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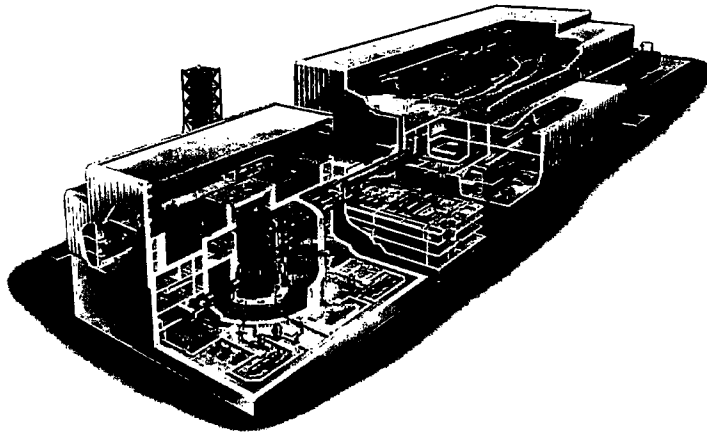
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“ABWR PRA-Bases Reliability”

Technical Report

ABWR PRA-Based Reliability

Approved by M.Ino
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Safety & Dynamics Engineering Group

Toshiba Corporation
System Design & Engineering Department



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Principal Analyst

Aaron M. Lee

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Reliability & Safety Consulting Engineers, Inc.
2220 Award Winning Way, Suite 200
Knoxville, TN 37932 USA

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1.0 INTRODUCTION

Revision 4 of the ABWR Design Control Document (DCDR4) includes evaluation of plant response to severe accidents in Tier 2 Chapter 19. Chapter 19 also contains the results of the original PRA studies performed by General Electric (GE) at the time of the DCDR4 submittal. As part of the DCDRA project, Toshiba is making improvements to the ABWR design. These improvements change some assumptions and inputs used by GE in the DCDR4 PRA evaluation. Also, PRA methodology has changed substantially since the issuance of DCDR4 in 1997. The Toshiba ABWR DCD Renewal and Amendment (DCDRA) project has performed a limited update of the original PRA studies to incorporate Toshiba ABWR design features and to verify that a more modern PRA treatment would not change the PRA conclusions and insights. This work included assessment of updated Initiating Event Frequencies and component reliability data. As a result, the information in the tables in DCD Appendix 19K of Reference 1 has been updated and is contained in this document.

The results of the PRA have been reviewed to determine the appropriate reliability and maintenance actions that should be considered throughout the life of an ABWR plant so that the PRA remains an adequate basis for quantifying plant safety. These actions comprise a part of the plant's reliability assurance program (RAP), which is discussed in Appendix 19K of Reference 3. The objective of the review was to determine the relative importance of prevention and mitigation features of the ABWR in satisfying the key PRA goals related to core damage frequency (CDF) and frequency of offsite release.

Table 19K-1 is a list of important systems and components ranked by Fussell-Vesely (F-V) importance. Table 19K-2 is a list of important systems and components listed by risk achievement worth (RAW) value. Table 19K-3 is a listing of important initiators and their contributions to core damage frequency (CDF). Table 19K-4 is a listing of systems and the recommended maintenance to be performed along with recommended intervals of the maintenance.

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

Event	Description	F-V (%)	RAW
RCIMAIN	RCIC UNAVAILABLE DUE TO TESTING OR MAINTENANCE	14.8	8.2
COND	CONDENSATE PUMPS NOT AVAILABLE	10.5	3.3
CRD	FAILURE OF CONTROL ROD DRIVE INJECTION TO MAINTAIN LEVEL	6.5	1.6
RPM001DW	PUMP C001 FAILS TO START	6.3	8.3
WPMPCCFRCWABC	RBCW CCFs BETWEEN DIV. A, B, & C	5.7	12500
WPMPCCFRSWABC	RSW CCFs BETWEEN DIV. A, B & C	5.7	12500
RLS039HW	LIMIT SWITCH FOR VALVE F039 FAILS	4.9	8.3
RLS045HW	LIMIT SWITCH FOR VALVE F045 FAILS	4.9	8.3
RLU001DW	LUBRICATION SYSTEM FAILS	3.1	8.3
RTU001DH	TURBINE MECHANICAL FAILURE	2.7	8.3
EBY1CCF	BATTERY CCF	2.5	4730
ELOOP1	LOSS OF OFF-SITE LINE 1 (1,1) POWER	2.2	3.2
RRMCOOL1	RCIC PUMP ROOM A.C. UNIT FAILS	1.7	8.3
RMV004HP	VALVE F004 FAILS CLOSED (NCFC)	1.5	8.3
RMV011HN ²	VALVE E51-F011 FAILS NOFO	1.5	8.3
RMV011HP ²	VALVE E51-F011 FAILS CLOSED NCFC	1.5	8.3
RMV037HR ²	F037 FAILS CLOSED (NCFC)	1.5	8.3
RPM001FR2	PUMP C001 FAILS TO RUN AFTER FIRST HOUR	1.2	8.4
PC_OTHER	FAILURE OF SRVS TO RECLOSE (PC_Other)	1.1	4.7
RISOLSIG	ISOLATION SIGNAL LOGIC FAILURE	1.0	8.3
2DPCCCFABC	RHR SUPPRESSION POOL COOLING A, B, AND C TRAIN LEVEL CCF	0.9	7.3

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

Event	Description	F-V (%)	RAW
COPS	FAILURE OF CONTAINMENT OVERPRESSURE PROTECTION SYSTEM	0.9	85.6
HPCFCCFBC	HPCF B AND C TRAIN LEVEL CCF	0.5	3.9
RLS037HW ¹	VALVE F037 LIMIT SWITCH FAILS	0.5	1.7
RLSTVSHW ¹	TURBINE TRIP / THROTTLE VALVE LIMIT SWITCH FAILS	0.5	1.7

1. Not considered for RAP due to low F-V importance and a low RAW value.

2. Valves that are closed during normal operation and fail to open 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 operations but during transients requiring RCIC operation, the bypass valve opens. Failure of this valve to open at a demand is shown as NCFC. Later in the transient this bypass valve, which is normally open at this time, should be closed on demand. A failure to do so is labeled NOFO.

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

Event	Description	F-V (%)	RAW
ILCCCFH ¹	CCF REMOTE MULTIPLEXING UNITS	0.1	18900
CCFMUX ¹	CCF OF TRANSMISSION NETWORK (EMS)	0.1	18900
CCFTLU ¹	CCF SYSTEM LOGIC UNIT FAILS	0.1	18900
WPMPCCFRCWABC	RBCW CCFS BETWEEN DIV. A, B, & C	5.7	12500
WPMPCCFRSWABC	RSW CCFs BETWEEN DIV. A, B & C	5.7	12500
EBY1CCF	BATTERY CCF	2.5	4730
PO	FAILURE OF SRVS TO OPEN	<0.1	119
COPS	FAILURE OF CONTAINMENT OVERPRESSURE PROTECTION SYSTEM	0.9	85.6
ARVCCFD	COMMON CAUSE FAILURE OF SRV's	0.3	67.0
WPMPCCFRCWBC	RBCW CCFS BETWEEN DIV. B & C	<0.1	40.2
WPMPCCFRSWBC	RSW CCFs BETWEEN DIV. B & C	<0.1	40.2
HFELEBHX	CCF OF WATER LEVEL 8 SENSORS MISCALIBRATED (4 DIV)	<0.1	36.9
DIV1MUX	DIVISION 1 TRANSMISSION NETWORK FAILURE (EMS)	<0.1	8.5
IRMU11	1ST ESF REMOTE MULTIPLEXING UNIT DIV 1 FAILS	<0.1	8.5
IRMU21	2ND ESF REMOTE MULTIPLEXING UNIT DIV 1 FAILS	<0.1	8.5
WPMPCCFRCWAB	RBCW CCFS BETWEEN DIV. A & B	<<0.1	8.4
WPMPCCFRCWAC	RBCW CCFS BETWEEN DIV. A & C	<<0.1	8.4
WPMPCCFRSWAB	RSW CCFs BETWEEN DIV. A & B	<<0.1	8.4
WPMPCCFRSWAC	RSW CCFs BETWEEN DIV. A & C	<<0.1	8.4
RPM001FR2	PUMP C001 FAILS TO RUN AFTER FIRST HOUR	1.2	8.4
RMV004HP	VALVE F004 FAILS CLOSED (NCFC)	1.5	8.4

Table 19K-2 (continued)
 ABWR SSCs With Moderate Risk Achievement Worth For CDF, Level 1 Analysis

Event	Description	F-V (%)	RAW
RMV011HN	VALVE E51-F011 FAILS NOFO	1.5	8.4
RMV011HP	VALVE E51-F011 FAILS CLOSED NCFC	1.5	8.4
RMV037HR	F037 FAILS CLOSED (NCFC)	1.5	8.4
RRMCOOL1	RCIC PUMP ROOM A.C. UNIT FAILS	1.7	8.4
RISOLSIG	ISOLATION SIGNAL LOGIC FAILURE	1.0	8.3
RTU001DH	TURBINE MECHANICAL FAILURE	2.7	8.3
RLU001DW	LUBRICATION SYSTEM FAILS	3.1	8.3
RLS039HW	LIMIT SWITCH FOR VALVE F039 FAILS	4.9	8.3
RLS045HW	LIMIT SWITCH FOR VALVE F045 FAILS	4.9	8.3
EAC69CH	DIV 1 SWGR FAILURE	<<0.1	8.3
EBS6C1H	SWITCHGEAR P/C 6C-1 FAILURE	<<0.1	8.3
EBS6C2H	BUS P/C 6C-2 FAILURE	<<0.1	8.3
EBSE1H	ESF DIV 1 480V MCC BUS FAILURE	<<0.1	8.3
EBSXX1H	ESF DIV 1 480V MCC BUS FAILURE	<<0.1	8.3
EDP101H	FAILURE OF DIV 1 DISTRIBUTION PANEL	<<0.1	8.3
RPR005BF	PRESSURE SENSOR E51-PIS-Z605 FAILS	<<0.1	8.3
WPMPCCFRCWA	RBCW CCFS WITHIN A DIVISION (A)	<0.1	8.3
WPMPCCFRSWA	RSW CCFs WITHIN A DIVISION (A)	<0.1	8.3
BXV005B	MANUAL VALVE B21-F005B FAILS CLOSED (NOFC)	<0.1	8.3
RFL007CF	SENSOR MISCALIBRATION	<0.1	8.3
RPR005CF	SENSOR MISCALIBRATION	<0.1	8.3
BCV003B	ISOLATION CHECK VALVE B21-F003B FAILS CLOSED	<0.1	8.3
BCV004B	ISOLATION CHECK VALVE B21-F004B FAILS CLOSED	<0.1	8.3

Table 19K-2 (continued)
 ABWR SSCs With Moderate Risk Achievement Worth For CDF, Level 1 Analysis

Event	Description	F-V (%)	RAW
ETR6C1H	TRANSFORMER T6C1 FAILS	<0.1	8.3
ETR6C2H	TRANSFORMER T6C2 FAILURE	<0.1	8.3
RCV003HP	CHECK VALVE E51-F003 FAILS TO OPEN	<0.1	8.3
RCV005HP	OUTBOARD CHECK VALVE F005 FAILS TO OPEN	<0.1	8.3
RCV038HP	CHECK VALVE F038 FAILS TO OPEN	<0.1	8.3
ECA021H	CABLE 21 FAILURE	<0.1	8.3
ECA022H	CABLE 22 FAILURE	<0.1	8.3
ECA040H	CABLE 40 FAILURE	<0.1	8.3
ECAXX1H	CABLE FAILURE	<0.1	8.3
RPM001FR1	PUMP C001 FAILS TO RUN FOR FIRST HOUR	<0.1	8.3
RFL007BF	FLOW SENSOR E51-FT007-2 FAILS	0.1	8.3
RMV035HQ	ISOLATION VALVE F035 FAILS CLOSED (NOFC)	0.1	8.3
RMV036HQ	ISOLATION VALVE F036 FAILS CLOSED (NOFC)	0.1	8.3
RMV039HQ	ISOLATION VALVE F039 FAILS CLOSED (NOFC)	0.1	8.3
RPM001DW	PUMP C001 FAILS TO START	6.3	8.3
RCIMAIN	RCIC UNAVAILABLE DUE TO TESTING OR MAINTENANCE	14.8	8.2
2DPCCCFABC	RHR SUPPRESSION POOL COOLING A, B, AND C TRAIN LEVEL CCF	0.9	7.3
ECB0A1H	OUTPUT CIRCUIT BREAKER OPEN	<<0.1	6.3
ECB301H	P/C 6C-1 INCOMING BKR 301 OPEN	<<0.1	6.3
ECB312H	SWITCHGEAR P/C 6C-1 FEED BREAKER 312 OPEN	<<0.1	6.3
ECB331H	P/C 6C-2 INCOMING BREAKER 331 OPEN	<<0.1	6.3
ECB410H	DIV 1 480V MCC INCOMING BREAKER 410 OPEN	<<0.1	6.3
ECB904H	6.9 kV BREAKER 904 OPEN	<<0.1	6.3

Table 19K-2 (continued)
 ABWR SSCs With Moderate Risk Achievement Worth For CDF, Level 1 Analysis

Event	Description	F-V (%)	RAW
ECB911H	6.9 kV BREAKER 911 OPEN	<<0.1	6.3
ECBX11H	DIV 1 480V MCC INCOMING BREAKER OPEN	<<0.1	6.3
ECBXX1H	SWITCHGEAR P/C 6C-2 FEED BREAKER OPEN	<<0.1	6.3
ILINK11	SLU/EMS LINK FOR DIVISION 1 SLU 1 FAILS	<<0.1	6.3
ILINK21	SLU/EMS LINK FOR DIVISION 1 SLU 2 FAILS	<<0.1	6.3
WAVR6AH	TEMPERATURE CONTROL VALVE P21-F006A FAILS CLOSED (NOFC)	<<0.1	6.3
WTE005A	TEMPERATURE ELEMENT P21-TE-005A FAILS LOW	<<0.1	6.3
WDCSCCFABC	RHR CORE FLOOD A, B, AND C TRAIN LEVEL CCF	0.5	6.1

1. Refers to Essential Communications Function equipment

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

Initiating Event	Events per year	Total CDF(/yr)	Contribution to CDF (%)
Station Blackout 0.5 to 2 hours	5.90E-7	1.38E-8	14.1
Station Blackout 2 to 8 hours	1.98E-7	3.47E-8	35.4
Station Blackout >8 hours	3.32E-8	3.32E-8	33.9
Isolation/Loss of Feedwater	2.93E-1	5.93E-9	6.1
Manual Reactor Shutdown	1.06E+0	2.90E-10	<1.0

Table 19K-4
Failure Modes and RAP Activities

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
RCIC System	System failure	See following items	See below	See below	6.49E-2
RCIC System	Unavailable due to test or maintenance	Monitor unavailable time, compare with assumed 2%	Annually	Level 1 analysis	N/A ¹
ECF	Common cause failure of all ECF to give proper signals	System functional test	3 months	Experience	5.9E-7
		Complete system test, error check	2 years	Experience	
One ESF RIF for Div 1 or one SLF/ECF Link for SLF Div 1	Failure of RIF or link between RIF and SLF	System functional test	3 months	Experience	N/A ¹
		Complete system test, error check	2 years	Experience	3.0E-4
RCIC Turbine & Pump (System Test)	Mechanical failure to operate	Turbine startup and operation; measure pump vibration velocity & displacement, flow, speed, diff. pressure.	3 months	Experience ²	N/A ¹
		Turbine inspection, refurbishment	5 years	Experience ²	
RPS Trip Logic Functions	Failure to trip upon demand	System functional test	3 months	Experience	3.0E-7
		Complete system test, error check	R/M outage	Experience	

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
RCIC Check Valve F038	Failure to open	Open and close during system test	2 years	Table 3.9-8 of Reference 3	N/A ¹
RCIC Check Valves F003 & F005	Failure to open	Open and close test	R/M outage	Experience ²	N/A ¹
RCIC Isolation Signal Logic	Failure to provide isolation signal when conditions warrant	Logic functional test	3 months	Experience	N/A ¹
RCIC Min Flow Bypass Valve (NOFO or NCFC)	Failure to operate because of mechanical problems	Stroke test	3 months	Experience ² ; ASME Code ISI	N/A ¹
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary.	10 years	Low failure rate; ASME Code ISI.	
	Failure to operate because of electrical problems	Electrical circuit test	3 months	Experience ²	
RCIC Injection Valve and Turbine Steam Supply Valve	Failure to open because of mechanical problems	Stroke test	3 months	Experience ² ; ASME Code ISI	N/A ¹
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary.	10 years	Low failure rate; ASME Code ISI.	

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
	Failure to open because of electrical problems	Electrical circuit test	3 months	Experience†	
RCIC Isolation Valves (NOFC)	Spurious failure because of mechanical problems	Stroke test	3 months	Experience ² ; ASME Code ISI	N/A ¹
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary.	10 years	Low failure rate; ASME Code ISI.	
	Spurious failure because of electrical problems	Electrical circuit test	3 months	Experience ²	
Limit Switch on RCIC Turbine Exhaust Isolation Valve	Failure of switch to change position when valve movement occurs	Observation of limit switch actuation during valve stroke test	3 months	Experience ²	N/A ¹
RCIC Flow Sensor FT-007-2	Sensor fails	Calibration of sensor	R/M outage	Experience	N/A ¹
	Miscalibration	Review calibration procedures for note about potential safety considerations	R/M outage	Judgment	
RCIC Pressure Sensor PIS-Z605	Sensor fails	Calibration of sensor	R/M outage	Experience	N/A ¹
	Miscalibration	Review calibration procedures for note about potential safety considerations	R/M outage	Judgment	

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
NBS Isolation Check Valves 003B & 004B	Fails to open	Leak rate test and subsequent operation of valves	R/M outage	Experience	6.05E-5
NBS Manual valve F005B (NOFC)	Normally open valve fails closed	Stroke test	R/M outage	Experience	1.75E-8
HPCF Maintenance Valve	Failure to open valve after maintenance	Independent verification of valve position following maintenance; position verification before startup	After maintenance, before startup	Judgment	1.0E-2
Switch Yard Equipment	Failure results in loss of offsite power	Inspect switch yard equipment for signs of incipient failure, such as insecure structures, degraded insulators, leaking oil. Use thermography to detect hot spots on transformers, insulators, circuit breakers & connectors. Repair as necessary. See also the following items.	3 years	Experience	1.0E-3
Switchyard Protective Relay	Relay failure to open or close on demand	Calibration, maintenance and test	1 year	Industry practice	N/A ³
Auxiliary Relay Panels	Failure to provide power to loads	Routine cleaning and inspection	2 years	Industry practice	N/A ³
Radio Batteries for microwave and fiber optic equipment	Battery failure	Routine test and maintenance	2 years	Industry practice	N/A ³

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Battery Chargers	Failure to provide charging current to batteries	Routine test and maintenance	18 months	Industry practice	N/A ³
Feedwater Pumps	Failure during operation	Walkdown/external visual observation:	1 week	Experience	N/A
		-Oil level			
		-Leaks			
		-Land vibration			
		Motor winding temperature, bearing temperature	1 week		
		Seal leakage, temperature, pressure	1 month		
		Oil sample/analyze	3 months		
Performance data:	3 months	Experience			
-Discharge pressure					
-Inlet pressure					
-Flow rate					
		-Peak vibration velocity			

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
		-Motor current			
RHR Flow Meters	Common mode miscalibration	Review calibration procedures for note about potential safety considerations	Annual	Judgment	5.0E-5
Level 2 Sensors	Common mode failure	Analyze Level 2 calibration data for trends of drifting or other CCF indications	R/M Outage	Judgment	2.4E-6
Level 8 Sensors	Common mode miscalibration	Review calibration procedures for note about potential safety considerations	Annual	Judgment	2.0E-5
Digital Trip Functions	Common cause failure to trip	Review trip unit test procedure to assure note about potential safety considerations	Annual	Judgment	3.0E-7
Wetwell/Drywell Vacuum Breakers	Fail to close or leakage after close	Cycle through full open to full close. Check for leakage	R/M Outage	Experience	Leakage probability = 3.42E-4 per demand for system Failure to close = 0.0005 per demand per valve

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
ADS System SRVs	Failure of several SRVs to open on demand or failure to remain open	Inspect and replace degradable parts and test for correct operation	5 years (max)	Environmental qualification	5.0E-6 (Operating) 6.0E-6 (Shutdown)
		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 OM-1	
		Control panel test	3 months	Experience	
Non - ADS SRVs	Common mode failure of several SRVs to open on demand or failure to remain open	Inspect and replace degradable parts and test for correct operation	5 years (max)	Environmental qualification	5.0E-6 (Operating) 6.0E-6 (Shutdown)
		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 OM-1	
		Control Panel Test	3 months	Experience	
LDF Fusible Plug Valves	Failure to open at temperature	Two of ten plugs replaced; tested to verify temperature setpoint	2 R/M outages	Judgment	1E-3
	Leakage	Inspect for leakage	R/M outage	Judgment	
ACIWA System	System unavailable	See following items	See below	See below	1E-2

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
ACIWA Flow Instrumentation	Failure to accurately monitor flow	Measure zero flow and full system flow	4 years	Judgment	N/A ⁴
ACIWA Manual Valves (in RHR System)	Stuck closed	Stroke test	3 months	Experience ² ; ASME Code ISI	N/A ⁴
Firewater System Pumps on Fire Truck	Failure of pumps to provide required flow at pressure	20 min pump at 100% rated flow, 1.13 MPa (150 psi)	1 year	Judgment	N/A ⁴
		10 min pump at 70% rated flow, 1.48 MPa (200 psi)	1 year	Judgment	
		10 min pump at 50% rated flow, 1.82 MPa (250 psi)	1 year	Judgment	
	Failure of system to deliver required flow	Test system flow with fire truck pumps, water from tanks & from UHS	4 years	Judgment	
		Test system flow with AC-driven and diesel-driven pumps, water from tanks & from UHS	4 years	Judgment	
ACIWA Diesel Pump	Failure to pump on demand	Pump start test	3 months	Experience	N/A ⁴
		Pump flow test	4 years	Experience	
RHR Non-Safety-Related Valve	Failure to open on demand	Manually open and close valve	2 years	Experience	N/A ⁴

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Piping of AC-Independent Water Addition System	Piping failure that precludes successful operation	Piping visual inspection under operating pressure to assure no leaks	5 years	Judgment	N/A ⁴
		Piping support visual inspection to assure structural adequacy	5 years	Judgment	
COPS System	System failure	See following items	See below	See below	1E-4
COPS AOVs	Inadvertently left closed following maintenance	Stroke test; position indication check; verification of local and control room indication following test	R/M outage	Experience	N/A ⁵
COPS Rupture Disks	Failure to open on demand	Disk replacement	5 years	ASME Code	N/A ⁵
		Verification of actuation within $\pm 5\%$ of rated pressure	5 years	ASME Code	
COPS Flow Lines	Flow blockage	Flow test to assure no blockage in line	5 years	Judgment	N/A ⁵
Fire Barriers Between Rooms	Failure to retain integrity	Inspection of fire barriers, including seals and penetrations	1 year & after major maintenance	Judgment	N/A
Smoke Removal System	Failure to maintain low room pressure	Operate system to assure that it functions as designed	1 year	Judgment	N/A

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Remote Shutdown Panel	Failure to provide control for reactor shutdown	Demonstrate ability to shut down reactor and remove decay heat by operation at remote shutdown panel	R/M outage	Judgment	N/A
RCIC System	Failure to start or operate RCIC from remote location	Start and operate RCIC from stations outside the main control room	10 years	Judgment	N/A
Control and Reactor Building and ECCS Room Watertight Doors	Failure to retain integrity	Inspection of watertight doors, including penetrations	1 year & after major maintenance	Judgment	1E-3
RSW and CWS Isolation Valves	Failure to close on demand	Stroke test	1 month	Experience	3.89E-3
RSW and CWS Pump Circuit Breakers	Failure to trip pump on demand	Breaker trip test to assure trip on demand	6 months	Judgment	1.10E-3
CRD System Flow Increase	Failure to increase CRD flow in shutdown	Review CRD operating procedures to assure that steps to provide increased flow are included	2 years	Reference 2	4.46E-4
DC Div 1 Distribution Panel (including Diode S1D)	Panel or diode failure	Panel function is demonstrated by system test	3 months	Experience	5.35E-6 (Operating) 7E-7 (Shutdown)

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Room Sump Level Switches	Failure to detect water in sump	Observation of proper operation upon actuation	Annual	Judgment	1E-3
Div 1 ECF	Failure	System functional test Complete system test, error check	3 months 2 years	Experience	6.3E-5
Sump Pumps	Failure to pump water out of sump	Start sump pump and observe operation	Annual	Judgment	1E-2
Overfill Line	Line clogged	inspect lines for debris	5 years	Judgment	1E-3
	Water seal dry	Observe level in seal	Weekly	Judgment	N/A
Room Drain Lines	Line clogged	Inspect lines for debris	5 years	Judgment	N/A
Combustion Turbine Generator (CTG)	Failure to start and run	Start and operate CTG at rated speed and load for 1 hour	3 months	Experience	4.55E-2
		Check oil levels, check for leaks	3 months	Experience	
		Sample, analyze oil. Replace as necessary	3 months	Experience	
		Inspect lube oil and fuel oil for deterioration. Replace oil filters as necessary; inspect inlet and outlet plenums and entire assembly	R/M outage	Experience	

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Structures of Emergency AC Power EDGs, 480 VAC Transformers, MCCs & circuit breakers; DC Batteries and Cable Trays; RHR Heat Exchangers; SLC Tank, Valves, Piping & Pumps; Valves, Piping & Pump of ACIWA; SWS pumps, pump house and air conditioner; & SRV Discharge Piping of the NBS	Structural failure of supports during seismic event	Seismic walkdown to assure structural integrity	10 years	Judgment	N/A
		Visual inspection, support structures & devices.	10 years	Judgment	N/A
		Post-earthquake evaluation	After OBE or larger quake	Judgment	N/A
Single Train of RHR System (Shutdown Cooling & LPFL Modes)	Common mode type failure	System walkdown to identify CCF type problems	R/M outage	Reference 2	6.58E-2 (SDC) 1.91E-2 (LPFL)

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Single Train of HPCF System	Common mode type failure	System walkdown to identify CCF type problems	R/M outage	Judgment	5E-2
Single Train of CUW System	Common mode type failure	System walkdown to identify CCF type problems	R/M outage	Judgment	N/A
Single Train of RSW System	Common mode type failure	System walkdown to identify CCF type problems	R/M outage	Judgment	N/A
Single Train of AC Electrical System	Common mode type failure	System walkdown to identify CCF type problems	R/M outage	Judgment	N/A
Emergency Diesel Generator	Failure to start and run	Start up to full load	1 month	Tech Spec	4.98E-2
CUW Isolation Valves (NO, FAI)	Failure to operate because of mechanical problems	Stroke test	3 months	Experience ² ; ASME Code ISI	3.89E-3
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary	10 years	Low failure rate; ASME Code ISI	
	Failure to operate because of electrical problems	Electrical circuit test	3 months	Experience ²	
CUW Remote Manual Shutoff Valve (NO, FAI)	Failure to operate because of mechanical problems.	Stroke test	Refueling outage	Judgment (non-safety-related)	3.89E-3

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
	Failure to operate because of electrical problems.	Electrical circuit test	Refueling outage	Judgment (non-safety-related)	
Operating RHR Shutdown Cooling Loop	Failure to Operate because of mechanical or electrical problems	See following items	See below	See below	1.1E-4
RHR 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 of Reference 3	N/A ⁶
RHR Injection Valves, F005	Failure to operate	Stroke test	Cold shutdown	Table 3.9-8 of Reference 3	N/A ⁶
RHR Isolation Valves, F010, F011	Failure to operate	Stroke test	Cold shutdown	Table 3.9-8 of Reference 3	N/A ⁶
RHR Admission Valves, F012	Failure to operate	Stroke test	3 months	Table 3.9-8 of Reference 3	N/A ⁶
RBCW Pumps	Failure to provide adequate flow at desired	Discharge pressure test, inlet pressure test, vibration test	3 months	Table 3.9-8	N/A

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
	pressure	Monitor pump parameters on the normally running pump to detect abnormalities	Weekly	Judgment	
RBCW Heat Exchangers	Plugging/Fouling	Monitor heat exchanger flow and delta temperature/pressure to detect existence of fouling	Weekly	Experience	3.60E-6
		Internal inspection of heat exchangers for plugging and fouling	R/M Outage	Experience	
RSW Pumps	Failure to provide adequate flow at desired pressure	Discharge pressure test, inlet pressure test, vibration test	3 months	Table 3.9-8	N/A
		Monitor pump parameters on the normally running pump to detect abnormalities	Weekly	Judgment	
RSW Strainers	Plugging	Monitor RSW flow rate and strainer delta pressure for indications of plugging	Weekly	Experience	5.92E-6
UHS Fans	Failure to provide adequate fan flow through tower	Flow test Vibration test	3 months	Experience	5.31E-3 (Running Probability)
		Inspection and cleaning/lubrication	R/M Outage	Experience	4.99E-3 (Standby Probability)

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
Control and Reactor Building, RSW Pump House, and ECCS Room Watertight Doors	Failure to retain integrity	Inspection of watertight doors, including penetrations	1 year & after major maintenance	Judgment	N/A
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 of Reference 3	N/A ⁷
HPCF Injection Valves F003 and F005	Failure to open because of mechanical problems	Stroke test	3 months	Experience; ASME code ISI	1.90E-6
		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 conduit test	3 months	Experience	
RHR Injection Valves F001, F003, F005, F006	Failure to open because of mechanical problems	Stroke test	3 months	Experience; ASME code ISI	N/A ⁶
		Visual and penetrant inspection of stem, ultrasonic inspection of stem; replace if necessary	10 years	Low failure rate; ASME code ISI	1.40E-7

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
	Failure to open because of electrical problems	Electrical conduit 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	N/A ⁶
ESF SLF Divisions	Failure to operate; failure to properly generate initiation signals	System functional test	3 months	Experience	1.07E-6
		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	N/A
Suppression Pool Temperature sensors T53-TRS-601A and B	Sensor fails	Calibration of sensor	R/M Outage	Experience	1.17E-6
	Common mode failure	Analyze Level 2 calibration data for trends of drifting or other CCF indications	R/M Outage	Judgment	1.36E-4
Containment Penetrations	Leakage	Periodic inspection of penetrations to detect indications of degradation	R/M Outage	Experience	N/A

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
		Local leak rate testing	R/M Outage (based on Tech Spec requirements)	Tech Spec	
Common Cause Failures					N/A
RHR System (Shutdown Cooling and LPFL Modes)	Common failure mode	System walkdown to identify CCF type problems	R/M Outage	Judgment	
- Pumps	- Start and run				
- Room Air Conditioners	- Start and run				
- Injection MOVs	- Open				
HPCF System	Common failure mode	System walkdown to identify CCF type problems	R/M Outage	Judgment	
- Pumps	- Start and run				
- Injection MOVs	- Open				
- F005	- Mispositioned	Position check	Quarterly		
RCW System	Common failure mode	System walkdown to identify CCF type problems	R/M Outage	Judgment	
- Pumps	- Run				

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

Component	Failure Mode/Cause	Recommended Maintenance	Test or Maintenance Interval	Basis	Unavailability, Failure Rate
RSW System	Common failure mode	System walkdown to identify CCF type problems	R/M Outage	Judgment	
- Pumps	- Run				
- Strainers	- Plug	Operation verification	Quarterly		
UHS System	Common failure mode	System walkdown to identify CCF type problems			
- Fans	- Run				
Emergency Diesel Generators	Common failure mode	Startup to full load	1 month	Tech Spec	
	- Start and run				

1. RCIC component failure rates are included within system unavailability.
2. These types of valves and turbines have been used in operating BWRs, so there is much experience to guide owners/operators in care of equipment.
3. Switchyard component failure rates are included within the switchyard equipment failure rate.
4. ACIWA component failure rates are included within the system unavailability.
5. COPS component failure rates are included within the system unavailability. (Failure of the rupture disks to actuate upon demand before structural failure of the containment dominate failure of COPS.)
6. RHR component failure rates are included within the system unavailability.
7. HPCF component failure rates are included within the system unavailability.

2.0 REFERENCES

1. ABWR Standard Safety Analysis Report, Revision 5, General Electric Company.
2. Johnson, N., et al, "Shutdown Probabilistic Risk Assessment", Reliability and Safety Consulting (RSC) Engineers, Inc., RSC 10-14, Revision 0, August 2010.
3. ABWR Design Control Document, Revision 4, General Electric Company.

Review and Quality Page

<p>Reviewer Directions:</p> <p>Provide detailed technical or global editorial comments here. Individual editorial or illustrative comments may be electronically provided (tracking) or attached to this review sheet.</p> <p>Resolution Process:</p> <p>Originator must provide resolutions for all comments.</p> <p>Reviewer is to approve all proposed resolutions prior to completing the review process. No review is complete until this step is accomplished.</p>		
Reviewer Comment	Originator Resolution of Comment	Reviewer Approval
1. Editorial comments only.	Incorporated.	CLE
2. Notes for tables should be numbered consistently within the document and should be 10pt font.	Incorporated.	CLE
3. F-V percentages in 19K-2 should be listed as <0.1 or <<0.1, not as 0.0 for consistency.	Incorporated.	CLE
4. Check document formatting for consistency with WG.	Incorporated.	CLE
5. Check that references are reported correctly according to WG. Dates and revision numbers should be included in these references as available (check Reference 2).	Added date and revision to Reference 2.	CLE