PRA EVALUATION:

PROPOSED CHANGES IN PRIMARY COMPONENT COOLING WATER TECH SPEC 3.7.3

Engineering Evaluation 94-

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1.0 Introduction

This evaluation documents the change in operational risk, at the system level (system availability) and at the plant level (core damage frequency), for a proposed change in the Allowed Outage Times (AOTs) for the Primary Component Cooling Water (PCC) System.

This is a follow-on evaluation from Engineering Evaluation 92-42[1], based on the actual submitted Tech Spec change[2], the most current Seabrook Station Probabilistic Safety Study (SSPSS-1993)[3], and more detailed documentation suitable for peer review.

2.0 Background

The current Primary Component Cooling Water Tech Spec (TS 3.7.3) applies AOTs to all four PCC pumps. These pumps are each 100% capacity and provide dual redundancy for each train. Thus, to define design operability, one train of PCC must contain one PCC pump and the associated flow paths to the PCC loads.

A new Tech Spec 3.7.3 has been proposed that brings this Tech Spec in line with the standard Tech Specs. The standard Tech Spec for PCC has a 72-hour AOT for a single train.

The new proposed Tech Spec is summarized below, with a comparison of the current Tech Specs.

	Allowed Outage Time	
Components Inoperable	Current TSs 3.7.3	Proposed TS 3.7.3
1 PCC pump	7 d	N/A [a]
2 PCC pumps, opposite loops	72 hr	N/A
2 PCC pumps, same loops	24 hr	72 hr
One loop (other than pumps)	not explicit	72 hr

[a] N/A = not applicable. These conditions would not be restricted by the proposed Tech Spec.

3.0 Discussion

This Tech Spec change impacts risk by increasing the likelihood that a PCC pump would be unavailable due to planned or unplanned maintenance. This change is evaluated by considering the impact on system unavailability (Section 3.1) and on the frequency of shutdown due to loss of one train of PCC (Section 3.2). These impacts are combined in the plant model to produce a delta core damage frequency (Section 3.3).

In addition, two sensitivity case are evaluated. The first (Case #1) examines the risk importance of the standby PCC pump. This case assumes the two standby PCC pumps are permanently removed. This is *not* a realistic calculation since the station is committed to maintaining the standby PCC pumps but is presented to examine the bounding case. An additional sensitivity case (Case #2) is included to examine the combined impact of the proposed Tech Spec changes for both SW (from Reference 5) and PCC.

3.1 PCC System Model

The PCC system is included in the current Seabrook PRA, SSPSS-1993 (the base case). This model includes the PCC pumps, the flow path through the safety loads, and the associated area ventilation. Attachment A is a summary of the PCC system model.

This evaluation considers only changes in maintenance unavailability due to the proposed change in Tech Specs. The following table describes how the changes from current to proposed Tech Specs have been modeled.

Components Inoperable	Current TS AOT	Proposed TS AOT	Changes Modeled ?	Comments
1 PCC pump (standby pump)	7 d	N/A	yes	Modeled as increased unplanned maintenance duration and new planned maintenance contribution, for each standby pump.
2 PCC pumps, from opposite loops (standby pumps)	72 hr	N/A	no	This combination is not modeled because of the low frequency of entering this condition, i.e., having one pump fail and the standby pump in the opposite train fail while the first one is being repaired.
2 PCC pumps, from same loop (loop)	24 hr	72 hr	yes	The failure of either PCC loop is assumed to require a plant shutdown due to loss of RCP motor cooling. This is modeled in the loss of one train PCC initiators.
One loop	not explicit	72 hr	yes	The unavailability of one loop is effectively modeled as the "2 pumps from the same loop" case (above).

The maintenance contribution to the PCC system model is described below (the Base Case model); then the model with the change in Tech Spec is presented (the "New" model).

(1) Base Case (Current) Maintenance Model

This model includes contributions from *unplanned maintenance*, based on the number of pumps, the maintenance frequency, and the maintenance duration, as follows:

- Standby PCC pump, for each loop, 7-day LCO:

MAINTA = MAINTB (train A , train B)

= 2 x ZMPOPF x ZMPLSD = 0.00906 (2 PCC pumps per loop)

where the frequency and duration variables are based on generic data from PLG-0500, as follows:

ZMPOPF = 1.58E-4 (mean) - Maint. Freq. - operating PCC pumps

ZMPLSD = 28.7 hr (mean) - Maint. Duration - pumps, 7-day LCO

These values are means of distributions developed from generic maintenance data, taken from PLG-0500[4]. Attachment B provides a sample of the generic data that is the basis for the distributions.

Maintenance assumptions in the current model:

- Maintenance frequencies and durations are based on generic industry data and not on Seabrook specific data due to the limited operational data. This data was collected by PLG from a number of nuclear plants for similar equipment and is judged to be reasonably representative of expected Seabrook experience. (Note that the mean maintenance duration is considerably less than the AOT based on actual experience, but mean maintenance duration increases with longer AOT.)
- No planned maintenance is done on the PCC system during power operation that makes a pump inoperable.
- No contribution is given to 2 PCC pumps in unplanned maintenance at the same time because of the low likelihood of dual pump failure or failure of the second pump while the first is being repaired.
- No explicit maintenance contribution is modeled for valves, instrumentation, etc., that would make a loop inoperable. The pump contribution is assumed to dominate maintenance unavailability.
- Maintenance contribution from failures of PCC pump-area ventilation is not included because of the large open area where the pumps are located. This would allow time for remedial action to be taken to keep the PCC system operational.

- Maintenance is unrecoverable. This assumption may be very conservative for some maintenance activities where the system could be restored quickly.

(2) New Maintenance Model

A "New" PCC model was developed to account for the proposed changes in Tech Specs. These changes impact the modeling of unplanned maintenance and planned maintenance, as follows:

Unplanned Maintenance:

- Standby PCC pump in each loop, no LCO:

MAINTA' = MAINTB' (train A, train B)

$= 2 \times \text{ZMPOPF} \times \underline{\text{ZMPCCD}} = 0.0308$ (2 PCC pumps per loop)

where the variables are based on generic data from PLG-0500, as follows:

ZMPCCD = 97.4 hr (mean) - Maint. Duration - PCC pumps, no LCO

Other variables - see current model

Maintenance assumptions:

- The standby PCC pump is modeled as though it would be repaired in unplanned maintenance with no special priority - consistent with other pumps with no LCO. This is believed to be conservative; a PCC pump failure would still receive high priority. The variable ZMPCCD was developed from the data variable ZMPNSD in PLG-0500, using generic data for SW and PCC pumps, judged to be more representative of the PCC and SW pumps at Seabrook. (See Attachment B for details.)

Planned Maintenance for the standby PCC pump in each loop:

PLMNTA = PLMNTB

$= 2 \times (1/4\ \text{yr}) \times (1\ \text{yr}/\ 8760\ \text{hr}) \times (336\ \text{hr}) = 0.0192$ (2 pumps per loop)

Assumptions:

- Each PCC pump is unavailable due to planned maintenance once every four years for 14 days (336 hrs).
- Planned maintenance is done on one pump at a time - no PLMNTA x PLMNTB terms.

The quantification for the "new" PCC model is in general as follows

PCC Unavail. = PCCpumps(hardware failure + **unplanned maint.** + **planned maint.**)
+ common components failure

where the terms in bold are the ones affected by the proposed Tech Spec change.

3) Sensitivity Cases

Two sensitivity cases were run. The first case (Case #1) assumes the standby PCC pumps, one in each train, are permanently unavailable. Unplanned maintenance on the operating PCC pumps is assumed to require a plant trip, and thus is reflected in the initiating event, loss of one PCC train. This is included as a bounding analysis. The results of this case are shown in the next section.

The second case (Case #2) combines the "new" Tech Specs for PCC with the "new" Tech Specs for SW. This shows the cumulative impact of these two proposed Tech Spec changes. Since the system results are the same as the "New" TS cases for PCC and SW, the system results for Case # 2 are not repeated.

4) Quantitative Results - Systems Analysis

The function of the Primary Component Cooling Water system is to cool safety related pumps and to remove decay heat from RHR and CBS heat exchangers.

The PCC system configuration is quantified for a number of different boundary conditions. Boundary conditions are the signals and support systems, external to the PCC system, that impact the system configuration. For example, with loss of offsite power (LOSP), the PCC pumps must restart, presenting a different failure mode - pump fails to start - that is not present when offsite power is available. The important boundary conditions for the PCC system are the number of support systems (e.g. AC power) available, LOSP, and 'P' signal present. The combination of two-train boundary conditions that are of interest is given below. Similar single-train configurations have also been quantified.

System Configuration	Number of Trains	LOSP Initiator	'P' Signal Present	Comment
PCC1 *	2			Normal configuration: 2 PCC pumps per train.
PCC2	2	x		Loss of offsite power: 2 PCC pumps per train; standby pump requires manual start.
PCC3	2		x	Normal pump configuration (4 PCC pumps), with additional containment isolation requirements.

* (This boundary condition is used for both general transients and small LOCA. As a result, the isolation of non-essential loads required given an "S" signal is included in PCC1. This results in a conservative quantification for general transient cases.)

With the maintenance contribution changes as described above, the PCC system unavailability changes as follows:

System Unavailability			Maintenance Contribution (Percent of TOTAL)	
System Configuration	TOTAL: (a) Base Case (b) New TS (c) Sen. Case #1	(Percent Change from Base Case)	Unplanned Maint.	Planned Maint.
PCC1 Normal configuration.	(a) 7.21E-7		2.9%	-
	(b) 7.59E-7	5.3%	9.5%	5.9%
	(c) 6.15E-6	~750 %	-	-
PCC2 Loss of offsite power.	(a) 2.80E-6		2.4%	-
	(b) 2.87E-6	2.5%	7.7%	4.9%
	(c) 1.82E-5	~550%	-	-
PCC3 Containment isolation.	(a) 2.21E-5		1.9%	-
	(b) 2.21E-5	< 0.1%	6.3%	3.9%
	(c) 2.75E-5	24.4%	-	-

See Attachment C for details of the maintenance quantification.

These results, both for the current and the new TS, are based on point estimate quantifications of the system. The current PCC system analysis in the SSPSS-1993 is quantified using Monte Carlo uncertainty methods. However, in comparing the small changes in system quantification that the change in Tech Specs produces, the effects of the Monte Carlo uncertainty overwhelm the results. Thus, to isolate the impact of the Tech Spec change alone, the system quantification for PCC is presented using point estimate.

The results at the system level indicate that the change in system unavailability for the new TS is small for all configurations, with a maximum change of ~5% from the base case. This change is insignificant in comparison to the uncertainty of the results. The change in system unavailability is small even though the relative importance of maintenance increased from ~3% to ~15% of the system total. This is due to the multiple redundancy in the system and also the way it is modeled, as follows:

- PCC1 - Normal configuration: 4 PCC pumps. Because of the redundancy with the PCC pumps and the common cause contribution modeled among the pumps, the standby pumps tend to contribute less to the overall system availability than the operating pumps.
- PCC2 - LOSP configuration: 4 PCC pumps. The operating PCC pumps will automatically load onto the diesel generators. The standby PCC pumps are modeled to start given successful manual actions. Because of the common cause modeled among the pumps, the standby pumps tend to contribute less to the overall system availability than the operating pumps.
- PCC3 - 'P' signal, containment isolation required. The system unavailability is dominated by failure of the isolation valves, which are not affected by pump maintenance.

Thus, the impact of the Tech Spec change on PCC system unavailability is insignificant, and it can be concluded that the impact on the plant model (i.e., core damage frequency) from these results would be negligible. These changes are included in the plant model evaluation in Section 3.3.

The sensitivity case #1 resulted in a significant increase in system unavailability, but still less than a factor of 10 increase from the base case. This shows the importance of the standby pumps but also the high reliability of the system without them.

3.2 Initiating Event - Loss of One Train PCC

Loss of either train of PCC would affect the plant power generation through PCC cooling to the RCP motors. This impact is modeled as two initiators, L1CCA and L1CCB. The frequency of loss of one PCC train is given by the frequency of loss of one PCC pump over one year of operation and failure of the other PCC pump while the first is being repaired. This also includes failure of the operating pump while the standby pump is out for maintenance - either planned or unplanned.

There are other combinations of valves, heat exchangers, etc. that could fail and contribute to loss of the train; however, they are not affected by this Tech Spec change.

The simplified equation for loss of one PCC train can be written as follows (assuming pump A is operating and pump C is in standby):

L1PCC = [FR(PmpA)*T(yr)] * [FS(PmpC) + FR(PmpC)*T(repair) + MNT(PmpC)]
+ [FF(Other Components)]

where:

FR(Pmp)= failure rate for operating PCC pump to continue to run
= 9.85E-6 / hr

FS(Pmp)= failure rate for standby PCC pump to start
= 1.61E-3 / demand

T(yr) = duration the operating PCC pump must run (hours per year times plant availability factor)
= 8760 hr per yr * 0.70

T(repair)= duration of unplanned maintenance on failed pump A,

MNT(Pmp)= pump unavailability due to planned and unplanned maintenance,

FF(Other Components) = failure frequency of combinations of other components in the PCC train failing over the operating year.

The two terms T(repair) and MNT(Pmp) are the ones that change due to the new Tech Spec AOT, as follows:

	Current TS Model	New TS Model
T(repair)	ZMPLSD = 28.7 hr	ZMPCCD = 97.4 hr
MNT(Pmp) = PM + UM		
PM Planned Maint.	none	(1/4)*(1/8760)*336 = 0.00959
UM Unplanned Maint.	ZMPOPF*ZMPLSD = 0.00453	ZMPOPF*ZMPCCD = 0.0154

where the variables are defined earlier. Note that the variables underlined are the ones that changed.

The results from the RISKMAN system initiator model are given below.

L1PCC	Initiator Frequency		Maintenance Contribution (Percent of TOTAL)	
	TOTAL	(Percent Change from Base Case)	Unplanned Maint.	Planned Maint.
Current TS Model (w/ point est. calc)	2.49E-3 per yr		11.0 %	-
New TS Model	3.75E-3 per yr	50.6 %	24.8 %	15.5 %
Sensitivity Case #1	6.30E-2 per yr	~2400 %	-	-

As explained in Section 3.1, these results were obtained using point estimate quantification, rather than Monte Carlo uncertainty calculations. This allows the change due strictly to change in the Tech Spec to be isolated. The detailed results for loss of one train of PCC are given in Attachment D.

Thus, the initiator frequency increases by about 50% over the base case. This increase is due to the significance of maintenance in the initiator model.

For the sensitivity case #1, the increase is about a factor of 24. This impact is more dramatic, since the assumption is that failure of either operating PCC pump would force a plant shutdown; no credit is given for the standby PCC pump.

3.3 Plant Model

The plant model has been quantified for four different cases in order to examine the impact of the PCC Tech Spec change on plant-level risk. The results are summarized as follows:

Plant Model Results	Mean Core Damage Frequency (per year)	Percent Change from Base Case
SSPSS-1993 Model - official Seabrook model, using Monte Carlo methods to calculate system unavailability distributions.	8.02E-5	
➡Base Case Model - 1993 model, with PCC point estimate calculations and PCC system model improvements.	5.94E-5	
New PCC Tech Spec - base case model, with New PCC TS modeled.	6.74E-5	13.5 %
Sensitivity Case #1 - base case model, with a single PCC pump per train - the upper bound case.	2.90E-3	~4800 %
Sensitivity Case #2 - base case model, with New PCC TS and New SW TS combined.	7.15E-5	20.4 %

SSPSS-1993. The SSPSS-1993 is the official full-power risk model for Seabrook. The plant model was quantified using mean values from system unavailabilities that were calculated using Monte Carlo methods to combine data uncertainty distributions. The SSPSS-1993 is the current best-estimate of risk from operation of Seabrook Station.

Base Case Model. The Base Case Model uses the SSPSS-1993 model, with several modeling changes in order to be able to evaluate the small changes that result from the PCC TS change. First, the PCC system unavailabilities are calculated using point estimate rather than Monte Carlo methods. While point estimate and Monte Carlo results are reasonably consistent, Monte Carlo methods are sensitive to the shapes of the input distributions, the initial random number "seed", and the number of samples taken. Monte Carlo methods give a better picture of the true nature of the uncertainty of our risk calculations, but this uncertainty tends to overwhelm the small changes that this Tech Spec change makes. Thus, to examine the "delta risk", point estimate calculations are performed on the part of the model where the changes are being made, i.e., the PCC system quantification.

The other modeling changes were made in the Base Case Model regarding the dominant sequences that involve PCC. Attachment E, Table E.1 contains the dominant core damage (CD) sequences for the Base Case (with the sequences that do not involve direct failure of PCC shaded). From this table, it can be seen that the dominant PCC sequences are loss of one train of PCC initiating a plant shutdown with subsequent failure of the opposite train of PCC. This subsequent failure of a PCC train is represented by split fractions PAA' and PB2'. Split fraction PAA' represents failure of PCC train A given failure of PCC train B (and similar for PB2'). These were quantified in the SSPSS-1993 using the PCC system boundary condition 1, for general transients and small LOCAs (see Section 3.1). However, the dominant cutset for this boundary condition is failure of the non-essential loads to isolate, given an S signal (from the small LOCA). This conservative modeling at the system level is significant for this evaluation of PCC Tech Spec change. Thus, split fractions PAA' and PB2' were modified to remove the contribution of the isolation valves.

The final modeling change made in the Base Case Model was to sequence #12 in Table E.1, FPCC3P*PB10: fire in the vicinity of the PCC pumps, disabling three pumps, with subsequent failure of the fourth due to hardware failure or maintenance unavailability. This sequence was modified to credit manual suppression of the fire when the fourth pump is in maintenance. This level of modeling detail was added to more realistically account for the presence of workers who could immediately detect a fire.

New PCC Tech Spec. This model uses the Base Case model discussed above with the PCC Tech Spec changes discussed in Section 3.1. Table E.2 presents the dominant core damage sequences with the new PCC Tech Spec modeled. By comparing with the dominant sequences in Table E.1, the most important change is clearly the change in initiating event frequency for loss of one train of PCC. The total CDF change due to changes in the PCC Tech Spec is about 8.0E-6 per year, or ~13%, compared to the range of the total CDF distribution which is approximately one order of magnitude (from 5th to 95th percentile). Thus, this is an insignificant change within the uncertainty bounds on the CDF distribution.

Sensitivity Case #1. This case models the PCC system assuming only one pump per train was available, i.e., assuming the standby pump had been permanently removed. This change is *not* being proposed in this Tech Spec change, but this sensitivity is presented to examine the upper bound case.

The change in CDF in the sensitivity case #1 is much more significant because of the importance of the loss of one PCC train initiator. Table E.3 presents the dominant core damage sequences with this sensitivity case. Using this sensitivity case, the Risk Achievement (RA) importance factor for this change can be calculated:

RA = 2.90E-3 / 5.94E-5 = 48.8

The standby PCC pump is clearly an important risk component as well as being important to reliable plant operation. Because of this, the standby pump would be treated as a high priority maintenance item and would be restored as soon as possible even if it were not under a Tech Spec clock.

Sensitivity Case #2 . Case #2 evaluates the combined impact of this PCC Tech Spec change and the SW Tech Spec change proposed in Reference 5. This is essentially the sum of the two changes separately since none of the dominant sequences (see Table E.4) involve both PCC and SW. The total CDF change is about 1.2E-5, or ~20%. While this is more significant than either change separately, it is still not significant compared to the uncertainty bound of the CDF distribution.

4.0 Conclusion

As a result of the quantitative evaluation above, the effect of the changes proposed for TS 3.7.3 is generally small for the PCC system unavailability and is significant for the PCC initiating event frequency. With these changes in the plant model, the overall result is insignificant to the core damage frequency. This evaluation is based on a conservative estimate of planned and unplanned PCC pump maintenance, which includes no credit for recovery of equipment during maintenance and models an extended maintenance duration associated with non-Tech Spec pumps.

The evaluation does *not* include the positive contributions due to removing the major PCC pump maintenance activities from outages. These contributions include reducing the unavailability of PCC pumps during outages and permitting more flexibility in outage planning. The outage effects are very sensitive to the configuration of the primary system, time after shutdown, other systems unavailable, etc. and thus are difficult to estimate.

As a result, the proposed Tech Spec change does not significantly increase the core damage risk within the bounds of the uncertainty.

5.0 References

1. North Atlantic Energy Service Corp., "PRA Evaluation: Change in Primary Component Cooling Water Tech Spec 3.7.3," Engineering Evaluation 92-42, Rev. 1, Feb. 1993.

2. NAESCo letter, T. Feigenbaum to USNRC, "License Amendment Request 93-01: 'Primary Component Cooling Water System OPERABILITY Requirements'," NYN-93031, Feb. 26, 1993.

3. North Atlantic Energy Service Corp., "Seabrook Station Probabilistic Safety Study - 1993 Update, (SSPSS-1993)," July 1993.

4. Pickard, Lowe and Garrick, Inc, "Data Base for Probabilistic Risk Assessment of Light Water Nuclear Power Plants - Maintenance Data," PLG-0500, Volume 3, Revision 1, August 1989.

5. North Atlantic Energy Service Corp., "PRA Evaluation: Proposed Changes Service Water Tech Spec 3.7.4," Engineering Evaluation 93-53, Dec. 1993.

Attachment A - PCC System Model Summary

This section contains a copy of the SSPSS-1993 Tier 1 system documentation for Primary Component Cooling Water. This is intended to give a summary description of the system, how it is modeled, and the base case results (Monte Carlo calculations).

SUMMARY: PRIMARY COMPONENT COOLING WATER SYSTEM

1.0 SYSTEM DESCRIPTION

Function - The PCC System supplies cooling water to prevent overheating of components which are needed for plant operation and to maintain core heat removal and RCP seal integrity.

Configuration - The PCC System consists of two separate closed-loop cooling systems. Each loop, or train, contains two full-capacity centrifugal PCC pumps, one vertical shell and straight tube heat exchanger, and one head tank. One pump operates in each loop, while the second pump serves as a standby. (See Figure 3.5-1 for Loop A, Figure 3.5-2 or Loop B.)

The RCP Thermal Barrier Cooling System (RCPTB) includes two heat exchangers, two full-capacity recirculation pumps, a head/relief tank, and motor-operated valves. (See Figure 3.5-3.)

Dependencies - The PCC System depends on the Service Water System to provide cooling to the PCC heat exchangers. A subsystem of the PAH Ventilation System provides redundant ventilation in the PCC pump area should the normal PAH Ventilation System fail to provide adequate ventilation (e.g., during a loss of off-site power).

The PCC, PAH Ventilation, and RCP Thermal Barrier Cooling Systems are dependent upon the essential Electric Power System for AC motor power for fans and pumps; control power (AC and/or DC) for the automatic operation of motors, dampers, valves, and actuation signals; and for monitoring and indication of system parameters. The pneumatic dampers and air- operated valves require compressed air for normal functioning; they fail safe on loss of instrument air.

The PCC System is also dependent on SSPS/ESFAS to provide isolation signals to nonessential loads.

Operation - During normal operation, both loops of the PCC System are operating with one pump per loop in operation and the other in standby. The pumps and the heat exchanger valves can be controlled from the main control board and from the remote safe shutdown panel. Given a P signal, the nonessential loads inside containment supplied by PCC are isolated. Given a T signal, the nonessential loads outside containment are isolated.

Potential for Event Initiation - Loss of either train of PCC during normal plant operation requires a reactor trip within ten minutes following a loss of PCC to the RCP motor coolers.

2.0 SYSTEM MODEL

The PCC System model includes two analyses:

- Availability of PCC, and
- Initiating event involving loss of one train of PCC.

Top Event Definition - The PCC System is analyzed for Top Event PA (loss of PCC Loop A) and Top Event PB (loss of PCC Loop B) in the support systems event tree under three general boundary conditions. In the first case, the unit requires a continuous supply of PCC after an initiating event occurs (with off-site power available). The second case corresponds to an unavailability of off-site power. For this case, the unit requires the PCC pumps to restart and operate for 24 hours after the emergency power sequencer functions. The third case is applied to initiating events which lead to the generation of a P signal, which requires nonessential cooling loads in the containment to be isolated.

The RCP Thermal Barrier Cooling System quantification is not included in Top Events PA and PB, nor is it used in the event tree model. Either seal injection from the charging pumps or seal cooling from the RCP Thermal Barrier Cooling System is sufficient to prevent thermal degradation of the RCP seals and subsequent leakage. However, since both of these methods require PCC, RCP seal failure (Top Event NL) is conditioned on availability of PCC alone. Thus, the RCP Thermal Barrier Cooling System is not included in any top event.

Success Criteria - Success of the PCC System is defined as success of one of two trains, with success of a train corresponding to success of one of two PCC pumps per loop to start automatically (for LOSP) and continue to operate for 24 hours.

Analysis Conditions - The PCC System analysis assumes the plant is operating at normal full power operation prior to the initiating event, with one pump in each loop operating and the other in standby.

No credit is taken for operator actions to recover failed equipment over the 24-hour period of this analysis.

The flow to PCC components may require some manual adjustment during the post-LOCA recirculation phase. These actions are assumed to be performed correctly and are not included in this analysis.

3.0 RESULTS

The PCC System quantification results are shown in Table 3.5-1. System cutset basic events are given in Table 3.5-2.

4.0 UPDATE HISTORY

The system analysis has evolved in the model updates as follows:

- SSPSA(1983) - The original system analysis.
- SSPSS-1986 - Several changes were made:

  The Tech Spec AOTs and test frequencies for PCC pumps were changed.

  The design of the Thermal Barrier Cooling System (TBC) was finalized and modeled. The function of the RCP thermal barrier cooling system to cool the seals on loss of injection was correctly modeled. The effect was to take the TBC system out of the plant model (because of the redundancy with seal injection and the dependency of both on PCC).

  Common cause modeling was expanded to include all four PCC pumps failing as a group.
- SSPSS-1989 - No significant changes.
- SSPSS-1990 - A detailed fault tree was developed using RISKMAN Release 2.0.
- SSPSS-1993 - Several changes were made:

  PAH ventilation was removed from the model, based on equipment qualification records and analysis of PCC area ventilation failure.

  The fault tree was updated using RISKMAN Release 4.0.

  Plant specific data was used for pump start and run and for maintenance unavailability.

  An operator action was added to the model to restart the standby pump on LOSP, since it will not restart automatically.

  A latent operator action was added to realign the pump flow when shifting pump service.

  The head tank instrument failure was added.

Table 3.5-1 PCC Quantitative Results

Two Train PCC: PCC1 = 6.7758E-07

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	[AO.CCV426.FO,AO.CCV427.FO,AO.CCV447.FO,AO.CCV448.FO]	3.990E-07	58.8860	58.8860	NORMAL
2	[PP.CCP11C.FR, PP.CCP11D.FR, PP.CCP11B.FR, PP.CCP11A.FR]	2.327E-07	34.3428	101.6854	NORMAL

Two Train PCC (given LOSP): PCC2 = 3.4546E-06

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	[PP.CCP11D.FS, PP.CCP11A.FS, PP.CCP11C.FS, PP.CCP11B.FS]	1.463E-06	42.3497	42.3497	NORMAL
2	[AO.CCV426.FO, AO.CCV427.FO, AO.CCV447.FO, AO.CCV448.FO]	5.791E-07	16.7633	59.1130	NORMAL
3	OE.RECOVER.FA * [PP.CCP11A.FS] * [PP.CCP11B.FS]	4.361E-07	12.6239	71.7369	NORMAL
4	OE.RECOVER.FA * [PP.CCP11A.FS, PP.CCP11B.FS]	3.214E-07	9.3036	81.0405	NORMAL
5	[PP.CCP11C.FR, PP.CCP11D.FR, PP.CCP11B.FR, PP.CCP11A.FR]	1.699E-07	4.9181	85.9586	NORMAL
6	OE.RECOVER.FA * [PP.CCP11B.FR, PP.CCP11A.FR]	1.221E-07	3.5344	89.4931	NORMAL

Table 3.5-1 PCC Quantitative Results (Continued)

Two Train PCC (given Large LOCA): PCC3 = 1.7856E-05

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	[AO.CCV32.FO, AO.CCV445.FO]	1.453E-05	81.3743	81.3743	NORMAL

Single Train (A) PCC: PA1 = 1.0614E-04

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	HX.CCE17A.GL	4.520E-05	42.5855	42.5855	NORMAL
2	TI.CCTE2171.FZ	2.564E-05	24.1569	66.7425	NORMAL
3	CV.CCV1.GL	1.198E-05	11.2870	78.0295	NORMAL
4	[AO.CCV426.FO, AO.CCV427.FO]	6.585E-06	6.2041	84.2336	NORMAL
5	[PP.CCP11A.FR]	2.407E-06	2.2678	86.5014	MAINTA
6	MO.SWV15.CL	2.187E-06	2.0605	88.5619	NORMAL
7	[PP.CCP11C.FR, PP.CCP11A.FR]	1.239E-06	1.1673	89.7292	NORMAL

Table 3.5-1 PCC Quantitative Results (Continued)

Single Train (A) PCC (given LOSP): PA2 = 3.4957E-04

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	OE.RECOVER.FA * [PP.CCP11A.FS]	1.886E-04	53.9527	53.9527	NORMAL
2	HX.CCE17A.GL	4.856E-05	13.8915	67.8443	NORMAL
3	OE.RECOVER.FA * [PP.CCP11A.FR]	2.331E-05	6.6683	74.5126	NORMAL
4	TI.CCTE2171.FZ	2.264E-05	6.4766	80.9892	NORMAL
5	[PP.CCP11A.FS]	1.478E-05	4.2281	85.2173	MAINTA
6	CV.CCV1.GL	1.284E-05	3.6731	88.8904	NORMAL

Single Train PCC (given Large LOCA): PA3 = 4.7380E-04

No.	*Cutset Basic Events*	*Value*	*Percent Importance*	*Cumulative Importance*	*Alignment*
1	[AO.CCV32.FO]	3.193E-04	67.3915	67.3915	NORMAL
2	HX.CCE17A.GL	4.852E-05	10.2406	77.6321	NORMAL
3	[AO.CCV32.FO, AO.CCV445.FO]	2.230E-05	4.7066	82.3388	NORMAL
4	TI.CCTE2171.FZ	2.049E-05	4.3246	86.6634	NORMAL
5	[AO.CCV57.FO, AO.CCV121.FO]	1.256E-05	2.6509	89.3143	NORMAL

Table 3.5-2 PCC Quantitative Basic Event Definitions

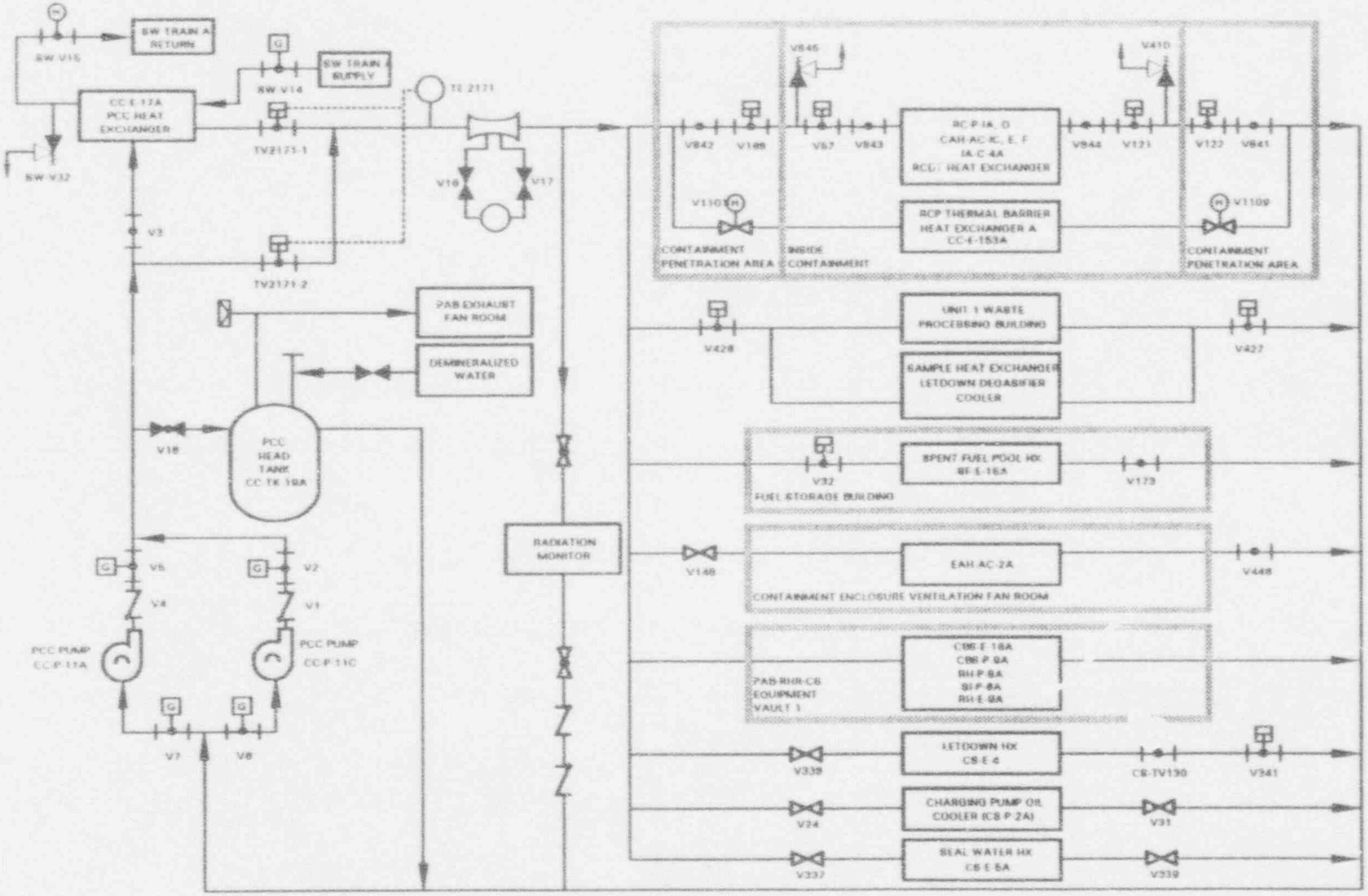
Basic Event	*Description*
XX.SLOCA.XX	SMALL LOCA, SGTR, OR SLB PRESENT
XX.LLOCA.XX	MEDIUM OR LARGE LOCA PRESENT
XX.TRANSIENT.XX	LONG TERM RHR COOLDOWN OR FEED & BLEED (TRANSIENTS)
XX.OSP.XX	LOSS OF OFFSITE POWER
XX.TRAINA.XX	TRAIN A SUPPORT SYSTEMS UNAVAILABLE
XX.TRAINB.XX	TRAIN B SUPPORT SYSTEMS UNAVAILABLE
XX.PCCVENT.XX	NORMAL VENTILATION FAILS
DP.PAHDP43A.FC	DAMPER PAH.DP.43A FAILS TO OPEN OR TRANSFERS CLOSED
FN.PAHFN42A.FS	FAN PAH.FN.42A FAILS TO START ON DEMAND
FN.PAHFN42A.FR	FAN PAH.FN.42A FAILS TO RUN
DP.PAHDP43B.FC	DAMPER PAH.DP.43B FAILS TO OPEN OR TRANSFERS CLOSED
FN.PAHFN42B.FS	FAN PAH.FN.42B FAILS TO START ON DEMAND
FN.PAHFN42B.FR	FAN PAH.FN.42B FAILS TO RUN
LV.PAHL25.PL	PAH INTAKE LOUVRE FAILS . PLUGGED
DP.PAHDP356.FC	TORNADO DAMPER PAH.DP.356 FAILS TO OPEN OR TRANSFERS CLOSED
DP.PAHDP357.FC	TORNADO DAMPER PAH.DP.357 FAILS TO OPEN OR TRANSFERS CLOSED
DP.PAHDP358.FC	TORNADO DAMPER PAH.DP.358 FAILS TO OPEN OR TRANSFERS CLOSED
PP.CCP11A.FR	PCC PUMP P.11A FAILS TO RUN
PP.CCP11B.FR	PCC PUMP P.11B FAILS TO RUN
PP.CCP11A.FS	PCC PUMP P.11A FAILS TO RESTART
PP.CCP11B.FS	PCC PUMP P.11B FAILS TO RESTART
PP.CCP11C.FR	PCC PUMP P.11C FAILS TO RUN
PP.CCP11D.FR	PCC PUMP P.11D FAILS TO RUN
PP.CCP11C.FS	PCC PUMP P.11C FAILS TO START
PP.CCP11D.FS	PCC PUMP P.11D FAILS TO START
VL.CCV7.CL	P.11A SUCTION GATE VALVE CC.V7 TRANSFERS CLOSED
VL.CCV5.CL	P.11A DISCHARGE GATE VALVE CC.V5 TRANSFERS CLOSED
CV.CCV4.CL	P.11A DISCHARGE CHECK VALVE CC.V4 TRANSFERS CLOSED
CV.CCV4.FO	P.11A DISCHARGE CHECK VALVE CC.V4 FAILS TO CLOSE ON PUMP TRIP
VL.CCV301.CL	P.11B SUCTION GATE VALVE CC.V301 TRANSFERS CLOSED
VL.CCV296.CL	P.11B DISCHARGE GATE VALVE CC.V296 TRANSFERS CLOSED
CV.CCV295.CL	P.11B DISCHARGE CHECK VALVE CC.V295 TRANSFERS CLOSED
CV.CCV295.FO	P.11B DISCHARGE CHECK VALVE CC.V295 FAILS TO CLOSE ON PUMP TRIP
VL.CCV6.CL	P.11C SUCTION GATE VALVE CC.V6 TRANSFERS CLOSED

Table 3.5-2 PCC Quantitative Basic Event Definitions

Basic Event	*Description*
VL.CCV2.CL	P.11C DISCHARGE GATE VALVE CC.V2 TRANSFERS CLOSED
CV.CCV1.FC	P.11C DISCHARGE CHECK VALVE FAILS TO OPEN OR TRANSFERS CLOSED
CV.CCV1.GL	P.11C DISCHARGE CHECK VALVE CC.V1 FAILS DUE TO GROSS LEAKAGE
VL.CCV300.CL	P.11D SUCTION GATE VALVE CC.V300 TRANSFERS CLOSED
VL.CCV299.CL	P.11D DISCHARGE GATE VALVE CC.V299 TRANSFERS CLOSED
CV.CCV298.FC	P.11D DISCHARGE CHECK VALVE FAILS TO OPEN OR TRANSFERS CLOSED
CV.CCV298.GL	P.11D DISCHARGE CHECK VALVE FAILS DUE TO GROSS LEAKAGE
HX.CCE17A.GL	TRAIN A HX E.17A EXCESSIVE LEAKAGE DURING OPERATION
HX.CCE17B.GL	TRAIN B HX E.17B EXCESSIVE LEAKAGE DURING OPERATION
BV.CCTV21711.CL	TRAIN A HX TEMP; CONTROL VALVE TV.2171.1 TRANSFERS CLOSED
BV.CCTV22711.CL	TRAIN B HX TEMP; CONTROL VALVE TV.2271.1 TRANSFERS CLOSED
BV.CCTV21712.OP	TRAIN A HX BYPASS VALVE TV.2171.2 TRANSFERS OPEN
BV.CCTV22712.OP	TRAIN B HX BYPASS VALVE TV.2271.2 TRANSFERS OPEN
VL.SWV14.CL	SW.TO.PCC HX TRAIN A INLET VALVE TRANSFERS CLOSED
VL.SWV12.CL	TRAIN B SW.TO.PCC HX INLET VALVE TRANSFERS CLOSED
MO.SWV15.CL	SW.TO.PCC HX TRAIN A OUTLET VALVE TRANSFERS CLOSED
MO.SWV17.CL	TRAIN B SW.TO.PCC HX OUTLET VALVE TRANSFERS CLOSED
AO.CCV426.FO	WPB TRAIN A SUPPLY ISOLATION VALVE FAILS TO CLOSE
AO.CCV447.FO	WPB TRAIN B SUPPLY ISOLATION VALVE FAILS TO CLOSE
AO.CCV427.FO	WPB TRAIN A RETURN ISOLATION VALVE FAILS TO CLOSE
AO.CCV448.FO	WPB TRAIN B RETURN ISOLATION VALVE FAILS TO CLOSE
AO.CCV168.FO	TRAIN A CONTAINMENT SUPPLY ISOLATION (OC) VALVE FAILS TO CLOSE
AO.CCV57.FO	TRAIN A CONTAINMENT SUPPLY ISOLATION (IC) VALVE FAILS TO CLOSE
AO.CCV122.FO	TRAIN A CONTAINMENT RETURN ISOLATION (OC) VALVE FAILS TO CLOSE
AO.CCV121.FO	TRAIN A CONTAINMENT RETURN ISOLATION (IC) VALVE FAILS TO CLOSE
AO.CCV175.FO	TRAIN B CONTAINMENT SUPPLY ISOLATION (OC) VALVE FAILS TO CLOSE
AO.CCV176.FO	TRAIN B CONTAINMENT SUPPLY ISOLATION (IC) VALVE FAILS TO CLOSE
AO.CCV257.FO	TRAIN B CONTAINMENT RETURN ISOLATION (OC) VALVE FAILS TO CLOSE
AO.CCV256.FO	TRAIN B CONTAINMENT RETURN ISOLATION (IC) VALVE FAILS TO CLOSE
AO.CCV32.FO	TRAIN A SPENT FUEL POOL HX ISOLATION VALVE FAILS TO CLOSE
AO.CCV445.FO	TRAIN B SPENT FUEL POOL HX ISOLATION VALVE FAILS TO CLOSE
AO.CCV341.FO	LTDN HX ISOLATION VALVE FAILS TO CLOSE
TK.CCTK19A.RT	PCC TRAIN A HEAD TANK RUPTURES DURING OPERATION
TK.CCTK19B.RT	PCC TRAIN B HEAD TANK RUPTURES DURING OPERATION
TI.CCTE2197.FM	TE.2197 INDICATES FALSE HIGH TEMPERATURE

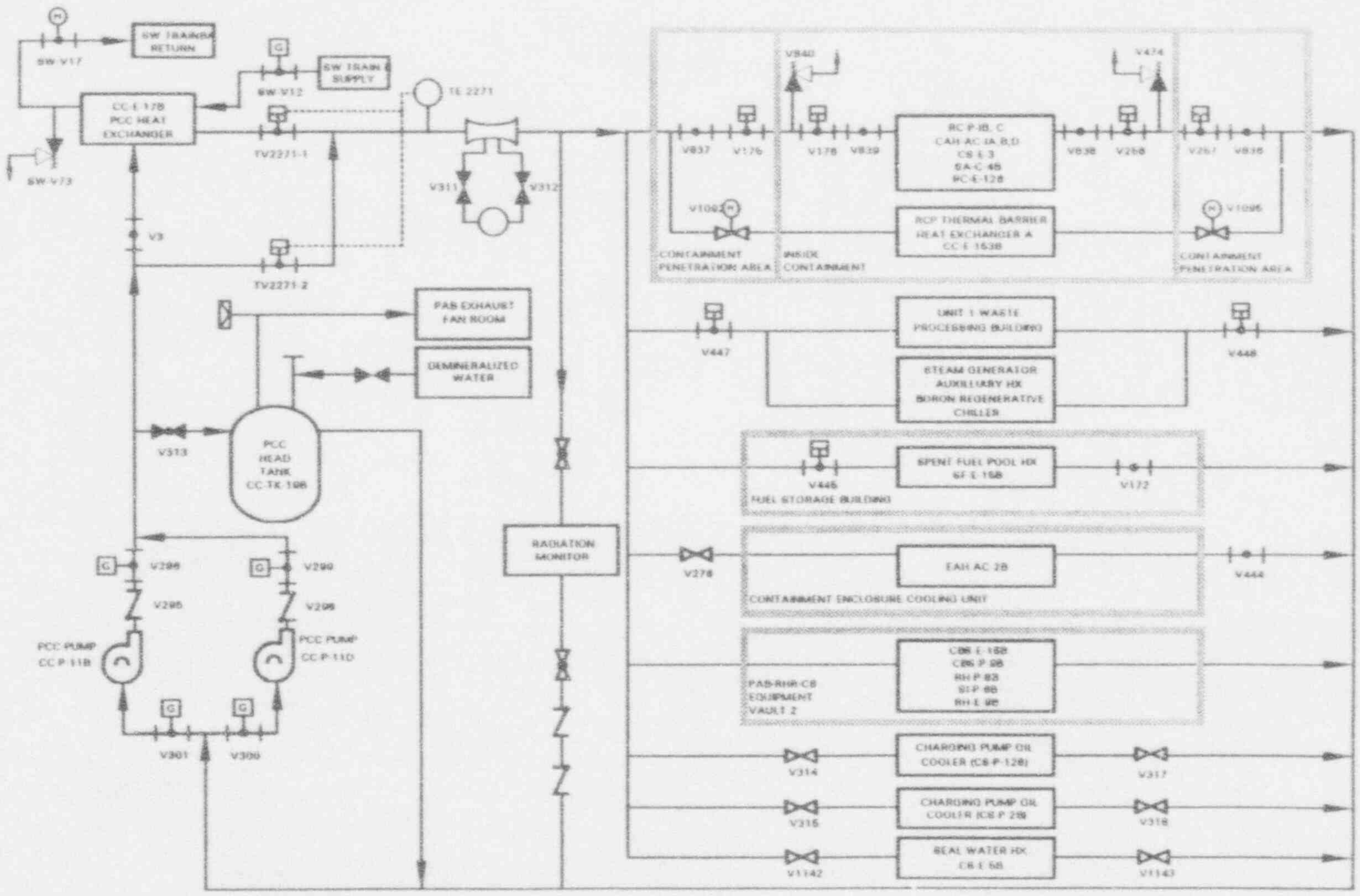
Table 3.5-2 PCC Quantitative Basic Event Definitions

Basic Event	*Description*
TI.CCTE2171.FM	TE.2171 INDICATES FALSE HIGH TEMPERATURE
TI.CCTE2297.FM	TE.2297 INDICATES FALSE HIGH TEMPERATURE
TI.CCTE2271.FM	TE.2271 INDICATES FALSE HIGH TEMPERATURE
OE.CCP11C.LT	PUMP DISCHARGE VALVE CC.V2 NOT RE.OPENED AFTER PUMP ROTATION
OE.CCP11D.LT	PUMP DISCHARGE VALVE CC.V299 NOT RE.OPENED AFTER PUMP ROTATION
OE.RECOVER.FA	OPERATOR FAILS TO RECOVER SYSTEM FAILURES
TI.CCTE2171.FZ	TE.2171 TRANSMITS FALSE LOW OR ZERO OUTPUT
TI.CCTE2271.FZ	TE.2271 TRANSMITS FALSE LOW OR ZERO OUTPUT
VL.CCV3.CL	CC.E.17A INLET ISOLATION VALVE TRANSFERS CLOSED
VL.CCV297.CL	CC.E.17B INLET ISOLATION VALVE TRANSFERS CLOSED
TI.TISH5397.FL	PCC PUMP AREA TEMP; INDICATOR TISH.5397 FAILS (D5079)
RL.CCA5962.FE	P.11C AUTOSTART RELAY FAILS TO ENERGIZE
RL.CCA7962.FE	P.11D AUTOSTART RELAY FAILS TO ENERGIZE
BK.CCA5952.FC	P.11A BREAKER FAILS TO OPEN AFTER P.11A TRIP
BK.CCA7952.FC	P.11B BREAKER FAILS TO OPEN AFTER P.11B TRIP
AO.CSTV130.FO	CS.TV.130 FAILS TO MODULATE TO MINIMUM FLOW (300 GPM)



* ALL VALVES ARE PREFIXED "CC" UNLESS OTHERWISE NOTED
* ALL COMPONENTS ARE IN THE PAB UNLESS OTHERWISE NOTED

Primary Comp. Cooling Water Train A	PCC
SSPSS-1993	Figure 3.5-1



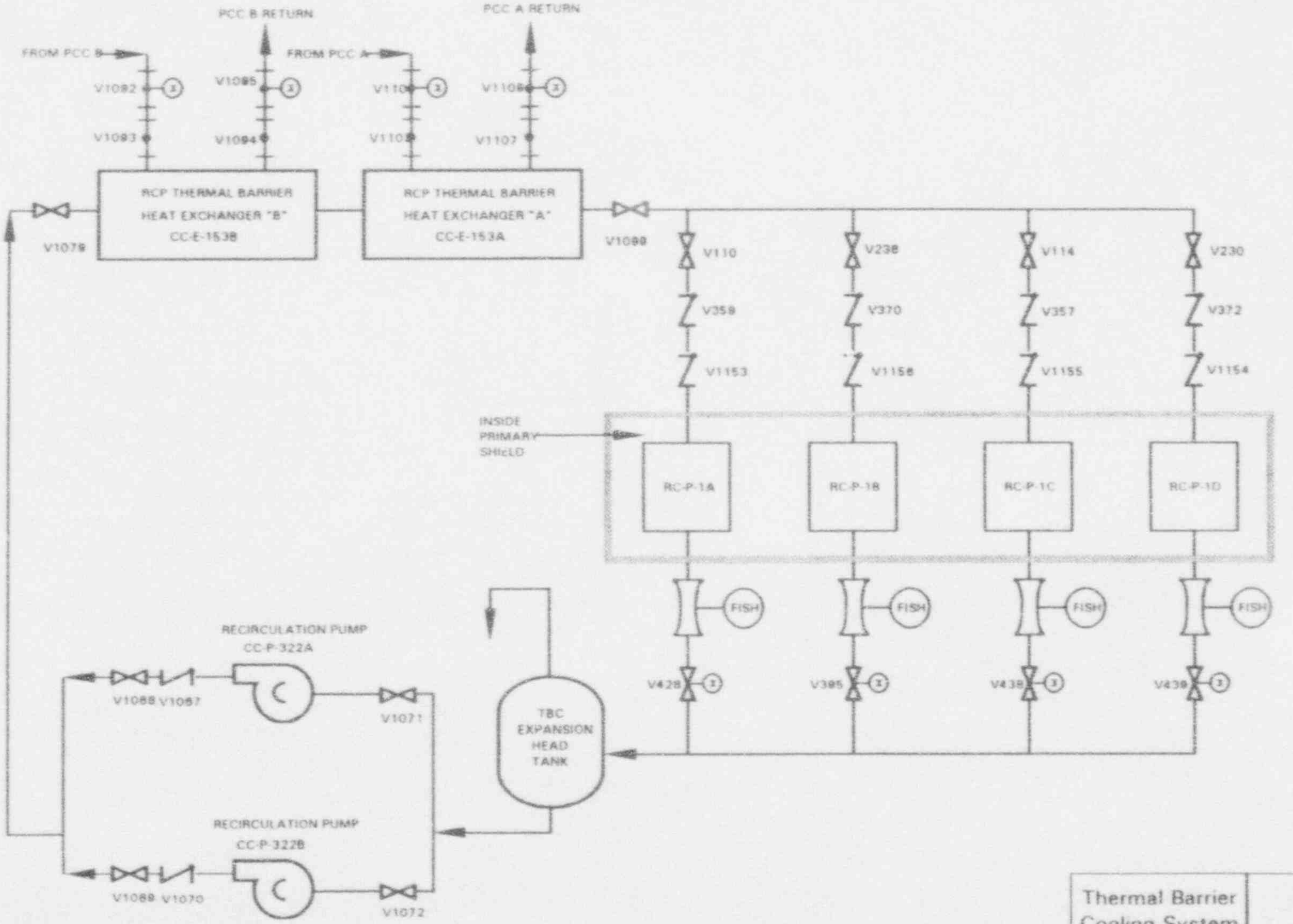
* ALL VALVES ARE PREFIXED "CC" UNLESS OTHERWISE NOTED
* ALL COMPONENTS ARE IN THE PAB UNLESS OTHERWISE NOTED

Primary Comp.
Cooling Water
Train B

SSPSS-1993

PCC

Figure 3.5-2



* ALL COMPONENTS ARE IN THE CONTAINMENT

Thermal Barrier Cooling System	PCC
SSPSS-1993	Figure 3.5-3

Attachment B - PCC Maintenance Data Details

This section contains the basis of two of the generic data distributions used for PCC maintenance duration. These are included for illustration purposes, to show the type of generic industry data that is used in this analysis. All the generic data distributions are taken from Reference 4.

• ZMPLSD	Maint. Duration	Pumps - 168 hour Tech Spec
• ZMPCCD	Maint. Duration	PCC pumps with no LCO (modified from ZMPNSD for pumps with no LCO to account for the high priority PCC pump maintenance is expected to be treated even with no LCO). This distribution is the same as the distribution ZMPSWD used in the Service Water Tech Spec evaluation.[5] It is included in Attachment B of Reference 5, and thus is not repeated here.