estimate assumptions. The following table provides the results of the sensitivity analyses.

Case	Parameter	Modification	Results
1	Heat Exchanger Plugging	Increase by factor of 25 to original template rate	CCDP = 6.2×10^{-4}, CDP = 8.0×10^{-5}, ΔCDP = 5.4×10^{-4}
2	Case 1 and reduced Common Cause Plugging Failure	Case 1 and reduce Alpha 2 to 0.01 and Alpha 3 to 0.005	CCDP = 1.1×10^{-4}, CDP = 8.0×10^{-5}, ΔCDP = 3.3×10^{-5}
3	**No heat exchanger plugging failures in LOCCW initiating events**	Set all plugging failures in initiating event model to zero	CCDP = 8.1×10^{-5}, CDP = 8.0×10^{-5}, ΔCDP = 1.0×10^{-6}
4	Truncation in GEM Analysis	Reduce GEM analysis truncation from 1E-16 to 1E-17	CCDP = 8.8×10^{-5}, CDP = 8.0×10^{-5}, ΔCDP = 7.6×10^{-6}

- The first sensitivity case utilizes the original SPAR template heat exchanger plugging rate (2.5E-06/hour) in the above described revised model. With the high plugging CCF (Alpha 2 of 0.169), this increases the LOCCW frequency to 3.7E-03 per year and the frequency of plugging of a single CCW heat exchanger as 2.2E-02 per year.

- The second sensitivity case utilizes the higher plugging failure rate but recognizes that if the plugging is gradual then the likelihood of a second heat exchanger plugging during the time it takes to clear the plugged heat exchanger is relatively small (see Reference 6) or that there is a good chance that the situation will be noticed prior to failure and steps taken to avoid the total loss of CCW. The resulting LOCCW frequency is 2.6E-04 per year.

- The third sensitivity study eliminates heat exchanger plugging as a cause of a loss of CCW initiating event. The resulting LOCCW frequency is 6.1E-05 per year.

- The fourth sensitivity study was run to confirm that the truncation used was sufficiently low. As noted above, the manner of introducing the CCF in the initiating event model requires that the truncation used to determine the cut sets

prior to the application of the recovery rules be sufficiently low to capture all important independent failures. The overall result of the sensitivity study is essentially the same as the condition analysis base case. The difference in the second digit of the importance exaggerates the true difference due to rounding off to two significant digits. The CCDP and importance of the individual sequences are also the same (except for similar rounding changes in the second digit) for the top six sequences with differences appearing in some subsequent sequences with CCDPs less than 4E-08. It should be noted that in the sensitivity study the CDP values were based on a 1E-16 truncation. If the CDP values had been redone using a 1E-17 truncation the CDP values would have increased resulting in a slight reduction in importance.

These results show the sensitivity of the importance of condition found at Watts Bar is strongly dependent on the assumptions concerning heat exchanger failures.

References

1. Watts Bar NRC Integrated Inspection Report 05000390/200405 and 05000391/200405, January 28, 2005.

2. NRC Integrated Inspection Report No. 05000390/2005007; Preliminary White Finding; Watts Bar Nuclear Power Plant, March 2, 2005.

3. WBAR_312_FTIE, obtained from Robert F. Buell, INEL, June 20, 2005.

4. Steven A. Eide, INL, E-mail to Bruce Mrowca, ISL, July 19, 2005 (See Appendix D).

5. David Getman, et. Al., “The SPAR-H Human Reliability Analysis Method,” NUREG/CR-XXXX, October 2003.

6. Thomas E. Wierman, INL, E-Mail to John A Schroeder, INL, July 28, 2005 (See Appendix D).

Table 1. Conditional core damage probabilities of dominating sequences.

Event tree name	Sequence no.	CCDP[1]	Contribution	ΔCDP[1]	Contribution
LOCCW	3-02-06	1.4E-5	16%	6.9E-6	92%
LOCCW	3-03-06	7.2E-7	1%	3.8E-7	5%
LOCCW	3-04-3	1.8E-7	<1%	9.4E-8	1%
Total (all sequences)[2]		8.8E-5	100%	7.5E-6	100%

1. Values are point estimates.
2. Total CCDP and ΔCDP includes all sequences (including those not shown in this table).

Table 2a. Event tree sequence logic for dominating sequences.

Event tree name	Sequence no.	Logic ("/" denotes success; see Table 2b for top event names)
LOCCW	3-02-06	IE-LOCCW /RPS /AFW LOSC /RCPT /RSD /BP1 BP2 HPI
LOCCW	3-03-06	IE-LOCCW /RPS /AFW LOSC /RCPT /RSD BP1 /BP2 HPI
LOCCW	3-04-3	IE-LOCCW /RPS /AFW LOSC /RCPT /RSD BP1 BP2 /ACC-M HPI-M

Table 2b. Definitions of top events listed in Table 2a.

Top Event	Definition
ACC-M	ACCUMULATOR 2-OF-3
AFW	AUXILIARY FEEDWATER
BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING)
BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING)
HPI	HIGH PRESSURE INJECTION
HPI-M	HIGH PRESSURE INJECTION 2/4 TRAINS
IE-LOCCW	TOTAL LOSS OF COMPONENT COOLING
LOSC	LOSS OF ALL SEAL COOLING
RCPT	REACTOR COOLANT PUMPS TRIPPED
RPS	REACTOR PROTECTION SYSTEM
RSD	RAPID SECONDARY DEPRESSURIZATION (<1710 PSI IN 2 HR)

Table 3. Conditional cut sets for the dominant sequences.

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)
Event Tree: LOCCW Sequence 3-02-06		
6.03E-06	42.6	IE->IE-D-LOCCW, IE-CCW-CF-HXPL-AANDC, /RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
3.40E-06	24.0	IE->IE-D-LOCCW, CCW-HTX-CF-FOUL3-3, IE-CCW-HTX-FOUL-HXA, /RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
2.30E-06	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1BB, FLAG-CCW-1B-RUNNING, IE-CCW-MDP-FR-1BB, /RCS-MDP-LK-BP1, RCS-MDP-LK-BP
2.30E-06	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1AA, FLAG-CCW-1A-RUNNING, IE-CCW-MDP-FR-1AA, /RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
1.42E-05	**100**	**Total (all cut sets)**[1]

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)
Event Tree: LOCCW Sequence 3-03-06		
3.05E-07	42.6	IE->IE-D-LOCCW, IE-CCW-CF-HXPL-AANDC, RCS-MDP-LK-BP1, /RCS-MDP-LK-BP2
1.72E-07	24.0	IE->IE-D-LOCCW, CCW-HTX-CF-FOUL3-3, IE-CCW-HTX-FOUL-HXA, RCS-MDP-LK-BP1, /RCS-MDP-LK-BP2
1.16E-07	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1AA, FLAG-CCW-1A-RUNNING, IE-CCW-MDP-FR-1AA, RCS-MDP-LK-BP1, /RCS-MDP-LK-BP2
1.16E-07	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1BB, FLAG-CCW-1B-RUNNING, IE-CCW-MDP-FR-1BB, RCS-MDP-LK-BP1, /RCS-MDP-LK-BP2
7.17E-07	**100**	**Total (all cut sets)**[1]

CCDP	Percent Contribution	Minimum Cut Sets (of basic events)
Event Tree: LOCCW Sequence 3-04-3		
7.63E-08	42.6	IE->IE-D-LOCCW, IE-CCW-CF-HXPL-AANDC, RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
4.31E-08	24.0	IE->IE-D-LOCCW, CCW-HTX-CF-FOUL3-3, IE-CCW-HTX-FOUL-HXA, RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
2.91E-08	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1AA, FLAG-CCW-1A-RUNNING, IE-CCW-MDP-FR-1AA, RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
2.91E-08	16.2	IE->IE-D-LOCCW, CCW-MDP-CF-RUN4-4, CCW-XHE-XL-1BB, FLAG-CCW-1B-RUNNING, IE-CCW-MDP-FR-1BB, RCS-MDP-LK-BP1, RCS-MDP-LK-BP2
1.79E-07	**100**	**Total (all cut sets)**[1]

1. Total Importance includes all cut sets (including those not shown in this table).

Table 4. Definitions and probabilities for modified and dominant basic events.

Name	Description	Calc. Prob.	La
CCW-HTX-CF-FOUL2-2	CCF DUE TO FOULING OF 2 OF 2 CCW HTXS GIVEN 1 HAS FOULED	1.69E-01	
CCW-HTX-CF-FOUL3-3	CCF DUE TO FOULING OF 3 OF 3 CCW HTX GIVEN 1 HAS FOULED	2.86E-02	
CCW-HTX-CF-HXAC	CCF OF CCW HEAT EXCHANGERS HX-A & C	1.22E-07	
CCW-HTX-FOUL-HXA	CCW HEATEXCHANGER HTXA FOULS DURING MISSION	2.40E-06	
CCW-HTX-FOUL-HXB	CCW HEAT EXCHANGER HTXB FOULS DURING MISSION	2.40E-06	
CCW-HTX-FOUL-HXC	CCW HEAT EXCHANGER HTX C FOULS DURING MISSION	2.40E-06	
CCW-HTX-PG-HXA	CCW HEAT EXCHANGER HXA PLUGS	7.20E-07	
CCW-HTX-PG-HXC	CCW HEAT EXCHANGER HXC PLUGS	7.20E-07	
CCW-HTX-PG-HXC-LCO	CCW HEAT EXCHANGER HX C PLUGS DURING LCO	2.16E-06	
CCW-MDP-CF-RUN4-4	CCF OF 4-OF-4 CCW PUMPS TO RUN GIVEN 1 FAILED	9.67E-04	
CCW-XHE-XL-1AA	OPERATOR FAILS TO RECOVER CCW PUMP 1A-A	1.00E+00	
CCW-XHE-XL-1BB	OPERATOR FAILS TO RECOVER CCW PUMP 1B-B	1.00E+00	
CCW-XHE-XM-HXB	CCW HEAT EXCHANGER B NOT UTILIZED	3.25E-02	
CVS-XHE-XM-CPP1AA	OPERATOR FAILS TO ALIGN ERCW TO CPP-1AA UPON LOSS OF CCW	1.50E-01 (TRUE) [1]	
FLAG-CCW-1A-RUNNING	CCW PUMP 1A-A IS RUNNING	5.00E-01	
FLAG-CCW-1B-RUNNING	CCW PUMP 1B-B IS RUNNING	5.00E-01	
IE-CCW-CF-HXPL-AANDC	CCF OF CCW HEAT EXCHANGERS A AND C PLUG	4.44E-05	
IE-CCW-HTX-FOUL-HXA	CCW HEAT EXCHANGER A FOULS	8.76E-04	
IE-CCW-HTX-FOUL-HXB	CCW HEAT EXCHANGER HX B FOULS	7.20E-06	
IE-CCW-HTX-FOUL-HXC	CCW HEAT EXCHANGER HX C FOULS	7.20E-06	
IE-CCW-HTX-PG-HXA	CCW HEAT EXCHANGER HX A PLUGS	2.63E-04	
IE-CCW-MDP-FR-1AA	CCW PUMP 1A-A FAILS TO RUN (INITIATING EVENT)	3.50E-02	
IE-CCW-MDP-FR-1BB	CCW PUMP 1B-B FAILS TO RUN (INITIATING EVENT)	3.50E-02	
IE-CCW-XHE-XM-HXB	CCW HEAT EXCHANGER NOT UTILIZED (INITIATING EVENT)	6.50E-03	
IE-D-LOCCW	TOTAL LOSS OF CCW DUMMY = 1.0	1.00E+00	
IE-D-LOCCW-A	PARTIAL LOSS OF CCW (DUMMY = 1.0)	1.00E+00	
RCS-MDP-LK-BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING OPEN) FAILS	1.25E-02	
RCS-MDP-LK-BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING OPEN) FAILS	2.00E-01	

1. Set to TRUE for the condition assessment

Appendix A

Event Tree and Fault Tree Figures and Recovery Tables

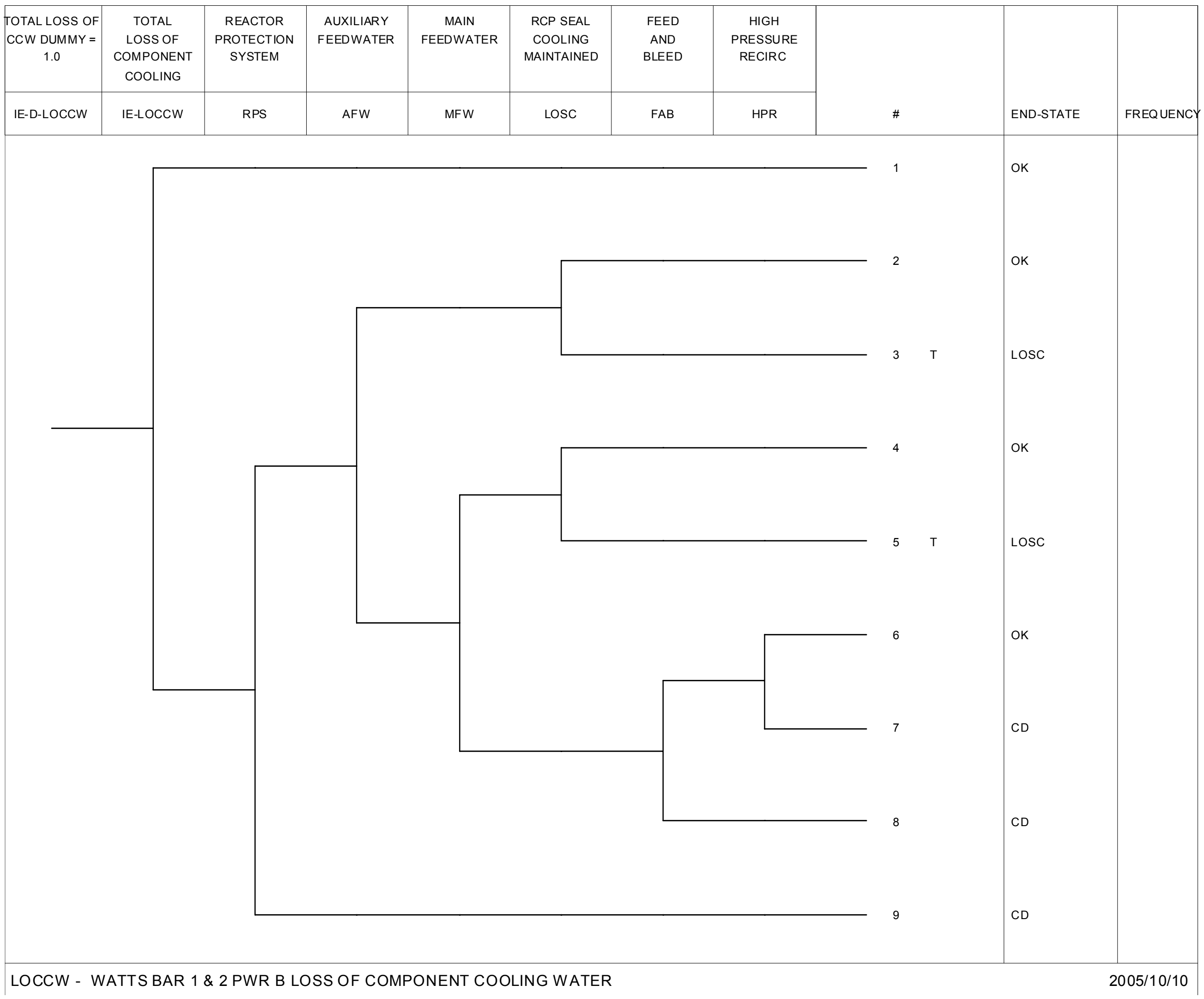


Figure A-1. LOCCW - Watts Bar 1 and 2 PWR B Loss of Component Cooling Water

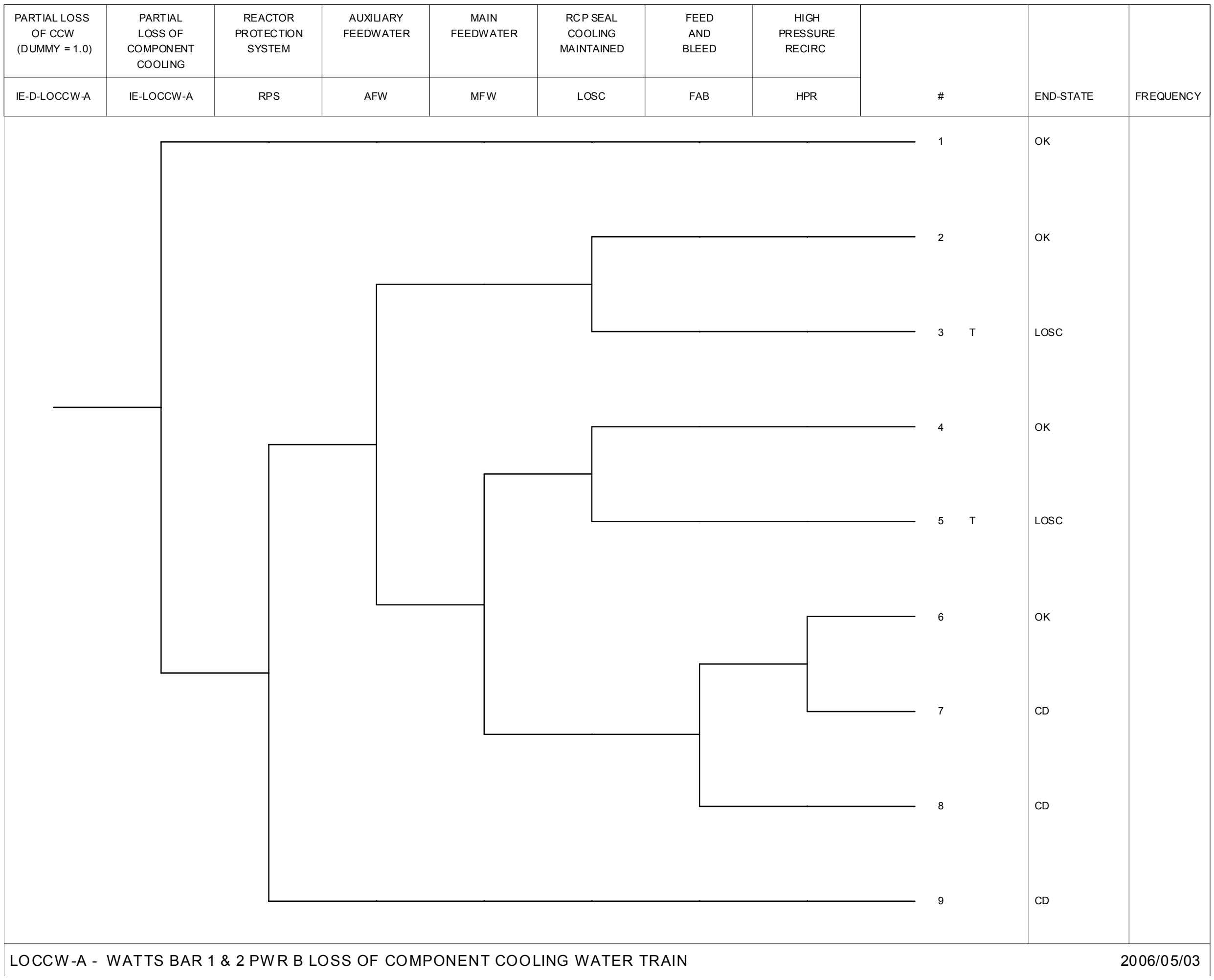


Figure A-2. LOCCW-A - Watts Bar 1 and 2 PWR B Loss of Component Cooling Water Train

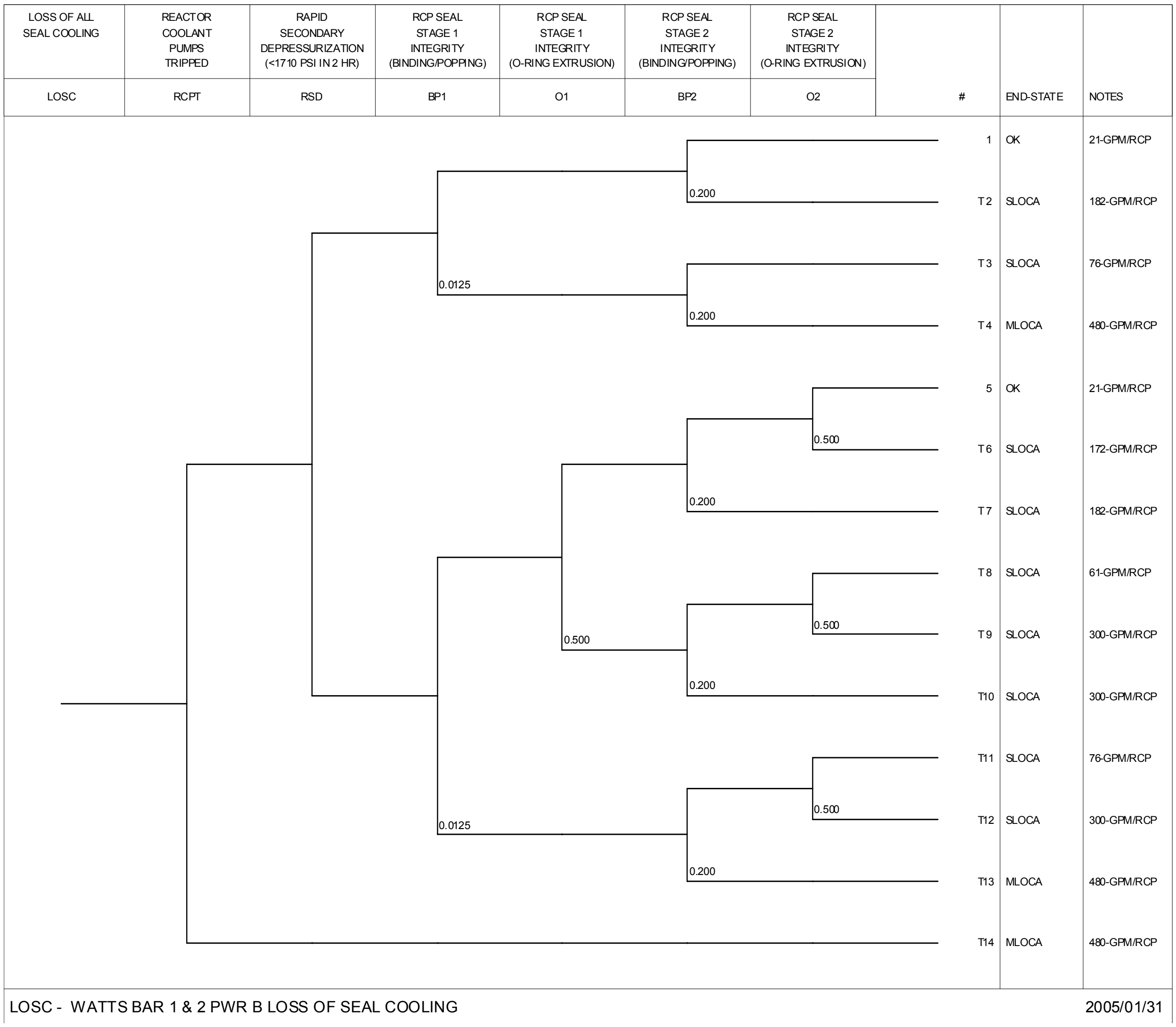


Figure A-3. LOSC - Watts Bar 1 and 2 PWR B Loss of Seal Cooling

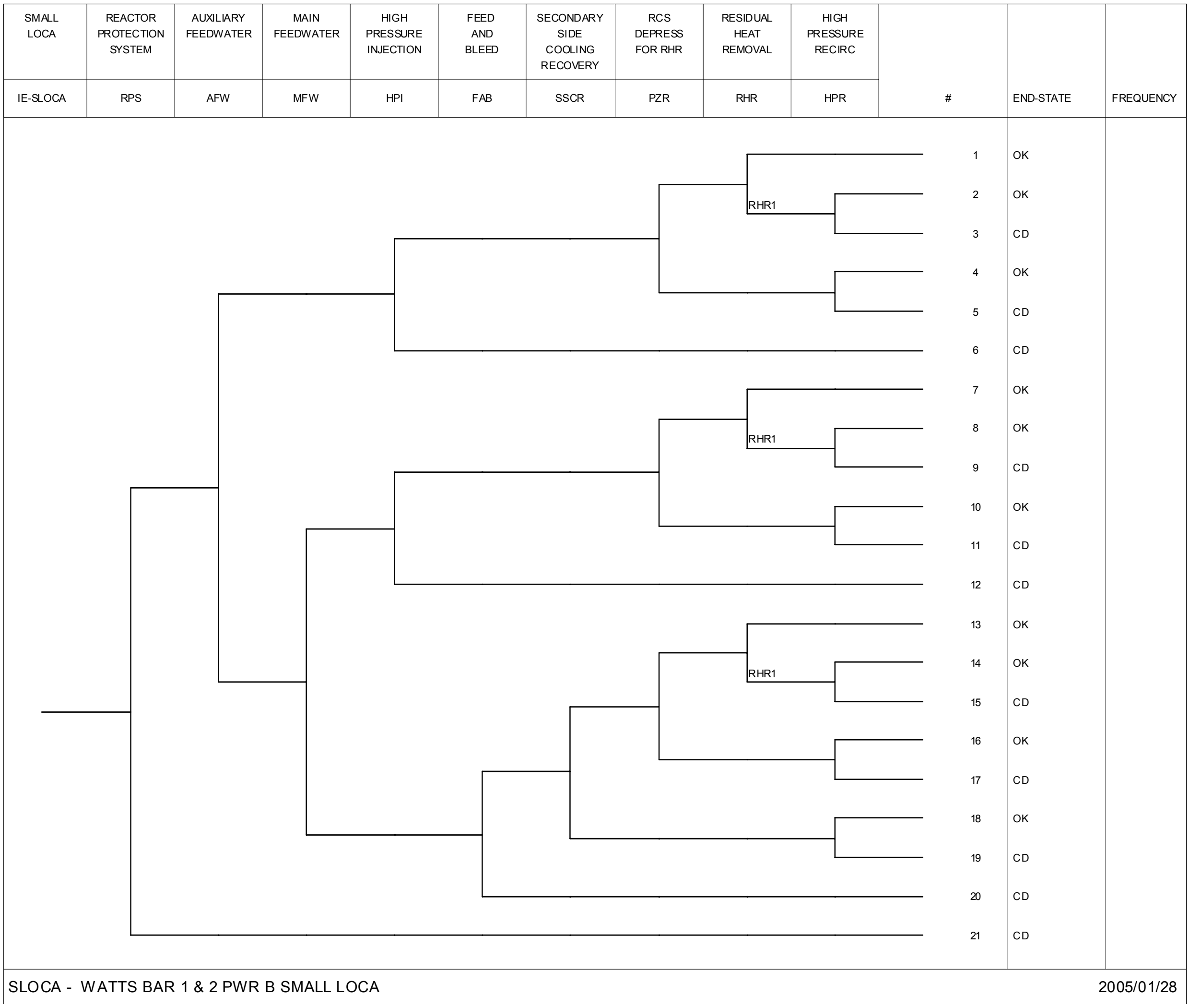


Figure A-4. SLOCA - Watts Bar 1 and 2 PWR B Small LOCA

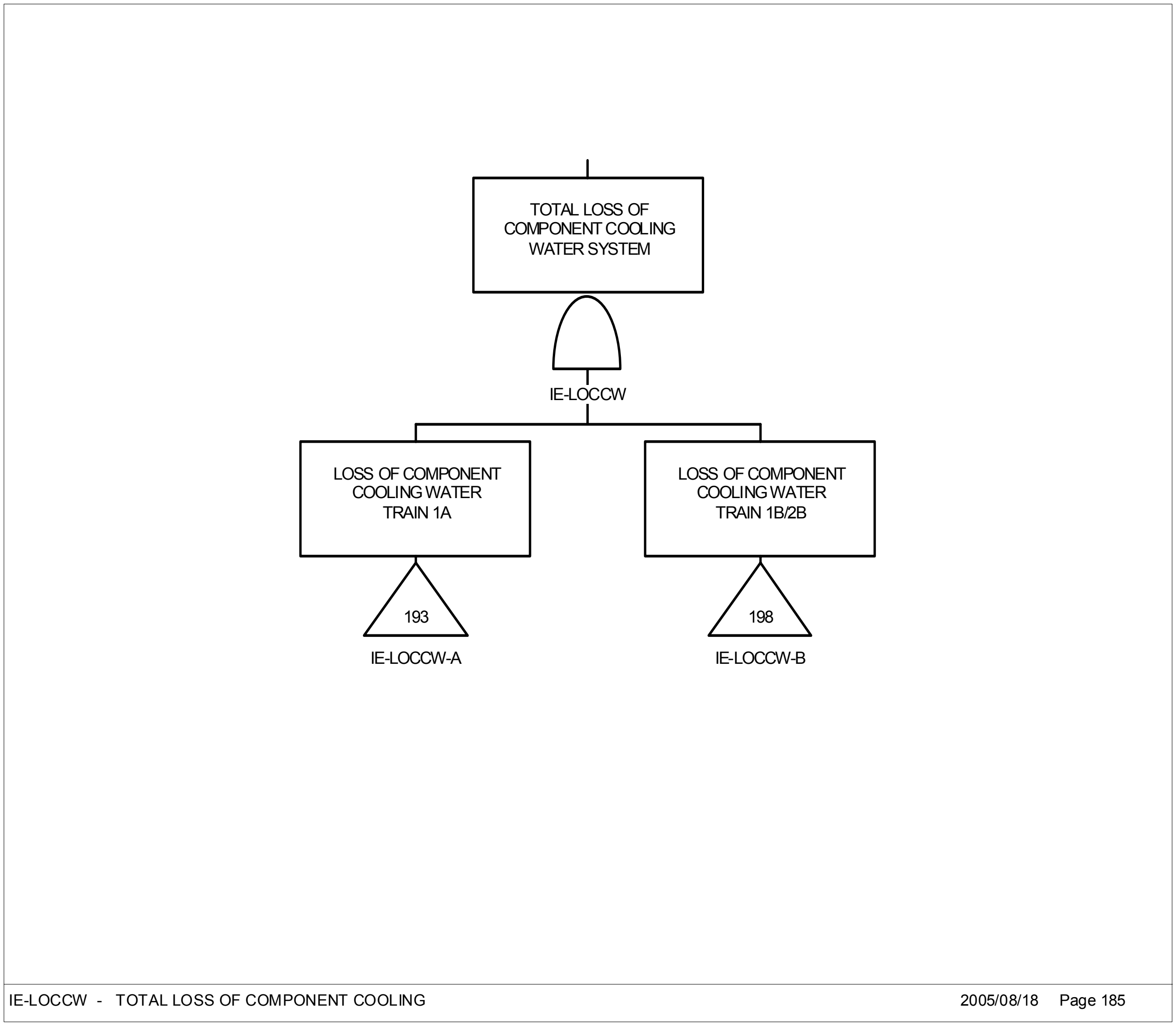
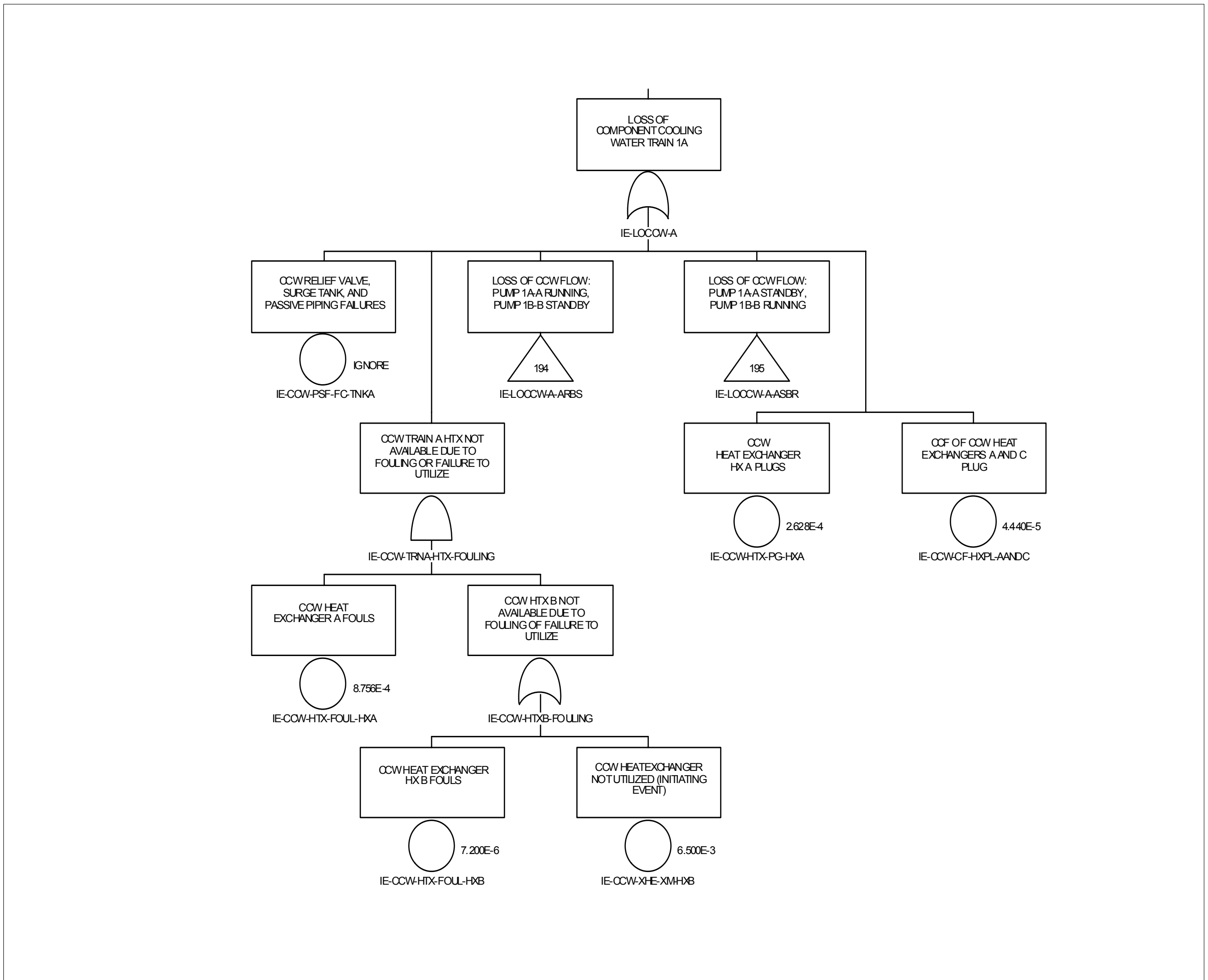


Figure A-5. IE-LOCCW - Total Loss of Component Cooling



IE-LOCCW-A - PARTIAL LOSS OF COMPONENT COOLING 2005/08/18 Page 193

Figure A-6. IE-LOCCW-A - Partial Loss of Component Cooling

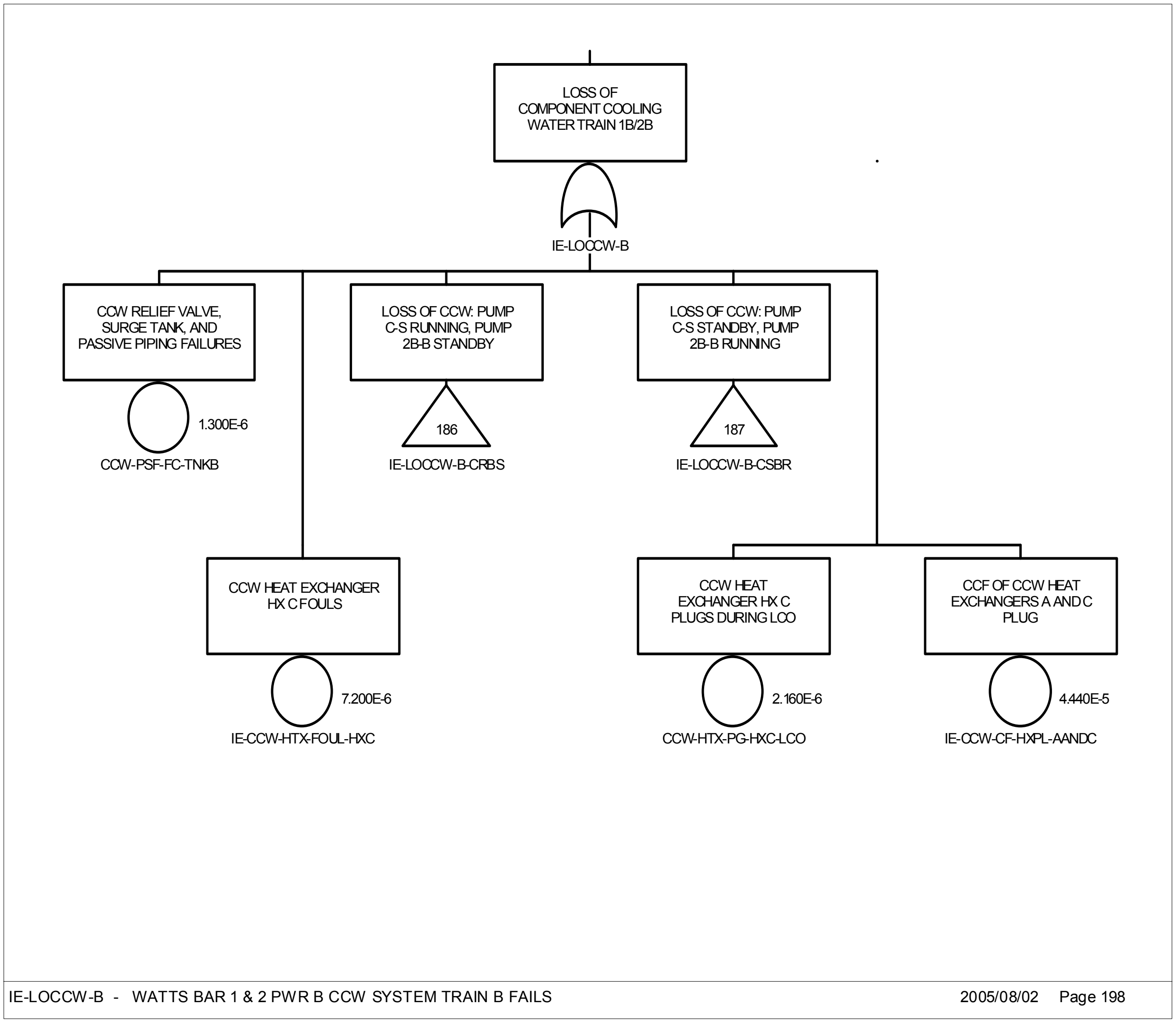


Figure A-7. IE-LOCCW-B - Watts Bar 1 and 2 PWR B CCW System Train B Fails

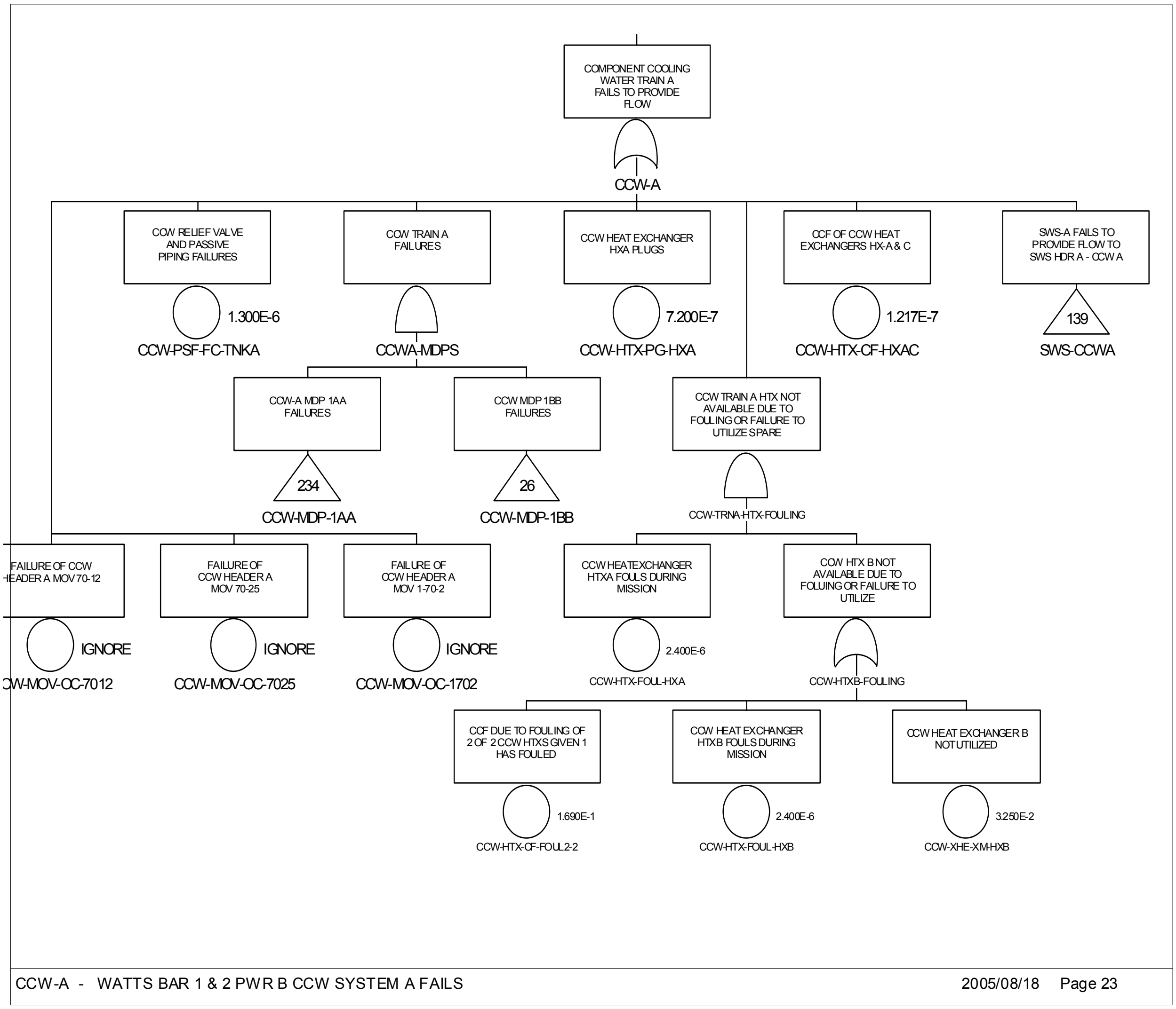
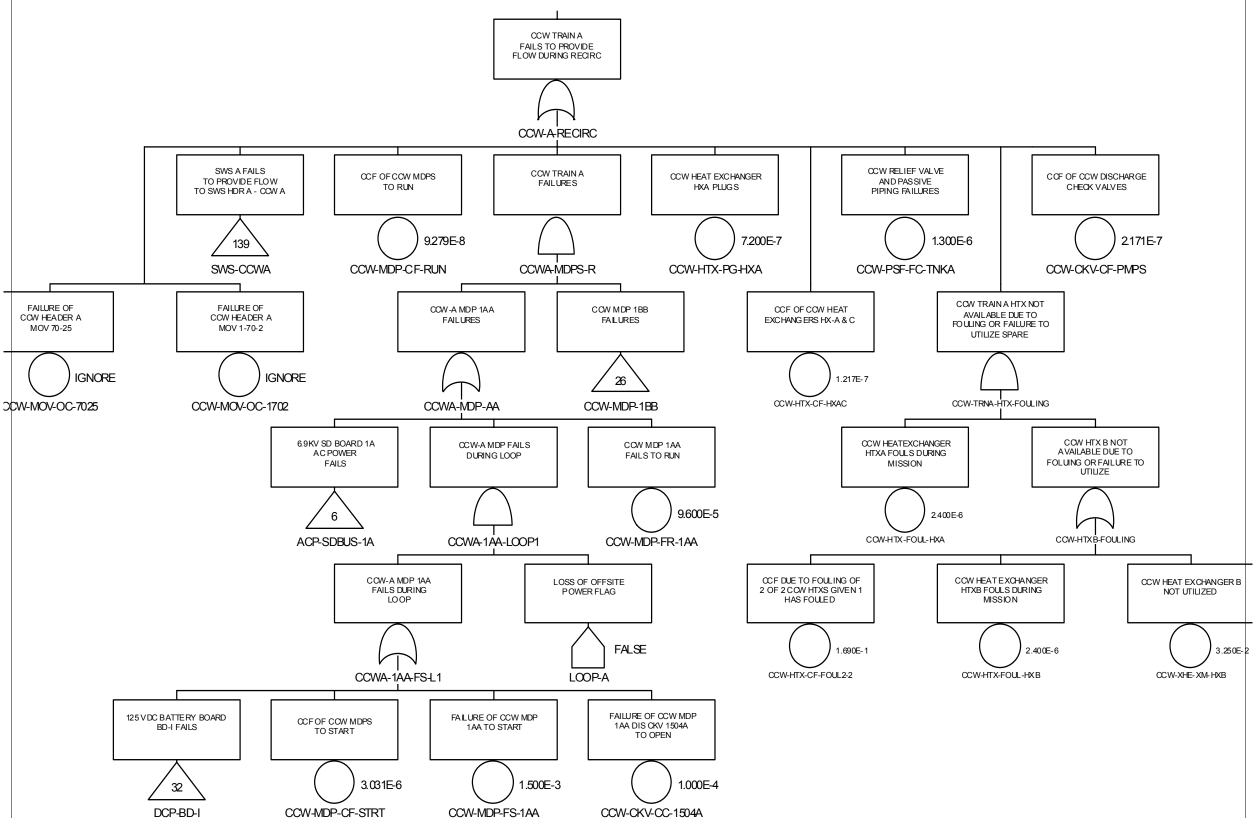


Figure A-8. CCW-A - Watts Bar 1 and 2 PWR B CCW System A Fails



CCW-A-RECIRC - WATTS BAR 1 & 2 PWR B CCW TRAIN A COOLING DURING RECIRC 2005/08/18 Page 24

Figure A-9. CCW-A-REC IRC - Watts Bar 1 and 2 PWR B CCW Train A Cooling During Recirc

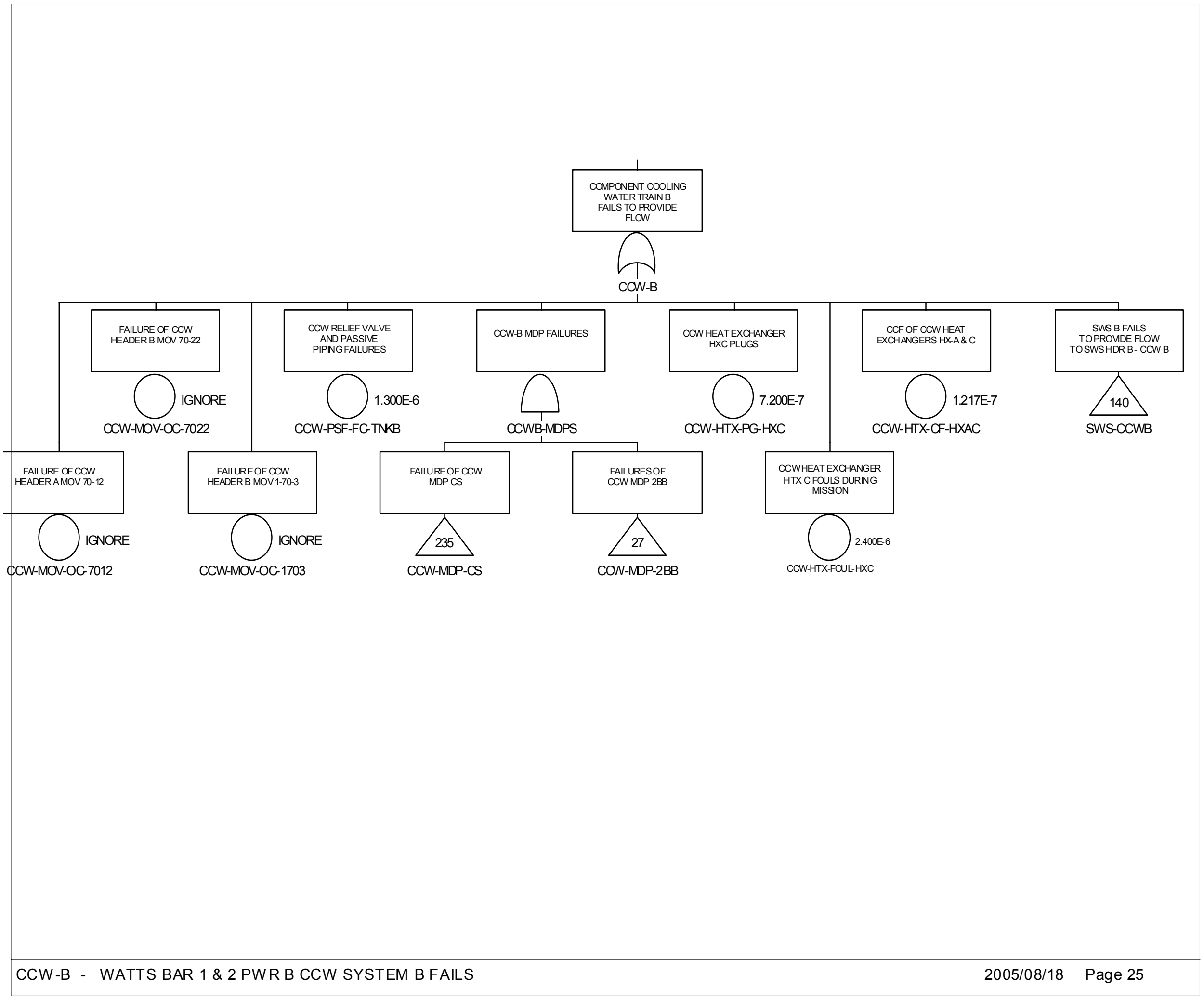


Figure A-10. CCW-B - Watts Bar 1 and 2 PWR B CCW System B Fails

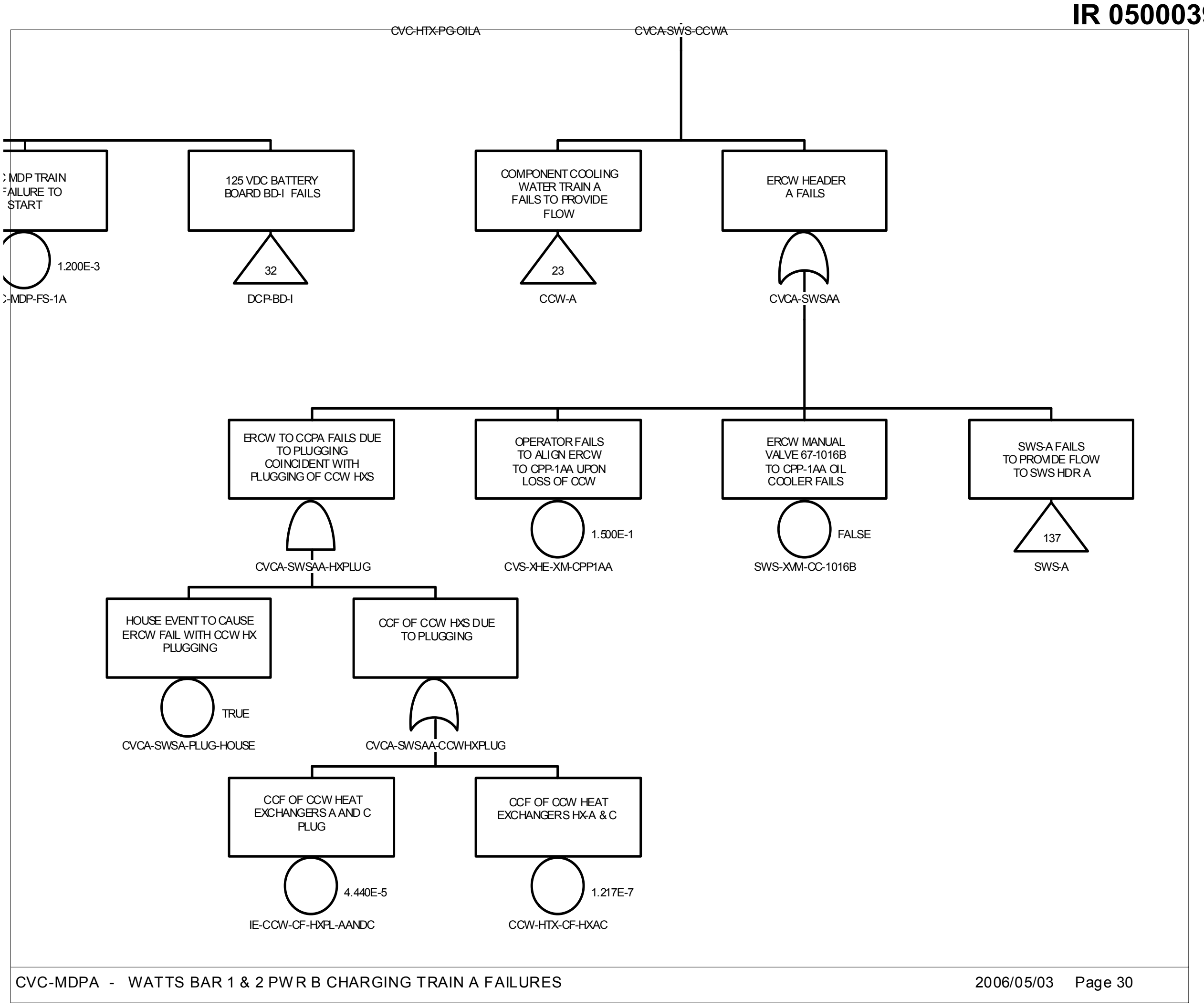


Figure A-11. CVC-MDPA - Watts Bar 1 and 2 PWR B Charging Train A Failures

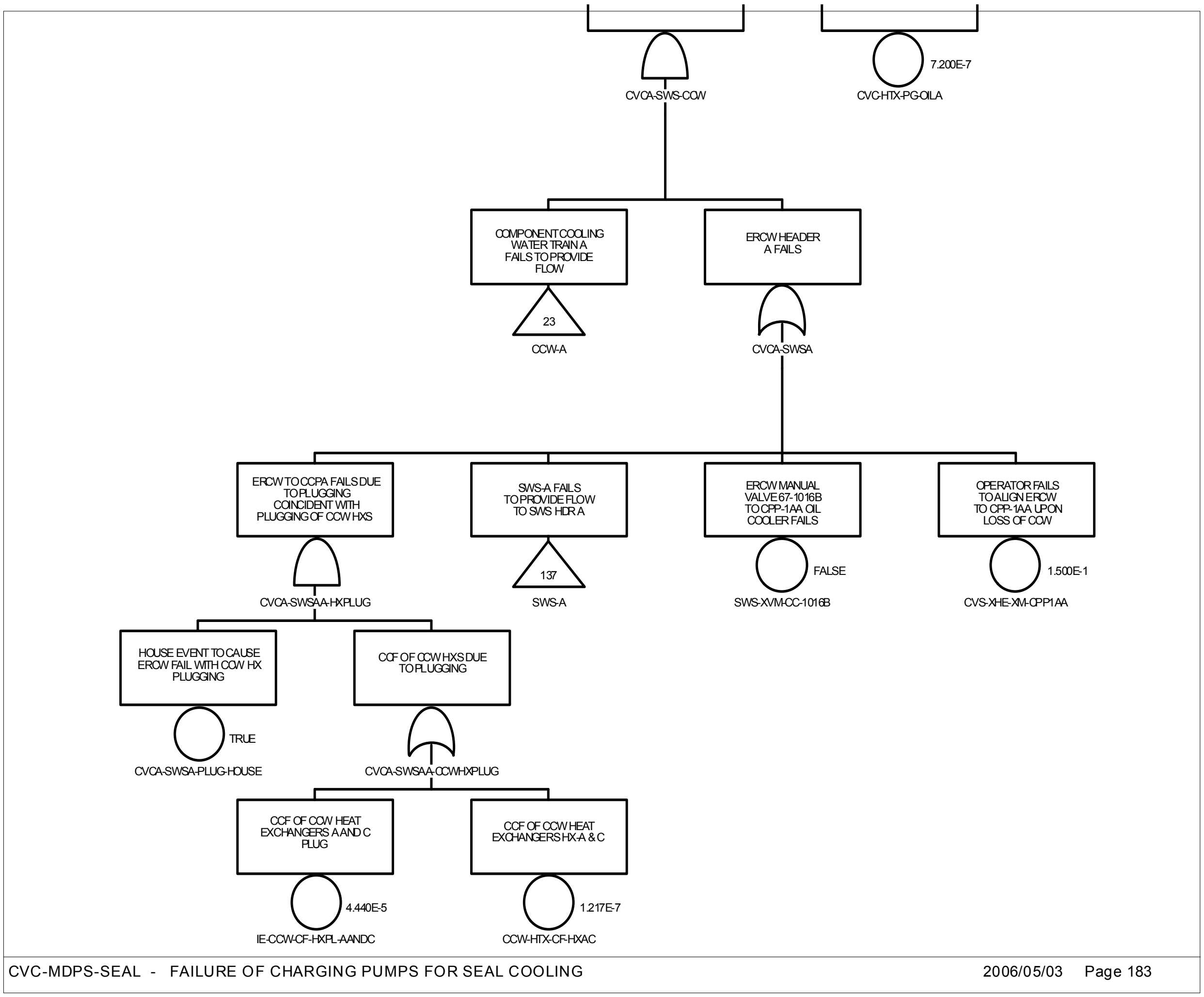


Figure A-12. CVC-MDPS-SEAL - Failure of Charging Pumps for Seal Cooling

Table A-1 Additional Recovery Rules for LOCCW and LOCCW-A Sequences

<table>
<tr><th>Recovery Rules for Sequences</th></tr>
<tr><td></td></tr>
<tr><td>| Add common cause failures to the cutsets. The</td></tr>
<tr><td>| CCF failure event is failure of 2-of-2 pumps to start</td></tr>
<tr><td></td></tr>
<tr><td>if init(IE-D-LOCCW)*CCW-MDP-FS-1BB * CCW-MDP-FS-2BB then</td></tr>
<tr><td>CopyRoot;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FS-1BB;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FS-2BB;</td></tr>
<tr><td>AddEvent = CCW-MDP-CF-STRT2-2;</td></tr>
<tr><td>endif</td></tr>
<tr><td></td></tr>
<tr><td>|</td></tr>
<tr><td>| CCF failure of 4-of-4 pumps to run, given that one has</td></tr>
<tr><td>| failed.</td></tr>
<tr><td>|</td></tr>
<tr><td></td></tr>
<tr><td>if init(IE-D-LOCCW)*CCW-MDP-FR-1BB-LCO * CCW-MDP-FR-2BB-LCO * CCW-MDP-FR-CS-LCO then</td></tr>
<tr><td>CopyRoot;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-1BB-LCO;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-2BB-LCO;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-CS-LCO;</td></tr>
<tr><td>AddEvent = CCW-MDP-CF-RUN4-4;</td></tr>
<tr><td>endif</td></tr>
<tr><td></td></tr>
<tr><td>if init(IE-D-LOCCW)*CCW-MDP-FR-1AA-LCO * CCW-MDP-FR-2BB-LCO * CCW-MDP-FR-CS-LCO then</td></tr>
<tr><td>CopyRoot;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-1AA-LCO;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-2BB-LCO;</td></tr>
<tr><td>DeleteEvent = CCW-MDP-FR-CS-LCO;</td></tr>
<tr><td>AddEvent = CCW-MDP-CF-RUN4-4;</td></tr>
<tr><td>endif</td></tr>
<tr><td></td></tr>
<tr><td>|</td></tr>
<tr><td>if FLAG-CCW-1A-RUNNING * FLAG-CCW-1B-RUNNING then</td></tr>
<tr><td>DeleteRoot;</td></tr>
<tr><td>endif</td></tr>
<tr><td>|</td></tr>
<tr><td>if FLAG-CCW-CS-RUNNING * FLAG-CCW-2B-RUNNING then</td></tr>
<tr><td>DeleteRoot;</td></tr>
<tr><td>endif</td></tr>
<tr><td>|</td></tr>
</table>

Table A-1 Additional Recovery Rules for LOCCW and LOCCW-A Sequences

Recovery Rules for Sequences
|CCf of 3 of 3 CCW hx due to fouling
|
if init(IE-D-LOCCW)*IE-CCW-HTX-FOUL-HXA * IE-CCW-HTX-FOUL-HXB * IE-CCW-HTX-FOUL-HXC then
Copyroot;
DeleteEvent = IE-CCW-HTX-FOUL-HXB;
DeleteEvent = IE-CCW-HTX-FOUL-HXC;
AddEvent = CCW-HTX-CF-FOUL3-3;
endif
|
|CCF of 2 of 2 CCW HX due to fouling
|
if init(IE-D-LOCCW)*IE-CCW-HTX-FOUL-HXA * IE-CCW-HTX-FOUL-HXC then
Copyroot;
DeleteEvent = IE-CCW-HTX-FOUL-HXC;
AddEvent = CCW-HTX-CF-FOUL2-2;
endif
| This rule adds common cause failures to the cutsets. The
| CCF failure event is failure of 2-of-2 pumps to run given
| that one pump is known to be failed.
|
if init(IE-D-LOCCW-A)*IE-CCW-MDP-FR-1AA*CCW-MDP-FR-1BB-LCO then
CopyRoot;
DeleteEvent = CCW-MDP-FR-1BB-LCO;
AddEvent = CCW-MDP-CF-RUN2-2;
endif
if init(IE-D-LOCCW-A)*IE-CCW-MDP-FR-1BB*CCW-MDP-FR-1AA-LCO then
CopyRoot;
DeleteEvent = CCW-MDP-FR-1AA-LCO;
AddEvent = CCW-MDP-CF-RUN2-2;
endif
|
|CCF of 2 of 2 HX due to fouling
|
if init(IE-D-LOCCW-A)*IE-CCW-HTX-FOUL-HXA*IE-CCW-HTX-FOUL-HXB then
CopyRoot;

Table A-1 Additional Recovery Rules for LOCCW and LOCCW-A Sequences

Recovery Rules for Sequences
DeleteEvent = IE-CCW-HTX-FOUL-HXB;
AddEvent = CCW-HTX-CF-FOUL2-2;
endif
if init(IE-D-LOCCW-A)* IE-CCW-CF-HXPL-AANDC then
DeleteRoot;
endif

Appendix B

Human Reliability Modeling

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: WBNP Event Name: IE- CCW-XHE-XM-HXB

Task Error Description: CCW HEAT EXCHANGER B NOT UTILIZED AFTER FOULING OF HX A (INITIATING EVENT)

Does this task contain a significant amount of diagnosis activity ? YES X NO _____

If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	**PSF Levels**	**Multiplier for Diagnosis**	**If non-nominal PSF levels are selected, please note specific reasons in this column**
1. Available Time	Inadequate	1.0[a]	Fouling assumed to be gradual and have several shifts to discover.
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1✓	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5	Prior to initiating event hence no stress.
	High	2	
	Nominal	1✓	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1✓	
4. Experience/ Training	Low	10✓	Unusual event.
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	Assumed.
	Available, but poor	5✓	
	Nominal	1	
	Diagnostic/symptom oriented	0.5	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1✓	
8. Work Processes	Poor	2	
	Nominal	1✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	PSF Levels	Multiplier for Action	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	Fouling is gradual and while may take an hour or so to execute several hours are available.
	Time available ≈ time required	10	
	Nominal	1	
	Available > 5x time required	0.1✓	
	Available > 50x time required	0.01	
2. Stress	Extreme	5	
	High	2	
	Nominal	1 ✓	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1✓	
4. Experience/ Training	Low	3✓	Not. a usual operation
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	Assumed
	Available, but poor	5✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1✓	
8. Work Processes	Poor	2	
	Nominal	1✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	Nom. Prob.	Time	Stress	Compl.	Exper./ Train.	Proced.	Ergon.	Fitness	Work Process	Prob.
Diag.	1.0E-2	x 0.01	x 1.0	X 1.0	X 10.0	X 5.0	x 1.0	x 1.0	x 1.0	5.0E-3
Action	1.0E-3	x 0.1	x 1.0	x 1.0	x 3.0	x 5.0	x 1.0	x 1.0	x 1.0	1.5E-3
Total										6.50E-3

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd error in the sequence, then the dependency is at least moderate. If this error is the 4th error in the sequence, then the dependency is at least high. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6	s	d	nc	a	low	
7	d	s	c	–	moderate	
8	d	s	nc	na	low	
9	d	s	nc	a	low	
10	d	d	c	–	moderate	
11	d	d	nc	na	low	
12	d	d	nc	a	low	
13					zero	

Using P = Task Failure Probability Without Formal Dependence (calculated on Page 2):

	For Complete Dependence the probability of failure	= 1.0
	For High Dependence the probability of failure	= (1 + P)/2
	For Moderate Dependence the probability of failure	= (1 +6P)/7
	For Low Dependence the probability of failure	= (1 + 19P)/20
✓	For Zero Dependence the probability of failure	= P

Task Failure Probability With Formal Dependence = (1 + (____ * ________)) / ____ = ______

Additional Notes:

SPAR Model Human Error Worksheet (Page 1 of 3)

Plant: WBNP Event Name: CCW-XHE-XM-HXB

Task Error Description: CCW HEAT EXCHANGER B NOT UTILIZED AFTER FOULING OF HX A

Does this task contain a significant amount of diagnosis activity ? YES X NO ____

If Yes, Use Table 1 below to evaluate the PSFs for the Diagnosis portion of the task before going to Table 2. If No, go directly to Table 2.

Table 1. Diagnosis worksheet.

PSFs	PSF Levels	Multiplier for Diagnosis	If non-nominal PSF levels are selected, please note specific reasons in this column
1. Available Time	Inadequate	1.0[a]	Fouling assumed to be gradual and have several shifts to discover.
	Barely adequate < 20 m	10	
	Nominal ≈ 30 m	1	
	Extra > 60 m	0.1✓	
	Expansive > 24 h	0.01	
2. Stress	Extreme	5✓	After an initiating event hence stress.
	High	2	
	Nominal	1	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1✓	
4. Experience/ Training	Low	10✓	Unusual event.
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	Assumed.
	Available, but poor	5✓	
	Nominal	1	
	Diagnostic/symptom oriented	0.5	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1✓	
8. Work Processes	Poor	2	
	Nominal	1✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

SPAR Model Human Error Worksheet (Page 2 of 3)

Table 2. Action worksheet.

PSFs	**PSF Levels**	**Multiplier for Action**	**If non-nominal PSF levels are selected, please note specific reasons in this column**
1. Available Time	Inadequate	1.0[a]	Fouling is gradual and while may take an hour or so to execute several hours are available.
	Time available ≈ time required	10	
	Nominal	1	
	Available > 5x time required	0.1✓	
	Available > 50x time required	0.01	
2. Stress	Extreme	5 ✓	After an initiating event hence stress.
	High	2	
	Nominal	1	
3. Complexity	Highly	5	
	Moderately	2	
	Nominal	1✓	
4. Experience/ Training	Low	3✓	Not. a usual operation.
	Nominal	1	
	High	0.5	
5. Procedures	Not available	50	Assumed.
	Available, but poor	5✓	
	Nominal	1	
6. Ergonomics	Missing/Misleading	50	
	Poor	10	
	Nominal	1✓	
	Good	0.5	
7. Fitness for Duty	Unfit	1.0[a]	
	Degraded Fitness	5	
	Nominal	1✓	
8. Work Processes	Poor	2	
	Nominal	1✓	
	Good	0.8	

a. Task failure probability is 1.0 regardless of other PSFs.

Table 3. Task failure probability without formal dependence worksheet.

Task Portion	**Nom. Prob.**	**Time**	**Stress**	**Compl.**	**Exper./ Train.**	**Proced.**	**Ergon.**	**Fitness**	**Work Process**	**Prob.**
Diag.	1.0E-2	x 0.01	x 5.0	X 1.0	X 10.0	X 5.0				2.5E-2
Action	1.0E-3	x 0.1	x 5.0	x 1.0	x 3.0	x 5.0	x 1.0	x 1.0	x 1.0	7.5E-3
Total										3.25E-2

SPAR Model Human Error Worksheet (Page 3 of 3)

For all tasks, except the first task in the sequence, use the table and formulae below to calculate the Task Failure Probability With Formal Dependence.

Table 4. Dependency condition worksheet.

Condition Number	Crew (same or different)	Location (same or different)	Time (close in time or not close in time)	Cues (additional or not additional)	Dependency	Number of Human Action Failures Rule
1	s	s	c	–	complete	If this error is the 3rd error in the sequence, then the dependency is at least moderate. If this error is the 4th error in the sequence, then the dependency is at least high. This rule may be ignored only if there is compelling evidence for less dependence with the previous tasks.
2	s	s	nc	na	high	
3	s	s	nc	a	moderate	
4	s	d	c	–	high	
5	s	d	nc	na	moderate	
6	s	d	nc	a	low	
7	d	s	c	–	moderate	
8	d	s	nc	na	low	
9	d	s	nc	a	low	
10	d	d	c	–	moderate	
11	d	d	nc	na	low	
12	d	d	nc	a	low	
13					zero	

Using P = Task Failure Probability Without Formal Dependence (calculated on Page 2):

For Complete Dependence the probability of failure = 1.0
For High Dependence the probability of failure = (1 + P)/2
For Moderate Dependence the probability of failure = (1 +6P)/7
For Low Dependence the probability of failure = (1 + 19P)/20
For Zero Dependence the probability of failure = P

Task Failure Probability With Formal Dependence = (1 + (____ * ________)) / ____ = ______

Additional Notes:

Appendix C

GEM Summary Report

C O N D I T I O N   A S S E S S M E N T

Code Version: 7:26	Model Version : 2005/08/12
Project : WBAR_3+IEFT	Duration (hrs) : 6.0E+003
User Name : IDAHO NATIONAL LABORATORY	Total CCDP : 8.8E-005
Event ID : ERCWXT	Total CDP : 8.0E-005
	Importance : 7.5E-006

Description : ERCW SUPPLY TO CHARGING PUMPS IS UNAVAILABLE

BASIC EVENT CHANGES

Event Name	Description	Base Prob	Curr Prob	Type
CVS-XHE-XM-CPP1AA	OPERATOR FAILS TO ALIGN ERCW	1.5E-001	1.0E+000	TRUE

SEQUENCE PROBABILITIES

Truncation : Cummulative : 100.0% Individual :   0.0%

Event Tree Name	Sequence Name	CCDP	CDP	Importance
LOCCW	3-02-06	1.4E-005	7.3E-006	6.9E-006
LOCCW	3-03-06	7.2E-007	3.4E-007	3.8E-007
LOCCW	3-04-3	1.8E-007	8.5E-008	9.4E-008
LODCB	02-02-06	6.2E-008	1.2E-008	4.9E-008
LOCCW-A	3-02-03	9.8E-008	6.0E-008	3.8E-008
LOCCW-A	3-02-06	3.6E-008	6.3E-009	2.9E-008
LOCCW-A	3-04-3	2.2E-008	3.3E-009	1.8E-008
LOOP	02-05	1.7E-008	4.5E-009	1.3E-008

NEGATIVE SEQUENCE PROBABILITIES

Truncation : Cummulative : 100.0% Individual :   0.0%

Event Tree Name	Sequence Name	CCDP	CDP	Importance

NOTE: Percent contribution to total Importance.

SEQUENCE LOGIC

Event Tree	Sequence Name	Logic	
LOCCW	3-02-06	IE-LOCCW	/RPS
		/AFW	LOSC
		/RCPT	/RSD
		/BP1	BP2
		HPI	
LOCCW	3-03-06	IE-LOCCW	/RPS

		/AFW	LOSC
		/RCPT	/RSD
		BP1	/BP2
		HPI	
LOCCW	3-04-3	IE-LOCCW	/RPS
		/AFW	LOSC
		/RCPT	/RSD
		BP1	BP2
		/ACC-M	HPI-M
LODCB	02-02-06	/RPS	/AFW
		/PORV	LOSC
		/RCPT	/RSD
		/BP1	BP2
		HPI	
LOCCW-A	3-02-03	IE-LOCCW-A	/RPS
		/AFW	LOSC
		/RCPT	/RSD
		/BP1	BP2
		/HPI	/PZR
		RHR1	HPR
LOCCW-A	3-02-06	IE-LOCCW-A	/RPS
		/AFW	LOSC
		/RCPT	/RSD
		/BP1	BP2
		HPI	
LOCCW-A	3-04-3	IE-LOCCW-A	/RPS
		/AFW	LOSC
		/RCPT	/RSD
		BP1	BP2
		/ACC-M	HPI-M
LOOP	02-05	/RPS	/EPS
		/AFW-L	/PORV-L
		LOSC-L	/RSD
		/BP1	BP2
		OPR-02H	HPI-L

Fault Tree Name	Description
ACC-M	ACCUMULATOR 2-OF-3
AFW	AUXILIARY FEEDWATER
AFW-L	AUXILIARY FEEDWATER DURING LOOP
BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING)
BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING)
EPS	EMERGENCY POWER
HPI	HIGH PRESSURE INJECTION

HPI-L	HIGH PRESSURE INJECTION
HPI-M	HIGH PRESSURE INJECTION 2/4 TRAINS
HPR	HIGH PRESSURE RECIRC
IE-LOCCW	TOTAL LOSS OF COMPONENT COOLING
IE-LOCCW-A	PARTIAL LOSS OF COMPONENT COOLING
LOSC	RCP SEAL COOLING MAINTAINED
LOSC-L	LOSS OF SEAL COOLING DURING LOOP
OPR-02H	OFFSITE POWER RECOVERY IN 2 HRS
PORV	PORVs ARE CLOSED
PORV-L	PORVS ARE CLOSED DURING LOOP
PZR	RCS DEPRESS FOR RHR
RCPT	REACTOR COOLANT PUMPS TRIPPED
RHR1	WATTS BAR 1 & 2 PWR B RESIDUAL HEAT REMOVAL (SLOCA)
RPS	REACTOR PROTECTION SYSTEM
RSD	RAPID SECONDARY DEPRESSURIZATION (<1710 PSI IN 2 HR)

SEQUENCE CUT SETS

Truncation: Cummulative: 100.0% Individual: 1.0%

Event Tree: LOCCW CCDF: 2.1E-005
Sequence: 3-02-06

CCDF	% Cut Set	Cut Set Events	
8.8E-006	42.58	/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-CF-HXPL-AANDC	
5.0E-006	24.01	/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-HTX-FOUL-HXA	CCW-HTX-CF-FOUL3-3
3.3E-006	16.22	/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-MDP-CF-RUN4-4
3.3E-006	16.22	/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-MDP-CF-RUN4-4

Event Tree: LOCCW CCDF: 1.0E-006
Sequence: 3-03-06

CCDF	% Cut Set	Cut Set Events	
4.4E-007	42.58	RCS-MDP-LK-BP1	/RCS-MDP-LK-BP2
		IE-CCW-CF-HXPL-AANDC	
2.5E-007	24.01	RCS-MDP-LK-BP1	/RCS-MDP-LK-BP2
		IE-CCW-HTX-FOUL-HXA	CCW-HTX-CF-FOUL3-3
1.7E-007	16.22	RCS-MDP-LK-BP1	/RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-MDP-CF-RUN4-4
1.7E-007	16.22	RCS-MDP-LK-BP1	/RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING

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		CCW-XHE-XL-1BB	CCW-MDP-CF-RUN4-4

Event Tree: LOCCW CCDF: 2.6E-007
Sequence: 3-04-3

CCDF	% Cut Set	Cut Set Events	
1.1E-007	42.58	RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-CF-HXPL-AANDC	
6.3E-008	24.01	RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-HTX-FOUL-HXA	CCW-HTX-CF-FOUL3-3
4.2E-008	16.22	RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-MDP-CF-RUN4-4
4.2E-008	16.22	RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-MDP-CF-RUN4-4

Event Tree: LODCB CCDF: 9.0E-008
Sequence: 02-02-06

CCDF	% Cut Set	Cut Set Events	
4.7E-008	52.93	CCW-MDP-FR-1AA	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
3.6E-008	39.70	SWS-STR-PG-A2AA	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
2.4E-009	2.65	ACP-BAC-LP-1A	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
1.8E-009	2.03	SWS-STR-CF-ALL	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	

Event Tree: LOCCW-A CCDF: 1.4E-007
Sequence: 3-02-03

CCDF	% Cut Set	Cut Set Events	
5.3E-009	3.73	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
5.3E-009	3.73	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
3.1E-009	2.18	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-HTX-PG-HXA	CCW-XHE-XL-LTRF
2.7E-009	1.86	CVC-MDP-TM-1B	RHR-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2

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		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
2.7E-009	1.86	CVC-MDP-TM-1B	RHR-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
2.2E-009	1.55	CVC-XHE-XM-VCTSWAP	RHR-HTX-TM-HXB
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
2.2E-009	1.55	CVC-XHE-XM-VCTSWAP	RHR-HTX-TM-HXB
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
1.8E-009	1.24	CVC-XHE-XM-VCTSWAP	RHR-FAN-TM-RHRRMB
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
1.8E-009	1.24	HPR-XHE-XM	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-MDP-CF-RUN2-2
1.8E-009	1.24	CVC-XHE-XM-VCTSWAP	RHR-FAN-TM-RHRRMB
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-XHE-XL-LTRF
		CCW-MDP-CF-RUN2-2	
1.8E-009	1.24	HPR-XHE-XM	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-MDP-CF-RUN2-2
1.8E-009	1.23	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		CCW-XHE-XL-LTRF	IE-CCW-HTX-FOUL-HXA
		CCW-HTX-CF-FOUL2-2	
1.7E-009	1.16	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-MDP-TM-1AA	CCW-XHE-XL-1BB
		CCW-XHE-XL-LTRF	
1.7E-009	1.16	RHR-MDP-TM-1B	CVC-XHE-XM-VCTSWAP
		CCW-MDP-TM-1BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1AA
		FLAG-CCW-1A-RUNNING	CCW-XHE-XL-1AA
		CCW-XHE-XL-LTRF	
1.6E-009	1.09	CVC-MDP-TM-1B	RHR-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2

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IE-CCW-HTX-PG-HXA CCW-XHE-XL-LTRF

Event Tree: LOCCW-A CCDF: 5.2E-008
Sequence: 3-02-06

CCDF	% Cut Set	Cut Set Events	
6.4E-009	12.32	SWS-STR-PG-B2BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1BB
		FLAG-CCW-1B-RUNNING	CCW-XHE-XL-1BB
		CCW-MDP-CF-RUN2-2	
6.4E-009	12.32	SWS-STR-PG-B2BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1AA
		FLAG-CCW-1A-RUNNING	CCW-XHE-XL-1AA
		CCW-MDP-CF-RUN2-2	
3.7E-009	7.20	SWS-STR-PG-B2BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-PG-HXA
2.2E-009	4.28	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	CCW-MDP-CF-RUN2-2
2.2E-009	4.28	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	CCW-MDP-CF-RUN2-2
2.1E-009	4.05	SWS-STR-PG-B2BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-FOUL-HXA
		CCW-HTX-CF-FOUL2-2	
2.0E-009	3.84	SWS-STR-PG-B2BB	CCW-MDP-TM-1BB
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	
2.0E-009	3.84	SWS-STR-PG-B2BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1BB
		FLAG-CCW-1B-RUNNING	CCW-MDP-TM-1AA
		CCW-XHE-XL-1BB	
1.3E-009	2.50	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-HTX-PG-HXA	
7.3E-010	1.41	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-HTX-FOUL-HXA	CCW-HTX-CF-FOUL2-2
6.9E-010	1.33	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-MDP-TM-1AA	CCW-XHE-XL-1BB
6.9E-010	1.33	CVC-MDP-TM-1B	HPI-MDP-TM-1B
		CCW-MDP-TM-1BB	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1AA
		FLAG-CCW-1A-RUNNING	CCW-XHE-XL-1AA
5.3E-010	1.03	CVC-MDP-TM-1B	HPI-MDP-FS-1B
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2

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                              IE-CCW-MDP-FR-1BB         FLAG-CCW-1B-RUNNING
                              CCW-XHE-XL-1BB            CCW-MDP-CF-RUN2-2
 5.3E-010          1.03       CVC-MDP-FS-1B             HPI-MDP-TM-1B
                             /RCS-MDP-LK-BP1            RCS-MDP-LK-BP2
                              IE-CCW-MDP-FR-1AA         FLAG-CCW-1A-RUNNING
                              CCW-XHE-XL-1AA            CCW-MDP-CF-RUN2-2
 5.3E-010          1.03       CVC-MDP-FS-1B             HPI-MDP-TM-1B
                             /RCS-MDP-LK-BP1            RCS-MDP-LK-BP2
                              IE-CCW-MDP-FR-1BB         FLAG-CCW-1B-RUNNING
                              CCW-XHE-XL-1BB            CCW-MDP-CF-RUN2-2
 5.3E-010          1.03       CVC-MDP-TM-1B             HPI-MDP-FS-1B
                             /RCS-MDP-LK-BP1            RCS-MDP-LK-BP2
                              IE-CCW-MDP-FR-1AA         FLAG-CCW-1A-RUNNING
                              CCW-XHE-XL-1AA            CCW-MDP-CF-RUN2-2

    Event Tree: LOCCW-A                                     CCDF:  3.2E-008
    Sequence:   3-04-3

 CCDF        % Cut Set                     Cut Set Events
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 5.6E-009         17.86   CVC-MDP-TM-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1AA
                          FLAG-CCW-1A-RUNNING       CCW-XHE-XL-1AA
                          CCW-MDP-CF-RUN2-2
 5.6E-009         17.86   CVC-MDP-TM-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1BB
                          FLAG-CCW-1B-RUNNING       CCW-XHE-XL-1BB
                          CCW-MDP-CF-RUN2-2
 3.3E-009         10.44   CVC-MDP-TM-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-HTX-PG-HXA
 1.9E-009          5.88   CVC-MDP-TM-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-HTX-FOUL-HXA
                          CCW-HTX-CF-FOUL2-2
 1.8E-009          5.56   CVC-MDP-TM-1B             CCW-MDP-TM-1BB
                          RCS-MDP-LK-BP1            RCS-MDP-LK-BP2
                          IE-CCW-MDP-FR-1AA         FLAG-CCW-1A-RUNNING
                          CCW-XHE-XL-1AA
 1.8E-009          5.56   CVC-MDP-TM-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1BB
                          FLAG-CCW-1B-RUNNING       CCW-MDP-TM-1AA
                          CCW-XHE-XL-1BB
 1.4E-009          4.29   CVC-MDP-FS-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1BB
                          FLAG-CCW-1B-RUNNING       CCW-XHE-XL-1BB
                          CCW-MDP-CF-RUN2-2
 1.4E-009          4.29   CVC-MDP-FS-1B             RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1AA
                          FLAG-CCW-1A-RUNNING       CCW-XHE-XL-1AA
                          CCW-MDP-CF-RUN2-2
 1.1E-009          3.57   CVC-XHE-XR-MDPB           RCS-MDP-LK-BP1
                          RCS-MDP-LK-BP2            IE-CCW-MDP-FR-1AA
                          FLAG-CCW-1A-RUNNING       CCW-XHE-XL-1AA

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		CCW-MDP-CF-RUN2-2	
1.1E-009	3.57	CVC-XHE-XR-MDPB	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1BB
		FLAG-CCW-1B-RUNNING	CCW-XHE-XL-1BB
		CCW-MDP-CF-RUN2-2	
7.9E-010	2.50	CVC-MDP-FS-1B	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-PG-HXA
6.6E-010	2.09	CVC-XHE-XR-MDPB	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-PG-HXA
4.4E-010	1.41	CVC-MDP-FS-1B	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-FOUL-HXA
		CCW-HTX-CF-FOUL2-2	
4.2E-010	1.33	CVC-MDP-FS-1B	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1BB
		FLAG-CCW-1B-RUNNING	CCW-MDP-TM-1AA
		CCW-XHE-XL-1BB	
4.2E-010	1.33	CVC-MDP-FS-1B	CCW-MDP-TM-1BB
		RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	
3.7E-010	1.18	CVC-XHE-XR-MDPB	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-HTX-FOUL-HXA
		CCW-HTX-CF-FOUL2-2	
3.5E-010	1.11	CCW-MDP-TM-1BB	CVC-XHE-XR-MDPB
		RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	
3.5E-010	1.11	CVC-XHE-XR-MDPB	RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	IE-CCW-MDP-FR-1BB
		FLAG-CCW-1B-RUNNING	CCW-MDP-TM-1AA
		CCW-XHE-XL-1BB	
3.3E-010	1.04	CCW-MDP-FS-1AA	CVC-MDP-TM-1B
		RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1BB	FLAG-CCW-1B-RUNNING
		CCW-XHE-XL-1BB	
3.3E-010	1.04	CCW-MDP-FS-1BB	CVC-MDP-TM-1B
		RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
		IE-CCW-MDP-FR-1AA	FLAG-CCW-1A-RUNNING
		CCW-XHE-XL-1AA	

Event Tree: LOOP CCDF: 2.5E-008
Sequence: 02-05

CCDF	% Cut Set	Cut Set Events	
7.4E-009	29.16	CCW-MDP-CF-STRT	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
1.6E-009	6.34	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FR-2A	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
1.6E-009	6.34	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA

		EPS-DGN-FR-2B	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
1.6E-009	6.11	EPS-XHE-XL-UNIT1	CCW-MDP-FS-1AA
		EPS-DGN-FR-1B	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
6.8E-010	2.70	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-TM-2B	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
6.8E-010	2.70	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FR-2B	EPS-DGN-TM-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
6.8E-010	2.70	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-TM-1B	EPS-DGN-FR-2A
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
6.8E-010	2.70	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-TM-2A	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
6.6E-010	2.60	EPS-XHE-XL-UNIT1	CCW-MDP-FS-1AA
		EPS-DGN-TM-1B	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
5.3E-010	2.09	CCW-CKV-CF-PMPS	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
3.0E-010	1.20	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FS-2A	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
3.0E-010	1.20	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FS-1B	EPS-DGN-FR-2A
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
3.0E-010	1.20	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FS-2B	EPS-DGN-FR-1B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
3.0E-010	1.20	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-FS-1B	EPS-DGN-FR-2B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	
3.0E-010	1.17	CCW-HTX-CF-HXAC	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
2.9E-010	1.15	EPS-XHE-XL-UNIT1	CCW-MDP-FS-1AA
		EPS-DGN-FS-1B	OEP-XHE-XL-NR02H
		/RCS-MDP-LK-BP1	RCS-MDP-LK-BP2
2.9E-010	1.15	EPS-XHE-XL-UNIT2	CCW-MDP-FS-1AA
		EPS-DGN-TM-1B	EPS-DGN-TM-2B
		OEP-XHE-XL-NR02H	/RCS-MDP-LK-BP1
		RCS-MDP-LK-BP2	

2.9E-010	1.15	EPS-XHE-XL-UNIT2 EPS-DGN-TM-1B OEP-XHE-XL-NR02H RCS-MDP-LK-BP2	CCW-MDP-FS-1AA EPS-DGN-TM-2A /RCS-MDP-LK-BP1
2.6E-010	1.02	SWS-STR-PG-A2AA EPS-XHE-XL-UNIT2 /RCS-MDP-LK-BP1	SWS-MDP-FS-LB OEP-XHE-XL-NR02H RCS-MDP-LK-BP2
2.6E-010	1.02	SWS-STR-PG-A2AA SWS-MDP-FS-HB /RCS-MDP-LK-BP1	EPS-XHE-XL-UNIT2 OEP-XHE-XL-NR02H RCS-MDP-LK-BP2

BASIC EVENTS (Cut Sets Only)

Event Name	Description	Curr Prob
ACP-BAC-LP-1A	DIVISION 1A AC POWER 6.9KV BUS FAILS	4.8E-006
CCW-CKV-CF-PMPS	CCF OF CCW DISCHARGE CHECK VALVES	2.2E-007
CCW-HTX-CF-FOUL2-2	CCF DUE TO FOULING OF 2 OF 2 CCW HTXS GIVEN 1	1.7E-001
CCW-HTX-CF-FOUL3-3	CCF DUE TO FOULING OF 3 OF 3 CCW HTX GIVEN 1	2.9E-002
CCW-HTX-CF-HXAC	CCF OF CCW HEAT EXCHANGERS HX-A & C	1.2E-007
CCW-MDP-CF-RUN2-2	CCF OF 2-OF-2 CCW PUMPS TO RUN GIVEN 1 FAILED	2.6E-002
CCW-MDP-CF-RUN4-4	CCF OF 4-OF-4 CCW PUMPS TO RUN GIVEN 1 FAILED	9.7E-004
CCW-MDP-CF-STRT	CCF OF CCW MDPS TO START	3.0E-006
CCW-MDP-FR-1AA	CCW MDP 1AA FAILS TO RUN	9.6E-005
CCW-MDP-FS-1AA	FAILURE OF CCW MDP 1AA TO START	1.5E-003
CCW-MDP-FS-1BB	FAILURE OF CCW MDP 1BB TO START	1.5E-003
CCW-MDP-TM-1AA	CCW PUMP 1A-A UNAVAILABLE DUE TO TEST AND MAI	8.0E-003
CCW-MDP-TM-1BB	CCW MDP 1BB UNAVAILABLE DUE TO TEST AND MAINT	8.0E-003
CCW-XHE-XL-1AA	OPERATOR FAILS TO RECOVER CCW PUMP 1A-A	1.0E+000
CCW-XHE-XL-1BB	OPERATOR FAILS TO RECOVER CCW PUMP 1B-B	1.0E+000
CCW-XHE-XL-LTRF	OPERATOR FAILS TO RECOVER CCW FOR LONG TERM D	1.0E+000
CVC-MDP-FS-1B	CVC MDP TRAIN B FAILURE TO START	1.2E-003
CVC-MDP-TM-1B	CHARGING PUMP 1B UNAVAILABLE DUE TO TEST AND	5.0E-003
CVC-XHE-XM-VCTSWAP	OPERATOR FAILS TO SWAP SUCTION FROM VCT TO RW	1.0E-002
CVC-XHE-XR-MDPB	OPERATOR FAILS TO RESTORE CHARGING PUMP 1B AF	1.0E-003
EPS-DGN-FR-1B	DIESEL GENERATOR B FAILS TO RUN	2.1E-002
EPS-DGN-FR-2A	DIESEL GENERATOR A FAILS TO RUN	2.1E-002
EPS-DGN-FR-2B	DIESEL GENERATOR 2B FAILS TO RUN	2.1E-002
EPS-DGN-FS-1B	DIESEL GENERATOR B FAILS TO START	4.0E-003
EPS-DGN-FS-2A	DIESEL GENERATOR A FAILS TO START	4.0E-003
EPS-DGN-FS-2B	DIESEL GENERATOR 2B FAILS TO START	4.0E-003
EPS-DGN-TM-1B	DIESEL GENERATOR B UNAVAILABLE DUE TO TEST AN	9.0E-003
EPS-DGN-TM-2A	DIESEL GENERATOR A UNAVAILABLE DUE TO TEST AN	9.0E-003
EPS-DGN-TM-2B	DIESEL GENERATOR 2B UNAVAILABLE DUE TO TEST A	9.0E-003
EPS-XHE-XL-UNIT1	OPERATOR FAILS TO CROSS-TIE UNIT 2 EDGS TO UN	2.0E-002
EPS-XHE-XL-UNIT2	UNIT 2 EDGS UNAVAILABLE; CROSS-TIED TO UNIT 2	9.8E-001
FLAG-CCW-1A-RUNNING	CCW PUMP 1A-A IS RUNNING	5.0E-001
FLAG-CCW-1B-RUNNING	CCW PUMP 1B-B IS RUNNING	5.0E-001
HPI-MDP-FS-1B	HPI MDP-1B FAILURE TO START	1.2E-003
HPI-MDP-TM-1B	HPI MDP 1B UNAVAILABLE DUE TO TEST AND MAINTE	5.0E-003
HPR-XHE-XM	OPERATOR FAILS TO INITIATE HPR	2.0E-003

Event Name	Description	Curr Prob
IE-CCW-CF-HXPL-AANDC	CCF OF CCW HEAT EXCHANGERS A AND C PLUG	4.4E-005
IE-CCW-HTX-FOUL-HXA	CCW HEAT EXCHANGER A FOULS	8.8E-004
IE-CCW-HTX-PG-HXA	CCW HEAT EXCHANGER HX A PLUGS	2.6E-004
IE-CCW-MDP-FR-1AA	CCW PUMP 1A-A FAILS TO RUN (INITIATING EVENT)	3.5E-002
IE-CCW-MDP-FR-1BB	CCW PUMP 1B-B FAILS TO RUN (INITIATING EVENT)	3.5E-002
OEP-XHE-XL-NR02H	OPERATOR FAILS TO RECOVER OFFSITE POWER IN 2	3.7E-001
RCS-MDP-LK-BP1	RCP SEAL STAGE 1 INTEGRITY (BINDING/POPPING O	1.3E-002
RCS-MDP-LK-BP2	RCP SEAL STAGE 2 INTEGRITY (BINDING/POPPING O	2.0E-001
RHR-FAN-TM-RHRRMB	RHR MDP 1B ROOM FAN UNAVAILABLE DUE TO T & M	2.0E-003
RHR-HTX-TM-HXB	RHR HEAT EXCHANGER HTX-B UNAVAILABLE DUE TO T	2.5E-003
RHR-MDP-TM-1B	RHR MDP 1B UNAVAILABLE DUE TO T & M	6.0E-003
SWS-MDP-FS-HB	ERCW PUMP H-B FAILS TO START	1.5E-003
SWS-MDP-FS-LB	FAILURE OF SWS MDP LB TO START	1.5E-003
SWS-STR-CF-ALL	CCF OF SERVICE WATER STRAINERS	3.7E-006
SWS-STR-PG-A2AA	SWS TRAIN 2A DISCH STRAINER A2AA FAILS	7.2E-005
SWS-STR-PG-B2BB	SWS TRAIN 2B DISCH TRAINER B2BB FAILS	7.2E-005

Appendix D

Referenced E-Mails

Delivered-To: bmrowca@infosyslabs.com
To: Robert F Buell <Robert.Buell@inl.gov>,
Thomas E Wierman <Thomas.Wierman@inl.gov>,
John A Schroeder <John.Schroeder@inl.gov>
Cc: bmrowca@islinc.com, dmr@nrc.gov
Subject: CCW Heat Exchanger Plugging Failure Rate
X-Mailer: Lotus Notes Release 6.5.1 January 21, 2004
From: Steven A Eide <Steven.Eide@inl.gov>
Date: Tue, 19 Jul 2005 16:24:12 -0600
X-MIMETrack: Serialize by Router on LNMAIL04/ENT/INEEL/US(Release 6.5.4 HF320|June 30, 2005) at
07/19/2005 04:24:11 PM,
Serialize complete at 07/19/2005 04:24:11 PM
X-mxGuard-Info: Processed by sd-islinc.com using mxGuard v1.6.2
X-mxGuard-Spool-ID: 7d456c96014452de
X-mxGuard-Sender: steven.eide@inl.gov
X-mxGuard-Native-RelayCount: 3
X-mxGuard-Spam-Score: 3
X-mxGuard-Spam-Probability: CLEAN
X-Note: This message has been scanned for spam and viruses by mxGuard for IMail (www.mxguard.com)

The existing component cooling water (CCW) template heat exchanger plugging rate of 2.5E-6/h is based on chemical industry data. I believe that this rate is too high for a clean water system such as the CCW. Because we do not have reliable data from EPIX on heat exchanger plugging, I reverted back to the following report to obtain a new rate:

Savannah River Site Generic Data Base Development (U)
WSRC-TR-93-262
C. H. Blanton and S. A. Eide
Westinghouse Savannah River Company
June 1993

That report recommends a heat exchanger fouling rate of 1.0E-7/h and a plugging rate of 3E-8/h (Table 6a in the report). I recommend that we use the 1.0E-7/h rate to cover fouling or plugging of CCW heat exchangers. The corresponding gamma distribution has alpha = 0.30 and beta = 3.00E+6h.

Steven A. Eide
INL
(208) 526-3797

From: John A Schroeder <John.Schroeder@inl.gov>
Date: Thu, 28 Jul 2005 16:28:31 -0600
X-MIMETrack: Serialize by Router on LNMAIL04/ENT/INEEL/US(Release 6.5.4 HF320|June 30, 2005) at
07/28/2005 04:28:33 PM,
Serialize complete at 07/28/2005 04:28:33 PM
Content-Type: multipart/alternative; boundary="=_alternative 007B76748725704C_="

This is a multipart message in MIME format.
--=_alternative 007B76748725704C_=
Content-Type: text/plain; charset="US-ASCII"

Bob,

The following is from our CCF expert.

John A. Schroeder
Idaho National Laboratory
Battelle Energy Alliance, LLC
P.O. Box 1625
Idaho Falls, ID 83415-3850

Ph: 208-526-8755
FAX: 208-526-2930
----- Forwarded by John A Schroeder/ROE/CC01/INEEL/US on 07/28/2005 04:27 PM -----

Thomas E Wierman/WIERTE/CC01/INEEL/US
07/28/2005 03:46 PM

To
John A Schroeder/ROE/CC01/INEEL/US@INEL
cc

Subject
Re: Fw: Watts Bar LOCCW

Alpha 2 of 0.16 is a valid CCF HTX plugging term. It means that IF a heat exchanger plugs, there is a very good chance that its redundant HTX will plug also. Most of the plugging events have to do with environmental factors. However, the CCF factors are based entirely on the RHR, CSS, and CSR systems. Meaning that all of these systems are cooled by service water or similar water quality. In addition, all of these heat exchangers are standby, no flow until demanded.

We have some unofficial idea that CCW HTX are not near as prone to CCF Alpha 2 approx 0.01. This may be due to the continuous flow or the lower failure rate where not as many failures are observed.

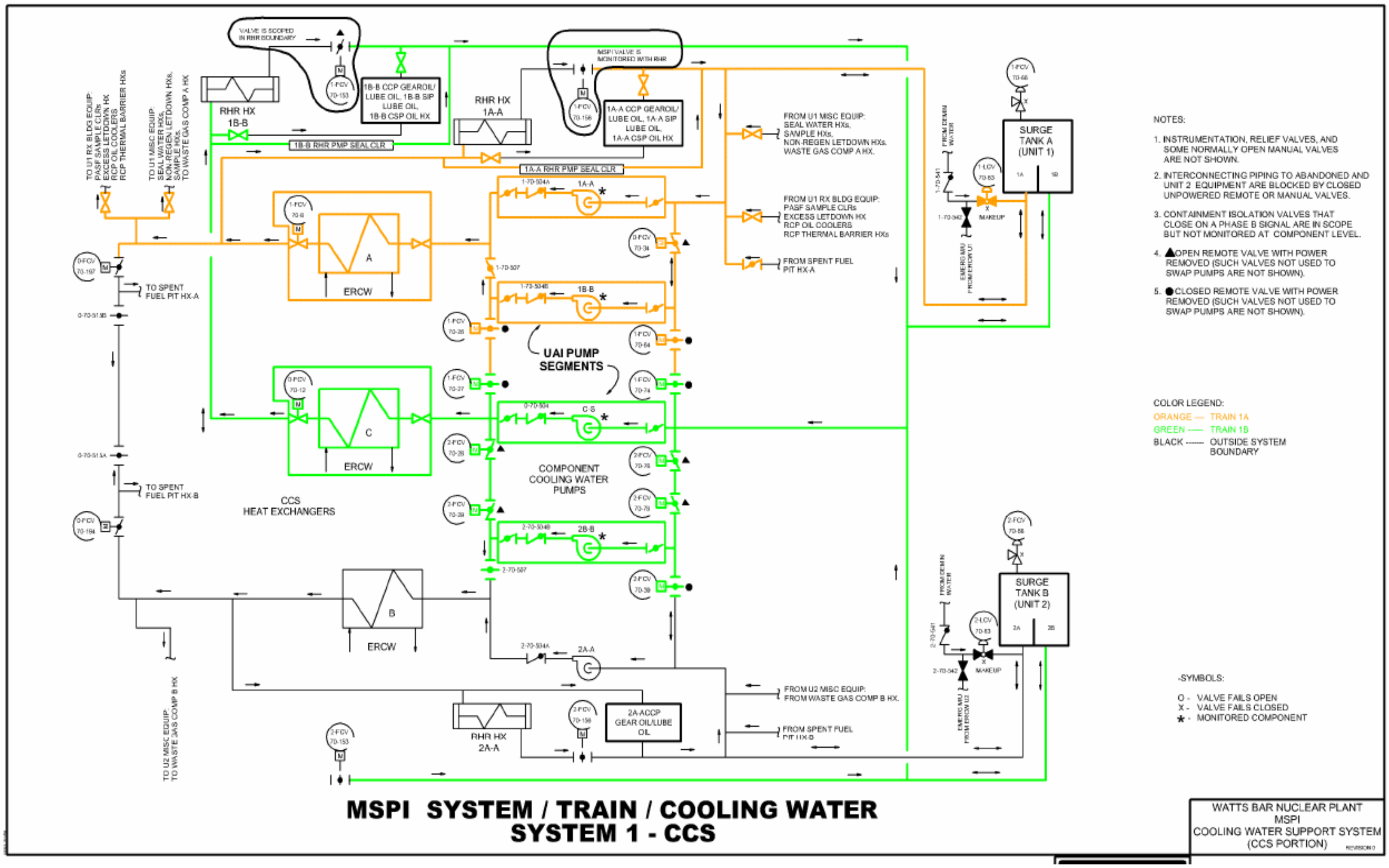
As to the modeling of 2 of 2 when 3 are installed, the acid test is whether the three are subjected to the same challenges, environment, etc. In this case it appears that the third is physically removed from the system and is not necessarily cycled in as a standby (abandoned in place). If this is the case, model the group as two, otherwise if it is only temporarily OOS the system may be modeled as three.

Thanks,

Thomas E. Wierman, Advisory Engineer
Risk, Reliability, and NRC Programs Department
Idaho National Laboratory
P. O. Box 1625 - 3865
Idaho Falls, ID 83415
208-526-3836

Appendix E

Component Cooling Water System Flow Diagram



MSPI SYSTEM / TRAIN / COOLING WATER SYSTEM 1 - CCS