19K PRA-Based Reliability and Maintenance

The information in this Appendix of the reference ABWR DCD, including all subsections and tables, is incorporated by reference with the following departures and supplements.

STD DEP T1 2.4-3 (Table 19K-1, Table 19K-2, Table 19K-3, Table 19K-4)

STD DEP T1 3.4-1 (Table 19K-1, Table 19K-2, Table 19K-3, Table 19K-4)

STP DEP T1 5.0-1 (Table 19K-4)

STD DEP 8.3-1 (Table 19K-1, Table 19K-2, Table 19K-3, Table 19K-4)

STP DEP 9.2-5 (Table 19K-1, Table 19K-2, Table 19K-3, Table 19K-4)

19K.3 Determination of "Important Structures, Systems and Components" for Level 1 Analysis

STD DEP T1 2.4-3

STD DEP T1 3.4-1

STD DEP 8.3-1

STP DEP 9.2-5

To determine which plant structures, systems and components (SSCs) are the most important with respect to CDF, the Level 1 analysis results were analyzed. The SSCs were listed in order of Fussell-Vesely (FV) importance, or the percent of cutsets that contribute to the CDF, as calculated by the CAFTA code. A second criterion for selecting SSCs was to consider those SSCs with high "risk achievement worth", or the increase in CDF if that SSC always fails. The ~~21~~ 14 SSCs of greatest importance, in that they had modest FV importance are shown in Table 19K-1. Nine *additional SSCs with modest values of risk achievement worth were considered. Not shown in Table 19K-1 are several human error contributions. Significant human errors are addressed in Subsection 19D.7.*

The ~~26~~ 23 SSCs in Table 19K-1 were further evaluated to eliminate those with a combination of low values for both FV importance and risk achievement worth. ~~The five SSCs meeting this criterion are so indicated. However, one of those five is retained because of its designation as a "critical task" in the human factors evaluation of Subsection 18E.2. The other four are not considered further in this subsection.~~

The ~~remaining 22~~ designated SSCs of Table 19K-1 should be included with important SSCs being considered for periodic testing and/or preventive maintenance (PM) as part of the Reliability Assurance Program (RAP) of the plant owner/operator. The reliability and maintenance actions suggested for the listed SSCs are identified in Subsection 19K.11.

A second table, Table 19K-2, was prepared to show those SSCs with small to moderate values of risk achievement worth. These SSCs all have very low Fussell-Vesely importance, indicating a low probability of failure. However, if they fail, the impact on CDF is not negligible. Most of these SSCs have the same risk achievement worth because their failure would result in failure of the RCIC system to perform its function.

Initiating events that are significant contributors to CDF in the Level 1 analysis are listed in Table 19K-3. There are ~~five~~ six *such events which are shown. The three most significant events~~, accounting~~* account *for more than one-half of the CDF~~, are all station blackout events~~*. The two most important events are isolation/loss of feedwater and unplanned manual reactor shutdown. Three station blackout events and turbine trip account for modest contributions to CDF. *~~, The next two events, contributing small fractions of CDF are isolation/loss of feedwater and manual reactor shutdown.~~ All other initiating events contribute small amounts to CDF.*

19K.7 Determination of "Important Structures, Systems and Components" for Flood Analysis

STP DEP T1 5.0-1

The flood analysis considers the potential for core damage from plant damage resulting from internal or external floods. *The important SSCs identified by this analysis are the ECCS room, RCW rooms and* all *control and reactor building external water tight doors*, including the watertight barriers on the equipment access to the diesel generator rooms*, which prevent water from flowing into rooms other than the one with the leak or from external flood sources to the safety-related buildings; isolation valves on the Reactor Service Water System and anti-siphon capability, which limit the amount of water spilled into the control building; circuit breakers that will trip RSW pumps, which also limits the amount of water spilled into the control building; isolation valves in the Circulating Water System (CWS); circuit breakers that will trip CWS pumps; level switches in the turbine building condenser pit and control building RCW rooms; sump pump operation; overfill lines in reactor building sumps on floor BIF; and room drain lines.*

19K.10 Identification of Important Capabilities Outside the Control Room

STP DEP T1 5.0-1

The identified activities outside the control room are:

(8) Closing the normally-open watertight door to the control room on notification of a main cooling reservoir breach.

19K.11.1 Component Inspections and Maintenance

STD DEP T1 2.4-3

STD DEP T1 3.4-1

STP DEP T1 5.0-1

STD DEP 8.3-1

STD DEP 9.2-5

The two individual *component types with the highest FV importances in the Level 1 analysis are the combustion turbine generator and the emergency diesel generators. Maintenance activities to assure high reliability of these components are discussed in 19K.11.10 and 19K.11.11.*

The Reactor Building Cooling Water System and the Reactor Service Water System have high FV importance with respect to common cause failure impacts, as these systems support a number of front-line safety systems. Maintenance and testing tasks are provided for the key components in each division, including pumps, heat exchangers and the service water cooling tower fans

The system of greatest FV importance with respect to outage time *is the RCIC System, which has been assigned a small unavailability for test and maintenance. The amount of time the RCIC System is unavailable because of test and maintenance should be monitored to assure that it remains within the specified assumption annually. Sensitivity studies of increased SSC unavailabilities showed that an increase in RCIC unavailability would cause the greatest increase in estimated core damage frequency of any SSC. The RCIC System was also found to be the most sensitive system to increased outage time assumptions. The highest contributor to uncertainties in the CDF as well as the CDF estimate was RCIC test and maintenance.*

STD DEP T1 2.4-3

The turbine of the RCIC System is an important component, as identified in Table 19K-1. Periodic startup and operation of the RCIC turbine is one way to monitor this turbine, and less frequent turbine inspection and refurbishment are also recommended. The RCIC pump is tested at the same time by measurement of speed, flow rate, differential pressure, and vibration. ~~The turbine lube oil pump operation and many~~ Many *of the RCIC valves are also tested when the turbine testing is done. These RAP activities are included in Table 19K-4.*

STD DEP T1 3.4-1

Trip logic ~~*unts*~~ *functions (~~TLUs~~*TLFs*) for the Reactor Protection System (RPS) represent another high importance component. Functional tests of these ~~TLUs~~*TLFs *are performed at frequent intervals by the online, self-test feature of ABWR solid-state logic. Additional offline, semi-automatic, end-to-end (sensor input to trip actuator) testing of ~~TLUs~~*TLFs*, which exercises the safety system logic and control logic processes, is important because it allows the detection of failures not sensed by the online system. The~~TLUs~~ TLF tests that are suggested as part of the RAP are given in Table 19K-4.*

Common-cause miscalibration of RHR flow meters, and of Level 8 sensors, and common-cause failure (CCF) of digital trip ~~modules (DTMs)~~ function (DTFs)*, and of Level 2 sensors, will have acceptable probabilities if adequate administrative controls*

are exercised. Calibration procedures for RHR flow meters and for Level 8 sensors should include notes about the safety importance of these instruments. Historical trend analysis should be performed for Level 2 sensors at each calibration. The procedure for testing ~~DTMs~~ DTFs *should include a warning about their importance to safety. Suggested RAP activities are given in Table 19K-4.*

19K.11.13 Flood Protection

STP DEP T1 5.0-1

The important SSCs for flood protection are the water tight doors on external entrances to the control and reactor buildings, including the watertight barriers on the equipment access to the diesel generator rooms, *and in ECCS and RCW rooms, the RSW and CWS isolation valves, anti-siphon capability, the circuit breakers that trip* the *RSW ~~and CWS~~ pumps and water level sensors in the turbine building condenser pit and control building RCW rooms; sump pump operation; overfill lines on reactor building sumps on floor BIF; and room drain lines (Subsection 19K.7). Periodically room water barriers should be inspected to assure that they will prevent the spread of flooding, room drain lines should be checked to ensure no blockage exists, RSW isolation valves (MOVs) should be stroke tested (normally accomplished by switching from one pump to the standby pump in a given loop), CWS isolation valves should be stroke tested, the ability of RSW ~~and CWS~~ pump circuit breakers to trip upon receipt of a trip signal should be demonstrated, as well as RSW System anti-siphon capability. These RAP activities are included in Table 19K-4.*

Table 19K-1 ABWR SSCs of Greatest Importance for CDF, Level 1 Analysis

SSC	Fussell-Vesely Importance (%)*	Risk Achievement Worth*
Cooling Water Divisions A, B, & C (CCF)		
~~*Multiplex Transmission Network (CCF)*~~		
Essential Communication Function (CCF)		
Service Water Cooling Tower Fans (CCF)		
RHR Core Flood System Failure (CCF)		
Trip Logic Function (CCF)		
Remote I/O Function Module (CCF)		
~~*Trip Logic Units*~~		
~~*Remote Multiplexing Units*~~		
~~*RCIC Turbine Lubrication System*~~		
HPCF System (CCF)		
HPCF Pump†		
~~*Single Offsite Power Line**~~		
~~*RCIC Min Flow Bypass Valve E51-F011 (NOFO)†*~~		
~~*RCIC Min Flow Bypass Valve E51-F011 (NCFC)†*~~		
~~*RCIC Injection Valve E51-F004 (NCFC)†*~~		
~~*RCIC Steam Supply Valve E51-F037 (NCFC)‡*~~		
~~*HPCF Maintenance Valve E22-F005B‡*~~		
~~*RCIC Isolation Signal Logic*~~		
~~*Both Offsite Power Sources.*~~		
~~*HPCF Pump*~~		
~~*SRVs*~~		
~~*RHR Flow Transmitters (CCF Miscalibration)*~~		
Cooling Water Divisions B & C (CCF)		
Cooling Water Divisions A & B (CCF)		
Cooling Water Divisions A & C (CCF)		
~~*Level 8 Sensors (CCF Miscalibration)*~~		
~~*Digital Trip Modules (CCF)*~~		
Digital Trip Function (CCF)		
SP Temp High (Loss of Pump Head)		
Suppression Pool Unavailable Due to Rupture		

* Not part of DCD (Refer to SSAR)

† SSCs with low FV importance and low risk achievement worth. Not considered further for RAP on the basis of Level 1 analysis.

‡ Valves that are closed during normal operation, and fail to open when required during a transient, are designated NCFC. Technically, they are “fail as is” conditions, which is closed. The minimum flow bypass valve is closed during normal operation, but during transients requiring RCIC operation, the bypass valve opens. Failure of this valve to open at that demand is shown as NCFC. Later in the transient this bypass valve, which is normally open at this time, should close on demand. If it fails to close, the shorthand description NOFO is used.

ƒ SSC with low FV importance and low risk achievement worth, but retained because of human factor importance.

Table 19K-2 ABWR SSCs With Moderate Risk Achievement Worth, Level 1 Analysis*

SSC	Fussell-Vesely Importance (%)†	Risk Achievement Worth†
RCIC Min Flow Bypass Valve E51-F011 (NOFO)		
RCIC Injection Valve E51-F004 (NCFC)		
RCIC Min Flow Bypass Valve E510F011 (NCFC)		
RCIC Steam Supply Valve E51-F037 (NCFC)		
Both Offsite Power Sources		
RCIC Isolation Signal Logic		
RHR Suppression Pool Cooling Failure (CCF)		
Div 1 **ECF** ~~*EMS*~~ Transmission Ntwk Failure		
~~*RCIC Steam Supply Bypass Valve F045 Limit Switch Fails*~~		
1st ESF **RIF** ~~*RMU*~~ Div 1 Fails		
2nd ESF **RIF** ~~*RMU*~~ Div 1 Fails		
1st ESF SLF Channel Div 1 Fails		
2nd ESF SLF Channel Div 1 Fails		
Failure of SP Temp Signal T53-TRS-601A & B		
~~*RCIC Pres Sensor PIS-Z605 Miscalibrated*~~		
~~*RCIC Flow Sensor FT-007-2 Miscalibrated*~~		
Diode SID Open		
~~*SP Temp High (Loss of Pump Head)*~~		
SLF/ECF ~~*SLU/EMS*~~ Link for Div 1 SLF 1 Fails (RCIC Fails)		
SLF/ECF ~~*SLU/EMS*~~ Link for Div 1 SLF 2 Fails (RCIC Fails)		

* ECF = Essential Communication Function
ESF = Essential Safety Feature
RIF = Remote Input/Output Function
SLF = Safety System Logic Function

† Not part of DCD (refer to SSAR)

Table 19K-3 ABWR Initiating Event Contribution to CDF, Level 1 Analysis

Initiating Event	Events per Year	Total CDF x 10^{8}*	Percent CDF Contribution*
Turbine Trip			

* Not part of DCD (Refer to SSAR)

Table 19K-4 Failure Modes and RAP Activities

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
~~*Multiplexers*~~	~~*Common cause failure of all MUX to give proper signals*~~	~~*System functional test*~~ ~~*Complete system test, error check*~~	~~*3 months*~~ ~~*2 years*~~	~~*Experience*~~ ~~*Experience*~~	~~*~~
ECF	**Common cause failure of all ECF to give proper signals**	**System functional test**	**3 months**	**Experience**	*
		Complete system test, error check	**2 years**	**Experience**	*
One ESF **RIF** ~~*SMU*~~ for Div 1 or one **SLF/ECF** ~~*SLU/EMS*~~ Link for **SLF** ~~*SLU*~~ Div 1	Failure of RIF or link between RIF and SLF ~~*Failure of remote multiplex unit or link between RMU and safety system logic unit*~~	System functional test	3 months	Experience	*
		Complete system test, error check	2 years	Experience	*
RPS **TLFs** ~~*Trip Logic Units*~~	Failure to trip upon demand	System functional test	3 months	Experience	*
		Complete system test, error check	R/M outage	Experience	
~~*RCIC Turbine Lube System*~~	~~*Lube oil pump failure*~~	~~*Lube oil pump operation and oil pressure check*~~	~~*3 months*~~	~~*Experience*~~	~~*~~
DTFs ~~*Digital Trip Modules*~~	Common cause failure to trip	*Review trip unit test procedure to assure note about potential safety considerations*	*Annual*	*Judgment*	*
Non-ADS SRVs	**Common mode failure of SRVs to open on demand or remain open**	**Inspect and replace degradable parts and test for correct operation**	**5 years (max)**	**Environmental qualification**	*
		Remove valve, test for setpoint pressure, adjust setpoint as necessary, test for seat leakage, repair. Stagger testing of valves, 50% at one outage	**3 years**	**Experience, ANSI/ASME OM1**	*

Table 19K-4 Failure Modes and RAP Activities (Continued)

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
DC Div 1 Distribution Panel **(including Diode S1D)**	Panel **or diode failure**	Panel function is demonstrated by system test	3 months	Experience	*
Div 1 ~~*EMS*~~ **ECF** Transmission Network	Network failure	System functional test	3 months	Experience	*
		Complete system test, error check	2 years	Experience	*
RBCW Pumps	**Failure to provide adequate flow at desired pressure**	**Discharge pressure test Inlet pressure test Flow test Vibration test**	**3 months**	**Table 3.9-8**	*
		Monitor pump parameters on the normally running pump to detect abnormalities	**Weekly**	**Judgment**	*
RBSW Pumps	**Failure to provide adequate flow at desired pressure**	**Discharge pressure test Inlet pressure test Flow test Vibration test**	**3 months**	**Table 3.9-8**	*
		Monitor pump parameters on the normally running pump to detect abnormalities	**Weekly**	**Judgment**	*

Table 19K-4 Failure Modes and RAP Activities (Continued)

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
RBCW Heat Exchangers	Plugging/fouling	Monitor heat exchanger flow and delta temperature/pressure to detect existence of fouling	Weekly	Experience	*
		Internal inspection of heat exchangers for plugging and fouling	R/M Outage	Experience	*
RBSW Strainers	Plugging	Monitor RBSW flow rate and strainer delta pressure for indications of plugging	Weekly	Experience	*
RBSW Cooling Tower Fans	Failure to provide adequate fan flow through tower	Flow test Vibration Test	3 months	Experience	*
		Inspection and cleaning/lubrication	R/M Outage	Experience	*
HPCF Pumps	Failure to provide adequate flow at desired pressure	Discharge pressure test Inlet pressure test Flow test Vibration test	3 months	Table 3.9-8	†††
HPCF Injection Valves F003 and F005	Failure to open because of mechanical problems	Stroke test	3 months	Experience; ASME Code ISI	†††
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary.	10 years	Low failure rate; ASME Code ISI.	*
	Failure to open because of electrical problems	Electrical circuit test	3 months	Experience	*

Table 19K-4 Failure Modes and RAP Activities (Continued)

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
RHR Injection Valves F001, F003, F005, F006	Failure to open because of mechanical problems	Stroke test	3 months	Experience; ASME Code ISI	††
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary.	10 years	Low failure rate; ASME Code ISI.	*
	Failure to open because of electrical problems	Electrical circuit test	3 months	Experience	*
RHR Heat Exchangers	Fouling	Monitor and trend delta-temperature across heat exchanger during RHR testing and operation	R/M Outage	Judgment	††
ESF SLF Divisions	Failure to operate; failure to properly generate initiation signals	System functional test	3 months	Experience	*
		Complete system test, error check	2 years	Experience	*
Suppression Pool	Loss of structural integrity; leakage	Periodic inspection of suppression pool structural elements to detect degradation, incipient leakage or corrosion	R/M Outage	Experience	*

Table 19K-4 Failure Modes and RAP Activities (Continued)

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Suppression Pool Temperature sensors T53-TRS-601A and B	Sensor fails	Calibration of sensor	R/M outage	Experience	*
	Common mode failure	Analyze Level 2 calibration data for trends of drifting or other CCF indications	R/M Outage	Judgment	*
Containment Penetrations	Leakage	Periodic inspection of penetrations to detect indications of degradation	R/M Outage	Experience	N/A
		Local leak rate testing	R/M Outage (based on Tech Spec requirements)	Tech Spec	*

* Not part of DCD (refer to SSAR)

‡‡ *RHR component failure rates are included within the system unavailability.*

†††HPCF component failure rates are included within the system unavailability