APPENDIX D

ASSESSMENT OF RBPI COVERAGE

Contents

Figures

Tables

ABBREVIATIONS AND ACRONYMS

A	Large Loss of Coolant Accident
AC	Vital AC Buses
ACBU1	Other Onsite Backup 1
ACC	Accumulators
ADS	Automatic Depressurization System
AFW	Auxiliary Feedwater
AM1	Alternate Makeup 1
AM2	Alternate Makeup 2
AOV	Air-Operated Valve
ARI	Alternate Rod Insertion
ASP	Accident Sequence Precursor
ASPC	Alternate Suppression Pool Cooling
AUXC1	Auxiliary Cooling 1
AUXC2	Auxiliary Cooling 2
BI	Borated Injection
BWR	Boiling Water Reactor
CCDP	Conditional Core Damage Probability
CCDF	Conditional Core Damage Frequency
CCF	Common Cause Failure
CCW	Component Cooling Water
CD	Core Damage
CDF	Core Damage Frequency
CHPI	Normally Running Makeup (Injection)
CHPR	Normally Running Makeup (During Recirculation)
CIV	Containment Isolation Valve
CONDA	Condenser Available
CRDS	Control Rod Drive Pumps
CS	Core Spray
CSR	Containment Spray Recirculation

CTS	Condensate Pumps
DBI	Design Basis Issue
DWS	Drywell Spray
EAC	Emergency AC Power (usually EDGs)
EDC	Battery-backed DC Buses
EDG	Emergency Diesel Generator
EPIX	Equipment Performance and Information Exchange System
EPS	Emergency Power System
ESAS1	Engineered Safety Actuation System 1
ESW	Emergency Service Water
GT	General Transients
HP1	High-Pressure 1
HPCI	High-Pressure Coolant Injection
HPCS	High-Pressure Core Spray
HPI	High-Pressure Injection System
HPR	High Head Safety Injection (During Recirculation)
HUM	Operator Action
HVAC	Heating, Ventilation, Air Conditioning
HVAC1	Heating, Ventilation, Air Conditioning 1
HVAC2	Heating, Ventilation, Air Conditioning 2
HVAC3	Heating, Ventilation, Air Conditioning 3
IA	Instrument Air Compressors
IC	Isolation Condenser
INEEL	Idaho National Engineering and Environmental Laboratory
IPE	Individual Plant Examination
IPEEE	Individual Plant Examinations for External Events
ISLOCA	Interfacing Systems LOCA
LER	Licensee Event Report
LERF	Large Early Release Frequency
LLOCA	Large Loss of Coolant Accident
LOCA	Loss of Coolant Accident

LOFW	Loss of Feedwater
LOHS	Loss of Heat Sink
LONHR	Loss of Normal Heat Removal
LOOP	Loss of Offsite Power Event
LOSP	Loss of Offsite Power
LP1	Low-Pressure 1
LP2	Low-Pressure 2
LP3	Low-Pressure 3
LPCI	Low-Pressure Coolant Injection
LPCS	Low-Pressure Core Spray
LPI	Low Pressure Injection
LPR	Low Pressure Recirculation
MDAFW	Motor-Driven Auxiliary Feedwater Pumps
MDPs	Motor Driven Pumps
MFW	Main Feedwater Pumps
MLOCA	Medium Loss of Coolant Accident
MOR	Monthly Operating Report
MOV	Motor-Operated Valve
MSIV	Main Steam Isolation Valve
NISP	Non-1E Startup Pumps
NRC	U.S. Nuclear Regulatory Commission
NRR	Nuclear Reactor Regulation
OA3	Alternate Air System 3
PORV	Power Operated Relief Valve
PPORV	Pressurizer Power Operated Relief Valves
PRA	Probabilistic Risk Assessment
PSRV	Pressurizer Safety Relief Valves
PWR	Pressurized Water Reactor
QHO	Quantitative Health Objective
RADS	Reliability and Availability Database System
RAW	Risk Achievement Worth

RBCLCW	Reactor Building Closed Loop Cooling Water
RBPI	Risk-Based Performance Indicator
RCIC	Reactor Core Isolation Cooling
RCPS	Reactor Coolant Pump Seals
RCS	Reactor Coolant System
RECIRC	Recirculation Pumps
RHR	Residual Heat Removal
ROP	Reactor Oversight Process
RPS	Reactor Protection System
RWST	Refueling Water Storage Tank
SCSS	Sequence Coding and Search System
SDC	Shutdown Cooling
SDP	Significance Determination Process
SG	Steam Generator
SGTR	Steam Generator Tube Rupture
S1	Medium Loss of Coolant Accident
S2	Small Loss of Coolant Accident
S3	Small-small Loss of Coolant Accident
SDAWF	Steam-Driven Auxiliary Feedwater Pumps
SGA	Steam Generator Atmospheric Dump Valves
SGS	Steam Generator Safety Valves
SI	Safety Injection
SLC	Standby Liquid Control
SLOCA	Small Loss of Coolant Accident
SPAR	Standardized Plant Analysis Risk
SPC	Suppression Pool Cooling
SRV	Safety Relief Valve
SRVS	Safety Relief Valves Steam
SSCs	Systems, Structures, and Components
SSW	Standby Service Water
SW2	Alternate Service Water 2

SW3	Alternate Service Water 3
SWS	Service Water System
T-AC	Transient - Initiated by Loss of Vital AC Buses
T-ATWS	Transient - Anticipated Transient without Scram
T-AUXC2	Transient - Initiated by Loss of Auxiliary Cooling 2
T-CCW	Transient - Initiated by Loss of Component Cooling Water
T-DC	Transient - Initiated by Loss of DC Buses
T-ESW	Transient - Initiated by Loss of Essential Service Water Pumps
T-EXFW	Transient - Excessive Feedwater Addition
T-HVAC1	Transient - Initiated by Loss of Heating, Ventilation, and Air Conditioning 1
T-HVAC2	Transient - Initiated by Loss of Heating, Ventilation, and Air Conditioning 2
T-IA	Transient - Initiated by Loss of Instrument Air Compressors
T-IFL	Transient - Internal Flood
T-IORV	Transient - Inadvertent Open Relief Valve
T-IORV/ SORV	Transient - Inadvertent or Stuck Open Relief Valve
T-LMFW	Transient - Loss of Main Feedwater
T-LOOP	Transient - Loss of Offsite Power
T-MSIV	Transient - Initiated by Loss of Main Steam Isolation Valve
T-NSW	Transient - Initiated by Loss of Normal Service Water Pumps
T-RX	Transient - Reactor Trip
T-SGTR	Transient - Steam Generator Tube Rupture
T-SLBIC	Transient - Steam Line Break Inside Containment
T-SLBOC	Transient - Steam Line Break Outside Containment
T-SW2	Transient - Initiated by Loss of Alternate Service Water 2
T-TBCLCW	Transient - Initiated by Loss of Turbine Building Closed Loop Cooling Water
T-TT	Transient - Turbine Trip
T-UHS	Transient - Loss of Ultimate Heat Sink
T-VAC	Transient - Initiated by Loss of Vital Instrument AC
TB	Turbine Bypass Valves
UA	Unavailability

UR	Unreliability
V	Interfacing System Loss of Coolant Accident
V&V	Validation and Verification
V-AR1	Interfacing System Loss of Coolant Accident in Alternate Recirculation 1
V-CCW	Interfacing System Loss of Coolant Accident in Component Cooling Water
V-CHPI	Interfacing System Loss of Coolant Accident in Normally Running Makeup (Injection)
V-HPI	Interfacing System Loss of Coolant Accident in High Head Safety Injection
V-LPI	Interfacing System Loss of Coolant Accident in Low Pressure Injection
V-RHR	Interfacing System Loss of Coolant Accident in Residual Heat Removal
VAC	Vital Instrument AC
VENT	Venting System

Appendix D: Assessment of RBPI Coverage

The purpose of this appendix is to show the extent of risk coverage by RBPIs associated with core damage sequences, to show which risk-significant contributors are not covered by RBPIs, and to indicate briefly why these elements are not covered by RBPIs.

How Coverage Is Assessed

Two approaches to assessment of the extent of RBPI coverage of core damage frequency have been applied.

One approach is based on element Risk Achievement Worth (RAW), which measures how quickly CDF increases if element performance degrades. Given the baseline CDF and the RAW associated with a given element, the magnitude of the CDF increment that could be caused by degradation of the element can be determined. For each plant examined here, this is done for all basic events appearing in its SPAR model (Ref. 1), and the extent of RBPI coverage is then assessed for each basic event whose failure could cause a CDF increment greater than 1.0E-6. This assessment is closely related to the method for selecting candidate RBPIs in the first place (see Section 3 of the main report, and Appendix A).

In addition, an assessment of RBPI coverage of dominant accident sequences (sequences whose frequency contributes most to overall CDF) was performed, based on results in the IPE Database (Ref. 2). Dominant accident sequences are examined to determine which contributors to risk are covered by an RBPI. This is similar to a Fussell-Vesely importance evaluation.

Results of Coverage Assessment

Table D-1 shows results for the RAW-importance-based assessment of coverage, derived from SPAR models for these plants. For those events whose failure could lead to an increase in CDF > 1.0E-6/y, typically about 40% of the events in the SPAR models are part of the RBPIs (20% of the initiating events, and in many cases over 40% of the mitigating system elements). Industry-trended initiating events typically account for another 20% or more of the initiating events.

Table D-1 Coverage of Risk-Significant Core Damage Elements from SPAR Models

Category	BWR 3/4 Plant 6	WE 4-Lp Plant 1	CE Plant 2	BWR 3/4 Plant 5	BWR 3/4 Plant 8
Total number of SPAR model elements whose failure can result in ΔCDF ≥ 1E-6/yr	248	249	249	188	173
Initiating Events	15	16	12	13	15
Mitigating System Elements	233	233	237	175	158
Elements covered by RBPI's					
Initiating Events	3/15 (20%)	3/16 (19%)	3/12 (25%)	3/13 (23%)	3/15 (20%)
Mitigating System Elements	105/233 (45%)	81/233 (35%)	94/237 (40%)	83/175 (47%)	70/158 (44%)
Elements covered by industry trend indicators					
Initiating Events	3/15 (20%)	4/16 (25%)	4/12 (33%)	3/13 (23%)	3/15 (20%)

Category	CE Plant 4	BWR 5/6 Plant 2	BWR 3/4 Plant 11	CE Plant 5	B&W Plant 4
Total number of SPAR model elements whose failure can result in ΔCDF ≥ 1E-6/yr	147	176	220	243	175
Initiating Events	13	12	19	13	13
Mitigating System Elements	134	164	201	230	162
Elements covered by RBPI's					
Initiating Events	3/13 (23%)	3/12 (25%)	3/19 (16%)	3/13 (23%)	3/13 (23%)
Mitigating System Elements	49/134 (37%)	78/164 (48%)	78/201 (39%)	95/230 (41%)	64/162 (40%)
Elements covered by industry trend indicators					
Initiating Events	4/13 (31%)	3/12 (25%)	3/19 (16%)	4/13 (31%)	4/13 (31%)

Category	BWR 3/4 Plant 15	WE 2-Lp Plant 5	BWR 3/4 Plant 18	CE Plant 12	WE 4-Lp Plant 22
Total number of SPAR model elements whose failure can result in ΔCDF ≥ 1E-6/yr	173	244	178	214	203
Initiating Events	15	13	14	13	14
Mitigating System Elements	158	231	164	201	189
Elements covered by RBPI's					
Initiating Events	3/15 (20%)	3/13 (23%)	3/14 (21%)	3/13 (23%)	3/14 (21%)
Mitigating System Elements	69/158 (44%)	96/231 (42%)	70/164 (43%)	88/201 (44%)	72/189 (38%)
Elements covered by industry trend indicators					
Initiating Events	3/15 (20%)	4/13 (31%)	3/14 (21%)	4/13 (31%)	4/14 (29%)

The following is a list of elements not explicitly covered by RBPI's but common to most plants:

- Batteries
- Circuit breakers
- Check valves
- Electrical buses
- Heat exchangers
- Human error
- Reactor protection system
- Safety relief valves
- Strainers
- Tanks

The following is a list of elements not explicitly covered by RBPI's but found in a small number of the plants:

- Atmospheric dump valves
- Automatic bus transfer switches
- Battery chargers
- Butterfly valves
- Chillers
- Dam
- Engine-driven pumps
- Fans
- Filters
- Heat trace
- Overhead/underground feeders
- Pipe segments
- Squibb valves
- Transformers
- Traveling screens

Tables D-2a through o show RBPI coverage of dominant accident sequences at the initiating event / system level for the plants for which SPAR Revision 3 models are available. The tables are derived from the IPE Database results for these plants. Almost all sequences are covered by multiple RBPIs. Most of the elements that are not covered are either not amenable to RBPI treatment, or appear in sequences that contribute a relatively small fraction of core damage frequency. Some are normally-operating systems credited for plant-specific reasons that do not appear in enough plant PRAs to have justified generically applicable RBPIs.

Figures D-1a through o show RBPI coverage of initiating events for the same plants, based on relative contribution to core damage frequency (full power, internal events), derived from the IPE Database for these plants.

Many initiating events occur too infrequently to permit timely quantification of declining performance, and RBPIs based on frequency of occurrence of individual initiating events in this category are therefore not defined. However, as discussed in Section 3.1.1 of the main report, initiating events contributing more than 1% on average to industry-wide CDF and which include one or more occurrences (industry wide) over the past 10 years are included in the industry-wide trends. They are tabulated below and reflected in the coverage assessment presented in Table D-1 and in Figures D-1a through o.

Industry Trend Indicators (Other than Plant-Specific RBPIs)
Loss of Offsite Power
Loss of Vital AC
Loss of Vital DC
Flood
Inadvertent open/stuck open relief valve
Steam generator tube rupture
Loss of instrument/control air
Small/very small LOCA

Elements Not Covered By RBPIs

There were only a few events from the IPE Database information in Tables D-2a through o that were not covered by either RBPIs or industry-wide trending. Tables D-2a through o, prepared using the IPE Database format, display ATWS events as if ATWS were an initiator. "ATWS" as such is not covered by an RBPI, but initiating events potentially leading to ATWS are covered as shown. Steam line break events appear as accident sequence initiators for a few plants. As discussed in Appendix A, steam line break events do not meet the criteria to be identified as risk significant, and are therefore not covered by an RBPI. Medium and large LOCAs are not covered because of their low frequencies. Certain support systems whose loss is an initiating event are monitored under the Mitigating Systems cornerstone (Service Water and Component Cooling Water in PWRs). Although there is no RBPI directly monitoring the frequency of total loss of these systems, the corresponding initiating events are therefore implicitly monitored at a lower level (the train level rather than the system level).

Table D-3 lists mitigating system elements appearing in Tables D-2a through o that are not covered by RBPIs, with an indication of why they are not covered.

Table D-2a RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - WE 4-Lp Plants 1 and 2 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
1	8.76E-06	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
2	3.43E-06	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
3	1.77E-06	T-LOOP	EAC	EDC			
4	1.66E-06	T-LOOP	AC	CHPI	MDAFW	AM2	
5	6.41E-07	T-LOOP	AC	CHPI	MDAFW	AM2	
6	6.40E-07	T-DC	CHPR	HPR	MDAFW	AM2	
7	4.46E-07	T-LOOP	AC	CHPI	MDAFW	AM2	
8	4.36E-07	T-LOOP	AC	LPR	MDAFW	AM2	
9	3.76E-07	T-LOOP	AC	EAC	AM2		
10	3.40E-07	T-LOOP	AC	PPORV	MDAFW	AM2	
11	3.40E-07	T-LOOP	AC	ESW	AM2		
12	3.13E-07	T-LOOP	AC	ESW	AM2		
13	3.02E-07	T-LOOP	EAC	EDC			
14	2.66E-07	T-LOOP	AC	EAC	CHPR	HPR	AM2
15	2.40E-07	T-LOOP	AC	EAC	CHPR	HPR	AM2
16	2.27E-07	T-LOOP	ESW	EDC			
17	1.96E-07	T-RX	MDAFW	AM2	HUM		
18	1.75E-07	A	LPR				
19	1.75E-07	T-LOOP	AC	CHPI	MDAFW	AM2	
20	1.74E-07	S2	ESAS1	HUM			
21	1.71E-07	T-LOOP	AC	LPR	MDAFW	AM2	
22	1.69E-07	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
23	1.62E-07	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
24	1.54E-07	T-LOOP	AC	ESW	AM2		
25	1.44E-07	T-LOOP	AC	PPORV	MDAFW	AM2	
26	1.31E-07	T-RX	RPS	MSIV	HUM		

Table D-2a (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES						
27	1.28E-07	T-LOOP	AC	ESW	AM2				
28	1.25E-07	S2	LPR	HUM					
29	1.14E-07	T-LOOP	AC	CHPR	HPR	MDAFW	AM2		
30	1.09E-07	T-LOOP	AC	EAC	CHPR	HPR	MDAFW	AM2	
31	1.09E-07	T-LOOP	AC	ESW	CHPI	AM2			
32	1.00E-07	T-ESW	ESW						
33	9.96E-08	T-LOOP	EAC	EDC					
34	9.84E-08	T-LOOP	AC	EAC	CHPI	AM2			
35	9.42E-08	T-RX	CHPR	HPR	MFW	NISP	MDAFW	AM1	AM2
36	9.29E-08	T-LOOP	EAC	EDC					
37	9.19E-08	T-RX	RPS	MFW	NISP	MDAFW	AM1	AM2	
38	7.91E-08	T-LOOP	AC	ESW	AM2				
39	7.80E-08	S2	ESAS1	HUM					
40	7.35E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2		
41	7.26E-08	T-SLBOC	ESAS1	HUM					
42	7.26E-08	T-SLBOC	ESAS1	HUM					
43	7.26E-08	T-LOOP	AC	EAC	CHPI				
44	7.17E-08	T-SLBIC	ESAS1	HUM					
45	7.17E-08	T-SLBIC	ESAS1	HUM					
46	7.17E-08	T-LOOP	AC	MDAFW	AM2	HUM			
47	7.15E-08	T-LOOP	AC	EAC	AM2				
48	7.00E-08	T-LOOP	EAC	EDC					
49	6.92E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2		
50	6.84E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2		
51	6.36E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2		
52	6.33E-08	T-LOOP	AC	EAC	AM2				
53	5.87E-08	T-LOOP	EAC	EDC					

Table D-2a (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR		ACCIDENT SEQUENCE FAILURES				
54	5.81E-08	T-LOOP	AC	ESW	EAC	AM2		
55	5.80E-08	T-LOOP	AC	EAC	AM2			
56	5.57E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2	
57	5.48E-08	T-DC	CHPI	MDAFW	AM2			
58	5.36E-08	T-LOOP	AC	CHPI	MDAFW	AM2		
59	5.11E-08	T-LOOP	AC	ESW	AM2			
60	4.88E-08	T-DC	MDAFW	AM2				
61	4.67E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2	
62	4.56E-08	T-LOOP	AC	ESW	AM2	HUM		
63	4.53E-08	A	LPI					
64	4.46E-08	T-LOOP	AC	ESW	CHPI	AM2		
65	4.41E-08	S2	LPR					
66	4.40E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2	
67	4.35E-08	T-LOOP	AC	ESW	AM2			
68	4.12E-08	T-LOOP	AC	EAC	AM2	HUM		
69	4.10E-08	T-LOOP	AC	EAC	CHPR	HPR	AM2	
70	4.08E-08	T-LOOP	AC	EAC				
71	4.07E-08	T-DC	PPORV	MFW	MDAFW	AM1	AM2	
72	3.74E-08	T-RX	CHPR	HPR	MFW	MDAFW	AM1	AM2
73	3.69E-08	T-LOOP	AC	ESW				
74	3.24E-08	T-LOOP	AC	EAC	AM2			
75	3.22E-08	S1	ESAS1	HUM				
76	3.18E-08	T-DC	LPR	MDAFW	AM2			
77	3.01E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2	
78	2.98E-08	T-LOOP	AC	EAC				
79	2.87E-08	T-LOOP	AC	ESW	AM2			
80	2.87E-08	T-LOOP	AC	CHPI	MDAFW	AM2		

Table D-2a (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
81	2.81E-08	T-LOOP	AC	MDAFW	AM2	HUM	
82	2.77E-08	A	ESAS1	HUM			
83	2.68E-08	T-LOOP	AC	MDAFW	AM2	HUM	
84	2.65E-08	A	LPR				
85	2.63E-08	A	LPR				
86	2.43E-08	S1	LPR				
87	2.39E-08	T-LOOP	AC	MDAFW	AM2	HUM	
88	2.38E-08	T-LOOP	AC	ESW	EAC	AM2	
89	2.28E-08	T-LOOP	EAC	EDC			
90	2.28E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
91	2.10E-08	T-LOOP	AC	CHPI	MDAFW	AM2	
92	2.01E-08	T-LOOP	AC	CHPI	MDAFW	AM2	
93	1.91E-08	T-LOOP	AC	ESW	AM2		
94	1.90E-08	A	LPR				
95	1.88E-08	A	LPR				
96	1.87E-08	T-LOOP	AC	EAC	AM2	HUM	
97	1.83E-08	S2	CHPR	HPR	LPR		
98	1.78E-08	T-LOOP	AC	ESW	AM2		
99	1.77E-08	T-LOOP	AC	CHPI	MDAFW	AM2	
100	1.72E-08	T-LOOP	AC	CHPR	HPR	MDAFW	AM2
101	3.87E-09	T-IFL					
102	1.68E-06	REMAINDER					

Table D-2b RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences -CE Plants 2 and 3 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
1	3.55E-06	T-CCW	CCW			
2	1.88E-06	T-LOOP	AC	CCW	ESAS1	HUM
3	1.59E-06	T-RX	RPS			
4	1.21E-06	A	RPS	BI		
5	1.07E-06	S2	HVAC3	HUM		
6	8.25E-07	S2	HPR			
7	7.50E-07	S1	HPI			
8	7.50E-07	S2	HPI			
9	7.39E-07	S2	CCW			
10	6.97E-07	S2	HVAC3			
11	6.95E-07	S2	HVAC3			
12	6.13E-07	T-HVAC1	HVAC1	ESAS1	HUM	
13	5.81E-07	T-DC	IA	OA3	MDAFW	SDAFW
14	5.75E-07	S2	HPI			
15	5.63E-07	S2	HPI			
16	5.42E-07	T-LMFW	MDAFW	SDAFW		
17	5.30E-07	T-HVAC1	HVAC1	ESAS1	HUM	
18	5.30E-07	T-HVAC1	HVAC1	ESAS1	HUM	
19	5.29E-07	T-LMFW	RPS			
20	5.17E-07	T-CCW	CCW			
21	5.17E-07	T-CCW	CCW			
22	5.16E-07	T-SW2	SW2		HPI	
23	5.10E-07	T-HVAC1	HVAC1	ESAS1	HUM	
24	5.10E-07	T-HVAC1	HVAC1	ESAS1	HUM	
25	4.85E-07	T-VAC	SW2		HPI	
26	4.80E-07	T-HVAC1	HVAC1	ESAS1	HUM	

Table D-2b (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
27	4.80E-07	T-LOOP	AC	EAC		
28	4.61E-07	V				
29	4.50E-07	S3	HPR			
30	4.50E-07	S3	HPR			
31	4.42E-07	T-LMFW	MFW	MDAFW	SDAFW	
32	4.35E-07	T-SW2	SW2	ESW	HPI	
33	4.01E-07	S3	CCW	HPI		
34	4.01E-07	S3	CCW	HPI		
35	3.99E-07	A	ACC			
36	3.96E-07	T-IFL	MDAFW	SDAFW		
37	3.95E-07	T-CCW	CCW			
38	3.77E-07	S3	HPI			
39	3.77E-07	S3	HPI			
40	3.66E-07	S2	HPI			
41	3.62E-07	T-IFL	SW2			
42	3.52E-07	T-LMFW	RPS			
43	3.44E-07	T-HVAC2	HVAC2	CCW	PPORV	HPI
44	3.37E-07	T-IFL	ESW	CCW	HPI	
45	3.22E-07	A	HPI	LPI		
46	3.21E-07	T-LOOP	AC	ESAS1	HUM	
47	3.07E-07	S3	HPI			
48	3.07E-07	S3	HPI			
49	3.07E-07	T-RX	RPS			
50	3.07E-07	T-VAC	VAC	RPS	PPORV	
51	3.04E-07	T-LOOP	AC	SW2	SDAFW	
52	3.02E-07	T-RX	RPS	PPORV		
53	3.01E-07	S3	HPI			

Table D-2b (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
54	3.01E-07	S3	HPI			
55	2.98E-07	T-LOOP	AC	PPORV	HPI	
56	2.88E-07	T-SLBOC	MDAFW	SDAFW		
57	2.88E-07	T-IFL	SW2	ESW		
58	2.83E-07	T-IFL	SW2	CCW	HPI	
59	2.83E-07	S2	HPI			
60	2.77E-07	T-CCW	CCW			
61	2.77E-07	S2	SW2	ESW		
62	2.74E-07	T-LOOP	AC	ESAS1	HUM	
63	2.73E-07	S2	ESW	CSR		
64	2.72E-07	T-RX	RPS			
65	2.71E-07	T-EXFW	MFW	MDAFW	SDAFW	
66	2.71E-07	T-LMFW	MFW			
67	2.54E-07	T-LOOP	AC	ESAS1	HUM	
68	2.46E-07	T-IFL	SW2	ESW	MDAFW	SDAFW
69	2.44E-07	T-CCW	CCW			
70	2.41E-07	T-DC	HVAC3			
71	3.35E-07	T-DC	MDAFW	SDAFW		
72	2.33E-07	A	RPS	BI		
73	2.31E-07	T-RX	RPS			
74	2.31E-07	T-RX	RPS			
75	2.26E-07	T-LOOP	AC	HVAC2	ESW	PPORV
76	2.26E-07	T-LOOP	AC	SDAFW		
77	2.24E-07	T-CCW	CCW			
78	2.23E-07	NOINFO				
79	2.21E-07	T-EXFW	MDAFW	SDAFW		
80	2.16E-07	T-CCW	CCW			

Table D-2b (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
81	2.13E-07	T-AC	HVAC2	PPORV	HUM	
82	2.13E-07	T-AC	HVAC2	PPORV	HUM	
83	2.13E-07	T-AC	MDAFW	SDAFW		
84	2.12E-07	S3	HVAC3			
85	2.12E-07	S3	HVAC3			
86	2.10E-07	T-SGTR	CCW	HUM		
87	2.08E-07	S3	HVAC3			
88	2.08E-07	S3	HVAC3			
89	2.07E-07	T-UHS	MDAFW	SDAFW		
90	2.07E-07	S2	HVAC3			
91	2.03E-07	S3	HPI			
92	2.03E-07	S3	HPI			
93	1.98E-07	T-SGTR	HPR	HUM		
94	1.97E-07	T-LOOP	AC	SDAFW		
95	1.96E-07	T-IFL	ESW	CCW	HPI	
96	1.96E-07	T-LOOP	AC	EAC	ESAS1	HUM
97	1.93E-07	T-IORV	AC	EAC		
98	1.84E-07	T-SGTR	SGS	HUM		
99	1.79E-07	S2	HPI			
100	1.78E-07	S2	HPR			
102	1.85E-04	REMAINDER				
101	1.18E-05	T-IFL				

Table D-2c RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 5 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES					
1	1.45E-05	T-LOOP	AC	EAC				
2	1.06E-05	T-LOOP	AC	EAC	RCIC			
3	8.22E-06	T-TT	SRVS	HPCI(HPCS)	HUM			
4	7.82E-06	T-NSW	RBCLCW	TBCLCW				
5	6.57E-06	T-IORV/SORV	SRVS	HPCI(HPCS)	HUM			
6	3.09E-06	T-TT	HP1	CTS	LP1	LP2	SPC	
7	1.87E-06	T-IA	IA	HP1	LP1	LP2	SPC	
8	1.52E-06	T-RX	SRVS	HPCI(HPCS)	RCIC	HUM		
9	1.50E-06	T-RX	SRVS	HPCI(HPCS)	HUM			
10	1.49E-06	T-IA	IA	HPCI(HPCS)	RCIC	LPCI	CS	LP1
11	1.28E-06	T-IA	IA	ADS	HPCI(HPCS)	RCIC		
12	1.19E-06	T-LOOP	AC	EAC	SRVS	HPCI(HPCS)	RCIC	
13	1.16E-06	T-TT	SRVS	ADS	HPCI(HPCS)	HUM		
14	9.25E-07	T-RX	CRDS	HPCI(HPCS)	CONDA	HUM		
15	9.05E-07	T-IORV/SORV	HPCI(HPCS)	LPCI	CS			
16	8.85E-07	T-RX	ADS	HPCI(HPCS)	RCIC	HP1		
17	8.57E-07	T-DC	HPCI(HPCS)	HUM				
18	8.35E-07	T-NSW	RBCLCW	TBCLCW	SRVS			
19	8.24E-07	T-DC	RCIC	HUM				
20	7.40E-07	T-LOOP	AC	EAC	SRVS	HPCI(HPCS)	RCIC	
21	7.02E-07	T-TT	SRVS	ADS	HPCI(HPCS)	RCIC	CONDA	
22	6.80E-07	T-TT	CRDS	RECIRC				
23	6.27E-07	T-TT	SRVS	LPCI	CS			
24	5.62E-07	T-RX	CRDS	CTS	LP1	LP2	SPC	
25	5.12E-07	T-AC	HPCI(HPCS)	RCIC	LPCI	CS	LP1	
26	9.82E-06	REMAINDER						
27		T-IFL						

Table D-2d RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 6 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
1	1.00E-06	T-DC	DC			
2	7.90E-07	T-UHS	HUM			
3	7.40E-07	T-TT	RPS	ARI	SLC	HUM
4	5.80E-07	T-LOOP	EDC	EAC		
5	3.90E-07	T-LOOP	AC	HPCI(HPCS)	RCIC	
6	3.20E-07	T-NSW	ESW	SW2	CONDA	HUM
7	3.05E-07	T-LMFW	HPCI(HPCS)	RCIC	MFW	HUM
8	2.30E-07	T-LOOP	EAC	AC	HPCI(HPCS)	RCIC
9	2.00E-07	T-LOOP	EAC	EDC		
10	1.80E-07	T-LOOP	EDC	EAC		
11	1.50E-07	T-LOOP	EAC	AC	HPCI(HPCS)	RCIC
12	1.50E-07	T-IORV/SORV	SRVS	SPC	HUM	
13	1.30E-07	T-MSIV	RPS	ARI	CONDA	HUM
14	1.30E-07	T-TT	CONDA	SPC	HUM	
15	1.28E-07	T-LOOP	AC	CONDA	SPC	HUM
16	1.26E-07	T-TT	RPS	ARI	SLC	HUM
17	1.02E-07	T-LOOP	EAC	AC	HPCI(HPCS)	RCIC
18	1.01E-07	T-LOOP	EAC	EDC		
19	1.00E-07	T-LOOP	EAC	EDC	HUM	
20	1.00E-07	T-LOOP	EAC	EDC		
21	1.89E-06	REMAINDER				
22	0.00E+00	T-IFL				

Table D-2e RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 8 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
1	7.15E-07	T-LOOP	EAC	EDC	CONDA		
2	3.64E-07	T-LOOP	EAC	ESW	SRVS	CONDA	
3	3.17E-07	T-LOOP	EAC	EDC	CONDA		
4	7.10E-08	T-LOOP	EAC	EDC	CONDA		
5	5.19E-08	T-LOOP	EAC	EDC	CONDA		
6	3.62E-08	T-RX	EAC	EDC	CONDA		
7	1.77E-08	T-LOOP	EAC	ESW	SRVS	CONDA	
8	1.16E-08	T-LOOP	EAC	ESW	SRVS	CONDA	
9	4.99E-09	T-RX	RPS	ARI	CONDA	HUM	
10	1.00E-09	T-RX	RPS	ARI	HUM		
11	1.00E-09	T-IORV/SORV	RPS	ARI	SRVS		
12	1.00E-09	T-LOOP	RPS	HUM			
13	1.00E-09	T-LMFW	RPS	ARI	MFW	HUM	
14	1.00E-09	T-MSIV	RPS	ARI	MSIV	CONDA	HUM
15	1.00E-09	T-IORV/SORV	RPS	ARI	SRVS		
16	1.00E-09	S1	LPCI	CS			
17	7.40E-09	A	LPCI	CS			
18	8.25E-08	T-LOOP	AC	SRVS			
19	5.56E-09	T-LOOP	AC	SRVS			
20	1.00E-09	T-MSIV	SRVS	LPCI	CS	CONDA	
21	1.00E-09	T-LMFW	SRVS	MFW	LPCI	CS	CONDA
22	1.00E-09	T-RX	LPCI	CS	CONDA	HUM	
23	8.15E-08	T-AC	AC	CONDA	SPC		
24	9.40E-08	T-AC	AC	CONDA	SPC		
25	4.97E-08	REMAINDER					
26		T-IFL					

Table D-2f RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - CE Plant 4 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES					
1	9.63E-08	T-RX	MDAFW	SDAFW	AM1	HUM		
2	1.07E-06	T-RX	MDAFW	SDAFW	AM1	HUM		
3	1.60E-08	T-RX	MDAFW	SDAFW	AM1	HUM		
4	2.01E-07	T-RX	MDAFW	SDAFW	AM1	HUM		
5	3.37E-08	T-RX	RCPS	HPI	MDAFW	SDAFW	AM1	HUM
6	2.48E-09	T-RX	RCPS	HPI	MDAFW	SDAFW	AM1	HUM
7	1.28E-08	T-RX	RCPS	HPI	MDAFW	SDAFW	AM1	HUM
8	3.91E-09	T-RX	RCPS	HPI	MDAFW	SDAFW	AM1	HUM
9	2.48E-09	T-RX	RCPS	HPI	MDAFW	SDAFW	AM1	HUM
10	1.27E-08	T-RX	RCPS	HPI				
11	1.32E-06	T-RX	RCPS	HPI				
12	8.23E-07	T-RX	RCPS	HPI				
13	1.85E-09	T-RX	RCPS	HPR				
14	2.25E-07	T-RX	RCPS	HPR				
15	1.88E-08	T-RX	RCPS	HPR				
16	1.50E-06	T-RX	HPR					
17	1.03E-08	T-RX	HPR					
18	6.96E-09	T-RX	HPR					
19	3.03E-08	T-RX	HPR					
20	3.70E-06	T-RX	HPR					
21	3.14E-09	S2	RPS	BI				
22	3.14E-09	S2	RPS	BI				
23	1.12E-09	S2	HPI					
24	2.08E-08	S2	HPI					
25	3.65E-07	S2	HPI					
26	2.97E-07	S2	HPI					
27	1.58E-10	S2	HPR					

Table D-2f (Continued)

IE RBPI
Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
28	5.86E-09	S2	HPR			
29	8.06E-08	S2	HPR			
30	5.86E-09	S2	HPR			
31	7.69E-08	S1	HPI			
32	6.30E-09	S1	HPR			
33	9.00E-10	S1	HPR			
34	5.86E-09	S1	HPR			
35	5.38E-08	A	ACC			
36	4.52E-09	A	HPR	LPR		
37	5.10E-08	A	HPR	LPR		
38	6.15E-08	T-SGTR	HPR	MSIV		
39	2.91E-08	T-SGTR	RPS	BI		
40	1.81E-09	T-SGTR	HPI	MDAFW	SDAFW	AM1
41	2.01E-09	T-SGTR	HPI	MDAFW	SDAFW	AM1
42	4.01E-09	T-SGTR	HPI	MSIV		
43	1.05E-09	T-SGTR	HPI	MSIV		
44	4.54E-08	T-SGTR	HPI	HPR		
45	6.08E-07	T-SGTR	HPR			
46	5.84E-08	V-LPI				
47	1.00E-13	V-LPI				
48	2.95E-07	V-LPR				
49	7.57E-10	V-CCW	RCPS	MDAFW	SDAFW	AM1
50	1.84E-07	V-CCW	RCPS			
51	9.40E-08	V-CCW	RCPS			
52	1.82E-08	V-CCW	RCPS	HPR		
53	2.32E-08	V-CHPI	CHPI			
54	1.03E-09	T-ATWS	RPS	BI		

Table D-2f (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
55	2.44E-07	T-ATWS	RPS	PSRV	PPORV
56	1.62E-08	T-ATWS	RPS	PSRV	
57	5.33E-07	T-IFL			
58	1.73E-07	T-IFL			
59	4.04E-07	T-IFL			
60	7.02E-09	T-IFL			
61	1.95E-07	T-IFL			
62	2.84E-07	T-IFL			
63	1.02E-07	T-IFL			
64	5.41E-08	T-IFL			
65	1.11E-07	T-IFL			
66	8.03E-09	T-IFL			
67	8.85E-09	T-IFL			

Table D-2g RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 5/6 Plant 2 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES					
1	4.34E-06	T-LOOP	AC	EAC	RCIC			
2	2.24E-06	T-LOOP	EAC	EDC				
3	1.58E-06	T-LOOP	AC	ADS	HPCI(HPCS)	RCIC	HP1	
4	1.30E-06	T-AC	HPCI(HPCS)	RCIC	LPCI	CS		
5	9.61E-07	T-AC	HVAC2	ESW	CS	LP1	HUM	
6	6.31E-07	T-LOOP	AC	EAC	HPCI(HPCS)	RCIC		
7	4.91E-07	T-AC	HPCI(HPCS)	RCIC	LPCI	LP1		
8	4.77E-07	T-AC	HPCI(HPCS)	CS	LP2	LP3	SPC	DWS

Table D-2g (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES										
9	3.52E-07	T-LOOP	AC	HPCI(HPCS)	RCIC	LPCI	CS	LP1					
10	3.28E-07	T-MSIV	SRVS	ADS	HPCI(HPCS)	RCIC	MFW						
11	3.05E-07	T-AC	ADS	HPCI(HPCS)	RCIC								
12	2.94E-07	T-MSIV	ADS	HPCI(HPCS)	RCIC	HP1							
13	2.88E-07	T-NSW	ADS	HPCI(HPCS)	HP1								
14	2.47E-07	T-AC	ADS	HPCI(HPCS)	RCIC								
15	2.42E-07	T-DC	HPCI(HPCS)	RCIC	LPCI	CS							
16	2.34E-07	T-DC	HPCI(HPCS)	LPCI	LP1								
17	1.73E-07	T-TBCLCW	ADS	HPCI(HPCS)	RCIC	HP1							
18	1.68E-07	T-DC	ADS	HPCI(HPCS)	RCIC								
19	5.33E-08	T-IFL	ADS	HPCI(HPCS)	HP1								
20	1.56E-07	T-LMFW	ADS	HPCI(HPCS)	RCIC	HP1							
21	1.55E-07	S1	HPCI(HPCS)	LPCI	CS	LP1							
22	1.51E-07	T-DC	ADS	HPCI(HPCS)									
23	1.44E-07	T-AC	HPCI(HPCS)	HP1	LPCI	LP1	LP2	LP3	SPC	DWS			
24	1.25E-07	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	LPCI	CS	CTS	LP1			
25	1.18E-07	T-LOOP	AC	EAC	SRVS	RCIC							
26	1.13E-07	T-RX	HPCI(HPCS)	MFW	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS
27	1.07E-07	S1	LP1	ASPC									
28	1.02E-07	T-IA	IA	ADS	HPCI(HPCS)	RCIC							
29	5.44E-08	S3	ADS	HPCI(HPCS)	RCIC	MFW	HP1						
30	5.44E-08	T-AC	HPCI(HPCS)	HP1	LPCI	LP1	LP2	LP3	SPC	DWS			
31	1.02E-07	T-RX	HPCI(HPCS)	MFW	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS
32	5.01E-08	A	HPCI(HPCS)	LPCI	CS	LP1							
33	2.20E-07	T-AC	HPCI(HPCS)	RCIC	LPCI	CS							
34	1.43E-07	T-IFL											
35	7.00E-07	REMAINDER											

Table D-2h RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plant 11 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES					
1	3.27E-05	T-LOOP	EAC	EDC				
2	2.76E-06	T-LMFW	ADS	HPCI(HPCS)	RCIC			
3	1.05E-06	T-MSIV	ADS	HPCI(HPCS)	RCIC			
4	1.04E-06	S1	LPCI	CS	CTS			
5	1.03E-06	T-TT	ADS	HPCI(HPCS)	RCIC	MFW		
6	9.96E-07	S1	ADS	HPCI(HPCS)				
7	9.87E-07	T-HVAC1	HVAC1	EDC	EAC			
8	9.67E-07	T-LOOP	EDC	EAC				
9	5.30E-07	T-LMFW	SPC	DWS	VENT			
10	5.29E-07	T-IORV/SORV	ADS	HPCI(HPCS)	RCIC	MFW		
11	5.07E-07	T-TT	SLC	CRDS				
12	3.97E-07	T-TT	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS
13	3.00E-07	S1	ASPC					
14	2.99E-07	T-ESW	HPCI(HPCS)	VENT				
15	2.07E-07	A	LPCI	CS	CTS			
16	1.79E-07	T-TT	SRVS	LPCI	CS	CTS	SPC	DWS
17	1.19E-07	T-MSIV	SLC	CRDS				
18	7.99E-08	S2	RPS					
19	7.80E-08	T-LMFW	ADS	HPCI(HPCS)	RCIC			
20	7.00E-08	A	ASPC					
21	5.85E-08	T-LOOP	EAC	EDC	HPCI(HPCS)	RCIC		
22	5.84E-08	T-LOOP	EAC	EDC	SRVS			
23	5.24E-08	S1	EAC	EDC				
24	5.05E-08	S2	ADS	HPCI(HPCS)	RCIC	MFW		
25	5.01E-08	T-MSIV	ADS	HPCI(HPCS)	RCIC			
26	4.96E-08	T-LOOP	AC	ADS	HPCI(HPCS)	RCIC		
27	4.93E-08	S1	LPCI	CS				

Table D-2h (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES						
28	4.60E-08	T-TT	SRVS	LPCI	CS				
29	4.55E-08	T-LMFW	HPCI(HPCS)	RCIC	LPCI	CS			
30	4.30E-08	T-AUXC2	AUXC2	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS
31	4.27E-08	S2	MFW	LPCI	CS	CTS			
32	4.00E-08	T-TT	RPS	RECIRC	HUM				
33	4.00E-08	T-TT	CRDS	RECIRC					
34	3.55E-08	T-ESW	ESW	CS					
35	3.00E-08	S1	RPS						
36	2.46E-08	S2	RPS						
37	2.18E-08	T-HVAC1	HVAC1	EAC	EDC				
38	2.10E-08	A	RPS						
39	1.97E-08	T-AUXC2	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS	
40	1.79E-08	T-MSIV	HPCI(HPCS)	RCIC	LPCI	CS			
41	1.59E-08	T-LMFW	HPCI(HPCS)	RCIC	LPCI	CS	CTS		
42	1.48E-08	T-TT	ADS	HPCI(HPCS)	RCIC	MFW			
43	1.48E-08	A	LPCI	CS	CTS				
44	1.45E-08	T-TT	ADS	HPCI(HPCS)	RCIC	MFW			
45	1.40E-08	T-TT	HPCI(HPCS)	HP1	SPC	DWS	VENT		
46	1.30E-08	S1	HPCI(HPCS)	LPCI	CS				
47	1.20E-08	T-TT	SRVS						
48	1.18E-08	S1	HPCI(HPCS)	LPCI	CS				
49	1.06E-08	T-MSIV	SRVS	LPCI	CS				
50	9.82E-09	T-MSIV	RPS	RECIRC	HUM				
51	9.82E-09	T-MSIV	CRDS	RECIRC					
52	9.21E-09	T-LOOP	EAC	EDC					
53	7.98E-09	S2	ASPC						
54	7.59E-09	S2	ADS	HPCI(HPCS)	RCIC	MFW			
55	7.39E-09	A							
56	4.85E-09	T-IA	IA	HPCI(HPCS)	RCIC	LPCI	CS		

Table D-2h (Continued)

IE RBPI
Industry-Wide Trending
System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES								
57	4.11E-09	T-AUXC2	SRVS	LPCI	CS						
58	3.60E-09	T-IORV/SORV	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS			
59	3.14E-09	T-IA	IA	ADS	HPCI(HPCS)	RCIC					
60	2.46E-09	S2	ASPC								
61	2.28E-09	T-TT	SRVS	HPCI(HPCS)	HP1	SPC	DWS	VENT			
62	1.81E-09	T-AUXC2	AUXC2	ADS	HPCI(HPCS)	RCIC	MFW				
63	1.70E-09	T-TT	CRDS	ADS	HPCI(HPCS)	RCIC					
64	1.65E-09	T-LMFW	SRVS								
65	1.64E-09	T-LOOP	AC	ADS	HPCI(HPCS)	RCIC					
66	1.62E-09	S1	LPCI	CS	SPC	DWS	VENT				
67	1.34E-09	T-ESW	ESW	SRVS	CS	VENT					
68	1.21E-09	T-TT	ADS	HPCI(HPCS)	RCIC	HUM					
69	1.09E-09	T-HVAC1	HVAC1	EAC	EDC	SRVS					
70	1.08E-09	T-MSIV	SRVS								
71	1.03E-09	T-IA	IA	HPCI(HPCS)	SPC	DWS	VENT				
72	8.82E-10	A	LPCI	CS	CTS	SPC	DWS	VENT			
73	8.01E-10	T-ESW	ESW	HPCI(HPCS)	RCIC	CS					
74	7.27E-10	T-TT	MFW	HP1	LPCI	CS	CTS	LP1	LP2	SPC	DWS
75	6.01E-10	T-TT	MFW	HP1	LPCI	CS	CTS	LP1	LP2	SPC	DWS
76	5.52E-10	T-MSIV	CRDS	ADS	HPCI(HPCS)	RCIC					
77	4.08E-10	S1	AC	ADS	HPCI(HPCS)						
78	3.00E-10	S1	AC	ASPC							
79	2.77E-10	T-ESW	ESW	ADS	HPCI(HPCS)	RCIC					
80	2.61E-10	T-MSIV	SRVS	SPC	DWS						
81	2.47E-10	T-AUXC2	AUXC2	SRVS	LPCI	CS	CTS				
82	2.30E-09	T-IFL	SRVS	LPCI	CS	CTS	SPC	DWS			
83	1.10E-09	T-IFL	SRVS	LPCI	CS	CTS	SPC	DWS			
84	2.00E-09	T-IFL	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS			
85	1.90E-08	T-IFL	ADS	HPCI(HPCS)	RCIC	MFW					

Table D-2h (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES									
86	3.80E-08	T-IFL	MFW	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS
87	1.50E-09	T-IFL	ADS	HPCI(HPCS)	RCIC	MFW						
88	4.90E-09	T-IFL	SRVS	LPCI	CS	CTS	SPC	DWS				
89	3.60E-10	T-IFL	SRVS	LPCI	CS	CTS						
90	1.70E-08	T-IFL	HPCI(HPCS)	RCIC	MFW	LPCI	CS	CTS				
91	8.00E-09	T-IFL	ADS	HPCI(HPCS)	RCIC	MFW						
92	1.50E-08	T-IFL	SRVS	LPCI	CS	CTS						
93	2.80E-08	T-IFL	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS	
94	7.50E-08	T-IFL	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS	VENT
95	1.50E-08	T-IFL	HPCI(HPCS)	RCIC	LPCI	CS	CTS					
96	1.90E-08	T-IFL	ADS	HPCI(HPCS)	RCIC							
97	3.90E-08	T-IFL	HP1	LPCI	CS	CTS	LP1	LP2	LP3	SPC	DWS	
98	2.20E-09	T-IFL	SRVS	HP1	LPCI	CS	CTS	LP1	LP2	LP3		
99	6.60E-10	T-IFL	ADS	HPCI(HPCS)	RCIC							
100	5.90E-09	T-IFL	SRVS	SPC	DWS							
101	4.80E-10	T-IFL	SRVS	LPCI	CS	CTS						
102	2.16E-07	T-IFL										

Table D-2i RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - CE Plant 5 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
1	6.59E-07	T-DC	MDAFW	SDAFW	
2	6.22E-07	T-DC	MDAFW	SDAFW	
3	5.91E-07	T-LOOP	AC	MDAFW	SDAFW
4	5.91E-07	T-LOOP	AC	MDAFW	SDAFW

Table D-2i (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
5	5.66E-07	T-DC	RPS			
6	5.34E-07	T-DC	RPS			
7	4.94E-07	S2	HPR	LPR		
8	4.68E-07	T-DC	MDAFW	HUM		
9	4.48E-07	T-SLBIC	MDAFW	SDAFW	HUM	
10	4.42E-07	T-DC	MDAFW	HUM		
11	4.25E-07	T-DC	MDAFW	SDAFW		
12	4.20E-07	T-LOOP	AC	MDAFW	HUM	
13	4.20E-07	T-LOOP	AC	MDAFW	HUM	
14	4.01E-07	T-DC	MDAFW	SDAFW		
15	3.81E-07	T-LOOP	AC	MDAFW	SDAFW	
16	3.81E-07	T-LOOP	AC	MDAFW	SDAFW	
17	3.73E-07	T-DC	MDAFW	SDAFW		
18	3.52E-07	T-DC	MDAFW	SDAFW		
19	3.34E-07	T-LOOP	AC	MDAFW	SDAFW	
20	3.34E-07	T-LOOP	AC	MDAFW	SDAFW	
21	3.33E-07	T-ESW	ESW			
22	3.19E-07	T-SLBIC	HUM			
23	3.00E-07	T-LMFW	MDAFW	SDAFW	HUM	
24	2.89E-07	T-SLBIC	SDAFW	HUM		
25	2.89E-07	T-ESW	ESW	HUM		
26	2.73E-07	T-LOOP	AC	MDAFW	SDAFW	HUM
27	2.65E-07	T-DC	MDAFW	HUM		
28	2.50E-07	T-DC	MDAFW	HUM		
29	2.48E-07	T-RX	RPS	PSRV		
30	2.37E-07	T-LOOP	AC	MDAFW	HUM	
31	2.37E-07	T-LOOP	AC	MDAFW	HUM	

Table D-2i (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
32	2.03E-07	T-RX	PSRV	HPR	LPR	AR1
33	2.03E-07	T-RX	PSRV	HPR	LPR	AR1
34	1.96E-07	T-DC	MDAFW	HUM		
35	1.91E-07	S1	IA	ESW		
36	1.90E-07	S3	HVAC1	HUM		
37	1.84E-07	T-DC	MDAFW	HUM		
38	1.75E-07	T-LOOP	AC	MDAFW	HUM	
39	1.75E-07	T-LOOP	AC	MDAFW	HUM	
40	1.75E-07	T-DC	MDAFW	SDAFW	HUM	
41	1.72E-07	A	IA	ESW	HUM	
42	1.65E-07	T-DC	MDAFW	SDAFW		
43	1.59E-07	T-DC	MDAFW	SDAFW		
44	1.56E-07	S1	HPR			
45	1.52E-07	S1	ESW			
46	1.51E-07	T-RX	RPS	PPORV		
47	1.50E-07	T-DC	MDAFW	SDAFW		
48	1.44E-07	S1	HPI			
49	1.43E-07	T-LOOP	AC	MDAFW	SDAFW	
50	1.43E-07	T-LOOP	AC	MDAFW	SDAFW	
51	1.40E-07	A	HPR	LPR		
52	1.40E-07	A	LPI			
53	1.39E-07	S3	MDAFW	SDAFW		
54	1.37E-07	A	ESW			
55	1.33E-07	T-SLBIC	HUM			
56	1.33E-07	T-ESW	ESW	MDAFW	SDAFW	
57	1.29E-07	S3	ESW	HUM		
58	1.29E-07	S3	CCW	HUM		

Table D-2i (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
59	1.29E-07	S3	CCW	HVAC1	HUM
60	1.29E-07	A	HPR	LPR	
61	1.25E-07	T-VAC	RPS		
62	1.20E-07	T-LOOP	AC	MDAFW	SDAFW
63	1.20E-07	T-LOOP	AC	MDAFW	SDAFW
64	1.17E-07	T-RX	RPS	HUM	
65	1.11E-07	T-DC	MDAFW	HUM	
66	1.04E-07	T-DC	MDAFW	HUM	
67	9.92E-08	T-LOOP	AC	MDAFW	HUM
68	9.92E-08	T-LOOP	AC	MDAFW	HUM
69	9.75E-08	T-RX	MDAFW	SDAFW	
70	9.24E-08	T-RX	RPS	PSRV	
71	9.24E-08	T-RX	RPS	PSRV	
72	9.21E-08	S2	HVAC1	HUM	
73	9.21E-08	S3	AR1		
74	8.90E-08	T-SGTR	HPI	HUM	
75	8.49E-08	T-LOOP	AC	MDAFW	HUM
76	8.49E-08	T-LOOP	AC	MDAFW	HUM
77	8.48E-08	T-SLBIC	SGA	SDAFW	
78	8.48E-08	T-SLBIC	SGA	SDAFW	
79	8.12E-08	T-VAC	MDAFW	SDAFW	
80	7.71E-08	T-LOOP	AC	MDAFW	SDAFW
81	7.60E-08	A	HVAC2	VAC	HUM
82	6.92E-08	T-RX	MDAFW	HUM	
83	6.79E-08	T-DC	MDAFW	HUM	
84	6.76E-08	T-LOOP	AC	MDAFW	SDAFW
85	6.74E-08	S2	MDAFW	SDAFW	
86	6.28E-08	T-RX	MDAFW	SDAFW	

Table D-2i (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
87	6.27E-08	S2	ESW	HUM		
88	6.27E-08	S2	CCW	HUM		
89	6.27E-08	S2	CCW	HVAC1	HUM	
90	6.12E-08	T-LOOP	AC	MDAFW	SDAFW	
91	6.02E-08	T-SLBIC	SGA	HUM		
92	6.02E-08	T-SLBIC	SGA	HUM		
93	5.86E-08	T-SLBIC	PPORV	SDAFW		
94	5.86E-08	T-SLBIC	PPORV	SDAFW		
95	5.77E-08	T-VAC	MDAFW	HUM		
96	5.67E-08	T-LMFW	SGA	MDAFW	SDAFW	HUM
97	5.67E-08	T-LMFW	SGA	MDAFW	SDAFW	HUM
98	5.59E-08	T-LMFW	RPS	PSRV		
99	5.58E-08	T-RX	ESW	PSRV		
100	5.58E-08	T-RX	ESW	PSRV		
101	5.31E-08	T-IFL	ESW			
102	1.51E-07	T-IFL	IA	AUXC1		
103	1.40E-05	REMAINDER				

Table D-2j RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - B&W Plants 4, 5 and 6 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
1	1.48E-06	T-IA	IA	HUM	
2	8.00E-07	A			
3	6.11E-07	T-LOOP	EAC	EDC	HUM
4	3.37E-07	T-UHS	HUM		

Table D-2j (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
5	3.14E-07	T-LOOP	EAC	EDC	HUM	
6	2.19E-07	T-LOOP	AC	HUM		
7	2.14E-07	T-LOOP	EAC	EDC	ACBU1	
8	1.78E-07	T-IA	IA	SDAFW	HUM	
9	1.78E-07	T-LOOP	EAC	EDC	ACBU1	
10	1.65E-07	T-IA	IA	PSRV	HUM	
11	1.48E-07	T-IA	IA	HUM		
12	1.48E-07	T-IA	IA	HUM		
13	1.30E-07	T-LOOP	EAC	EDC	ACBU1	
14	1.24E-07	T-LMFW	MFW	HUM		
15	1.10E-07	T-LOOP	EAC	EDC	ACBU1	
16	1.01E-07	T-LOOP	EAC	EDC	SDAFW	HUM
17	9.95E-08	T-IA	IA	AM1	HUM	
18	8.38E-08	T-LOOP	EAC	EDC	HUM	
19	7.34E-08	T-LOOP	EAC	EDC		
20	7.22E-08	T-IA	IA	HUM		
21	6.93E-08	T-LOOP	EAC	EDC	SDAFW	HUM
22	6.75E-08	T-UHS	HUM			
23	6.48E-08	T-LOOP	AC	HUM		
24	6.11E-08	T-LOOP	EAC	EDC	HUM	
25	6.11E-08	T-LOOP	EAC	EDC		
26	5.94E-08	T-IA	IA	AM1	HUM	
27	5.94E-08	T-IA	IA	AM1	HUM	
28	5.78E-08	T-LOOP	EAC	EDC	HUM	
29	5.15E-08	T-LOOP	EAC	EDC		
30	4.98E-08	T-RX	MFW	HUM		
31	7.00E-06	S1	HUM			
32	7.00E-07	A	HUM			

Table D-2j (Continued)

IE RBPI

Industry Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
33	7.00E-07	A	HUM			
34	2.60E-07	S2	HUM			
35	1.90E-07	A	LPR			
36	1.90E-07	S1	LPR			
37	1.40E-07	A	LPI			
38	1.06E-07	S2	HPI			
39	7.00E-08	S1	HUM			
40	6.23E-08	A	SW3			
41	3.98E-08	A	LPI			
42	3.20E-08	T-SGTR	AR1	HUM		
43	3.20E-08	T-SGTR	AR1	HUM		
44	3.20E-08	T-SGTR	AR1	HUM		
45	2.90E-08	T-SGTR	HUM			
46	2.16E-08	T-SGTR	HPI	HUM		
47	2.08E-08	T-SGTR	HPI	HUM		
48	1.60E-08	T-SGTR	TB	HUM		
49	1.39E-08	T-SGTR	HUM			
50	1.28E-08	T-SGTR	HPI	HUM		
51	1.53E-07	T-IFL	ESW	SW2	HUM	
52	1.53E-07	T-IFL	ESW	HUM		
53	1.53E-07	T-IFL	ESW	HUM		
54	1.03E-07	T-IFL	ESW	AM1	HUM	
55	1.03E-07	T-IFL	ESW	SW2	AM1	HUM
56	1.03E-07	T-IFL	ESW	AM1	HUM	
57	1.02E-07	T-IFL	ESW	SW2	HUM	
58	9.18E-08	T-IFL	ESW	HUM		
59	7.44E-08	T-IFL	ESW	AM1	HUM	
60	7.44E-08	T-IFL	ESW	AM1	HUM	

Table D-2j (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
61	7.44E-08	T-IFL	ESW	SW2	AM1	HUM
62	7.05E-08	T-IFL	AC	EAC	HUM	
63	6.80E-08	T-IFL	ESW	SW2	HUM	
64	6.80E-08	T-IFL	ESW	SW2	HUM	
65	6.80E-08	T-IFL	ESW	HUM		
66	6.80E-08	T-IFL	ESW	HUM		
67	6.80E-08	T-IFL	ESW	HUM		
68	6.80E-08	T-IFL	ESW	SW2	HUM	
69	6.80E-08	T-IFL	ESW	HUM		
70	6.80E-08	T-IFL	ESW	HUM		
71	6.80E-08	T-IFL	ESW	SW2	HUM	
72	6.12E-08	T-IFL	ESW	AM1	HUM	
73	6.12E-08	T-IFL	ESW	AM1	HUM	
74	6.12E-08	T-IFL	ESW	AM1	HUM	
75	6.12E-08	T-IFL	ESW	SW2	AM1	HUM
76	6.12E-08	T-IFL	ESW	SW2	AM1	HUM
77	6.12E-08	T-IFL	ESW	AM1	HUM	
78	5.58E-08	T-IFL	HUM			
79	5.53E-08	T-IFL	AC	EAC	HUM	
80	5.44E-08	T-IFL	ESW	SW2	HUM	
81	5.10E-08	T-IFL	ESW	HUM		
82	5.10E-08	T-IFL	ESW	SW2	HUM	
83	5.10E-08	T-IFL	ESW	HUM		
84	5.05E-08	T-IFL	ESW	EAC	HUM	
85	4.90E-08	T-IFL	ESW	SW2	HUM	
86	4.75E-08	T-IFL	ESW	SW2	HUM	
87	4.65E-08	T-IFL	AC	EAC	HUM	
88	4.59E-08	T-IFL	ESW	AM1	HUM	
89	4.59E-08	T-IFL	ESW	AM1	HUM	

Table D-2j (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
90	4.59E-08	T-IFL	ESW	SW2	AM1	HUM
91	4.76E-08	T-LOOP	EAC	EDC	HUM	
92	4.45E-08	T-IA	IA	AM1	HUM	
93	4.37E-08	T-LOOP	AC	HUM		
94	3.77E-08	T-LOOP	EAC	EDC	ACBU1	
95	3.76E-08	T-IFL	ESW	SW2	HUM	
96	3.76E-08	T-IFL	ESW	HUM		
97	3.76E-08	T-IFL	ESW	HUM		
98	3.76E-08	T-IFL	ESW	HUM		
99	3.76E-08	T-IFL	ESW	HUM		
100	3.76E-08	T-IFL	ESW	SW2	HUM	
101	3.75E-08	T-UHS	PSRV	HUM		
102	3.74E-08	T-IFL	AM1	HUM		
103	3.70E-08	T-LOOP	EAC	EDC		
104	3.67E-08	T-IFL	ESW	SW2	HUM	
105	3.67E-08	T-IFL	ESW	HUM		
106	3.67E-08	T-IFL	ESW	HUM		
107	3.67E-08	T-IFL	ESW	SW2	HUM	
108	3.67E-08	T-IFL	ESW	HUM		
109	3.67E-08	T-IFL	ESW	HUM		
110	3.66E-08	T-LOOP	EAC	EDC	SDAFW	HUM
111	3.65E-08	T-RX	AC	EAC	HUM	
112	3.56E-08	T-IA	HUM			
113	3.56E-08	T-IA	HUM			
114	3.52E-08	T-LOOP	EAC	EDC	ACBU1	SDAFW
115	3.51E-08	T-LMFW	PSRV	MFW		
116	2.15E-06	T-IFL				
117	1.16E-06	REMAINDER				

Table D-2k RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plants 15 and 16 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
1	6.47E-07	T-LOOP	AC	EDC	HUM		
2	3.61E-07	T-TT	HPCI(HPCS)	RCIC	MFW	HUM	
3	3.55E-07	T-LMFW	HPCI(HPCS)	RCIC	HUM		
4	3.38E-07	T-MSIV	RPS	ARI	HUM		
5	3.35E-07	T-LOOP	AC	HPCI(HPCS)	RCIC	HUM	
6	3.23E-07	T-LOOP	EAC	EDC			
7	2.59E-07	T-MSIV	HPCI(HPCS)	RCIC	HUM		
8	2.59E-07	A	LPCI	CS	CTS		
9	2.49E-07	T-UHS	HPCI(HPCS)	RCIC	HUM		
10	1.92E-07	T-TT	RPS	ARI	SRVS	HUM	
11	1.74E-07	T-LMFW	CRDS	HPCI(HPCS)			
12	1.56E-07	T-LOOP	AC	EDC	HUM		
13	1.32E-07	T-LOOP	EAC	EDC			
14	1.28E-07	S1	ADS	HPCI(HPCS)			
15	1.09E-07	T-TT	RPS	ARI	HUM		
16	1.05E-07	T-IORV/SORV	SPC	HUM			
17	1.00E-07	T-TT	RPS	ARI	SRVS	HPCI(HPCS)	
18	9.00E-08	A					
19	8.35E-08	T-TT	RPS	ARI	HUM		
20	6.65E-08	T-IFL	AC	EAC	HPCI(HPCS)	RCIC	HUM
21	6.26E-08	T-LOOP	AC	HPCI(HPCS)	RCIC	HUM	
22	5.61E-08	T-TT	RPS	ARI	HUM		
23	5.35E-08	T-TT	RPS	ARI	SPC	HUM	
24	1.93E-09	V-LPI	LPCI				
25	1.50E-09	V-HPI	LPCI				
26	8.05E-08	T-IFL					
27	8.12E-07	REMAINDER					

Table D-21 RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - WE 2-Lp Plants 5 and 6 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
1	1.00E-05	T-IFL	IA			
2	4.40E-07	T-IA				
3	5.00E-06	T-LOOP	AC	MDAFW	SDAFW	HUM
4	3.00E-06	T-IA	IA			
5	1.56E-06	T-RX	MFW	MDAFW	SDAFW	HUM
6	2.50E-06	A	HUM			
7	2.20E-06	S1	HUM			
8	1.20E-06	A	LPR			
9	2.40E-06	S1	LPR			
10	6.30E-07	T-ESW	CCW	HVAC1		
11	2.43E-06	T-RX	RCPS	CHPI	HPI	
12	2.05E-06	T-LOOP	AC	HVAC1		
13	1.39E-06	T-DC	DC	ESW		
14	1.70E-06	S2	HPI			
15	1.10E-06	T-SGTR	SGS	HUM		
16	3.90E-06	T-SGTR	SGS	HUM		
17	8.00E-07	T-SGTR	PPORV	AR1		
18	2.00E-07	T-SGTR	PPORV	SGA		
19	2.30E-07	T-LOOP	EAC	EDC	HUM	
20	2.39E-06	T-LOOP	EAC	EDC	HUM	
21	1.80E-07	T-LOOP	EAC	EDC	SDAFW	
22	3.50E-07	S2	HPR	AR1		
23	1.13E-06	S2	HVAC1	HPR		
24	9.23E-07	S2	HPR	AR1		
25	2.40E-08	T-LOOP	AC	CCW		
26	7.76E-07	T-LOOP	AC	HPR	LPR	

Table D-2l (Continued)

IE RBPI
Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
27	3.50E-08	T-SGTR		HPI	HUM	
28	5.65E-07	T-SGTR		NISP	MDAFW	HUM
29	2.60E-08	T-LOOP	EAC	EDC	RCPS	
30	2.34E-07	T-LOOP	RCPS			
31	5.50E-08	V-RHR	LPR			
32	1.75E-07	V-RHR	LPR			
33	8.30E-08	T-RX	RPS	HUM		
34	7.70E-08	T-RX	RPS	HUM		
35	2.80E-08	T-LMFW	RPS	PSRV	PPORV	
36	1.32E-07	T-RX	RPS	PSRV	PPORV	
37	2.10E-08	A	LPI			
38	5.50E-08	S1	HPI	LPI		
39	1.50E-10	T-IFL	MDAFW	SDAFW	HUM	
40	5.70E-10	T-IFL	MDAFW	SDAFW		

Table D-2m RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - BWR 3/4 Plants 18 and 19 (IPE Data Base Results)

IE RBPI
Indudstry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES			
1	5.28E-07	T-LOOP	AC	EAC		
2	1.60E-07	S1	HUM			
3	2.70E-08	T-LOOP	HPI	HUM	AC	
4	2.21E-08	T-LOOP	AC	EAC		
5	2.05E-08	T-ATWS	RPS	CONDA	HUM	
6	1.80E-08	T-LOOP	HPCI(HPCS)	RCIC	AC	EAC
7	1.34E-08	T-LOOP	HPI	HUM	AC	
8	1.16E-08	T-RX	ADS	DC		

Table D-2m (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
9	1.10E-08	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
10	8.96E-09	T-LOOP	HP1	LPCI	SPC	AC	
11	8.12E-09	T-RX	DC				
12	7.76E-09	T-ATWS	RPS	LPCI	CS	CONDA	HUM
13	7.59E-09	T-LOOP	SPC	HUM	AC		
14	7.00E-09	T-LOOP	HP1	SPC	HUM	AC	
15	6.90E-09	T-LOOP	HP1	SPC	HUM	AC	
16	6.72E-09	T-LOOP	HP1	HUM	AC		
17	6.13E-09	T-ATWS	RPS	CONDA	HUM		
18	5.83E-09	T-ATWS	RPS	CONDA	HUM		
19	5.77E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
20	5.66E-09	A	LPCI	CS			
21	5.53E-09	T-LOOP	HPCI(HPCS)	RCIC	HUM	AC	
22	5.43E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
23	5.10E-09	T-RX	HPCI(HPCS)	RCIC	HP1	HUM	
24	5.02E-09	S2	HPCI(HPCS)	HUM			
25	4.60E-09	A	SPC	AC			
26	4.46E-09	T-LOOP	HP1	LPCI	SPC	AC	
27	4.44E-09	T-LOOP	LPCI	SPC	HUM	AC	
28	3.88E-09	T-ATWS	RPS	HP1	CONDA	HUM	
29	3.83E-09	S1	HPCI(HPCS)	HUM			
30	3.78E-09	T-LOOP	SPC	HUM	AC		
31	3.62E-09	T-ATWS	RPS	HPCI(HPCS)	CONDA	HUM	
32	3.46E-09	T-LOOP	HP1	HUM	AC		
33	3.42E-09	T-LOOP	SPC	HUM	AC		
34	3.38E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	HUM
35	3.33E-09	T-LOOP	LPCI	SPC	HUM	AC	
36	3.33E-09	T-LOOP	HP1	HUM	AC		
37	2.86E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
38	2.77E-09	T-LOOP	LPCI	SPC	HUM	AC	
39	2.63E-09	T-LOOP	HPCI(HPCS)	RCIC	HUM	AC	
40	2.57E-09	T-RX	HPCI(HPCS)	RCIC	HUM		
41	2.57E-09	A	SPC				

Table D-2m (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
42	2.42E-09	T-LOOP	HP1	LPCI	SPC	HUM	AC
43	2.40E-09	T-LOOP	HUM	AC			
44	2.26E-09	T-LOOP	HP1	HUM	AC		
45	2.21E-09	T-ATWS	RPS	CONDA	HUM		
46	2.16E-09	S2	HPCI(HPCS)	MFW	HUM		
47	2.15E-09	T-LOOP	HPCI(HPCS)	HP1	AC	EAC	
48	2.10E-09	A	HUM				
49	2.08E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	HUM
50	2.05E-09	T-LOOP	HP1	HUM	AC		
51	1.97E-09	T-LOOP	HP1	LPCI	SPC	AC	
52	1.96E-09	T-LOOP	HP1	LPCI	SPC	AC	
53	1.90E-09	T-LOOP	HUM	AC			
54	1.89E-09	T-LOOP	HP1	SPC	HUM	AC	
55	1.82E-09	T-ATWS	RPS	SLC	CONDA		
56	1.79E-09	T-LOOP	HP1	SPC	AC		
57	1.74E-09	T-ATWS	RPS	MFW	CONDA	HUM	
58	1.72E-09	T-LOOP	HP1	SPC	HUM	AC	
59	1.70E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HUM	
60	1.66E-09	T-LOOP	HP1	LPCI	SPC	HUM	AC
61	1.62E-09	T-ATWS	RPS	RECIRC	CONDA		
62	1.50E-09	T-LOOP	HP1	SPC	HUM	AC	
63	1.43E-09	T-ATWS	RPS	MFW	HUM		
64	1.39E-09	A	HUM				
65	1.38E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HP1	HUM
66	1.33E-09	T-LOOP	HP1	HUM	AC		
67	1.19E-09	T-ATWS	RPS	HUM			
68	1.15E-09	T-LOOP	HP1	LPCI	SPC	VENT	AC
69	1.14E-09	T-LOOP	HUM	AC			
70	1.13E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
71	1.13E-09	A	LPCI	CS	DC		
72	1.13E-09	T-LOOP	HP1	HUM	AC		
73	1.12E-09	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
74	1.10E-09	T-LOOP	HP1	SPC	HUM	AC	

Table D-2m (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
75	1.10E-09	T-ATWS	RPS	MFW	HP1	CONDA	HUM
76	1.09E-09	T-LOOP	HP1	HUM	AC		
77	1.05E-09	T-RX	HPCI(HPCS)	RCIC	MFW	HUM	
78	1.03E-09	T-LOOP	HP1	SPC	HUM	AC	
79	1.03E-09	T-ATWS	RPS	HPCI(HPCS)	MFW	CONDA	HUM
80	1.03E-09	T-LOOP	HP1	HUM	AC	NSW	
81	1.02E-09	T-LOOP	HP1	HUM	AC		
82	1.01E-09	T-LOOP	HP1	AC			
83	9.90E-10	T-LOOP	HP1	LPCI	SPC	AC	
84	9.80E-10	T-LOOP	HP1	SPC	AC		
85	9.75E-10	T-LOOP	HP1	LPCI	SPC	AC	
86	9.53E-10	S2	HPCI(HPCS)	MFW	HUM		
87	9.41E-10	T-LOOP	HP1	SPC	DWS	HUM	AC
88	9.41E-10	T-LOOP	HP1	HUM	AC		
89	9.18E-10	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
90	9.15E-10	A	SPC	AC			
91	9.03E-10	T-LOOP	HUM	AC			
92	8.85E-10	T-LOOP	HP1	SPC	DWS	AC	
93	8.62E-10	T-ATWS	RPS	CONDA	HUM		
94	8.50E-10	T-LOOP	HP1	SPC	HUM	AC	
95	8.16E-10	T-LOOP	HP1	LPCI	CS	AC	
96	8.00E-10	T-LOOP	AC	EAC			
97	7.93E-10	T-LOOP	LPCI	CS	HUM	AC	
98	7.88E-10	T-LOOP	HPCI(HPCS)	RCIC	HP1	HUM	AC
99	7.55E-10	A	SPC				
100	7.28E-10	T-LOOP	HP1	HUM	AC		
101	1.52E-07	REMAINDER					
102		T-IFL					

Table D-2n RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences WE 4-Lp Plants 22 and 23 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
1	2.14E-05	T-CCW	HUM	CCW	
2	1.27E-05	S2	HUM		
3	5.99E-06	T-CCW	HUM	CCW	
4	3.98E-06	T-AC	SDAFW	HVAC1	
5	3.26E-06	S2	HUM		
6	2.88E-06	T-SGTR	SGS	HUM	
7	2.56E-06	T-CCW	HUM		
8	2.38E-06	T-AC	ESW		
9	2.12E-06	T-CCW	HUM	CCW	
10	1.90E-06	T-AC	HUM	HVAC1	
11	1.80E-06	T-AC	ESW		
12	1.77E-06	T-AC	HUM	CCW	
13	1.69E-06	T-CCW	HUM	CCW	
14	1.30E-06	S1	HUM		
15	1.29E-06	T-CCW	HUM	CCW	
16	1.22E-06	T-DC	MDAFW	SDAFW	HUM
17	1.16E-06	T-AC	AC	EAC	
18	1.14E-06	T-CCW	HUM	CCW	
19	1.07E-06	T-IFL	ESW		
20	1.06E-06	T-IFL	ESW		
21	9.84E-07	T-CCW	HUM	CCW	
22	9.59E-07	T-LOOP	AC	ESW	
23	9.51E-07	T-ESW	ESW		
24	8.94E-07	T-AC	AC	EAC	
25	8.61E-07	T-RX	ESW		
26	8.50E-07	S2			
27	8.46E-07	S2			
28	7.78E-07	T-TT	ESW		
29	7.70E-07	S2	HUM		
30	7.37E-07	T-DC	MDAFW	SDAFW	HUM
31	7.19E-07	T-CCW	HUM	CCW	
32	5.96E-07	T-AC	HVAC1		
33	5.95E-07	T-CCW	HUM	CCW	

Table D-2n (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES				
34	5.93E-07	T-LMFW	ESW				
35	5.56E-07	T-AC	CCW				
36	5.42E-07	T-AC	ESW				
37	5.39E-07	T-LOOP	AC	EAC			
38	5.34E-07	T-AC	HUM	CCW			
39	5.13E-07	T-LOOP	AC	EAC			
40	5.10E-07	A	ACC				
41	4.99E-07	T-LOOP	SDAFW	HVAC1			
42	4.85E-07	T-SGTR	LPR	HUM			
43	4.84E-07	T-TT	RPS	PPORV	MDAFW	SDAFW	HUM
44	4.77E-07	T-IFL	HVAC1				
45	4.75E-07	T-CCW	HUM	CCW			
46	4.75E-07	T-CCW	HUM	CCW			
47	4.73E-07	T-CCW	HUM	CCW			
48	4.52E-07	T-IFL	CCW				
49	4.32E-07	S2					
50	4.27E-07	T-RX	HVAC1				
51	4.25E-07	T-LOOP	AC	EAC			
52	4.05E-07	A					
53	3.86E-07	T-TT	CCW				
54	3.66E-07	S1	HUM				
55	3.64E-07	T-LOOP	SDAFW	HVAC1			
56	3.62E-07	T-CCW	HUM	CCW			
57	3.58E-07	T-IFL	CCW				
58	3.53E-07	T-MSIV	SDAFW	HVAC1			
59	3.47E-07	T-AC	HUM				
60	3.44E-07	T-RX	HUM	HVAC1			
61	3.42E-07	T-RX	HUM	HVAC1			
62	3.41E-07	T-SGTR	LPR	HUM			
63	3.39E-07	T-CCW	HUM	CCW			
64	3.23E-07	T-SGTR	LPR	HUM			
65	3.21E-07	T-IFL	SDAFW	HVAC1			
66	3.14E-07	T-SGTR	HUM				
67	3.13E-07	T-RX	CCW				

Table D-2n (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
68	3.12E-07	T-LMFW	RPS	PPORV	HUM
69	3.11E-07	T-TT	HUM	HVAC1	
70	3.09E-07	T-TT	HUM	HVAC1	
71	3.08E-07	T-TT	HUM	CCW	
72	3.06E-07	T-CCW	HUM	CCW	
73	2.94E-07	T-LMFW	ESW		
74	2.85E-07	T-CCW	HUM	CCW	
75	2.83E-07	T-TT	ESW		
76	2.79E-07	T-TT	HUM	CCW	
77	2.76E-07	T-CCW	HUM	CCW	
78	2.73E-07	T-LOOP	ESW		
79	2.68E-07	T-CCW	HUM	CCW	
80	2.63E-07	T-CCW	HUM	CCW	
81	2.63E-07	T-CCW	HUM	CCW	
82	2.56E-07	T-VAC	MDAFW	HUM	
83	2.52E-07	T-DC	MDAFW	SDAFW	HUM
84	2.40E-07	T-MSIV	HUM	HVAC1	
85	2.39E-07	T-AC	AC	EAC	
86	2.37E-07	T-LMFW	RPS	PPORV	
87	2.37E-07	T-LMFW	HUM	HVAC1	
88	2.35E-07	T-LMFW	HUM	HVAC1	
89	2.35E-07	T-CCW	HUM	CCW	
90	2.33E-07	T-SGTR	HUM		
91	2.31E-07	S2	HUM		
92	2.31E-07	S2	HUM		
93	2.31E-07	T-CCW	HUM	CCW	
94	2.31E-07	T-CCW	HUM	CCW	
95	2.28E-07	T-TT	RPS	PPORV	HUM
-96	2.27E-07	T-LOOP	ESW		
97	2.25E-07	T-LOOP	ESW		
98	2.24E-07	S2	HUM		
99	2.24E-07	T-CCW	HUM	CCW	
100	2.23E-07	S2	HUM		

Table D-2n (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES
102	6.08E-05	REMAINDER	
101	3.06E-06	T-IFL	

Table D-2o RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences - CE Plant 12 (IPE Data Base Results)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES	
1	9.98E-07	T-LOOP	EAC	EDC
2	7.73E-07	S3	CCW	
3	7.00E-07	S3	HPI	
4	7.00E-07	S3	HPR	AR1
5	5.95E-07	S3	HPI	
6	5.15E-07	T-LOOP	EAC	EDC
7	4.35E-07	S3	HPI	
8	4.26E-07	S3	ESAS1	
9	2.82E-07	T-CCW	CCW	HUM
10	2.73E-07	S3	ESW	
11	2.21E-07	S2	CCW	
12	2.00E-07	S2	HPI	
13	2.00E-07	S2	HPR	
14	1.99E-07	S3	HPI	
15	1.99E-07	S3	HPR	
16	1.97E-07	T-SLBOC	HPI	
17	1.45E-07	A	CCW	
18	1.31E-07	A	LPI	
19	1.31E-07	A	HPR	

Table D-2o (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
20	1.31E-07	A	HPR		
21	1.28E-07	T-DC	DC	EDC	
22	1.28E-07	T-DC	DC	EDC	
23	1.24E-07	S2	HPI		
24	1.22E-07	T-SLBOC	HPI		
25	1.22E-07	S2	ESAS1		
26	1.14E-07	S2	HPI		
27	1.12E-07	T-SLBOC	HPI		
28	9.68E-08	A	ACC		
29	9.68E-08	A	ACC		
30	9.68E-08	A	ACC		
31	9.68E-08	A	ACC		
32	9.68E-08	A	ACC		
33	9.68E-08	A	ACC		
34	9.68E-08	A	ACC		
35	9.68E-08	A	ACC		
36	9.68E-08	A	ACC		
37	9.68E-08	A	ACC		
38	9.68E-08	A	ACC		
39	9.68E-08	A	ACC		
40	9.38E-08	T-LOOP	EAC	EDC	HUM
41	9.35E-08	T-LOOP	EAC	EDC	
42	8.14E-08	A	HPR		
43	8.04E-08	T-ESW	ESW	HUM	
44	7.98E-08	A	ACC		
45	7.98E-08	A	ACC		
46	7.80E-08	S2	ESW		

Table D-2o (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
47	7.47E-08	A	HPR		
48	7.34E-08	T-LOOP	EAC	EDC	HUM
49	7.32E-08	T-LOOP	EAC	EDC	
50	7.07E-08	S3	HPR		
51	7.07E-08	S3	HPR		
52	7.03E-08	S3	CCW		
53	7.03E-08	S3	ESW		
54	6.66E-08	T-DC	DC	EDC	
55	6.66E-08	T-DC	DC	EDC	
56	6.54E-08	S3			
57	6.54E-08	S3			
58	6.48E-08	T-SGTR	CHPI	HPI	
59	6.48E-08	T-SGTR	CHPI	HPI	
60	6.35E-08	A	LPI		
61	5.78E-08	S3	HPR	AR1	
62	5.68E-08	T-LOOP	EAC	EDC	HUM
63	5.68E-08	T-LOOP	EAC	EDC	HUM
64	5.66E-08	T-LOOP	EAC	EDC	
65	5.66E-08	T-LOOP	EAC	EDC	
66	5.27E-08	A	LPI		
67	5.22E-08	S3	HPI		
68	5.22E-08	S3	HPI		
69	5.11E-08	A	ESW		
70	4.89E-08	T-DC	MDAFW	SDAFW	
71	4.89E-08	T-DC	MDAFW	SDAFW	
72	4.84E-08	T-LOOP	EAC	EDC	HUM
73	4.83E-08	A	LPI		

Table D-2o (Continued)

IE RBPI
Industry-Wide Trending
System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES		
74	4.83E-08	S3	HPR		
75	4.83E-08	S3	HPR		
76	4.82E-08	T-LOOP	EAC	EDC	
77	4.69E-08	T-DC	MDAFW	SDAFW	
78	4.69E-08	T-DC	MDAFW	SDAFW	
79	4.37E-08	T-DC	DC	EDC	HUM
80	4.27E-08	S3	HPR		
81	4.27E-08	S3	HPR		
82	4.13E-08	T-LMFW	RPS		
83	4.13E-08	T-LMFW	RPS		
84	3.64E-08	S3	HPI		
85	3.64E-08	S3	HPI		
86	3.40E-08	T-DC	MDAFW	SDAFW	
87	3.40E-08	T-DC	MDAFW	SDAFW	
88	3.37E-08	S3	HPR		
89	3.37E-08	S3	HPR		
90	3.32E-08	S3	HUM		
91	3.32E-08	S3	HUM		
92	3.29E-08	T-LOOP	EAC	EDC	HUM
93	3.29E-08	T-LOOP	EAC	EDC	HUM
94	3.28E-08	T-LOOP	EAC	EDC	
95	3.28E-08	T-LOOP	EAC	EDC	
96	3.18E-08	T-DC	MDAFW	SDAFW	
97	3.18E-08	T-DC	MDAFW	SDAFW	
98	3.15E-08	S3	HPI		
99	3.11E-08	T-DC	MDAFW	SDAFW	
100	3.11E-08	T-DC	MDAFW	SDAFW	

Table D-2o (Continued)

IE RBPI

Industry-Wide Trending

System RBPI

SEQ	CDF	INITIATOR	ACCIDENT SEQUENCE FAILURES
101	3.10E-08	T-RX	RPS
102	3.10E-08	T-RX	RPS
103	3.08E-08	S3	HUM
104	3.08E-08	S3	HUM
105	3.01E-08	A	LPI
106	1.62E-06	V-AR1	AR1
107	1.21E-07	V-HPI	HPI
109	7.90E-06	REMAINDER	
108	5.00E-07	T-[illegible]	

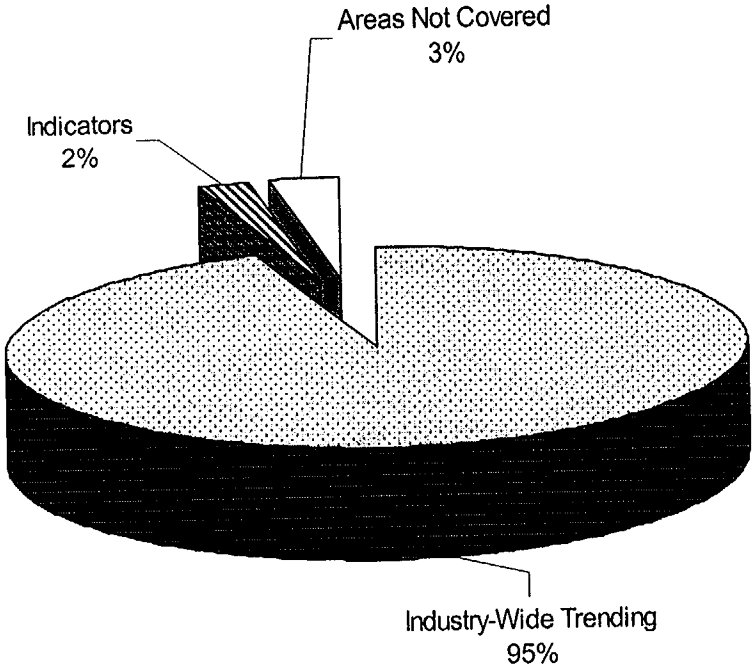

Figure D-1a RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for WE 4-Lp Plants 1&2

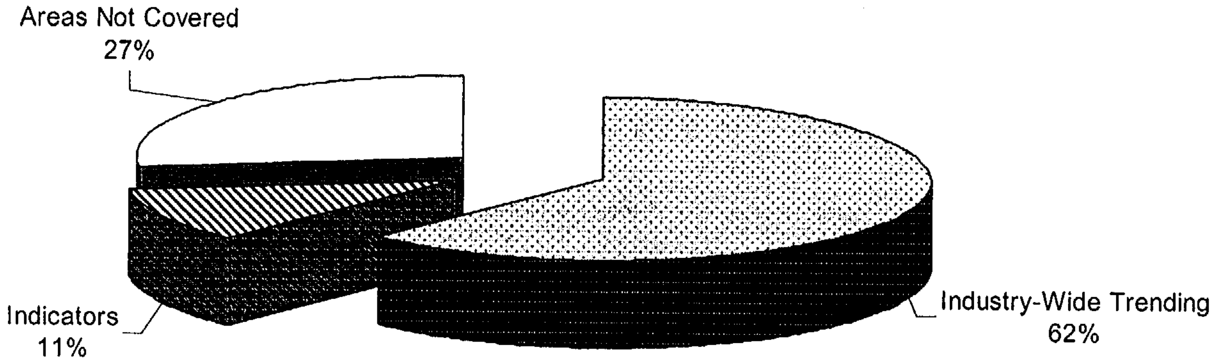

Figure D-1b RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for CE Plants 2&3

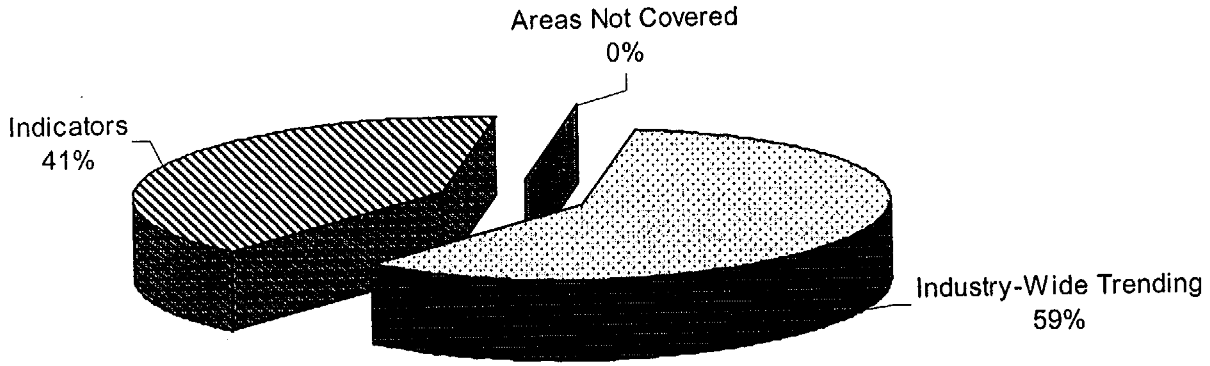

Figure D-1c RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plant 5

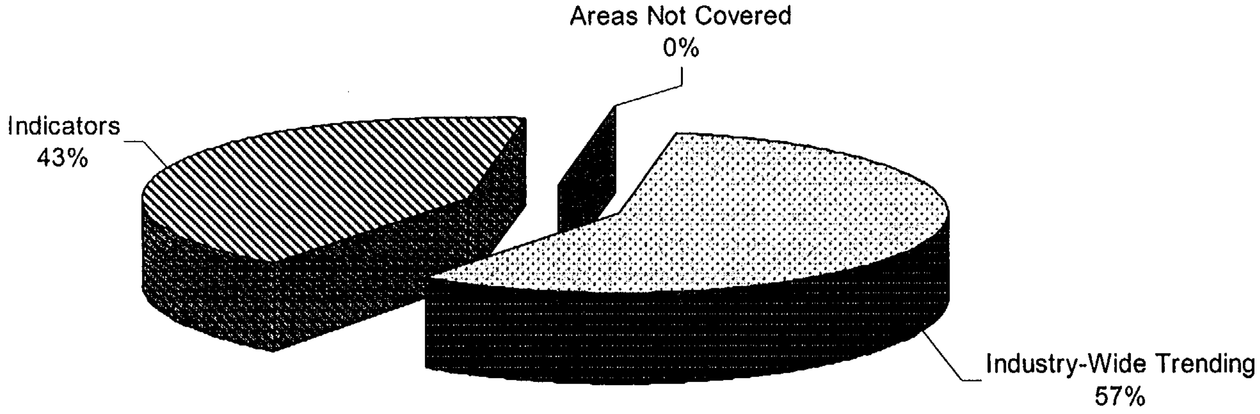

Figure D-1d RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plant 6

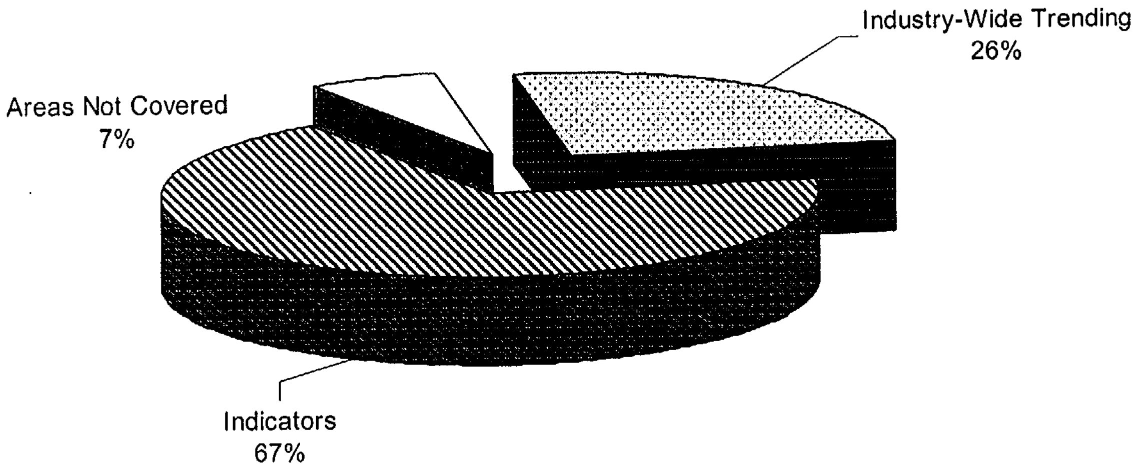

Figure D-1e RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for CE Plant 4

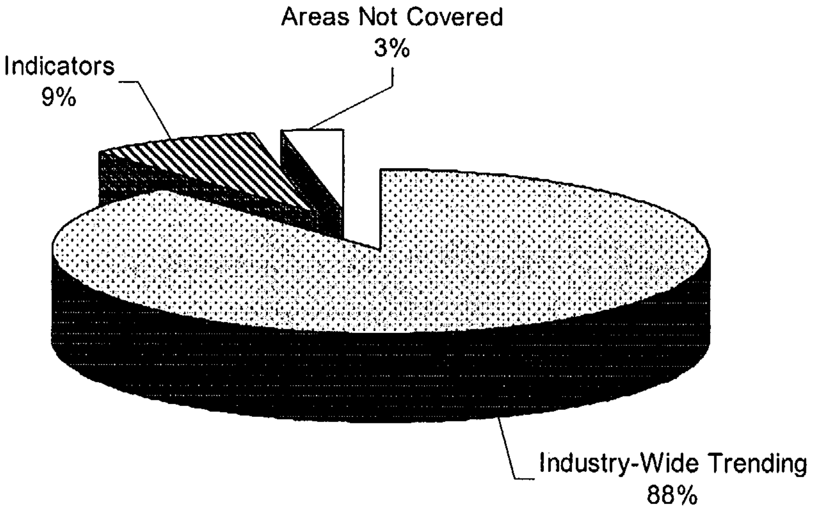

Figure D-1f RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 5/6 Plant 2

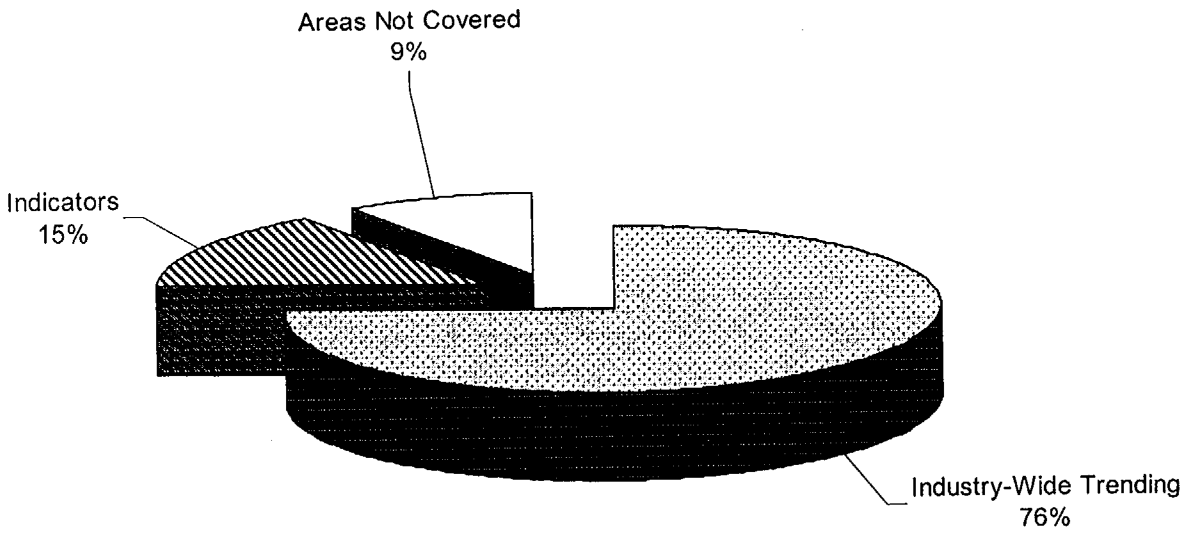

Figure D-1g RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plant 11

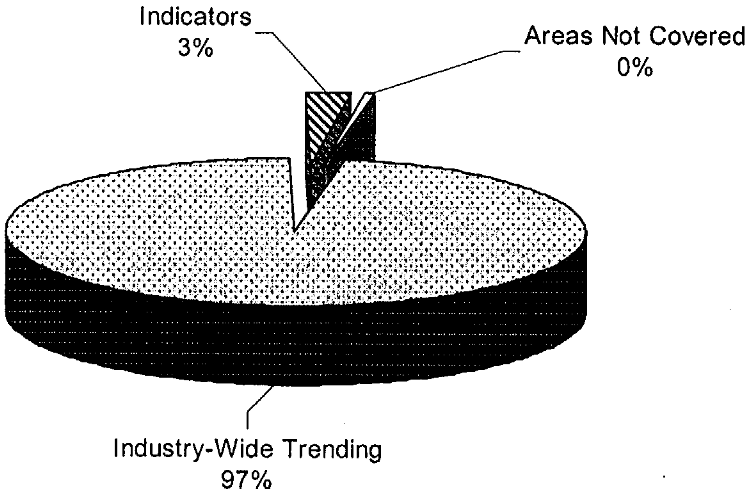

Figure D-1h RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plant 8

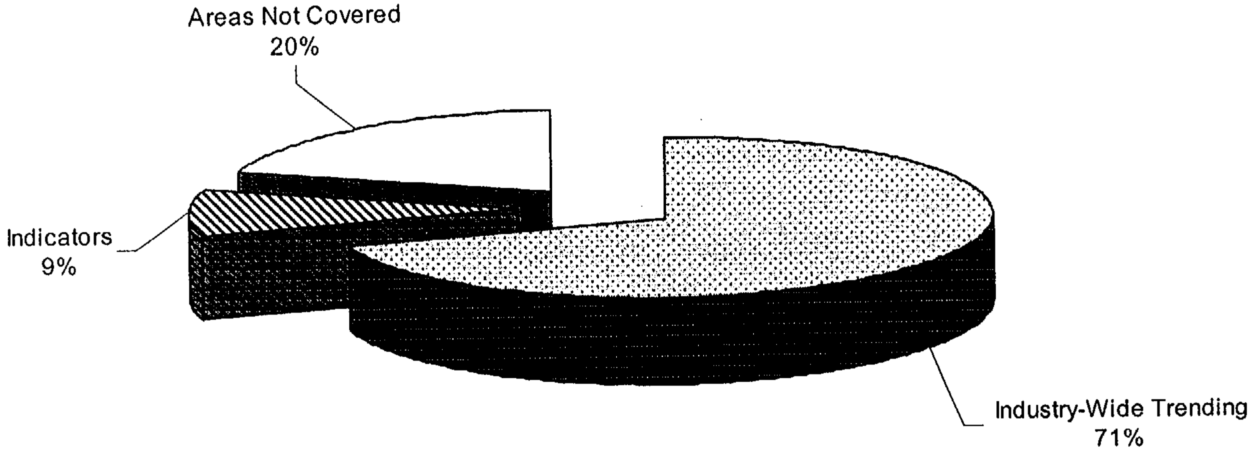

Figure D-1i RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for CE Plant 5

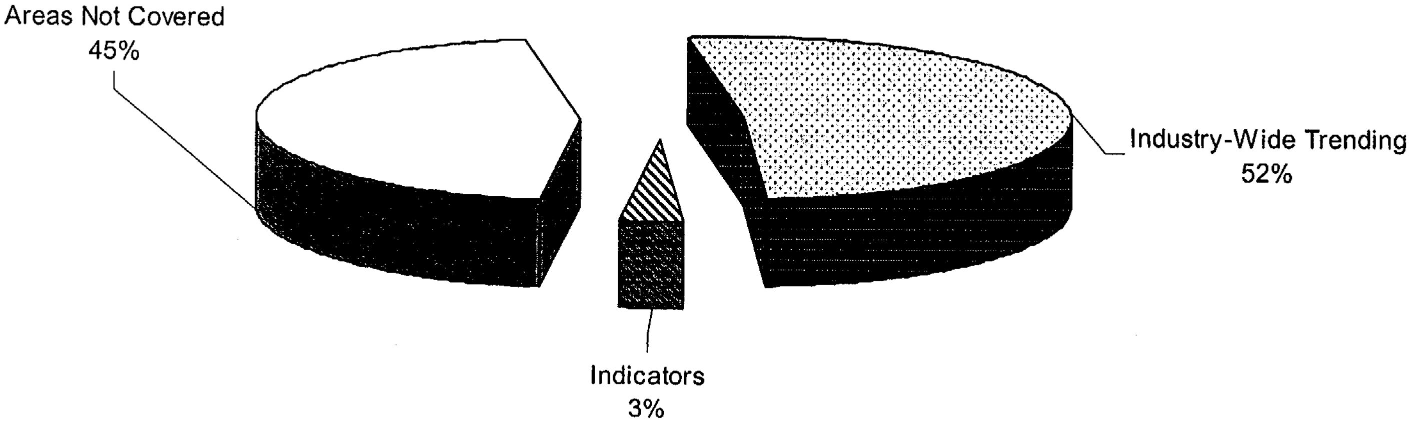

Figure D-1j RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for B&W Plants 4,5&6

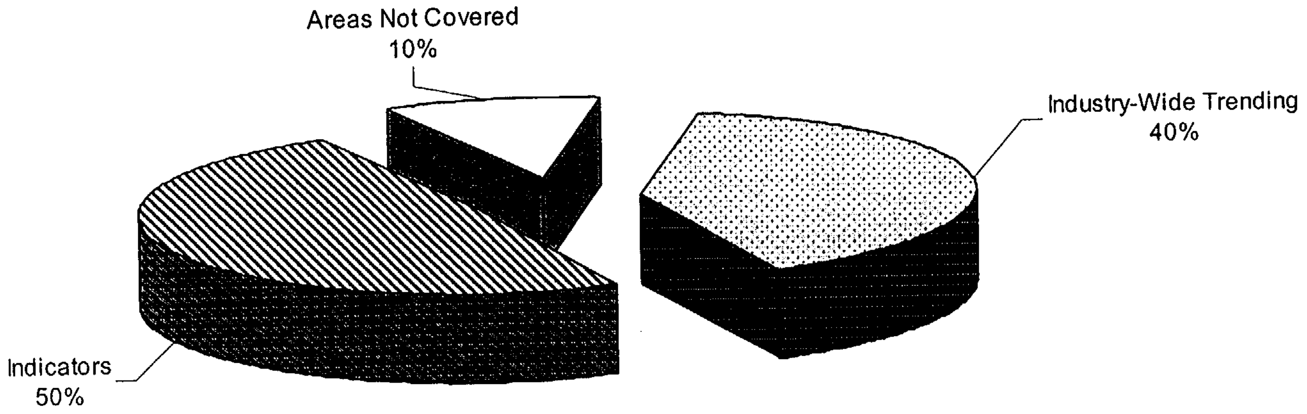

Figure D-1k RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plants 15&16

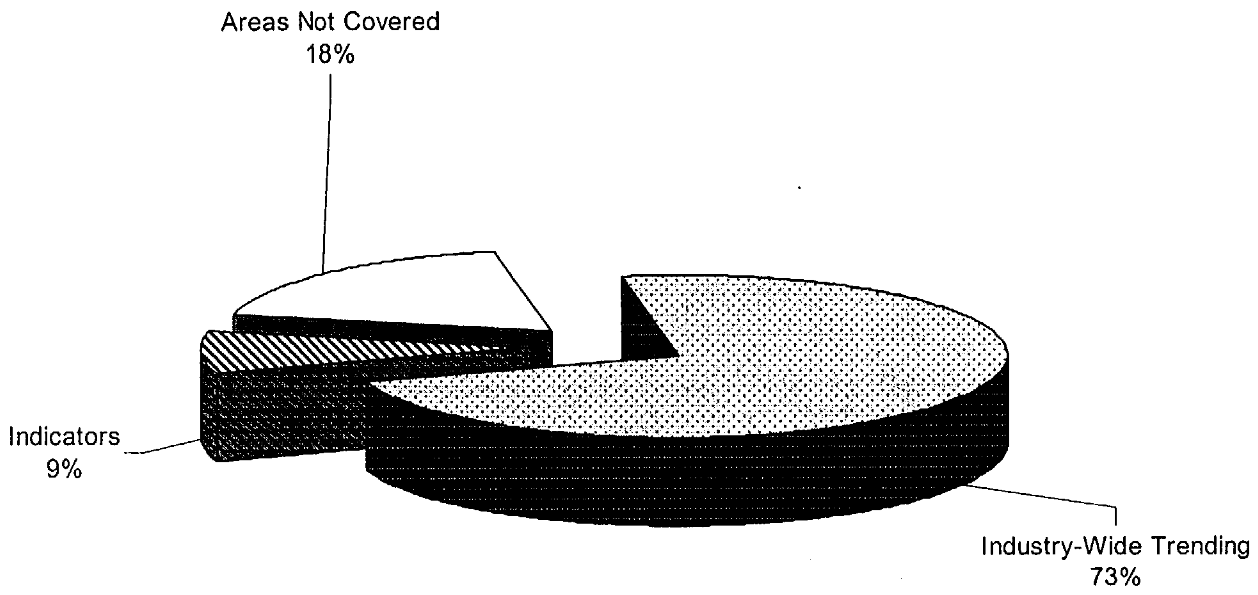

Figure D-11 RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for WE 2-Lp Plants 5&6

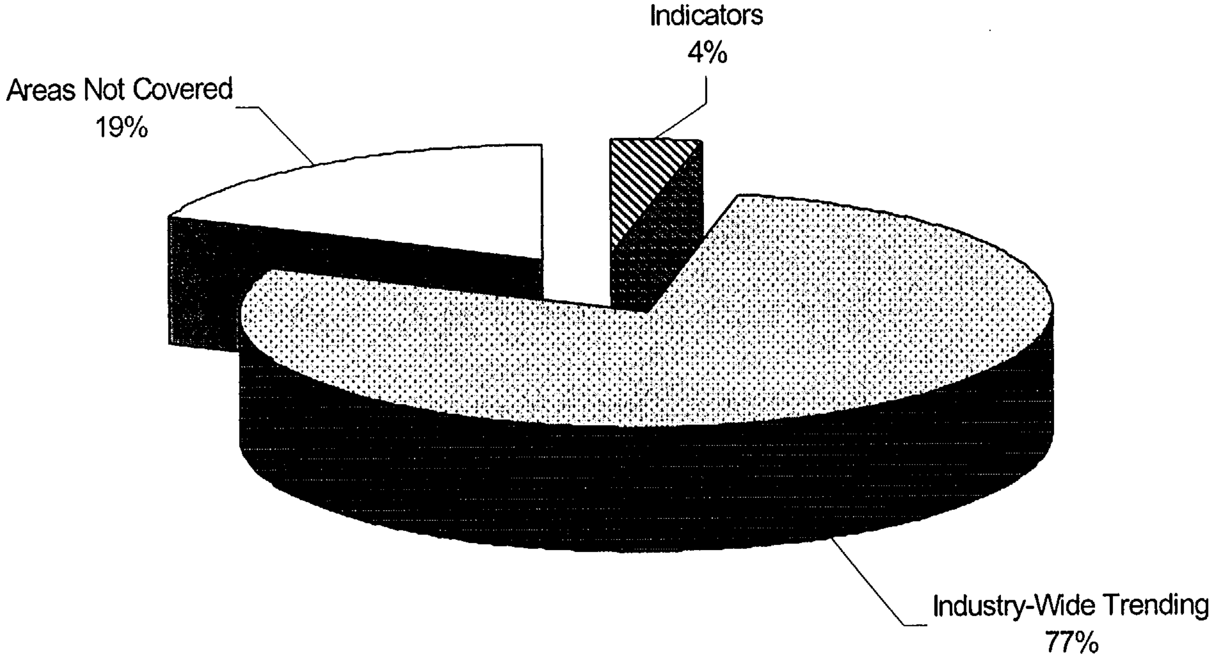

Figure D-1m RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for BWR 3/4 Plants 18&19

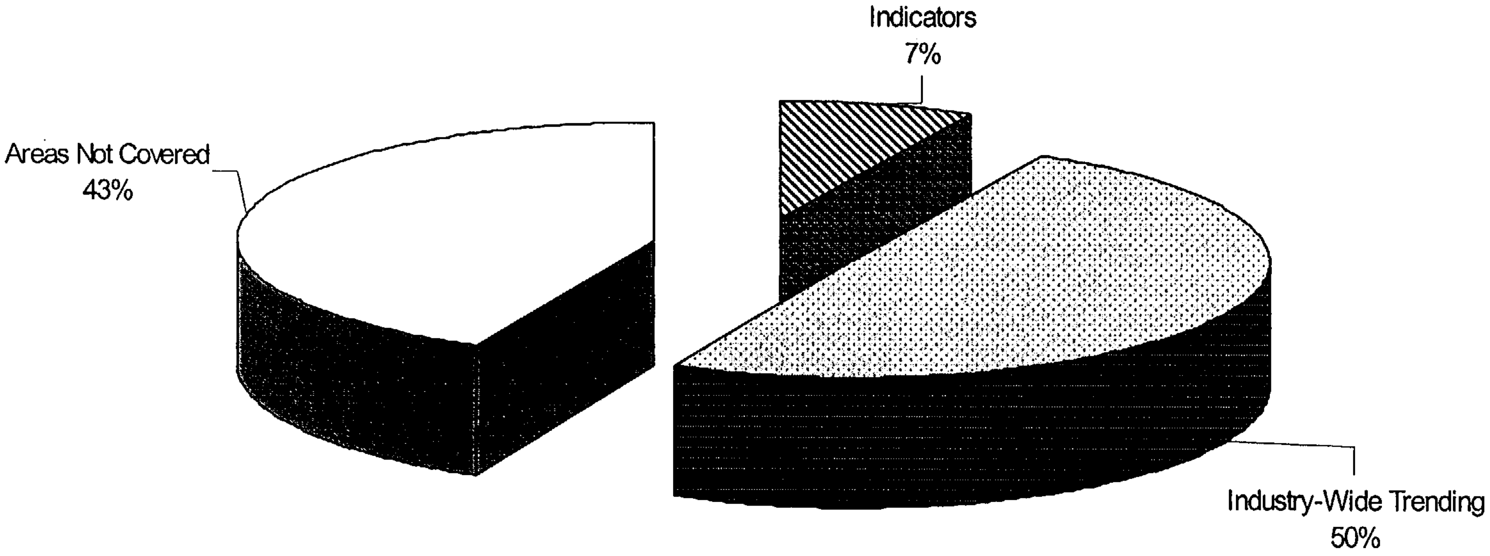

Figure D-1n RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for WE 4-Lp Plants 22&23

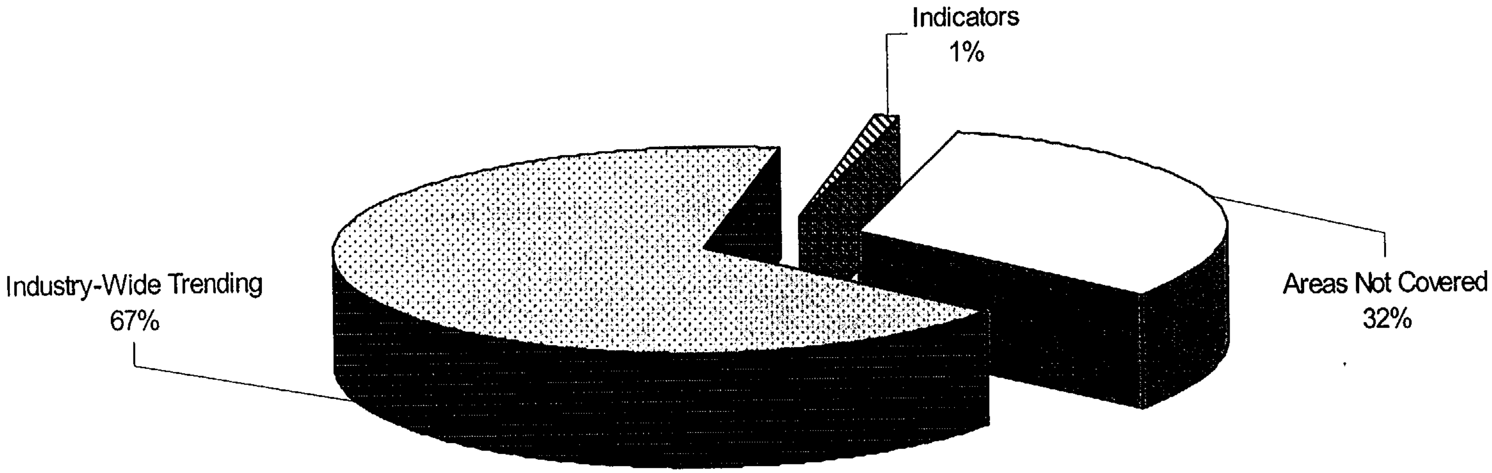

Figure D-1o RBPI Coverage of Dominant Full Power Internal Event Core Damage Sequences by Initiating Events for CE Plant 12

Table D-3 Mitigating System Elements That Appear in Dominant Core Damage Sequences but Are Not Covered by RBPIs

PWRs	
Element	**Reason for No RBPI**
Post-Accident Human Action	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Steam Generator Safety Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Vital AC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Heating/Ventilation/Air Conditioning	Loss of HVAC with support systems available is not risk-significant at most plants
Reactor Protection System	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Plant-specific Other Onsite AC Backup	Not generically important
Plant-specific Alternate Makeup	Not generically important
Plant-specific Alternate Recirculation	Not generically important
Plant-specific Auxiliary Cooling	Not generically important
Boron Injection	Not generically important
Normally Running Makeup	Not generically important
Containment Spray Recirculation	Not generically important
DC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Battery-backed DC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Engineered Safety Actuation System	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Instrument Air Compressors	Not generically important (and industry-trended as initiating event)
Low Pressure Injection	Most hardware shared with Residual/Decay Heat Removal, which is covered by an RBPI
Main Feedwater Pumps	Data not currently available to support RBPI quantification of post-accident reliability; monitored as initiating event RBPI
Main Steam Isolation Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Non-1E Startup Pumps	Not generically important
Plant-specific Alternate Air Systems	Not generically important
Pressurizer Safety Relief Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Reactor Coolant Pump Seals	Not generically important
Steam Generator Atmospheric Dump Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Plant-specific Alternate Service Water Systems	Not generically important
Turbine Bypass Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Vital Instrument AC	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Safety Injection System Accumulators	Not amenable to PI treatment (timely quantification directly from performance data not possible)

Table D-3 (Continued)

BWRs	
Element	**Reason for No RBPI**
Post-Accident Human Action	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Reactor Protection System	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Vital AC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Automatic Depressurization	Low potential for risk-significant impact
Plant-specific High Pressure Systems	Not generically important
Low Pressure Coolant Injection	Most hardware shared with Suppression Pool Cooling, which is covered by an RBPI
Main Feedwater	Data not currently available to support RBPI quantification
DC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Alternate Rod Insertion	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Alternate Suppression Pool Cooling	Not generically important
Plant-specific Auxiliary Cooling Systems	Not generically important
Control Rod Drive Pumps	Not generically important
Low Pressure Core Spray	Not generically important
Condensate Pumps	Not generically important
Battery-backed DC Buses	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Heating/Ventilation/Air Conditioning	Loss of HVAC with support systems available is not risk-significant at most plants
Instrument Air Compressors	Not generically important (and industry-trended as an initiating event)
Plant-specific Low Pressure Systems	Not generically important
Main Steam Isolation Valves	Not amenable to PI treatment (timely quantification directly from performance data not possible)
Reactor Building Closed Loop Cooling Water	Not generically important
Recirculation Pumps	Not generically important
Standby Liquid Control	Not generically important
Safety Relief Valves Steam	Not generically important
Plant-specific Alternate Service Water	Not generically important
Turbine Building Closed Loop Cooling Water	Not generically important
Drywell Spray	Most hardware shared with Suppression Pool Cooling, which is covered by an RBPI
Venting	Not amenable to PI treatment (timely quantification directly from performance data not possible)

D.1 References

1. Long, S. M., P. D. Reilly, E.G. Rodrick, and M. B. Sattison, "Current Status of the SAPHIRE Models for ASP Evaluations," Proceedings of the 4th International Conference on Probabilistic Safety Assessment and Management (PSAM 4), pp. 1195-1199, September 13-18, 1998.

2. Su, T. M., et al., "Individual Plant Examination Database – User's Guide," NUREG-1603, U.S. NRC, April 1997.

APPENDIX E

RBPI DATA COLLECTION AND ANALYSIS

Contents

Tables

Appendix E: RBPI Data Collection and Analysis

E.1 Data Collection Methodology

In order to validate the proposed risk-based performance indicators (RBPIs) developed for at power internal events, data were collected, analyzed, and compared with plant-specific thresholds. That process is summarized in Section 5 of the main report. This appendix presents the actual data collected for the 44 plants (30 sites) covered. The Standardized Plant Analysis Risk (SPAR) models (Ref. 1) used to develop thresholds were baselined to represent industry performance as of 1996. The data collection, in general, covers the period 1997 through 1999.

Proposed full power, internal event RBPIs include initiating events, mitigating system unavailabilities, mitigating system unreliabilities, and component class unreliabilities. The data sources used for each of these RBPI types are listed below:

1. Initiating events – U.S. Nuclear Regulatory Commission report on initiating event frequencies (Ref. 2) for 1997 and 1998; Reactor Oversight Program (ROP) web-based data (Ref. 3) for 1999 for general transient (GT) and loss of heat sink (LOHS). No data are available for loss of feedwater (LOFW) for 1999 (pending analysis of Licensee Event Reports).

2. Mitigating system unavailability – ROP web-based data for 1999.

3. Mitigating system unreliability – Equipment Performance and Information Exchange (EPIX) database (Ref. 4), as processed by the Reliability and Availability Database System (RADS) software (Ref. 5). The years 1997 through 1999 were covered.

4. Component class unreliability – Same as for mitigating system unreliability. The years 1997 through 1999 were covered.

Data collection periods, determined by statistical analyses summarized in Appendix F, are the following:

1. Initiating events – one year (1999) for GT and three years for LOHS and LOFW (1997 – 1999)

2. Mitigating system unavailability – one year (1999)

3. Mitigating system unreliability – three years (1997 – 1999)

4. Component class unreliability – three years (1997 – 1999).

E.2 Data Collection Results

Data collection results for the four types of RBPIs are presented in Tables E-1 through E-4.

Table E-1 Plant Data for Initiating Event RBPIs

Plant	GT[a]	LOHS[b]	LOFW[c]
BWRs			
BWR 123 Plant 1	0/8169h[d]	0/23627h	0/15458h
BWR 123 Plant 2	1/8056h	2/22394h	0/14338h
BWR 3/4 Plant 1	3/8087h	1/24979h	0/16892h
BWR 3/4 Plant 2	0/8760h	0/24987h	0/16227h
BWR 3/4 Plant 3	2/8551h	0/25063h	0/16512h
BWR 3/4 Plant 4	3/7716h	0/24206h	0/16490h
BWR 3/4 Plant 5	0/8596h	0/22638h	0/14042h
BWR 3/4 Plant 6	0/7389h	0/23243h	0/15854h
BWR 3/4 Plant 8	2/8367h	0/23605h	0/15238h
BWR 3/4 Plant 11	0/7598h	0/23005h	0/15407h
BWR 3/4 Plant 12	1/8642h	1/24579h	0/15937h
BWR 3/4 Plant 13	1/7863h	0/24385h	0/16522h
BWR 3/4 Plant 15	1/8664h	0/25316h	0/16652h
BWR 3/4 Plant 16	0/8157h	0/24484h	0/16327h
BWR 3/4 Plant 18	1/8246h	0/20533h	0/12287h
BWR 3/4 Plant 19	0/8562h	0/17573h	0/9011h
BWR 5/6 Plant 2	0/7124h	1/23669h	0/16545h
BWR 5/6 Plant 5	Data not gathered	0/15518h	0/15518h
BWR 5/6 Plant 8	0/6134h	0/19103h	No data
PWRs			
B&W Plant 3	0/8375h	0/23903h	0/15528h
B&W Plant 4	2/7521h	0/19394h	0/11873h
B&W Plant 5	4/7530h	1/21562h	0/14032h
B&W Plant 6	0/8691h	0/21941h	0/13250h
B&W Plant 7	0/7857h	0/24002h	0/16145h
CE Plant 1	0/7283h	0/23336h	0/16053h
CE Plant 2	1/8332h	2/24029h	0/15697h
CE Plant 3	0/7453h	0/23004h	0/15551h
CE Plant 4	0/7836h	0/23265h	0/15429h
CE Plant 5	1/5446h	0/5446h	No data
CE Plant 10	0/7505h	0/21582h	0/14077h

Table E-1 (Continued)

Plant	GT[a]	LOHS[b]	LOFW[c]
PWRs			
CE Plant 11	1/7721h	1/22544h	0/14823h
CE Plant 12	3/7849h	0/23151h	1/15302h
WE 2-Lp Plant 5	1/7701h	1/22748h	0/15047h
WE 2-Lp Plant 6	0/8726h	0/22555h	0/13829h
WE 3-Lp Plant 5	3/8575h	0/23534h	0/14959h
WE 3-Lp Plant 10	0/8760h	0/23242h	0/14482h
WE 3-Lp Plant 11	1/7619h	0/24454h	0/16835h
WE 4-Lp Plant 1	0/8689h	0/23086h	0/14397h
WE 4-Lp Plant 2	3/8094h	0/24247h	0/16153h
WE 4-Lp Plant 10	No data	0/4698h	0/4698h
WE 4-Lp Plant 11	No data	0/5759h	0/5759h
WE 4-Lp Plant 22	0/8760h	0/24314h	1/15554h
WE 4-Lp Plant 23	0/8226h	0/24954h	1/16728h
WE 4-Lp Plant 28	0/7643h	0/23668h	1/16025h

a. A one-year data collection interval applies (1999). The 1999 data were obtained from the ROP (Ref. 3).

b. A three-year data collection interval applies (1997 – 1999). 1997 and 1998 data were obtained from the initiating events study update (Ref. 2), while the 1999 data were obtained from the ROP.

c. A three-year data collection interval applies (1997 – 1999). However, this RBPI is not covered under the ROP, so the results presented in this table include only 1997 and 1998. (1999 Licensee Event Reports will need to be reviewed to identify scrams that are LOFW, as defined in the initiating events study.)

d. The numbers indicate the number of events and the number of critical hours.

Table E-2 Plant Data for Mitigating System Train Unavailability RBPIs[a]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
BWRs				
BWR 123 Plant 1	145.0h/17520h[b]	113.6h/8169h	NA	539.9h/35040h
BWR 123 Plant 2	135.7h/17520h	134.3h/8056h	NA	83.5h/35040h
BWR 3/4 Plant 1	528.5h/69696h	114.9h/8035h[c]	154.9h/8166h	629.4h/33988h
BWR 3/4 Plant 2	528.5h/69696h	73.3h/8760h	32.7h/8761h	286.0h/35044h
BWR 3/4 Plant 3	132.0h/17520h	35.3h/8551h	29.6h/8551h	139.9h/17520h
BWR 3/4 Plant 4	130.9h/17520h	52.2h/7716h	165.7h/7716h	214.1h/17520h
BWR 3/4 Plant 5	51.4h/17520h	20.8h/8562h	47.1h/8592h	0.0h/17520h
BWR 3/4 Plant 6	228.8h/17520h	15.4h/7364h	73.7h/7364h	147.2h/17618h
BWR 3/4 Plant 8	661.3h/35040h[d]	233.5h/8367h	419.8h/8367h[e]	137.4h/17520h
BWR 3/4 Plant 11	260.1h/35040h	134.7h/7627h	136.2h/7627h	202.9h/17520h
BWR 3/4 Plant 12	693.7h/34948h	710.6h/8642h[d]	157.5h/8642h	90.3h/17520h
BWR 3/4 Plant 13	590.5h/33124h	108.0h/7863h	121.0h/7863h	57.0h/17520h
BWR 3/4 Plant 15	270.8h/17514h	140.7h/8664h	74.9h/8664h	158.6h/17520h
BWR 3/4 Plant 16	390.3h/17514h	168.2h/8157h	64.6h/8157h	228.2h/17520h
BWR 3/4 Plant 18[f]	369.8h/17328h	3704.5h/8246h[g]	137.4h/8246h	94.0h/17520h
BWR 3/4 Plant 19[f]	305.4h/17328h	144.7h/8562h	155.1h/8562h	131.6h/17520h
BWR 5/6 Plant 2	624.3h/17520h[h]	32.7h/7124h	108.4h/7124h	76.5h/17520h
BWR 5/6 Plant 5	NA	NA	NA	NA
BWR 5/6 Plant 8	49.7h/26280h	101.9h/6159h	101.9h/6159h	114.5h/16914h
PWRs				
B&W Plant 3	200.1h/17520h	92.1h/16892h	MDP (NA) TDP (65.5h/16876h)	80.3h/17545h
B&W Plant 4	399.7h/17518h[i]	81.4h/15310h	MDP (44.9h/12494h) TDP (0.0h/6247h)	366.8h/17224h
B&W Plant 5	413.9h/17420h[i]	46.8h/15694h	MDP (45.9h/14034h) TDP (22.0h/7017h)	234.8h/17042h
B&W Plant 6	384.2h/17520h[i]	44.5h/17520h	MDP (119.0h/17520h) TDP (7.8h/8760h)	215.4h/17568h

Table E-2 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
PWRs				
B&W Plant 7	242.5h/17518h	87.2h/15716	MDP (16.5h/15716h) TDP (47.4h/7858h)	625.5h/17518h
CE Plant 1	32.8h/16502h	0.1h/14772h	MDP (34.6h/7362h) TDP (4.9h/7362h)	81.9h/17172h
CE Plant 2	115.2h/17520h	119.6h/16664h	MDP (0.0h/8332h) TDP (48.3h/16665h)	181.4h/17520h
CE Plant 3	131.0h/17520h	165.8h/14906h	MDP (18.0h/7453h) TDP (66.9h/14906h)	243.9h/17520h
CE Plant 4	167.4h/17568h	19.7h/15672h	MDP (7.7h/7836h) TDP (48.9h/7836h)	36.8h/17568h
CE Plant 5	200.2h/17520h	92.5h/11154h	MDP (54.1h/11154h) TDP (35.6h/5577h)	71.8h/17520h
CE Plant 10	320.7h/17520h	27.2h/15010h	MDP (164.3h/15010h) TDP (61.9h/7505h)	168.4h/17520h
CE Plant 11	180.2h/17520h	98.3h/15444h	MDP (166.6h/15444h) TDP (77.9h/7722h)	34.7h/17520h
CE Plant 12	86.7h/16866h	113.5h/15592h	MDP (104.8h/15694h) TDP (36.2h/7847h)	123.5h/17472h

Table E-2 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
PWRs				
WE 2-Lp Plant 5	236.4h/17520h	21.5h/15402h	MDP (33.5h/7701h) TDP (32.0h/7701h)	286.1h/17520h
WE 2-Lp Plant 6	176.1h/17520h	21.8h/17452h	MDP (36.4h/8726h) TDP (21.6h/8726h)	448.0h/17520h
WE 3-Lp Plant 5	133.7h/17520h	136.4h/17198h	MDP (27.4h/17198h) TDP (11.5h/8599h)	51.3h/17520h
WE 3-Lp Plant 10	455.1h/17520h	13.8h/17520h	MDP (42.5h/17520h) TDP (16.9h/8760h)	0.0h/17520h
WE 3-Lp Plant 11	393.5h/17520h	6.2h/15868h	MDP (42.5h/15430h) TDP (36.6h/6900h)	17.9h/17268h
WE 4-Lp Plant 1	61.5h/17520h	SI MDP (19.1h/17378h) CVC MDP (94.4h/17378h)	MDP (29.8h/8689h) DDP (34.1h/8689h)	1.6h/17520h
WE 4-Lp Plant 2	58.6h/17520h	SI MDP (138.4h/16188h) CVC MDP (344.4h/16188h)	MDP (19.2h/8094h) DDP (89.9h/8094h)	139.6h/17520h
WE 4-Lp Plant 10	NA	NA	MDP (NA) TDP (NA)	NA
WE 4-Lp Plant 11	NA	NA	MDP (NA) TDP (NA)	NA
WE 4-Lp Plant 22	168.0h/17520h	270.0h/35040h	MDP (66.1h/17520h) TDP (100.9h/8760h)	76.7h/17520h

Table E-2 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
PWRs				
WE 4-Lp Plant 23	207.4h/17520h	162.4h/32908h	MDP (108.5h/16452h) TDP (137.9h/8226h)	143.9h/17520h
WE 4-Lp Plant 28	114.1h/33218h	171.7h/31131h	MDP (28.7h/15582h) TDP (7.9h/7772h)	79.6h/17351h

a. Unavailability data obtained from the ROP. Planned outage hours and unplanned outage hours were used. Fault exposure time was used only if a corresponding demand failure is not in the EPIX database. Only data for1999 were used.
b. The hours are the total outage hours (planned, unplanned, and sometimes fault exposure hours) and the total train hours during which the system is required to be available. A footnote indicates the cases where the fault exposure hours were used.
c. Includes fault exposure time of 65.3 hours.
d. Includes fault exposure time of 168 hours.
e. Includes fault exposure time of 361.4 hours.
f. The swing EDG unavailability was counted for each unit.
g. Includes fault exposure time of 3550.4 hours.
h. Includes fault exposure time of 324 hours.
i. B&W Plants 4 through 6 do not have emergency diesel generators. Results are for the two hydro units.
j. Includes fault exposure time of 69.2 hours.

Table E-3 Plant Data for Mitigating System Unreliability RBPIs[a]

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
BWRs				
BWR 123 Plant 1	EDG FTS (0/113.8)[b] EDG FTLR (0/154.2) EDG FTR (1/491.3h)	TDP FTS (0/30.4) TDP FTR (0/60.9h) MOV FTO (0/121.8)	TDP FTS (No data)[c] TDP FTR (No data) MOV FTO (No data)	MDP FTS (1/259.1) MDP FTR (0/5925.0h)
BWR 123 Plant 2	EDG FTS (0/51.7) EDG FTLR (0/49.8) EDG FTR (0/142.5h)	TDP FTS (1/33.8) TDP FTR (0/67.6h) MOV FTO (0/135.3)	TDP FTS (No data) TDP FTR (No data) MOV FTO (No data)	MDP FTS (0/312.5) MDP FTR (0/8036.7h)
BWR 3/4 Plant 1	EDG FTS (1/183.0) EDG FTLR (0/174.0) EDG FTR (0/219.0h)	TDP FTS (1/15.0) TDP FTR (0/11.2h) MOV FTO (0/84.0)	TDP FTS (0/21.0) TDP FTR (0/7.5h) MOV FTO (0/72.0)	MDP FTS (0/168.1) MDP FTR (0/575.3h)
BWR 3/4 Plant 2	EDG FTS (3/264.3) EDG FTLR (0/237.3) EDG FTR (1/263.9)	TDP FTS (0/18.0) TDP FTR (0/12.0h) MOV FTO (0/96.0)	TDP FTS (1/27.0) TDP FTR (0/12.7h) MOV FTO (0/84.0)	MDP FTS (0/269.3) MDP FTR (0/1128.3h)
BWR 3/4 Plant 3	EDG FTS (No data) EDG FTLR (No data) EDG FTR (No data)	TDP FTS (0/27.3) TDP FTR (0/16.1h) MOV FTO (0/16.0)	TDP FTS (0/38.0) TDP FTR (0/16.0h) MOV FTO (0/16.0)	MDP FTS (0/296.7) MDP FTR (0/6207.1h)
BWR 3/4 Plant 4	EDG FTS (2/177.5) EDG FTLR (2/152.7) EDG FTR (0/1039.1h)	TDP FTS (0/26.0) TDP FTR (0/16.0h) MOV FTO (0/16.0)	TDP FTS (0/38.0) TDP FTR (0/16.0h) MOV FTO (0/16.0)	MDP FTS (0/313.7) MDP FTR (0/6413.2h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
BWR 3/4 Plant 5	EDG FTS (1/76.4) EDG FTLR (No data) EDG FTR (0/335.9h)	TDP FTR (0/23.1) TDP FTR (0/27.7h) MOV FTO (No data)	TDP FTS (0/15.8) TDP FTR (0/7.9h) MOV FTO (0/15.8)	MDP FTS (0/272.7) MDP FTR (0/7621.5h)
BWR 3/4 Plant 6	EDG FTS (0/68.3) EDG FTLR (0/77.4) EDG FTR (0/149.8h)	TDP FTS (0/54.1) TDP FTR (0/37.2h) MOV FTO (0/50.8)	TDP FTS (0/43.8) TDP FTR (0/45.4h) MOV FTO (0/79.7)	MDP FTS (0/280.6) MDP FTR (1/3538.0h)
BWR 3/4 Plant 8	EDG FTS (0/238.6) EDG FTLR (0/180.0) EDG FTR (0/172.5h)	TDP FTS (0/27.5) TDP FTR (No data) MOV FTO (0/26.6)	TDP FTS (0/19.4) TDP FTR (0/0.0h) MOV FTO (0/22.4)	MDP FTS (0/242.4) MDP FTR (1/1733.8h)
BWR 3/4 Plant 11	EDG FTS (0/199.4) EDG FTLR (0/195.4) EDG FTR (0/794.5h)	TDP FTS (0/16.0) TDP FTR (0/12.2h) MOV FTO (0/15.9)	TDP FTS (0/18.9) TDP FTR (1/27.4h) MOV FTO (0/12.0)	MDP FTS (0/194.8) MDP FTR (0/4852.7h)
BWR 3/4 Plant 12	EDG FTS (No data) EDG FTLR (No data) EDG FTR (No data)	TDP FTS (No data) TDP FTR (No data) MOV FTO (0/14.5)	TDP FTS (0/14.5) TDP FTR (1/31.7h) MOV FTO (0/15.9)	MDP FTS (0/227.8) MDP FTR (0/2273.7h)
BWR 3/4 Plant 13	EDG FTS (No data) EDG FTLR (No data) EDG FTR (No data)	TDP FTS (No data) TDP FTR (No data) MOV FTO (0/13.4)	TDP FTS (0/13.4) TDP FTR (0/13.4h) MOV FTO (0/14.9)	MDP FTS (0/220.8) MDP FTR (0/2455.6h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
BWR 3/4 Plant 15	EDG FTS (0/413.5) EDG FTLR (0/295.6) EDG FTR (0/1040.4h)	TDP FTS (0/44.8) TDP FTR (0/8.9h) MOV FTO (0/11.9)	TDP FTS (0/37.3) TDP FTR (0/13.4h) MOV FTO (0/14.9)	MDP FTS (0/202.9) MDP FTR (0/1180.0h)
BWR 3/4 Plant 16	EDG FTS (No data) EDG FTLR (1/143.6) EDG FTR (No data)	TDP FTS (0/42.0) TDP FTR (0/5.8h) MOV FTO (0/11.9)	TDP FTS (0/35.2) TDP FTR (0/13.3h) MOV FTO (0/14.9)	MPD FTS (0/197.8) MDP FTR (0/1269.9h)
BWR 3/4 Plant 18	EDG FTS (2/232.6)[d] EDG FTLR (No data) EDG FTR (No data)	TDP FTS (0/22.6) TDP FTR (No data) MOV FTO (0/13.2)	TDP FTS (0/24.5) TDP FTR (0/36.8h) MOV FTO (0/24.5)	MDP FTS (0/589.5) MDP FTR (0/93.8h)
BWR 3/4 Plant 19	EDG FTS (0/81.9) EDG FTLR (0/0.4) EDG FTR (No data)	TDP FTS (0/22.6) TDP FTR (No data) MOV FTO (0/13.2)	TDP FTS (2/20.8) TDP FTR (0/31.2h) MOV FTO (0/83.2)	MDP FTS (0/303.6) MDP FTR (0/67.5h)
BWR 5/6 Plant 2	EDG FTS (0/171.3) EDG FTLR (0/96.8) EDG FTR (0/333.5h)	MPD FTS (0/31.2) MDP FTR (0/19.5h) MOV FTO (0/39.9) HPCS EDG FTS (0/100.8) HPCS EDG FTLR (0/59.2) HPCS EDG FTR (0/227.7h)	TDP FTS (0/20.6) TDP FTR (0/17.3h) MOV FTO (0/38.6)	MDP FTS (0/204.8) MDP FTR (0/2893.7h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
BWR 5/6 Plant 5	EDG FTS (0/139.7) EDG FTLR (0/88.8) EDG FTR (0/406.3h)	TDP FTS (No data) TDP FTR (No data) MOV FTO (No data)	TDP FTS (1/33.5) TDP FTR (0/91.3h) MOV FTO (0/31.5)	MDP FTS (0/938.0) MDP FTR (0/5919.8h)
BWR 5/6 Plant 8	EDG FTS (1/209.6) EDG FTLR (2/149.6) EDG FTR (1/245.6h)	MDP FTS (1/27.8) MDP FTR (0/38.3) MOV FTO (0/25.4) HPCS EDG FTS (0/78.6) HPCS EDG FTLR (0/66.6) HPCS EDG FTR (0/146.7h)	TDP FTS (2/17.6) TDP FTR (0/45.0h) MOV FTO (0/14.6)	MDP FTS (1/153.8) MDP FTR (0/4215.5h)
PWRs				
B&W Plant 3	EDG FTS (0/143.7) EDG FTLR (0/97.8) EDG FTR (0/270.6h)	MDP FTS (0/80.3) MDP FTR (0/56.7h)	MDP FTS (2/74.5) MDP FTR (0/1649.5) TDP FTS (1/113.1) TDP FTR (0/225.8h)	MDP FTS (0/61.5) MDP FTR (0/840.8h)
B&W Plant 4	HYDRO FTS[e] (2/1322.0) HYDRO FTLR (2/604.2) HYDRO FTR (0/2423.7h)	MDP FTS (0/478.1) MDP FTR (0/38429.3h)	MDP FTS (0/121.4) MDP FTR (0/116.9h) TDP FTS (0/29.3) TDP FTR (0/15.6h)	MDP FTS (0/398.8) MDP FTR (0/29648.9h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
B&W Plant 5	Data listed under B&W Plant 4	MDP FTS (0/392.9) MDP FTR (0/39198.6h)	MDP FTS (0/107.5) MDP FTR (0/75.3h) TDP FTS (1/41.2) TDP FTR (0/17.6h)	MDP FTS (0/163.6) MDP FTR (0/28233.0h)
B&W Plant 6	Data listed under B&W Plant 4	MDP FTS (0/401.1) MDP FTR (2/39878.3h)	MDP FTS (0/86.2) MDP FTR (0/73.1h) TDP FTS (0/31.9) TDP FTR (0/17.6h)	MDP FTS (0/166.2) MDP FTR (0/28519.2h)
B&W Plant 7	EDG FTS (0/79.5) EDG FTLR (1/169.4) EDG FTR (No data)	MDP FTS (0/146.0) MDP FTR (0/5919.3h)	MDP FTS (1/47.9) MDP FTR (No data) TDP FTS (0/25.2) TDP FTR (No data)	MDP FTS (0/124.0) MDP FTR (2/367.7h)
CE Plant 1	EDG FTS (0/59.9) EDG FTLR (1/111.5) EDG FTR (0/258.4h)	MDP FTS (0/343.6) MDP FTR (0/122.8h)	MDP FTS (0/97.3) MDP FTR (0/214.0h) TDP FTS (0/119.8) TDP FTR (0/40.7h)	MDP FTS (0/176.6) MDP FTR (0/4388.3h)
CE Plant 2	EDG FTS (4/164.6) EDG FTLR (1/144.7) EDG FTR (1/285.4h)	MDP FTS (0/259.8) MDP FTR (0/90.0h)	MDP FTS (0/74.1) MDP FTR (0/49.2h) TDP FTS (1/125.1) TDP FTR (0/216.5h)	MDP FTS (0/212.5) MDP FTR (0/2165.3h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
CE Plant 3	EDG FTS (1/129.7) EDG FTLR (0/104.8) EDG FTR (0/234.4h)	MDP FTS (0/302.2) MDP FTR (0/147.9h)	MDP FTS (0/68.8) MDP FTR (0/28.1h) TDP FTS (1/106.3) TDP FTR (0/177.4h)	MDP FTS (0/192.3) MDP FTR (0/1908.1h)
CE Plant 4	EDG FTS (1/141.0) EDG FTLR (0/92.9) EDG FTR (0/297.1h)	MDP FTS (0/329.0) MDP FTR (0/79.0h)	MDP FTS (0/121.5) MDP FTR (0/139.7h) TDP FTS (2/108.4) TDP FTR (0/95.3h)	MDP FTS (0/127.2) MDP FTR (1/1905.9h)
CE Plant 5	EDG FTS (0/86.4) EDG FTLR (0/88.6) EDG FTR (0/459.8h)	MDP FTS (0/302.1) MDP FTR (0/228.3h)	MDP FTS (0/191.3) MDP FTR (0/1251.1h) TDP FTS (0/18.4) TDP FTR (0/11.3h)	MDP FTS (No data) MDP FTR (No data)
CE Plant 10	EDG FTS (0/24.0) EDG FTLR (0/24.0) EDG FTR (0/48.1h)	MDP FTS (0/96.2) MDP FTR (0/84.2h)	MDP FTS (0/84.8) MDP FTR (0/622.7h) TDP FTS (1/48.1) TDP FTR (0/12.0h)	MDP FTS (0/113.4) MDP FTR (0/1473.1h)
CE Plant 11	EDG FTS (0/24.0) EDG FTLR (0/24.0) EDG FTR (0/48.1h)	MDP FTS (No data) MDP FTR (No data)	MDP FTS (1/94.6) MDP FTR (0/524.3) TDP FTS (0/100.2) TDP FTR (0/74.8h)	MDP FTS (0/78.7) MDP FTR (0/704.7h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
CE Plant 12	EDG FTS (No data) EDG FTLR (0/7385.1) EDG FTR (No data)	MDP FTS (0/90.3) MDP FTR (0/44.1h)	MDP FTS (0/5.3) MDP FTR (0/15.9h) TDP FTS (No data) TDP FTR (No data)	MDP FTS (0/204.6) MDP FTR (0/1226.3h)
WE 2-Lp Plant 5	EDG FTS (1/77.5) EDG FTLR (0/77.5) EDG FTR (0/526.8h)	MDP FTS (0/26.2) MDP FTR (0/13.0h)	MDP FTS (0/63.4) MDP FTR (0/216.4h) TDP FTS (0/53.8) TDP FTR (0/54.5h)	MDP FTS (0/72.2) MDP FTR (0/1050.1h)
WE 2-Lp Plant 6	EDG FTS (0/81.1) EDG FTLR (0/79.2) EDG FTR (0/4498.8h)	MDP FTS (0/19.2) MDP FTR (0/3.9h)	MDP FTS (0/34.2) MDP FTR (0/2197.0h) TDP FTS (0/39.3) TDP FTR (0/2210.2h)	MDP FTS (0/78.7) MDP FTR (0/3379.0h)
WE 3-Lp Plant 5	EDG FTS (1/128.7) EDG FTLR (0/95.5) EDG FTR (0/125.2h)	MDP FTS (0/151.2) MDP FTR (0/37069.6h)	MDP FTS (0/268.8) MDP FTR (0/344.9h) TDP FTS (0/80.4) TDP FTR (1/37.2h)	MDP FTS (0/88.9) MDP FTR (0/980.2h)
WE 3-Lp Plant 10	EDG FTS (2/98.6) EDG FTLR (0/98.6) EDG FTR (0/192.0h)	MDP FTS (0/195.8) MDP FTR (0/52232.3)	MDP FTS (0/90.6) MDP FTR (0/0.6h) TDP FTS (0/45.3) TDP FTR (0/0.3h)	MDP FTS (0/17.2) MDP FTR (0/2521.4h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
WE 3-Lp Plant 11	EDG FTS (0/49.3) EDG FTLR (0/49.3) EDG FTR (0/96.0h)	MDP FTS (0/97.7) MDP FTR (0/51067.1h)	MDP FTS (0/90.0) MDP FTR (No data) TDP FTS (1/45.0) TDP FTR (No data)	MDP FTS (0/79.7) MDP FTR (0/760.7h)
WE 4-Lp Plant 1	EDG FTS (0/104.5) EDG FTLR (0/6.6) EDG FTR (0/493.4h)	SI MDP FTS (No data) SI MDP FTR (No data) CVC MDP FTS (No data) CVC MDP FTR (No data)	MPD FTS (0/39.5) MDP FTR (0/34.1h) DDP FTS (1/66.6) DDP FTR (0/42.4h)	MDP FTS (0/70.6) MDP FTR (0/997.5h)
WE 4-Lp Plant 2	EDG FTS (0/119.3) EDG FTLR (0/2.3) EDG FTR (0/431.1h)	SI MDP FTS (No data) SI MDP FTR (No data) CVC MDP FTS (No data) CVC MDP FTR (No data)	MDP FTS (0/35.3) MDP FTR (0/27.9h) DDP FTS (0/54.8) DDP FTR (0/38.1h)	MDP FTS (0/64.0) MDP FTR (0/865.5h)
WE 4-Lp Plant 10	EDG FTS (0/58.1) EDG FTLR (0/54.1) EDG FTR (0/67.9h)	MDP FTS (0/84.2) MDP FTR (0/24.0h)	MDP FTS (0/86.1) MDP FTR (0/216.5h) TDP FTS (0/88.2) TDP FTR (0/24.0h)	MDP FTS (0/212.3) MDP FTR (0/29371.2h)
WE 4-Lp Plant 11	EDG FTS (1/114.3) EDG FTLR (0/106.2) EDG FTR (0/112.7h)	MDP FTS (0/80.2) MDP FTR (0/24.0h)	MDP FTS (0/118.2) MDP FTR (0/433.1h) TDP FTS (0/76.2) TDP FTR (0/24.0h)	MDP FTS (0/148.2) MDP FTR (0/27356.9h)

Table E-3 (Continued)

Plant	EPS	HPI/ HPCI/ HPCS	AFW/ RCIC	RHR
WE 4-Lp Plant 22	EDG FTS (0/199.6) EDG FTLR (0/158.7) EDG FTR (2/318.4h)	SI MDP FTS (1/157.6) SI MDP FTR (0/97.4h) CVC MDP FTS (0/225.1) CVC MDP FTR (1/26205.3h)	MDP FTS (1/76.1) MDP FTR (0/600.6h) TDP FTS (4/69.0) TDP FTR (0/58.9h)	MDP FTS (0/63.7) MDP FTR (0/1493.3h)
WE 4-Lp Plant 23	EDG FTS (No data) EDG FTLR (No data) EDG FTR (No data)	SI MDP FTS (0/193.3) SI MDP FTR (0/97.9h) CVC MDP FTS (1/191.2) CVC MDP FTR (0/26222.5h)	MDP FTS (0/79.1) MDP FTR (1/494.0h) TDP FTS (1/92.0) TDP FTR (1/129.8h)	MDP FTS (0/61.0) MDP FTR (0/912.4h)
WE 4-Lp Plant 28	EDG FTS (1/4.1) EDG FTLR (0/170.6) EDG FTR (0/503.8h)	MDP FTS (0/1256.5) MDP FTR (0/640.2h)	MDP FTS (0/54.7) MDP FTR (0/56.1h) TDP FTS (No data) TDP FTR (No data)	MDP FTS (0/75.7) MDP FTR (0/1178.0h)

a. Three years of EPIX data were used (1997 – 1999).
b. The numbers in parentheses indicate the number of failures and the number of demands (or hours).
c. "No data" indicates that either EPIX has no data, or the RADS data load of the EPIX file did not include this component.
d. The swing EDG was included with this plant.
e. B&W Plants 4 through 6 do not have emergency diesel generators. Results are for the two hydro units.

Table E-4 Plant Data for Component Class Unreliability RBPIs[a]

Plant	AOV	MOV	MDP
BWRs			
BWR 123 Plant 1	AOV FTO/C (No data)[b]	MOV FTO/C (1/1439.8)[c]	MDP FTS (5/518.0) MDP FTR (2/21525.5h)
BWR 123 Plant 2	AOV FTO/C (0/67.6)	MOV FTO/C (1/1607.1)	MDP FTS (3/571.5) MDP FTR (3/19.8h)
BWR 3/4 Plant 1	AOV FTO/C (No data)	MOV FTO/C (0/2141.3)	MDP FTS (0/921.1) MDP FTR (3/243846.8h)
BWR 3/4 Plant 2	AOV FTO/C (No data)	MOV FTO/C (1/3471.7)	MDP FTS (0/476.3) MDP FTR (0/171234.6h)
BWR 3/4 Plant 3	AOV FTO/C (No data)	MOV FTO/C (4/1875.4)	MDP FTS (5/1013.4) MDP FTR (7/74560.2h)
BWR 3/4 Plant 4	AOV FTO/C (No data)	MOV FTO/C (3/1915.4)	MDP FTS (4/974.3) MDP FTR (1/74560.1h)
BWR 3/4 Plant 5	AOV FTO/C (No data)	MOV FTO/C (4/4279.8)	MDP FTS (3/2680.1) MDP FTR (2/305694.7h)
BWR 3/4 Plant 6	AOV FTO/C (0/31.8)	MOV FTO/C (1/1798.9)	MDP FTS (0/2810.0) MDP FTR (1/139113.9h)
BWR 3/4 Plant 8	AOV FTO/C (No data)	MOV FTO/C (0/767.6)	MDP FTS (0/852.1) MDP FTR (7/157109.1h)
BWR 3/4 Plant 11	AOV FTO/C (No data)	MOV FTO/C (0/83.8)	MDP FTS (1/960.7) MDP FTR (1/94373.4h)
BWR 3/4 Plant 12	AOV FTO/C (No data)	MOV FTO/C (1/1974.3)	MDP FTS (0/1394.7) MDP FTR (0/101670.6h)
BWR 3/4 Plant 13	AOV FTO/C (No data)	MOV FTO/C (0/1439.9)	MDP FTS (0/408.0) MDP FTR (0/101670.5h)
BWR 3/4 Plant 15	AOV FTO/C (No data)	MOV FTO/C (3/803.2)	MDP FTS (0/960.4) MDP FTR (0/252.0h)
BWR 3/4 Plant 16	AOV FTO/C (No data)	MOV FTO/C (0/681.2)	MDP FTS (1/560.4) MDP FTR (0/94.4h)
BWR 3/4 Plant 18	AOV FTO/C (No data)	MOV FTO/C (0/1036.8)	MDP FTS (1/1989.3) MDP FTR (0/26280.1h)
BWR 3/4 Plant 19	AOV FTO/C (No data)	MOV FTO/C (0/998.9)	MDP FTS (0/1740.8) MDP FTR (0/39420.1)

Table E-4 (Continued)

Plant	AOV	MOV	MDP
BWRs			
BWR 5/6 Plant 2	AOV FTO/C (No data)	MOV FTO/C (0/1668.8)	MDP FTS (1/843.4) MDP FTR (0/26141.4h)
BWR 5/6 Plant 5	AOV FTO/C (No data)	MOV FTO/C (1/2364.1)	MDP FTS (0/1598.5) MDP FTR (0/111976.1h)
BWR 5/6 Plant 8	AOV FTO/C (No data)	MOV FTO/C (13/1668.2)	MDP FTS (6/852.0) MDP FTR (0/178596.1h)
PWRs			
B&W Plant 3	AOV FTO/C (0/28.4)	MOV FTO/C (0/3496.7)	MDP FTS (7/733.5) MDP FTR (1/148761.7h)
B&W Plant 4	AOV FTO/C (0/241.7)	MOV FTO/C (0/790.0)	MDP FTS (0/998.4) MDP FTR (1/157924.4h)
B&W Plant 5	AOV FTO/C (0/130.0)	MOV FTO/C (1/26616.7)	MDP FTS (0/664.0) MDP FTR (0/157828.5h)
B&W Plant 6	AOV FTO/C (1/148.1)	MOV FTO/C (2/357.5)	MDP FTS (0/653.6) MDP FTR (2/169839.6h)
B&W Plant 7	AOV FTO/C (0/40.4)	MOV FTO/C (0/784.8)	MDP FTS (1/1564.1) MDP FTR (2/0.2h)
CE Plant 1	AOV FTO/C (0/8.0)	MOV FTO/C (0/1270.4)	MDP FTS (3/1741.3) MDP FTR (1/23627.8h)
CE Plant 2	AOV FTO/C (0/488.9)	MOV FTO/C (4/701.2)	MDP FTS (2/1681.1) MDP FTR (0/47808.1h)
CE Plant 3	AOV FTO/C (0/477.0)	MOV FTO/C (2/737.8)	MDP FTS (1/1710.4) MDP FTR (2/47274.1h)
CE Plant 4	AOV FTO/C (4/175.1)	MOV FTO/C (0/766.9)	MDP FTS (6/3198.2) MPD FTR (5/122989.3h)
CE Plant 5	AOV FTO/C (No data)	MOV FTO/C (1/1053.6)	MDP FTS (0/726.8) MDP FTR (0/0.2h)
CE Plant 10	AOV FTO/C (0/3.9)	MOV FTO/C (1/932.7)	MDP FTS (3/1867.5) MPD FTR (1/27665.6h)
CE Plant 11	AOV FTO/C (0/3.9)	MOV FTO/C (0/637.1)	MDP FTS (2/1746.3) MPD FTR (0/27665.6h)

Table E-4 (Continued)

Plant	AOV	MOV	MDP
PWRs			
CE Plant 12	AOV FTO/C (1/19.6)	MOV FTO/C (4/839.4)	MDP FTS (1/3088.2) MDP FTR (4/167660.9h)
WE 2-Lp Plant 5	AOV FTO/C (0/258.6)	MOV FTO/C (0/149.4)	MDP FTS (0/342.0) MDP FTR (0/0.1h)
WE 2-Lp Plant 6	AOV FTO/C (0/152.4)	MOV FTO/C (0/199.9)	MDP FTS (0/267.1) MDP FTR (0/0.1h)
WE 3-Lp Plant 5	AOV FTO/C (1/818.7)	MOV FTO/C (0/1989.5)	MDP FTS (1/509.1) MDP FTR (0/0.1h)
WE 3-Lp Plant 10	AOV FTO/C (2/12.0)	MOV FTO/C (1/456.0)	MDP FTS (0/645.7) MDP FTR (0/0.1h)
WE 3-Lp Plant 11	AOV FTO/C (0/15.0)	MOV FTO/C (0/453.0)	MDP FTS (1/447.4) MDP FTR (0/0.0h)
WE 4-Lp Plant 1	AOV FTO/C (No data)	MOV FTO/C (0/60.7)	MDP FTS (0/578.1) MDP FTR (0/262800.1h)
WE 4-Lp Plant 2	AOV FTO/C (No data)	MOV FTO/C (0/112.8)	MDP FTS (1/825.4) MDP FTR (1/262800.1h)
WE 4-Lp Plant 10	AOV FTO/C (0/567.0)	MOV FTO/C (0/3206.6)	MDP FTS (0/829.8) MDP FTR (1/26352.5h)
WE 4-Lp Plant 11	AOV FTO/C (0/414.9)	MOV FTO/C (0/2573.1)	MDP FTS (0/759.6) MDP FTR (0/26352.5h)
WE 4-Lp Plant 22	AOV FTO/C (0/122.3)	MOV FTO/C (1/824.2)	MDP FTS (2/1006.4) MDP FTR (1/0.2h)
WE 4-Lp Plant 23	AOV FTO/C (0/163.9)	MOV FTO/C (1/789.9)	MDP FTS (1/564.6) MDP FTR (1/0.2h)
WE 4-Lp Plant 28	AOV FTO/C (0/80.1)	MOV FTO/C (1/496.3)	MDP FTS (0/2100.6) MDP FTR (0/25523.1h)

a. Three years of EPIX data were used (1997 – 1999).
b. "No data" indicates that either EPIX has no data on this component class, or the RADS data load of the EPIX file did not include this component class.
c. Numbers in parentheses indicate number of failures and number of demands (or hours).

E.3 Data Analysis

Data analysis involves converting the data collected into RBPI values to compare with thresholds. The data conversion and threshold comparison requires a decision rule, as explained in Appendix F. Plant-specific thresholds are presented in Appendix A. RBPI definitions, data, and calculational procedures are discussed in Appendix H.

For initiating event RBPIs, the decision rule involves calculation of a frequency using a Bayesian update process. The prior is a constrained, non-informative prior based on the industry mean frequency, as outlined in Appendix F. The data presented in Table E-1 are the evidence. The resulting posterior frequency is then compared with the RBPI's plant-specific thresholds presented in Appendix A to determine whether the indicated performance band is green, white, yellow, or red.

For mitigating system unavailability RBPIs, the decision rule involves calculating train unavailability by dividing the outage hours by the required hours (both presented in Table E-2). A Bayesian update process was not used for unavailability because the data are not available in a format suitable for such a process. (Bayesian updates of unavailability data have been performed in cases where the data were divided into outage frequencies and outage durations, but data available from the ROP are not broken down in this manner.) The resulting train unavailability is then compared with the plant-specific thresholds presented in Appendix A.

Mitigating system unreliability RBPIs are more complex than the unavailability or initiating event RBPIs. Train unreliability typically involves several components and failure modes. The train unreliability data collected are presented in Table E-3. Each component failure mode (probability or failure rate) was calculated using a Bayesian update process and a constrained, non-informative prior based on the industry mean. These updated component failure mode probabilities (or failure rates) were then inserted into the SPAR train fault tree to determine which performance band was indicated. Train components not covered by the EPIX data were kept at their baseline values in this calculation. (In practice, only a few plant unreliability RBPIs had enough failures to require actual SPAR recalculations of train unreliability.)

Many of the mitigating system unreliability RBPIs did not satisfy all of the misclassification criteria discussed in Appendix F. In particular, most of these RBPIs have the potential for indicating performance in the white band, when performance is actually at its baseline level. Therefore, for each white performance indication, an additional calculation is performed to determine the probability of obtaining the observed data, given that performance is at its baseline level. That calculation is also explained in Appendix F.

Finally, component class unreliability RBPIs were calculated similarly to mitigating system unreliability. For the air-operated and motor-operated valve component classes, unreliability was defined as failure to open or close upon demand. For the motor-operated pump class, unreliability was defined as failure to start and run upon demand. A mission time of 24 hours was assumed for all such pumps. Again, for each white performance indication, an additional calculation is performed to determine the probability of obtaining the observed data, given that performance is at its baseline level.

Results of the data analysis task are presented in Section 5 of this report.

E.4 References

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4. *Equipment Performance and Information Exchange System (EPIX), Volume 1 – Instructions for Data Entry, Maintenance Rule and Reliability Information Module*, INPO 98-001, Institute of Nuclear Power Operations, February 1998 (database covering information through the third quarter of 1999).

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APPENDIX F

STATISTICAL METHODS AND RESULTS

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Appendix F: Statistical Methods and Results

F.1 Basic Definitions

The terminology is as follows.

GW = threshold between green and white performance bands, the value that raises the core damage frequency (CDF) above the baseline value by 1E-6/calendar year.

WY = threshold between white and yellow bands, the value that raises the CDF above the baseline value by 1E-5/calendar year.

YR = threshold between yellow and red bands, the value that raises the CDF above the baseline value by 1E-4/calendar year.

Throughout this appendix, the term "calendar year" is shorthand for "7000 critical hours." The thresholds are shown conceptually in Figure F-1. The solid circle marks the baseline, an industry average, which is in the green band but often rather close to the green-white threshold.

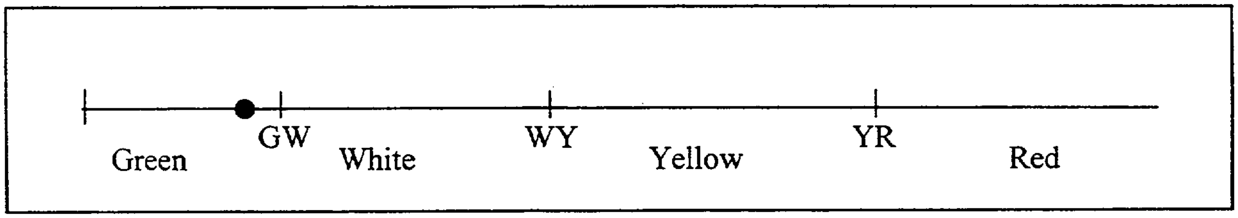

Figure F-1 Diagram of the Performance Bands and Their Thresholds

F.2 Initiating Events

F.2.1 Decision Rules for Declaring Plant in Each Performance Band

Use the following type of rule to declare that the plant is in a particular performance band. The observation time is expressed here in calendar years, treating 7000 critical hours as equivalent to one calendar year. Denote the observation time by t calendar years, and let n be the number of events that occur in a monitoring period of t years.

Estimate the frequency of events, λ, by $\lambda^* = (n + a)/(t + b)$, where a and b are predefined constants. If $a > 0$ and $b > 0$ this is a Bayesian estimate corresponding to a gamma(a, b) prior distribution, with prior mean a/b. The parameters have the intuitive interpretation of a events in time b, prior to the current data.

We consider several choices of a and b:

- a and b correspond to the variability across the industry, as estimated by the initiating-event study (Poloski et al. 1998). The industry mean is a/b, which is also the baseline value used in this study. [In the initiating-event report, several of the relevant Bayes distributions are lognormal. They are converted to gamma distributions here by matching moments. This appears acceptable in this case, because the distributions are not extremely skewed – gamma shape parameters near 0.5 or larger, lognormal error factors smaller than 6.]

- $a = 1/2$ and b is such that a/b equals the industry mean. These are the parameters for the constrained noninformative prior (Atwood 1996), constrained by the mean. This is a generalization of the Jeffreys noninformative prior, corresponding in one formal mathematical sense to knowledge of the mean but ignorance otherwise.
- $a = 0$ and $b = 0$. Then λ^* is the classical maximum likelihood estimate, making no use of prior belief.

The prior distributions considered here are shown in Table F-1. In each case the constrained noninformative prior has a smaller value of a than the industry prior, and therefore a larger variance. The initiating-event report expresses frequencies as events per critical year. They are converted here to per calendar year, assuming 7000 critical hours per calendar year. Therefore, the mean frequencies given here are numerically smaller than those in the report, by a factor of 7000/8760 = 0.8.

Table F-1 Non-zero Prior Distributions Considered for the Initiating Events

Indicator	Type of gamma prior distribution	a	b (cal. years)
Trans.Init., BWR	Industry variability	8.81	6.78
Trans.Init., BWR	Constrained noninformative	0.5	0.385
Trans.Init., PWR	Industry variability	6.59	6.59
Trans.Init., PWR	Constrained noninformative	0.5	0.50
LOFW	Industry variability	0.805	11.85
LOFW	Constrained noninformative	0.5	7.36
LOHS, BWR	Industry variability	23.8	102.6
LOHS, BWR	Constrained noninformative	0.5	2.16
LOHS, PWR	Industry variability	1.11	11.6
LOHS, PWR	Constrained noninformative	0.5	5.23
LOOP	Industry variability	2.0	54.3
LOOP	Constrained noninformative	0.5	13.6

The decision rule is

If $\lambda^* \geq$ GW, the performance indication is white.
If $\lambda^* \geq$ WY, the performance indication is yellow.
If $\lambda^* \geq$ YR, the performance indication is red.

This can be rewritten in terms of cutoffs on the observed number of events, n, in t calendar years.

If $n \geq c_W$, the performance indication is white, where $c_W = (t + b)^*\mathrm{GW} - a$.
If $n \geq c_Y$, the performance indication is yellow, where $c_Y = (t + b)^*\mathrm{WY} - a$.
If $n \geq c_R$, the performance indication is red, where $c_R = (t + b)^*\mathrm{YR} - a$.

In brief, c_X is the number of events that must be seen to declare the performance indication to be in performance band X; because c_X is typically not an integer, the next largest integer must be observed. Table F-2 shows these cutoffs, the numbers of events corresponding to each performance band, for BWR 3/4 Plant 18. The monitoring periods shown are not the same for all the kinds of initiating events.

Table F-2 Cutoffs for Assigning Performance Bands to BWR 3/4 Plant 18, for Three Decision Rules

Observation time (plant calendar years)	Cutoff [a]								
	Prior from industry variability			Constrained noninformative prior			$a = b = 0$ (cutoffs = expected counts)		
	W	Y	R	W	Y	R	W	Y	R
Transient Initiator									
1	6.8	52.7	512.5	2.3	10.4	92.3	2.0	7.9	67.0
2	8.8	60.6	579.5	4.3	18.3	159.3	4.0	15.8	134.0
3	10.8	68.5	646.5	6.3	26.2	226.3	6.0	23.7	201.0
Loss of Feedwater									
1	3.1	31.3	307.6	2.01	20.4	200.1	0.3	2.5	24.0
2	3.4	33.8	331.6	2.3	22.9	224.1	0.6	5.0	48.0
3	3.7	36.3	355.6	2.6	25.5	248.1	0.9	7.5	72.0
Loss of Heat Sink									
1	18.7	328.4	3395.	0.8	10.2	103.8	0.4	3.4	33.0
2	19.1	331.8	3428.	1.2	13.6	136.8	0.8	6.8	66.0
3	19.5	335.2	3461.	1.6	17.04	169.8	1.2	10.2	99.0
Loss of Offsite Power									
1	0.16	1.2	10.7	0.07	0.3	2.9	0.04	0.06	0.23
2	0.20	1.3	10.9	0.11	0.4	3.1	0.08	0.12	0.46
3	0.23	1.3	11.2	0.15	0.5	3.3	0.12	0.17	0.69
4	0.27	1.4	11.4	0.19	0.5	3.6	0.16	0.23	0.92
5	0.31	1.4	11.6	0.23	0.6	3.8	0.20	0.29	1.15
10	0.51	1.7	12.8	0.42	0.9	4.9	0.39	0.58	2.3
20	0.90	2.3	15.1	0.81	1.4	7.2	0.78	1.16	4.6

[a] *a.* Declare that the plant is in the corresponding performance zone if and only if the observed number of events is at the cutoff or above.

For example, consider loss of heat sink with three years of monitoring time. The green-white threshold is 0.41 initiators per calendar year (Table A.1.4-13, Appendix A). Therefore, the expected count in three years for a GW plant is 1.23 events, shown in the table as 1.2. Two events must be observed in three years for the zero-prior rule to declare the plant white. This is also true if the constrained noninformative prior is used, because the cutoff is 1.6. If instead the industry prior is used, 20 events (the only way to get 19.5 or more) must be observed in three years to declare the plant white.

Note that in many cases, a very large number of events must be observed for a Bayesian rule to declare a yellow or red performance indication. The most extreme example is LOHS with the industry-variability prior. This prior is gamma with shape parameter 23.8 and scale parameter

102.6 calendar years. This distribution has mean 0.25 and standard deviation 0.05. The prior probability of red band performance is the integral of this density from 33 to infinity, and equals 0.0 to the accuracy of SAS calculation. Therefore, it takes over 3000 observed events to overcome the prior distribution and put the indication (the posterior mean) into the red band. This would never happen in practice – plant managers or NRC regulators would intervene first. This illustrates that if the prior distribution makes the red or yellow band incredible, the Bayesian method will not declare that the plant is in that performance band. Nevertheless, the Bayesian method may correctly detect that the plant is worse than green.

LOOP events are too rare to be monitored as a plant-specific indicator. Even if performance is at the yellow-red threshold, it takes nearly five years before a single LOOP event is expected.

Table F-3 shows the same information for WE 4-Lp Plant 22.

Table F-3 Cutoffs for Assigning Performance Bands to WE 4-Lp Plant 22, for Three Decision Rules

Observation time (plant cal. years)	Cutoff[a]								
	Prior from industry variability			Constrained noninformative prior			*a* = *b* = 0 (cutoffs = expected counts)		
	W	Y	R	W	Y	R	W	Y	R
Transient Initiator									
1	7.1	60.2	585.4	2.2	12.7	116.5	1.8	8.8	78.0
2	8.9	69.01	663.4	4.0	21.5	194.5	3.6	17.6	156.0
3	10.7	77.8	741.4	5.8	30.3	272.5	5.4	26.4	234.0
Loss of Feedwater									
1	9.5	91.7	950.1	6.19	59.7	618.1	0.8	7.2	74.0
2	10.3	98.9	1024.1	6.99	66.9	692.1	1.6	14.4	148.0
3	11.1	106.1	1098.1	7.79	74.1	766.1	2.4	21.6	222.0
Loss of Heat Sink									
1	1.9	17.8	187.9	0.99	8.8	92.9	0.24	1.5	15.0
2	2.2	19.3	202.9	1.2	10.3	107.9	0.48	3.0	30.0
3	2.4	20.8	217.9	1.5	11.8	122.9	0.72	4.5	45.0
Loss of Offsite Power									
1	0.16	1.26	12.9	0.07	0.36	3.4	0.04	0.06	0.27
2	0.20	1.32	13.2	0.11	0.42	3.7	0.08	0.12	0.54
3	0.23	1.38	13.5	0.15	0.48	4.0	0.12	0.18	0.81
4	0.27	1.44	13.7	0.19	0.54	4.3	0.16	0.24	1.08
5	0.31	1.5	14.01	0.23	0.60	4.5	0.20	0.30	1.4
10	0.51	1.8	16.7	0.62	0.89	5.9	0.39	0.59	2.7
20	0.90	2.4	18.1	0.81	1.5	8.6	0.78	1.18	5.4

[a] Declare that the plant is in the corresponding performance zone if and only if the observed number of events is at the cutoff or above.

F.2.2 Properties of Rules, as Function of Monitoring Period

How long a monitoring period should be used? A shorter time period gives quicker decisions, but a longer time has smaller probability of a misclassification. To help evaluate the tradeoff, consider now the probability of various misclassifications.

The following false positives and false negatives were judged to be of greatest interest:

- Declare performance white (or worse), if it is truly at baseline – a false positive
- Declare performance green, if it is truly YR – a false negative
- Declare performance green, if it is truly WY – a false negative

In every case, the true state of the plant is separated from the declared state, although in the first case the separation is small if the baseline is close to the green-white threshold. Of the two false negatives, the first is a particular instance of "declare performance green if it is red," because YR is one of the possible values in the red band. This false negative may have very small probability for many decision rules, and may not lead to a good way of selecting a decision rule. Therefore, the second false negative is also considered.

The probability of a false positive or false negative will be written using the notation for conditional probability, and abbreviated as follows:

- Pr(W | baseline) = Pr(declare performance white or worse, if it is truly at baseline)
- Pr(G | YR) = Pr(declare performance green, if truly at the yellow-red threshold)
- Pr(G | WY) = Pr(declare performance green, if truly at the white-yellow threshold)

In terms of the number of events in the observation time, the above misclassification probabilities are:

- Pr(W | baseline) = Pr(observe c_W or more events | frequency = baseline)
- Pr(G | YR) = Pr(observe fewer than c_W events | frequency = YR)
- Pr(G | WY) = Pr(observe fewer than c_W events | frequency = WY)

These numbers are easily calculated using the Poisson distribution. The Poisson distribution is commonly used for modeling event counts. It arises whenever:

- events occur with a constant frequency
- the event count in one time period is independent of the event count in any nonoverlapping period
- exactly simultaneous events do not occur (that is, common-cause events can be ignored)

The calculation is illustrated for Pr(W | baseline) for loss of heat sink at BWR 3/4 Plant 18, with 3 years of observation, and use of the constrained noninformative prior. Let *N* denote the random number of transients involving loss of heat sink that might occur.

$\Pr(W \mid \text{baseline} = \Pr(\text{declare performance white or worse} \mid \text{true frequency} = \text{baseline})$

$= \Pr(N > 1.6 \mid \lambda = 0.232, t = 3)$ from Table F-2

$= \Pr(N \geq 2 \mid \lambda\text{t} = 0.696\ )$

$= 1 - \Pr(N < 2 \mid \lambda\text{t} = 0.696\ )$

$= 1 - e^{-0.696}[0.696^0 / 0! \ + \ 0.696^1 / 1!]$ by the formula for Poisson probabilities

$= 0.154$

Calculations for the other cases are similar.

F.2.3 Choice of a Rule and a Monitoring Period

To choose an appropriate rule and monitoring period, the following criteria were used:

$\Pr(\ W \mid \text{baseline}\ ) \leq 0.20$

$\Pr(\ G \mid YR\ ) \leq 0.05$

$\Pr(\ G \mid WY\ ) \leq 0.10$.

These three probability criteria were chosen for the following reasons. One very important characteristic of RBPIs is that they must not indicate green performance when the RBPI is actually performing at the red level (an unacceptable level of performance). This is termed a false-negative misclassification. Therefore, the probability criterion for this characteristic was chosen to be a very low value, 0.05. This criterion implies that if the RBPI is actually performing at the level of the YR interface, then there is less than a 0.05 probability that the RBPI performance evaluation will indicate green. However, it was found during the statistical analysis that this criterion generally did not distinguish between the rules and monitoring periods evaluated. (This criterion is generally easy to meet.) Therefore, a second, similar criterion was added, that of indicating green when the RBPI performance is actually at the WY interface. Because this type of false-negative misclassification is not as important as the green indication when performance is at the YR interface, a higher misclassification probability was used, 0.10. Finally, another important characteristic of RBPIs is that they should not indicate white performance when the RBPI is actually at baseline (green) performance. This criterion can be difficult to meet if the GW threshold is close to the baseline performance level, which is often the case for some RBPIs. Therefore, a 0.20 probability was chosen for this false-positive criterion.

The approach used was to select the prior distribution that satisfied all three criteria in the shortest monitoring period. Monitoring periods of from one to five years were considered.

Sometimes the criteria on the false negatives could not be met with a monitoring period of up to five years. This was the case for LOOP. In such a case, no RBPI was defined. That kind of initiating event will be treated by other means.

Sometimes, on the other hand, the two criteria on false negatives were met, but the criterion on false positives could not be met. This is the case when the baseline and the green-white threshold are very close together, but the other thresholds are farther apart. In this case, an RBPI rule and a monitoring period were selected, but it was recognized that false positives are relatively frequent, and a declaration of white should not be regarded as definitive. To quantify the departure from greenness, a supplementary probability was calculated. For example, suppose that two events occurred, and that this was enough to declare performance white. The probability

Pr(two or more events | baseline)

was calculated, to indicate the likelihood of observing such data even when performance is at baseline. If this probability is large, then the observed data are consistent with baseline performance, and there is a significant possibility that this indication is a false positive. If instead the probability is small, then the data are not consistent with baseline performance, and the declaration of white should be regarded more seriously.

Calculated misclassification probabilities, for various priors and monitoring periods, are shown in Section F.6. In that section, Table F-6 presents sample calculations for the LOHS initiator. Also, Table F-8 summarizes the results for all of the RBPIs.

F.3 Mitigating Systems

F.3.1 Unreliability

F.3.1.1 Decision Rules

Because some systems have diverse trains, it was decided to base the decision rules on trains, not systems. Even for a train, however, the unreliability depends on several parameters. For example, pump failure to start, pump failure to run, and valve failure to open are distinct train failure modes, corresponding to distinct parameters p_{FTS}, λ_{FTR}, and p_{FTO}.

This multiplicity of parameters has the following consequence. Different combinations of parameters can result in the same CDF, but different train unreliabilities. This occurs, for example, in a multiple train system when the different failure modes have different susceptibility to common-cause failures. Nevertheless, for simplicity of presentation, it was decided to base the RBPI on train unreliability. Examination of the cutsets in the SPAR model allowed the train unreliability to be expressed as a simple algebraic function of the parameters. The base calculation was made assuming that Pr(FTS), Pr(FTR during the PRA mission), and any other parameters were each above their baseline values by the same multiplicative factor. This gave values of the parameters for ΔCDF = 1.E-6, 1.E-5, and 1.E-4. The corresponding threshold train unreliabilities were then found, using the previously found algebraic function. The decision rule then was based on monitoring the plant and collecting data, estimating the parameters, calculating the corresponding estimate of train unreliability, and comparing this estimate to the previously calculated thresholds.

F.3.1.2 Performance of Decision Rules

Several misclassification probabilities then had to be calculated. For example, consider the calculation of Pr(G | YR). The plant is assumed to be at the YR threshold, but this can occur in many ways – various combinations of the parameters can result in ΔCDF = 1.E-4. For example, suppose that the train has three failure modes that are monitored, so three parameters to be considered. Then four sets of assumptions were made. First, it was assumed that exactly one of the three parameters was high and that the others remained at their baseline values. This gave three sets of assumptions, one set for each selected parameter. Finally, it was assumed that all the parameters were above their baseline values by the same multiplicative factor. For each of these four sets of assumptions, the probability that the plant would be declared green was found. This gave four values for Pr(G | YR). All of these probabilities should be acceptably small if the decision rule and corresponding monitoring period are to be used.

The actual calculation of the misclassification probabilities was performed by Monte Carlo simulation, as follows. One of the above sets of assumptions was made, defining the parameter values. A monitoring period was assumed, giving an assumed total number of demands and running hours for all the similar trains at the plant under consideration. Random "data" were then generated using a random number generator. For example a number of failures to start in the plant's assumed number of demands was randomly generated, as was a number of failures to run in the plant's assumed hours. From these data, the Bayesian estimates of the parameters were constructed. These estimates were plugged into the algebraic formula to calculate estimated train unreliability. The estimated unreliability was compared with the thresholds, and performance was assigned to the appropriate performance band. If the assumption was that performance was at YR, and the "data" resulted in a classification of green, this was a misclassification. The process was repeated many times, with many randomly generated "data" sets. The true probability, Pr(G | YR), was estimated as the fraction of times that misclassifications occurred. When 400,000 "data" sets were used, the estimated misclassification probability was accurate except perhaps in the third significant digit.

Some calculated misclassification probabilities, for various priors and monitoring periods, are shown in Section F.6 in Table F-6. Results for all of the RBPIs are summarized in Table F-8.

Just as discussed above for initiating events, for some mitigating systems the desired misclassification probabilities could not be achieved. If the criteria on false negatives were not met, industry trending was recommended.

In some cases the criterion on false positives could not be met, because the GW threshold is very close to the baseline. Therefore, a supplementary probability was calculated as follows. First, the estimated train unreliability was calculated; for this discussion, call the value $UR_{est.}$ If $UR_{est.}$ was larger than GW, performance was declared white. Then the probability was found of getting data that would produce a value this large or larger, if in fact performance were at the baseline level. Conceptually, we considered all possible data sets (for example, possible counts of failures to start in the monitored number of demands and of failures to run in the monitored number of hours) that could have been obtained. We then noted which ones would result in an estimated train unreliability as large as $UR_{est.}$ or larger. We then calculated the total probability of those data sets, assuming that performance was at the baseline level. If this probability is large, it means that the observed data could easily arise when performance is at the baseline level. If the probability is small, on the other hand, it means that the observed data are inconsistent with the baseline probabilities. This probability, a "p-value" for testing whether the plant is at baseline, was reported along with the declaration that the plant is white.

F.3.2 Unavailability

The general method is illustrated here by the emergency power (EP) and reactor core isolation cooling (RCIC) systems at BWR 3/4 Plant 18.

The WANO EDG data for planned and unplanned unavailability were studied, covering the last quarter of 1995 through the first two quarters of 1999, 45 months at 71 sites. The data were taken from recent electronic files, similar to those described by INPO (1996). The observed unavailability for each site was computed as:

(planned outage EDG-hours + unplanned outage EDG-hours)/(total required EDG-hours).

The observed unavailability varied greatly across the industry, from 2.5E-4 for BWR 123 Plant 3 to 2.9E-2 for WE 2-Lp Plant 3. The 5th and 95th percentiles (4th and 68th ranked sites) differed by a factor of 9.

Likewise, the WANO RCIC data were studied over the same time period, at 20 BWR units. The observed unavailability for each unit was computed as:

(planned outage RCIC-hours + unplanned outage RCIC-hours)/(total required RCIC-hours).

The observed unavailability varied greatly, from 3E-3 at BWR 3/4 Plant 4 to 5.6E-2 at BWR 5/6 Plant 3. The 5th and 95th percentiles (2nd and 29th ranked units) differed by a factor of 12.5.

Quick examination of data for other systems revealed similar variation among units. Therefore, we decided that only site-specific data were appropriate for estimating the variability of outage data at a plant. Site-specific, rather than plant-specific, data seemed acceptable, because for most systems the differences between plants at a single site were small. The calculations are illustrated below for EDGs and RCIC at BWR 3/4 Plant 18.

At BWR 3/4 Plant 18, data on required EDG hours were present for 126 EDG-months (3 EDGs, 45 months, with data missing for one calendar quarter) and data on outages were present for 125 EDG-months (for the above 126 EDG-months, outage data was missing for one case). The observed outage hours did not follow any simple distribution; 38% of the values were zero, and the largest value was 107 hrs. Similarly, the required hours did not follow any simple distribution; for three fourths of the EDG-months, the EDG was expected to be available for the entire calendar time, but there was one case when an EDG was expected to be available only 1.8 hours. Therefore, we did not model these distributions by simple parametric distributions such as lognormal or beta, but instead treated the observed values as the exact discrete distribution.

Similarly, at BWR 3/4 Plant 18, data on RCIC required hours were present for 84 RCIC months (2 RCIC systems, 45 months, with data missing for one calendar quarter). The reactor was too cold for the RCIC system to operate at all during 19 of those months, so there were 65 calendar months when the system was expected to be available for at least part of the month.

For EDGs we simulated from the observed distribution of required hours by making many copies of this data set of 126 records, and then putting the values of each variable in random order. Similarly, we made many copies of the 125 outage values and put them in random order. This gave 2,048,000 pairs (outage hours, required hours), with the values randomly paired. Table F-4 shows records 100-110 of this data set. Note that for most records the outage hours are smaller than the required hours. For record 108, however, the random pairing resulted in outage hours that are greater than the required hours. Such cases are unusual – record 108 is the first such occurrence in the data set.

Table F-4 Selected Records from the Constructed EDG Data Set

Record number	Outage hours	Required hours
100	9.5	744
101	0.0	745
102	0.0	720
103	2.7	179
104	0.0	720
105	0.0	744
106	0.0	744
107	0.0	206
108	2.1	1.8
109	42.6	744
110	2.2	720

The same method was used to simulate RCIC unavailability data.

To simulate GW, WY, or YR, we multiplied the outage hours by a factor, called a *multiplier* in the discussion here. Whatever multiplier was tried, the same multiplier was used for every record in the data set of about two million pairs. For any record, if the resulting outage hours (= original outage hours times the multiplier) were more than the required hours, the outage hours for that record were reduced to the required hours. The unavailability was then calculated, as the total outage hours divided by the total required hours. Trial and error found that the multipliers led to the corresponding unavailabilities shown in Table F-5.

Table F-5 Multipliers to Produce Selected Unavailabilities in Simulated Data

EDG		RCIC	
Multiplier	Resulting Unavailability	Multiplier	Resulting Unavailability
1.0	0.0123	1.0	0.00760
2.87	0.0350 (=GW)	2.91	0.0220 (=GW)
5.64	0.0680 (=WY)	19.8	0.120 (=WY)
133.6	0.4000 (=YR)		

The multiplier of 1.0 should produce an unavailability of 0.0125 for EDGs and 0.00766 for RCIC, the unavailabilities seen in the data. Instead, it produces slightly smaller unavailabilities because some of the random pairings gave outage times greater than the required times, and those outage times were reduced.

The next task was to estimate the probability of misclassification, assuming that the true unavailability was at one of the thresholds. Therefore, we applied the appropriate multiplier to the data, so that the overall unavailability was equal to the threshold of interest. We then treated the records as sequential months for one EDG train or one RCIC system, and calculated the total outage hours and required hours during various time periods such as 12 months. For example, each 12-record subset of the data gave a simulated observed unavailability for one year. Based on the many time periods, such as the nonoverlapping 12-month periods, that occurred in the data set of approximately two million months, we found the fraction of times when the observed unavailability fell above or below the various thresholds. Results are summarized in Section F.6, Table F-8. The simulation process outlined is one of several that could have been used. Other methods will be investigated in the Phase-2 work.

F.4 Component Classes

A *component class* consists of all components of a particular type, such as all turbine-driven pumps, or all motor-operated valves in selected systems. The individual components in a component class may have different parameters or mission times. If the parameters or mission times differed greatly between systems, so that the components had widely varying baseline unreliabilities, a different approach would be required. However, in each group considered the components have similar unreliabilities. Therefore, the thresholds used are based on the *typical* component unreliabilities. This is the same approach as used above for identical trains, only now the component unreliabilities are used instead of the train unreliabilities.

Only unreliability is considered for component classes, not unavailability. This is because an appropriate way to analyze unavailability is not clear.

F.5 Trending

If the data are too sparse for trustworthy RBPIs, an alternative is to trend data from the industry as a whole. One must then decide exactly what should be measured for trending. This section discusses ways to make the trending portion of the effort consistent with the plant-specific monitoring portion.

For a class of initiating events (such as LOOP events), the Bayes estimate of the event frequency is calculated for each year, using a prior distribution related to historic industry performance and using the data from the entire industry for the year. The approach was chosen to keep the presentation consistent with the other RBPIs.

The rules used for plant-specific RBPIs for unreliability of mitigating systems are based on estimated unreliability. Therefore, for consistency of presentation, any industry unreliabilities that are trended are treated in a similar way. The train unreliability is estimated, using a prior distribution related to historic industry performance and a Bayesian estimate based on all the data from all the plants (or all the plants from a portion of the industry, such as the PWRs or the BWRs, if more appropriate). A value is calculated based on each year's data, and the values are plotted.

F.6 Results for Decision Rules and Data Collection Intervals

This section summarizes the performance of the various decision rules and monitoring periods. Detailed results are given for one initiating event, illustrating the method. A later table (Table F-8) summarizes the conclusions from examination of the full results for all initiating events, mitigating systems, and component classes.

Table F-6 shows the misclassification probabilities for loss-of-heat-sink initiating events, for monitoring periods from one to five years. The calculations were performed for two plants, WE 4-Lp Plant 22 and BWR 3/4 Plant 18. The recommended rule and monitoring period is highlighted. This is the rule that satisfies, in the shortest time, the three constraints on the misclassification probabilities listed in Section F-2.3.

Table F-6 Misclassification Probabilities for Loss-of-Heat-Sink (LOHS) Initiating Events

Baseline and Threshold Values

Site	Baseline	G-W Threshold DCDF = 1.0E-6/y	W-Y Threshold DCDF = 1.0E-5/y	Y-R Threshold DCDF = 1.0E-4/y
WE 4-Lp Plant 22	0.096/y (PWR average)	0.24/y	1.5/y	15/y
BWR 3/4 Plant 18	0.23/y (BWR average)	0.41/y	3.4/y	33/y

Data Rule and Data Collection Interval Selection

One-Year Data Collection Interval Results

Data Rule	Predicted/Baseline (No Events During Data Collection Interval)	Misclassification Probability (G|YR) (P < 0.05)	Misclassification Probability (G|WY) (P < 0.10)	Misclassification Probability (W|Base) (P < 0.20)
Zero prior	0.00 (0.00)[a]	0.000 (0.000)	0.223 (0.033)	0.091 (0.207)
Constrained	0.84 (0.68)	0.000 (0.000)	0.223 (0.033)	0.091 (0.207)
Industry prior	0.92 (0.99)	0.000 (0.003)	0.558 (1.000)	0.004 (0.000)

	Number of Events Required During Data Collection Interval to Exceed Threshold		
Data Rule	G-W	W-Y	Y-R
Zero prior	1 (1)[a]	2 (4)	15 (33)
Constrained	1 (1)	9 (11)	93 (104)
Industry prior	19 (9)	18 (329)	188 (3395)

a. Format is: result for WE 4-Lp Plant 22 (result for BWR 3/4 Plant 18)

Two-Year Data Collection Interval Results

Data Rule	Predicted/Baseline (No Events During Data Collection Interval)	Misclassification Probability (G|YR) (P < 0.05)	Misclassification Probability (G|WY) (P < 0.10)	Misclassification Probability (W|Base) (P < 0.20)
Zero prior	0.00 (0.00)[a]	0.000 (0.000)	0.050 (0.001)	0.174 (0.371)
Constrained	0.72 (0.52)	0.000 (0.000)	0.199 (0.009)	0.016 (0.079)
Industry prior	0.85 (0.98)	0.000 (0.000)	0.423 (1.000)	0.001 (0.000)

Table F-6 (Continued)

	Number of Events Required During Data Collection Interval to Exceed Threshold		
Data Rule	G-W	W-Y	Y-R
Zero prior	1 (1)[a]	3 (7)	30 (66)
Constrained	2 (2)	11 (14)	108 (137)
Industry prior	3 (20)	20 (332)	203 (3428)

a. Format is: result for WE 4-Lp Plant 22 (result for BWR 3/4 Plant 18)

Three-Year Data Collection Interval Results

Data Rule	Predicted/Baseline (No Events During Data Collection Interval)	Misclassification Probability (G|YR) $(P < 0.05)$	Misclassification Probability (G|WY) $(P < 0.10)$	Misclassification Probability (W|Base) $(P < 0.20)$
Zero prior	0.00 (0.00)[a]	0.000 (0.000)	0.011 (0.000)	0.249 (0.154)
Constrained	0.63 (0.42)	0.000 (0.000)	0.062 (0.000)	0.034 (0.154)
Industry prior	0.79 (0.97)	0.000 (0.000)	0.174 (0.996)	0.003 (0.000)

	Number of Events Required During Data Collection Interval to Exceed Threshold		
Data Rule	G-W	W-Y	Y-R
Zero prior	1 (2)[a]	5 (11)	45 (99)
Constrained	2 (2)	12 (18)	123 (170)
Industry prior	3 (20)	21 (336)	218 (3461)

a. Format is: result for WE 4-Lp Plant 22 (result for BWR 3/4 Plant 18)

Four-Year Data Collection Interval Results

Data Rule	Predicted/Baseline (No Events During Data Collection Interval)	Misclassification Probability (G|YR) $(P < 0.05)$	Misclassification Probability (G|WY) $(P < 0.10)$	Misclassification Probability (W|Base) $(P < 0.20)$
Zero prior	0.00 (0.00)[a]	0.000 (0.000)	0.002 (0.000)	0.318 (0.237)
Constrained	0.57 (0.35)	0.000 (0.000)	0.017 (0.000)	0.057 (0.067)
Industry prior	0.74 (0.96)	0.000 (0.000)	0.062 (0.939)	0.007 (0.000)

	Number of Events Required During Data Collection Interval to Exceed Threshold		
Data Rule	G-W	W-Y	Y-R
Zero prior	1 (2)[a]	6 (14)	60 (132)
Constrained	2 (3)	14 (21)	138 (203)
Industry prior	3 (20)	23 (339)	233 (3494)

a. Format is: result for WE 4-Lp Plant 22 (result for BWR 3/4 Plant 18)

Five-Year Data Collection Interval Results

Data Rule	Predicted/Baseline (No Events During Data Collection Interval)	Misclassification Probability (G|YR) $(P < 0.05)$	Misclassification Probability (G|WY) $(P < 0.10)$	Misclassification Probability (W|Base) $(P < 0.20)$
Zero prior	0.00 (0.00)[a]	0.000 (0.000)	0.005 (0.000)	0.084 (0.111)
Constrained	0.51 (0.30)	0.000 (0.000)	0.005 (0.000)	0.084 (0.111)
Industry prior	0.70 (0.95)	0.000 (0.000)	0.020 (0.805)	0.013 (0.000)

Table F-6 (Continued)

	Number of Events Required During Data Collection Interval to Exceed Threshold		
Data Rule	G-W	W-Y	Y-R
Zero prior	2 (3))[a]	8 (17)	75 (165)
Constrained	2 (3)	15 (24)	153 (236)
Industry prior	3 (21)	24 (343)	248 (3527)

a. Format is: result for WE 4-Lp Plant 22 (result for BWR 3/4 Plant 18)

Summary

Using the misclassification probability limits shown in the tables for G|YR, G|WY, and W|Base, the constrained, non-informative prior and a three-year data collection interval are appropriate for the LOHS RBPI.

Two sites, BWR 3/4 Plant 18 and WE 4-Lp Plant 22, were used for the study of most decision rules and monitoring periods. The unreliabilities of mitigating systems and component classes were more complex, and the results seemed more variable, than for initiating events or unavailabilities. Therefore, two additional sites were used for unreliability: BWR 5/6 Plant 2 and CE Plant 2.

Some of the plants have not reported demands for some components of some systems. For those systems at those plants, data could not be simulated and misclassification probabilities could not be found. Table F-7 shows the mitigating systems and component classes that were studied, and the failure modes that were modeled.

A summary of the results is given in Table F-8.

F.7 References

Atwood, C. L., 1996, "Constrained Noninformative Priors in Risk Assessment," *Reliability Engineering and System Safety*, Vol. 53, pp. 37-46.

Poloski, J. P., et al., 1998, *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995*, NUREG/CR-5750, INEEL/EXT-98-00401.

INPO, 1996, "World Association of Nuclear Operations (WANO) Performance Indicator Program Utility Data Coordinator Reference Notebook," INPO 96-003, Institute of Nuclear Power Operations, September 1996.

Table F-7 Plants and Systems Examined for Misclassification Probabilities

	BWR 3/4 Plant 18	WE 4-Lp Plant 22	BWR 5/6 Plant 2	CE Plant 2
EP	no run hours reported	FTS, FTLR, FTR	FTS, FTLR, FTR	FTS, FTLR, FTR
HPCI, HPCS, HPI	no run hours reported (HPCI)	not analyzed – yellow not reached	FTS, FTR, FTO (inj. valve), no other valves (HPCS)	FTS, FTR (HPI)
RCIC	Unit 2: FTS, FTR, FTO	—	FTS, FTR, FTO	—
AFW motor train	—	FTS, FTR	—	FTS, FTR
AFW turbine train	—	FTS, FTR	—	FTS, FTR
RHR	no run hours reported	FTS, FTR, no valves	FTS, FTR, no valves	FTS, FTR, no valves
AOVs	no demand data	FTO/C	FTO/C	FTO/C
MOVs	FTO/C	FTO/C	FTO/C	FTO/C
MDPs	FTS, FTR	FTS, FTR	FTS, FTR	FTS, FTR

Table F-8 Recommended Decision Rules and Data Collection Intervals

RBPI	Prior Distribution	Data Collection Interval	Comments
Initiating Event			
GT	Constr. Noninf.	1 year	
LOHS and LOFW	Constr. Noninf.	3 years	For LOFW, 1 year with a zero-prior rule could also have been chosen
Mitigating System			
Unavailability	Zero prior	1 year	Given the format of the unavailability data, only a non-Bayesian decision rule was evaluated (Sec. F-3.2).
Unreliability	Constr. Noninf.	3 years	In general, the unreliability RBPIs do not meet all three misclassification probability goals. They almost always meet the goal of $\Pr(G \mid YR) < 0.05$, generally do not meet the goal of $\Pr(G \mid WY) < 0.10$, and several do not meet the goal of $\Pr(W \mid \text{baseline}) < 0.20$. Therefore, for cases where a white color is indicated, the probability of observing that performance, given that the plant is still at baseline, is also printed.
Component Class	Constr. Noninf.	3 years	Same comments as those listed for mitigating system unreliability.

APPENDIX G

DEVELOPMENT OF RISK-BASED PERFORMANCE INDICATORS: PROGRAM OVERVIEW

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Executive Summary

The purpose of this document is to provide an overview of the current effort to develop risk-based performance indicators (RBPIs). The development of RBPIs is being undertaken as a possible enhancement to the Revised Reactor Oversight Process. However, at the present time, no decision has been made in that regard pending further development and evaluation. This work will be coordinated with the concurrent efforts to risk-inform 10 CFR Part 50.

In developing RBPIs, "performance" refers to those activities in design, procurement, construction, operation and maintenance that support achievement of the objectives of the cornerstones of safety in the Reactor Oversight Process.

SECY 99-007, "Recommendations for Reactor Oversight Process Improvements," Attachment 2, "Technical Framework for Licensee Performance Assessment," lists the key attributes of performance within each cornerstone. RBPIs provide performance measures that are related as explicitly as practical to the risk-significant elements of these key attributes.

Collectively, the RBPIs will have the following characteristics:

- The RBPIs should be compatible with, and complementary to, the risk-informed inspection activities of the oversight process.
- The RBPIs should cover all modes of plant operation.
- Within each mode, the RBPIs should cover risk-important SSCs to the extent practical.
- The RBPIs should be capable of implementation without excessive burdens to licensees or NRC in the areas of data collection and quantification.
- To the extent practical, the RBPIs should identify declining performance before performance becomes unacceptable, without incorrectly identifying normal variations as degradations (i.e., avoid false-positive indications and false-negative indications).
- The RBPIs should be amenable to establishment of plant-specific thresholds consistent with the Revised Reactor Oversight Process.

Risk-significant changes in performance areas such as maintenance, testing, training, and quality assurance are expected to manifest themselves as changes in the values of the RBPIs. Some risk-significant performance areas cannot be measured by the RBPIs and will be covered through the risk-informed inspections outlined in the Revised Reactor Oversight Process. Design issues relating to performance under the cornerstone objectives will be reflected in individual RBPIs (such as system unavailability) and/or through the Significance Determination Process that will be applied to inspection findings. Both the RBPIs and the risk-informed inspection findings provide performance indications that can be evaluated in a consistent and risk-informed process to assess licensee performance.

The RBPIs will provide potential benefits to the Revised Reactor Oversight Process as follows:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state-of-the art models, data and methods for these areas;
- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

A graded threshold approach consistent with the Reactor Oversight Process will be used for the RBPIs. This approach will incorporate sufficient margins of safety to provide the NRC staff with the opportunity to take appropriate action to correct performance degradations before they become unacceptable. The greater coverage of risk-significant performance afforded by the RBPIs will allow for concomitant changes to inspections in those areas covered by the RBPIs and the explicit identification of risk-significant areas that the inspection program must cover.

The process for assessing licensee performance in the Revised Reactor Oversight Process is illustrated in Figure ES-1. The parts of the diagram in bold indicate how RBPIs will fit into the existing process. Some of the current Reactor Oversight Process performance indicators will be replaced with improved RBPIs. In addition to providing plant-specific information, the RBPI program results will provide industry-wide trends, including risk-significant trends on performance elements that are difficult, if not impossible, to trend on a plant-specific basis. This includes Accident Sequence Precursor (ASP) events, less-frequent initiators (e.g., loss of offsite power, steam generator tube rupture, and small loss-of-coolant accidents), and common-cause failure (CCF) events. When combined with the plant-specific RBPI trends, these additional trends and associated insights on key contributors provide information to assist in selecting areas for risk-informed inspection activities and to assess, in part, the effectiveness of the Revised Reactor Oversight Process.

RBPIs are developed by:

- Determining the risk-significant key attributes of each cornerstone
- Determining the elements of each of the risk-significant key attributes
- Obtaining performance data for each of these elements
- Identifying indicators from the data that are capable of detecting performance changes in a timely manner

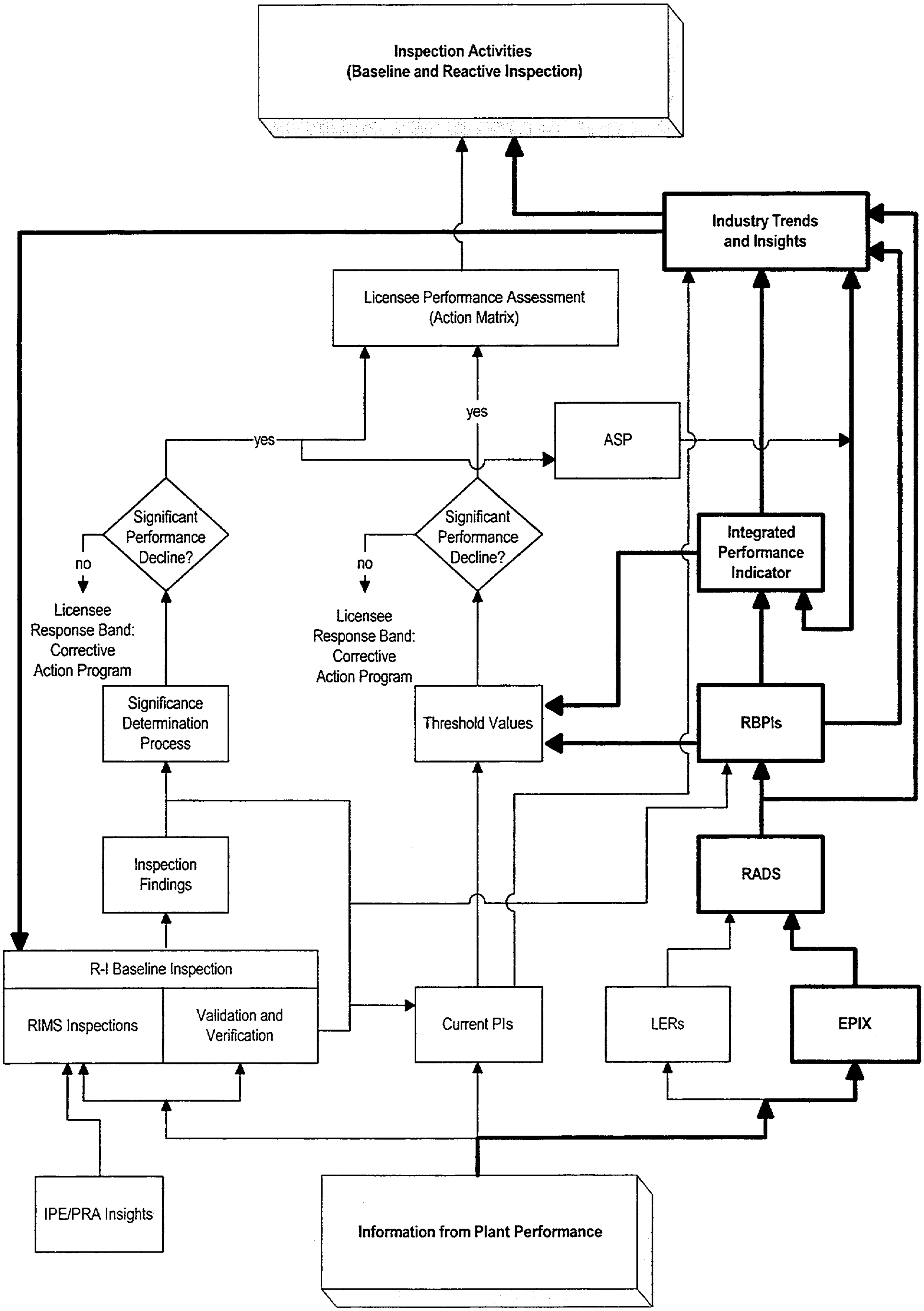


Figure ES-1. Assessment of Licensee Performance Under the Revised Reactor Oversight Process

- Identifying performance thresholds from the data consistent with a graded approach to performance evaluation outlined in the performance thresholds conceptual framework of SECY 99-007.

Development of RBPIs will be accomplished in phases and will follow the following steps:

- Issue an RBPI program overview white paper for stakeholder comment;
- Brief the ACRS and Commission on the RBPI development plan outlined in the program overview white paper;
- Issue a Phase-1 RBPI development progress report, including example RBPIs, for stakeholder comment;
- Brief of the ACRS and Commission on the Phase-1 RBPI development progress;
- Issue a Phase-2 RBPI development progress report, including example of RBPIs, for stakeholder comment;
- Brief of the ACRS and Commission on the Phase-2 development progress.

The RBPI development will be closely coordinated with the Office of Nuclear Reactor Regulation (NRR). Throughout the RBPI development process, there will be numerous interactions with internal and external stakeholders to ensure that their feedback is appropriately incorporated.

Phase-1 of the RBPI development will concentrate on indicators that are related to the initiating event cornerstone, the mitigating system cornerstone, and the containment portion of the barrier integrity cornerstone. Specifically, these will include:

- Reliability indicators for the mitigating system cornerstone;
- Containment;
- Fire;
- Shutdown;
- Industry trends.

The fire and shutdown indicators will be developed consistent with the current state of the art models, methods and data for these areas.

Additional phases will address:

- An integrated indicator;
- Improvements to the indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data;
- Additional unavailability indicators with plant-specific thresholds;
- Other external events (e.g., seismic and wind);
- Follow-on work to improve existing indicators in response to NRC and/or industry lessons learned from the Revised Reactor Oversight Process implementation.

The data sources and models needed for RBPI development already exist or are being developed under separate and multi-purpose programs (e.g., studies of system and component reliabilities and initiating event frequencies). Development and implementation of the RBPIs require the implementation of the industry Equipment Performance Information Exchange (EPIX) database and the associated NRC data extraction and analysis software called Reliability and Availability Data System (RADS). Further research work on risk models and insights for external events and shutdown will be needed to better satisfy the RBPI development objectives in those areas.

ABBREVIATIONS AND ACRONYMS

ACRS	Advisory Committee on Reactor Safeguards
AFW	auxiliary feedwater
ASP	Accident Sequence Precursor
BWR	boiling water reactor
CCF	common cause failure
CCW	component cooling water
CDF	core damage frequency
EPIX	Equipment Performance and Information Exchange System
FSAR	Final Safety Analysis Report
INEEL	Idaho National Engineering and Environmental Laboratory
IPE	individual plant examination
IPEEE	individual plant examination of external events
LB	licensing basis
LER	Licensee Event Report
LOCA	loss-of-coolant accident
MOR	monthly operating report
NEI	Nuclear Energy Institute
NPRDS	Nuclear Plant Reliability Data System
PORV	pilot-operated relief valve
POS	plant operating state
PRA	probabilistic risk assessment
PWR	pressurized water reactor
RADS	Reliability and Availability Database System
RBPI	risk-based performance indicator
RCS	reactor coolant system
RG	Regulatory Guide
RHR	residual heat removal
RPS	reactor protection system
SALP	Systematic Assessment of Licensee Performance
SDP	Significance Determination Process

SCSS	Sequence Coding and Search System
SGTR	Steam Generator Tube Rupture
SPAR	Simplified Plant Analysis Risk
SSC	systems, structures, and components
SW	Service Water
TMI	Three Mile Island

1. Purpose

The purpose of this document is to provide an overview of the current effort to develop risk-based performance indicators (RBPIs). The development of RBPIs is being undertaken as a possible enhancement to the Revised Reactor Oversight Process discussed in SECY 99-007 (Ref. 1) and SECY-99-007A (Ref. 2). However, at the present time, no decision has been made in that regard pending further development and evaluation. This work will be coordinated with the concurrent efforts to risk-inform 10 CFR Part 50.

This document addresses three major areas:

- the definition of RBPIs,
- the benefits of RBPIs in the Revised Reactor Oversight Process, and
- the process of developing RBPIs.

The Revised Reactor Oversight Process uses performance indicators and findings from risk-informed inspections to assess plant performance relative to the "cornerstones of safety." The RBPIs will improve the Revised Reactor Oversight Process as follows:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state of the art models, data and methods for these areas;
- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

2. What Are RBPIs?

2.1 Concept of Performance and Definition of RBPIs

With regard to the Reactor Oversight Process, “performance” refers to those activities in design, procurement, construction, maintenance and operation that support achievement of the objectives of the cornerstones of safety in the Reactor Oversight Process.

The Reactor Oversight Process samples plant behavior in order to verify that licensee performance is meeting the cornerstone of safety objectives. Two kinds of information are obtained in this sampling process: information obtained through inspections, and information obtained through monitoring of performance indicators. The term “sample” is used to emphasize that the Reactor Oversight Process does not inspect or monitor every possible aspect of plant behavior. Rather, it is designed to gather sufficient information in enough different areas to be able to support the conclusion that the licensee’s performance is effective.

Risk-significant performance changes generally affect system characteristics such as frequency of events and reliability, availability, or capability of systems, structures, and components (SSCs). Here, “capability” refers to the physical capacity of the system to accomplish a given function, such as “deliver required flow at a given pressure,” or “successfully bear a given load.” Availability refers to the fraction of time that the SSC is capable of performing its function. Reliability refers to the probability that a given SSC will function on demand and during the required mission time, given that it was available.

SECY 99-007, “Recommendations for Reactor Oversight Process Improvements,” Attachment 2, “Technical Framework for Licensee Performance Assessment,” lists the key attributes of performance within each cornerstone. RBPIs provide performance measures that are related as explicitly as practical to the risk-significant elements of these key attributes.

Collectively, the RBPIs will have the following characteristics:

- The RBPIs should be compatible with, and complementary to, the risk-informed inspection activities of the oversight process.
- The RBPIs should cover all modes of plant operation.
- Within each mode, the RBPIs should cover risk-important SSCs to the extent practical.
- The RBPIs should be capable of implementation without excessive burdens to licensees or NRC in the areas of data collection and quantification.
- To the extent practical, the RBPIs should identify declining performance before performance becomes unacceptable, without incorrectly identifying normal variations as degradations (i.e., avoid false-positive indications and false-negative indications).

- The RBPIs should be amenable to establishment of plant-specific thresholds consistent with the Revised Reactor Oversight Process.

2.2 Kinds of Performance That RBPIs Can Measure

The development of RBPIs will assess performance in the first three cornerstones of safety: initiating events, mitigating systems, and containment barrier integrity. To the extent possible, the RBPIs will correspond directly to quantities that appear explicitly in models of CDF or LERF. The cornerstones of safety for emergency preparedness, radiation safety, and safeguards are not part of the present development.

Figure 1 shows the risk-based hierarchy and associated levels of indication that will form the bases for the risk based PIs. The cornerstones of safety of the Revised Reactor Oversight Process have a direct relationship to key parts of the risk logic. In particular, Figure 1 shows the levels of RBPIs that devolve from industry and sequence level indications under the mitigating systems cornerstone. These further devolve to system, train, and basic event indicators which are constituent parts of plant risk. In this sense, the lower level indicators are "leading" indicators of overall risk. A similar scheme applies to indicators for other cornerstones.

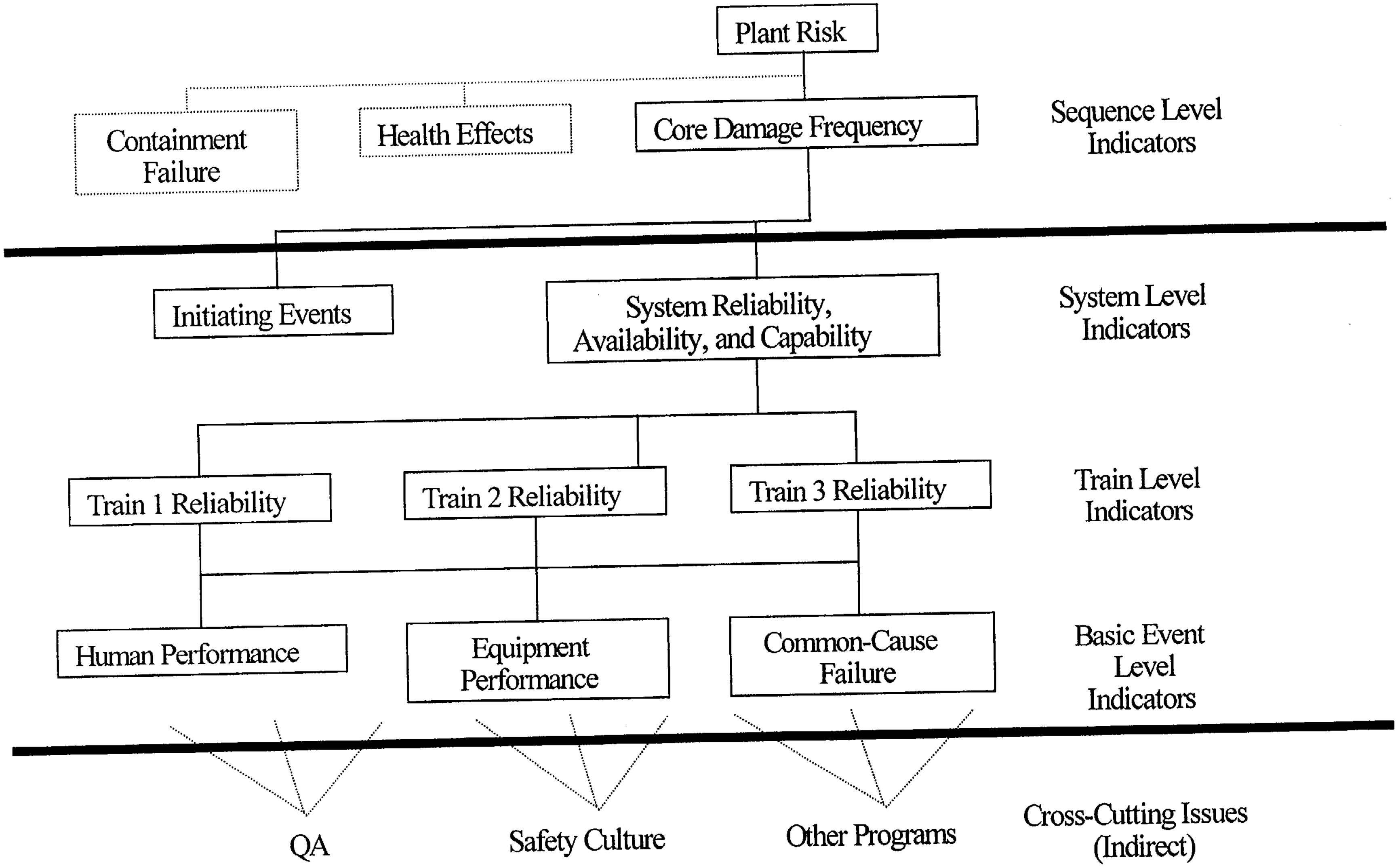
As shown in Figure 1, CDF explicitly depends on quantities such as the reliability and availability of certain systems, trains, and components, as well as human performance. RBPIs defined in terms of these quantities are direct indicators. Other performance influences on CDF, such as QA or safety culture, are not explicitly part of the calculation of CDF. Instead, their impact is related through the reliability, availability, and capability of systems, trains, and components that do affect CDF directly.

The conditions that contribute to the probability of failing to mitigate the consequences of an initiating event include:

- equipment unavailability due to maintenance;
- equipment unavailability due to test;
- the probability that an undetected equipment failure has occurred in standby and not been picked up in a test, or was picked up in a test and the item is now under repair;
- the probability of failure of equipment to function "on demand"; and
- the probability of failure of equipment to function during the required mission time ("fail to run/operate").

The RBPI development will address direct indicators: quantitative measures of performance in areas whose influence on CDF and on containment performance is explicit. RBPIs will reflect significant changes in these performance parameters for a broad set of systems and operational aspects associated with licensee performance under the cornerstones of safety.

Figure 1.
Elements of Risk



2.3 Graded Approach to Performance Evaluation

To the extent practical, the graded performance approach and the risk concepts used in the current Reactor Oversight Process will be used in the development of RBPI performance threshold values. Thresholds for each indicator will be based, to the extent practical, on the plant-specific impact on CDF (or LERF) of changes in the indicator value. The existing SECY 99-007 concepts of performance areas will be preserved, but the thresholds will be more plant specific. However, for any particular RBPI that applies to the industry or a group of plants, thresholds will differ only to the extent that the risk sensitivity to that performance varies substantially from one plant to another. This would occur if substantial design features and plant-specific operating history varied significantly among plants. For example, there may be different thresholds from emergency diesel generator (EDG) reliability among plants with two, three, or four EDGs. Within a group of plants with two EDGs, the threshold would likely be common unless the differences in risk sensitivity to EDG reliability were significant enough to warrant further refinement.

3. Benefits of RBPIs

3.1 Existing Oversight Processes

The Revised Reactor Oversight Process monitors performance on the basis of objective indicators and risk-informed inspection relating to the cornerstones of safety objectives. The risk-informed baseline inspections will cover those risk-significant aspects of licensee performance not adequately covered by performance indicators. NRC interaction with licensees will be based on the risk significance of that performance. The Revised Reactor Oversight Process has defined a set of performance indicators for measuring performance associated with each cornerstone of safety.

3.2 How RBPIs Improve the Revised Reactor Oversight Process

RBPIs are intended to increase the breadth and depth of the risk coverage of the current indicators, which will allow for concomitant changes to the risk-informed baseline inspections. The RBPIs will provide benefits to the Revised Reactor Oversight Process as summarized below:

- Reliability indicators will be developed at the component/train/system level;
- Indicators for shutdown modes and fire events will be developed consistent with the current state of the art models, data and methods for these areas;
- The RBPI threshold values will be more plant-specific to reflect risk-significant differences in plant designs;
- An indicator will be developed that will provide the capability to consistently assess the integrated risk significance of the performance indicators and the inspection findings on overall plant performance. This will provide an additional input to the Action Matrix;
- Trending of risk-significant performance at an industry-wide level, including insights and identification of key contributors to any observed trends, will be provided. This will include trending of existing indicators and other performance data such as ASP events and common-cause failure events that cannot be tracked at a plant-specific level.

The process for assessing licensee performance in the Revised Reactor Oversight Process is illustrated in Figure 2. The parts of the diagram in bold indicate how RBPIs will fit into the existing process. Plant performance information is derived from licensee performed tests and inspections as well as NRC initiated inspection activities. This ensemble of performance information is evaluated through either the SDP for inspection findings or the risk-based framework of the PIs. Therefore, licensee performance assessment involves the combination of performance data derived from both NRC inspections and performance indicator data. Risk-based PIs are expected to provide the bulk of PI data. The NRC inspection activities cover areas not amenable to PI development and provide continuing validation and verification for the PIs through a sample of licensee activities related to performance (see Section 4.3 on PI validation and verification).

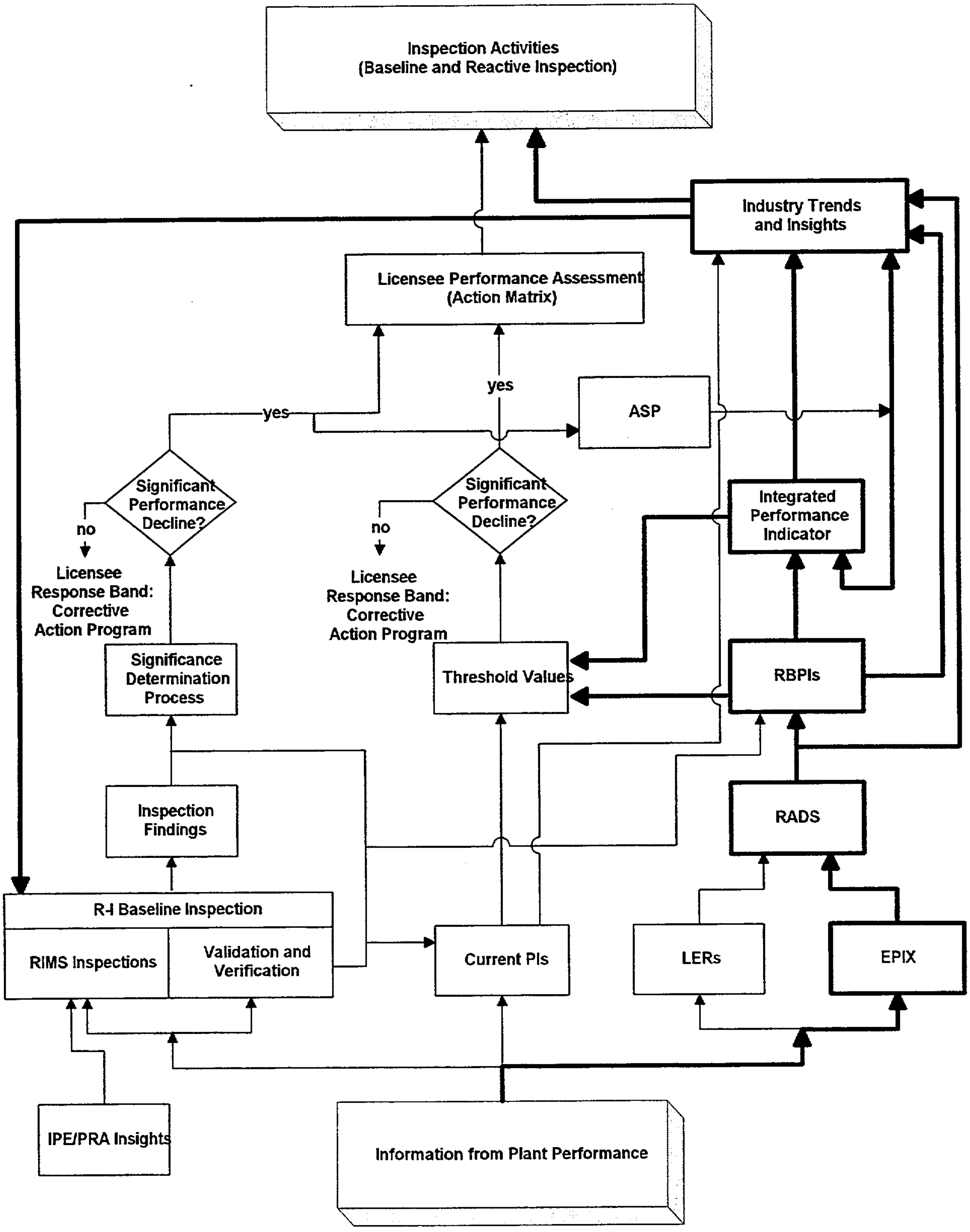


Figure 2. Assessment of Licensee Performance Under the Revised Reactor Oversight Process

In addition to providing plant-specific information, the RBPI program results will provide industry-wide trends (Ref. 3), including risk-significant trends on performance elements that are difficult, if not impossible, to trend on a plant-specific basis. This includes Accident Sequence Precursor (ASP) events (Ref. 4), less-frequent initiators (e.g., loss of offsite power, steam generator tube rupture, and small loss-of-coolant accidents), and common-cause failure (CCF) events. Because more data are available at the industry level, trends emerging at the industry level may be apparent before they are noticed at any given plant. When combined with the plant-specific RBPI trends, these additional trends and associated insights on key contributors provide information to assist in selecting areas for risk-informed inspection activities and to assess, in part, the effectiveness of the Revised Reactor Oversight Process.

The integrated indicator will reflect the combined risk significance of changes occurring in all monitored performance areas. Thresholds established for an individual RBPI reflect the risk significance of changes in that individual RBPI, with all other aspects of performance assumed to be nominal (i.e., green band). If only one area of performance is changing, assessment of its RBPI with respect to its threshold provides a satisfactory understanding of the risk significance of the change. However, if multiple areas of performance are changing, the overall risk significance of the changes should be assessed through an integrated indicator. By showing the degree to which the changes cause synergistic effects on risk, the integrated indicator furnishes additional input to the overall plant assessment. The thresholds for evaluating the significance of changes in the integrated indicator will use the concepts in RG 1.174 for evaluating the performance changes.

3.3 How the Revised Reactor Oversight Process Addresses Design (Capability) Issues

Problems with design (capability) issues can affect plant risk. As a result of design features, hardware performance may degrade prematurely in some areas, or undetected design errors could affect a system response to certain challenges. As stated earlier, there is a direct relationship between capability and availability. An SSC that is incapable of performing its safety function is also unavailable.

If a design deficiency affects the performance of a SSC, it will be detected through licensee problem identification programs, risk-informed baseline inspections, and/or through SSC performance data. If the design deficiency is detected through licensee or NRC inspections, its risk significance will be determined by the Significance Determination Process. Design deficiencies that are not amenable to detection by normal testing and routine surveillance activities will require properly focused design inspections by either NRC or licensees to detect their presence. Once found, the design deficiency represents performance data that can be evaluated through the SDP and/or PI framework as appropriate. When the design deficiency is reflected in the SSC performance data, the corresponding RBPIs will reflect the significance of the performance degradation, typically through degradations in reliability or availability of affected systems and components. Therefore, in both cases, the Revised Reactor Oversight Process will address design deficiencies and their risk significance.

3.4 How the Revised Reactor Oversight Process Addresses Cross-Cutting Issues

Some aspects of performance are "cross-cutting" in the sense that they affect multiple systems through similar if not identical causal factors. This could be manifested as a greater likelihood for common cause failure amongst redundant components or as a general decrease in reliability or availability of plant safety equipment. The oversight process will address cross-cutting issues in four ways:

- Indicators will cover a broad sample of performance to ensure that there are indicators capable of detecting risk-significant changes in programmatic performance areas.
- Indicators at the higher levels of Figure 1 (e.g., the integrated indicator) can show the impact of cross-cutting issues, even if individual lower-level indicators do not.
- Indicators that cover performance across system / train boundaries (e.g., component-level indicators) can show the impact of cross-cutting issues, even if individual system-level or train-level indicators do not. In addition, special inspections will be performed to address some cross-cutting issues.
- Potentially risk-significant cross-cutting issues not covered by indicators will be addressed through specific inspection areas (e.g., problem identification and corrective action program inspections).

4. The Process of Developing RBPIs

Development of RBPIs begins with the set of existing models, analyses, and databases that reflect risk performance of operating plants. These tools will be used in the selection of RBPIs. The process includes a validation and verification effort that covers initial and continuous use of RBPIs.

4.1 Existing Models, Analyses, and Databases

The initial development of RBPIs will rely on the adaptation of readily available models, analyses, and data. This section discusses the models, analyses, and databases that are required for the development of RBPIs. These include the SPAR models (Ref. 5); system reliability, component reliability, and event frequency analyses (Refs. 6, 7); and the EPIX (Ref. 8) and RADS (Ref. 9) databases.

The current set of models, analyses, and databases primarily cover risk performance relating to core damage frequency from internal events. Initial development in the areas of the containment barrier function, external events, and shutdown operation will use insights from currently available analyses such as IPEs, IPEEEs, and existing PRA studies of low-power/shutdown risk. Further improvements to risk models for external events, containment barrier, and shutdown operations may be needed to better satisfy the RBPI development objectives (see Section 4.2) in those areas. Based on the results of future research, enhancements to the initial set of RBPIs may be made.

Existing Standardized Plant Analysis Risk (SPAR) models, as well as system, component, and event frequency assessment models, will be used in RBPI development to:

- group similar plants so that a given set of RBPIs applies to the entire group
- select and formulate RBPIs for each plant group
- evaluate plant-specific baseline values for each RBPI
- evaluate plant-specific RBPI thresholds
- quantify integrated indicators.

The SPAR models are a set of CDF models developed by the NRC for all U.S. commercial nuclear reactors. These SPAR models are an outgrowth of the Accident Sequence Precursor program (Ref. 4). The ASP program identifies precursors to core damage events. Experience in the ASP program indicates that SPAR results and IPE results show a reasonable consistency. The more significant differences are usually due to credit for systems and procedures at plants that were not included in the original SPAR models (such as cross-tie capabilities or additional equipment).

Ongoing system and component reliability studies systematically evaluate operational data of risk-significant systems at nuclear power plants. These studies estimate system unreliability based on operational data and then to compare the results with data, models, and assumptions used in PRA/IPEs. They provide an engineering analysis of the risk-significant factors affecting system unreliability and determine trends or patterns in industry performance.

The system and component reliability studies will be used in the RBPI effort to:

- establish potential groupings of plants with respect to system configuration,
- identify system/train definitions and boundaries,
- establish baseline train and system performance levels (for plants, groups of plants, and the industry as a whole, as appropriate),
- identify important types of CCFs and human errors, and
- provide baseline performance data input to the integrated indicator models.

The report *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 – 1995* (Ref. 6) provides a summary of initiating event data (unplanned, manual, and automatic reactor trips) between 1987 and 1995 for power operation. The report identifies risk-significant initiators and their frequency of occurrence. The report *Evaluation of Loss of Offsite Power Events at Nuclear Power Plants: 1980 – 1996* (Ref. 7) focuses specifically on loss of offsite power initiators at power and during shutdown operations. The report analyzed and trended the underlying causes of loss of offsite power, and showed differences between types of events in both calendar-time trending and degree of plant-to-plant variation.

The EPIX database is an industry-sponsored effort to collect performance information for key components in or affecting risk-significant systems as identified in plant maintenance rule programs. EPIX is a replacement for the Nuclear Plant Reliability Data System (NPRDS) database (Ref. 10). (Data reporting to NPRDS stopped at the end of 1996.) All nuclear utilities have submitted reliability data for entry into EPIX. The RBPI development will use EPIX data to support the evaluation of mitigating system RBPIs. The Reliability and Availability Data System (RADS) (Ref. 9) will be used to analyze the EPIX and other relevant data to determine component, train, and system performance.

RADS provides reliability and availability data and parameter estimation capability for use in risk-informed applications and regulations. It imports data from EPIX as well as other established supplemental sources. The RADS program is under development, with a beta version that began testing in September 1999. The production version of RADS is scheduled for June 2000.

For external events, containment, and shutdown, there are fewer models, analyses, and databases available than for internal events, as noted above. Therefore, RBPI development will rely on insights from existing risk analyses in these areas. These include IPEs and a limited number of Level-3 PRAs for containment issues, IPEEEs for external events, and the limited number of PRAs for shutdown operations.

4.2 RBPI Selection

Figure 3 shows the process for selecting potential RBPIs for evaluation and development. This process includes the following:

- Determining the risk-significant key attributes of each cornerstone
- Determining the elements of each of the risk-significant key attributes
- Obtaining performance data for each of these elements
- Identifying indicators from the data that are capable of detecting performance changes in a timely manner
- Identifying performance thresholds from the data consistent with a graded approach to performance evaluation outlined in the performance thresholds conceptual framework of SECY 99-007.

The process shown in Figure 3 imposes two tests on candidate indicators. First, degraded performance in the indicated area must be risk-significant. Second, operational conditions (frequency of challenges, etc.) must be such that there is a significant statistical chance that degraded performance will be detected by the indicator within a reasonable time. The process in Figure 3 identifies areas for inspection that are risk-significant but not practical to monitor directly. This process also shows the relationship of individual RBPIs to the formulation of an integrated indicator. Finally, after a set of indicators and inspections has been identified, the process calls for an assessment of the risk coverage. The Revised Reactor Oversight Process is predicated on obtaining a sufficient sample of performance in risk-significant areas. It is desirable to understand the degree of coverage afforded by a complement of indicators and inspections.

External events are potentially risk-significant because they can causally link equipment failures whose coincidence is risk-significant and would be unlikely to occur as a result of independent causes. For example, a severe earthquake may damage multiple SSCs whose coincident failure without the earthquake would be extremely unlikely. The potential to link failure events is the reason that scenario types such as "fire" and "internal flood" are frequently discussed together with truly ex-plant external events such as seismic events and high winds.

Conditions that strongly affect the formulation of performance indicators for these events are the following:

- For external events such as earthquake and high wind, the hazard function is not under the control of the licensee. This sets external events apart from the kinds of initiating events that the licensee can affect (e.g., most internal-events transients).
- The initiating event frequency is low enough that data on equipment performance in "real" challenges are sparse.
- Certain mitigating features are not readily testable to produce typical performance indicator data.

Figure 3.
Developing Indicators for Internal Events/Full Power
Sheet 1

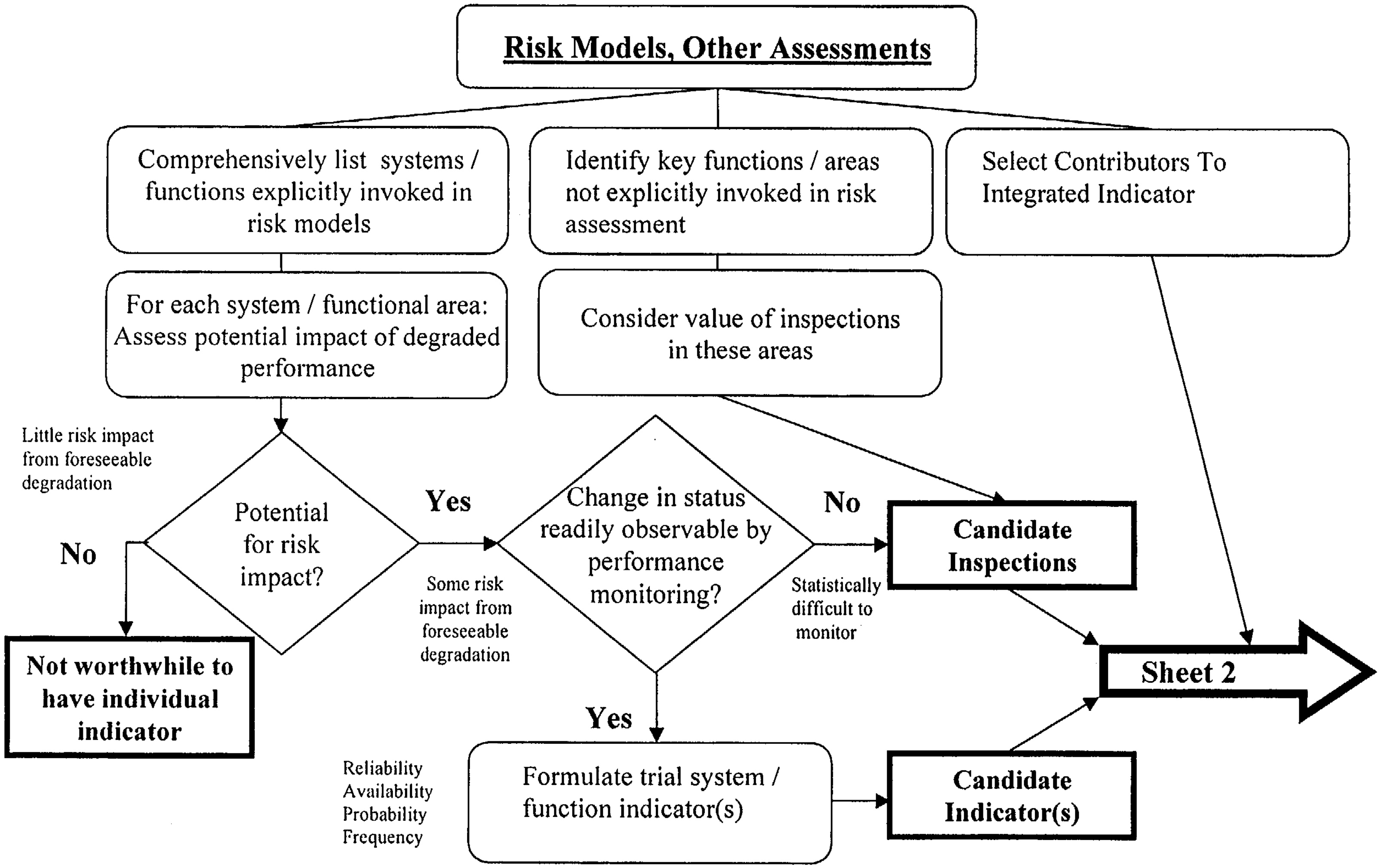
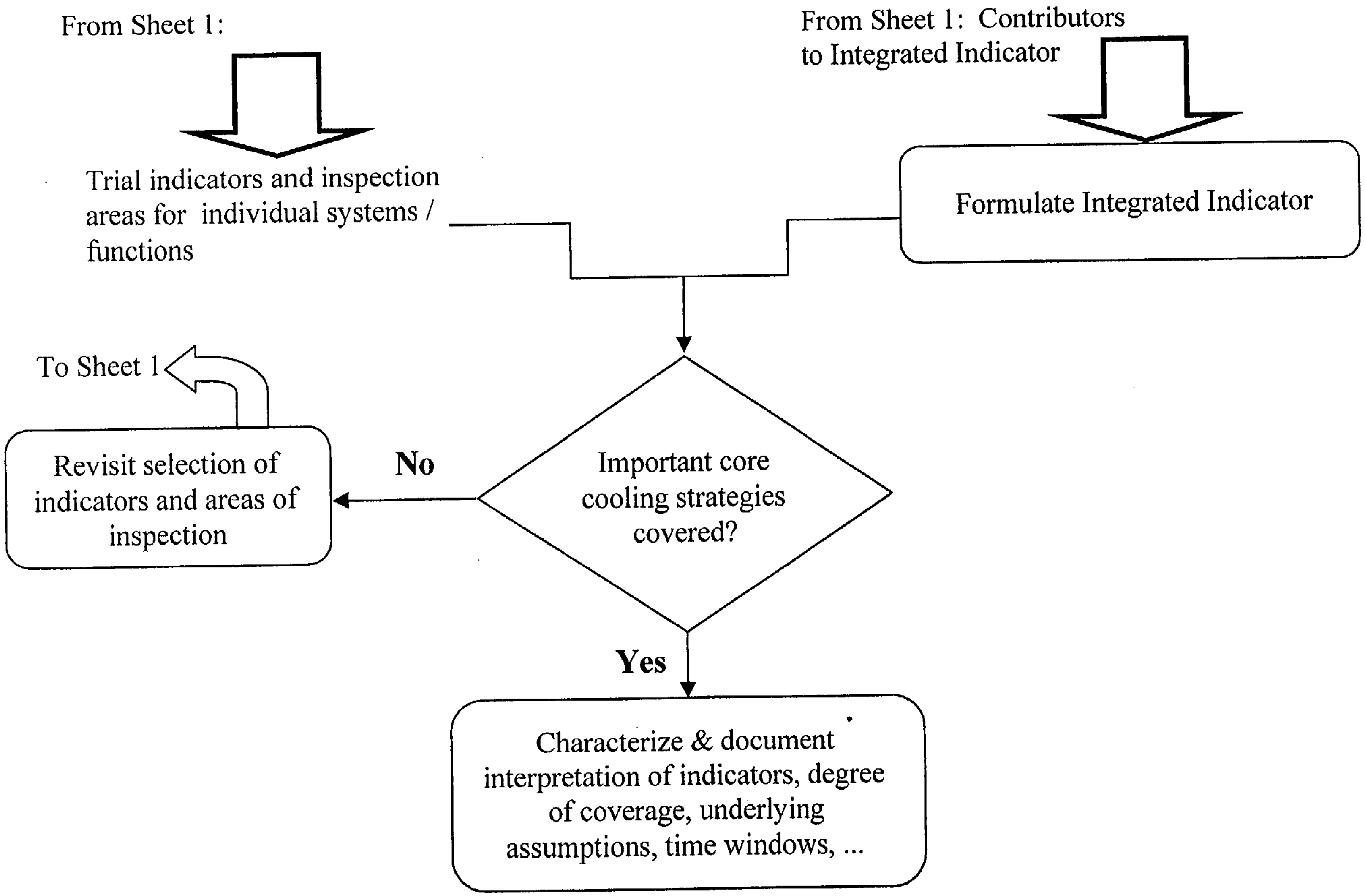


Figure 3.
Developing Indicators for Internal Events/Full Power

Sheet 2



The process for identifying indicators for external events will be similar to that in Figure 3 but will also take into account these factors.

It is widely agreed that shutdown risk is strongly dependent on plant operating state (POS). Correspondingly, the development of risk-based performance indicators will recognize that the risk profile at shutdown varies as RCS conditions change and mitigating systems are taken out of service.

Conditions that affect the formulation of RBPIs for shutdown include:

- Initiators will involve events leading directly to loss of decay heat removal, or loss of inventory leading to loss of decay heat removal, including human errors.
- Risk in the plant operating states (POSs) varies. POSs having high decay heat with reduced inventory tend to be more risk-significant.
- Operator recovery actions play a more prominent role affecting risk.
- There are significant differences in equipment availability between shutdown and at-power modes.

The process for identifying indicators during shutdown operation will be similar to that in Figure 3, but taking into account these key factors.

4.3 Validation and Verification

RBPIs will be validated and verified (V&V) in two phases. The first includes V&V activities undertaken as part of the development and testing of RBPIs. This involves steps similar to those described in SECY 99-007, Attachment 1, for the PIs used in the initial implementation of the Revised Reactor Oversight Process. This includes the following: (1) a systematic process to identify areas where PIs are needed and what kinds of PIs can potentially provide the level of monitoring desired; (2) assuring that the potential PIs satisfy the attributes that have been identified for successful PI development; (3) testing the PIs to assure credibility of results and practicality of implementation.

The second V&V phase involves activities that are an ongoing and integral part of the reactor oversight inspection process. This involves two V&V activities. The first relates to confirming through inspection, Maintenance Rule activities, and audit that the data and calculations that are the basis for the RBPIs are properly monitored, recorded, and calculated. The second aspect relates to inspection activities that verify that "true" performance characteristics are being captured by the RBPIs. The second aspect of validation and verification would involve inspections that determine whether the licensee's problem identification and corrective actions are performing adequately to detect (through testing, inspection or design reviews) faulted and defective conditions that would affect whether an SSC was capable of performing its risk-significant function. If the SSC were incapable of performing its risk-significant safety function and this were not detected by licensee activities (testing, inspection, design review), then the validity of the data used for the associated RBPI would be in question. This would indicate a weakness in licensee problem identification and corrective action programs.

4.4 Summary of Expected Accomplishments and RBPI Development Activities

This RBPI development will:

- Develop a rationale for choosing RBPIs and identifying thresholds for these indicators. This includes:
  - a rationale for grouping plants according to the applicability of indicators and thresholds;
  - formulation of indicators for each group;
  - quantification of thresholds and baseline values that are plant-specific if possible, and in any case group-specific.

- Apply this rationale to:
  - full power (to develop a more comprehensive set of indicators);
  - shutdown;
  - external events.

- Characterize the degree of coverage of the proposed indicator set for each plant group, including identification of important areas not covered by indicators.

- Develop a protocol as well as an automated process for quantifying the indicators:
  - data needed;
  - calculations;
  - quantification of trends.

- Develop an indicator that highlights the integrated impact of current performance levels on CDF. This indicator will provide additional information to the action matrix by supplementing the information provided by RBPIs that are defined for specific systems and component groups.

Development of RBPIs will be accomplished in phases and will follow the following steps:

- Issue an RBPI program overview white paper for stakeholder comment;
- Brief the ACRS and Commission on the RBPI development plan outlined in the program overview white paper;
- Issue a Phase-1 RBPI development progress report, including example RBPIs, for stakeholder comment;
- Brief the ACRS and Commission on the Phase-1 RBPI development progress;
- Issue a Phase-2 RBPI development progress report, including example of RBPIs, for stakeholder comment;
- Brief the ACRS and Commission on the Phase-2 development progress.

The RBPI development will be coordinated with the Office of Nuclear Reactor Regulation (NRR). Throughout the RBPI development process, there will be numerous interactions with internal and external stakeholders to ensure that their feedback is appropriately incorporated.

Table 1 presents a summary of the present status of both the current oversight process indicators and a set of potential RBPIs. In the table, phases 1 and 2 refer to current and future work on the development of RBPIs. Also shown in the cornerstone column in Table 1 is the integration of initiating events and mitigating systems into reactor safety performance (currently represented by core damage frequency). Both full power and shutdown/refueling plant operating modes are identified in Table 1.

The current regulatory oversight process indicators are presented in column four in Table 1. The development of these indicators is discussed in detail in SECY 99-007 and SECY 99-007A (Refs. 1 and 2).

Phase 1 of the RBPI development will concentrate on indicators that are related to the initiating event cornerstone, the mitigating system cornerstone, and the containment portion of the barrier integrity cornerstone. Specifically, these will include:

- Component/train/system reliabilities;
- Containment;
- Fire;
- Shutdown;
- Industry trends.

The fire and shutdown indicators will be developed consistent with the current state of the art models, methods and data for these areas.

Additional phases will address:

- An integrated indicator;
- Improvements to the indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data;
- Additional unavailability indicators with plant-specific thresholds;
- Follow-on work to improve existing indicators in response to NRC and/or industry lessons learned from the Revised Reactor Oversight Process implementation.

Table 1. Current and Potential Performance Indicators

Phase	Cornerstone	Operating Mode	Revised Reactor Oversight Process Indicators	Potential Risk-Based Performance Indicators
1	Initiating Events	Power	Unplanned reactor scrams Reactor scrams with loss of normal heat removal Unplanned reactor power changes	Loss of feedwater frequency Loss of ultimate heat sink frequency Loss of offsite power frequency
		Shutdown/ Refueling	Shutdown margin (future)	Loss of offsite power frequency Loss of residual heat removal system frequency Loss of inventory frequency
	Mitigating Systems	Power	Safety system unavailability Safety system functional failures Safety system unreliability (future)	Basic event level reliability - Pumps (motor and turbine) [key risk systems] - Valves [key risk systems] - Common-cause failure - Operator performance in response to transients Train level reliability - Emergency diesel generators - Auxiliary feedwater pump trains - Auxiliary feedwater injection paths - PWR high pressure injection pump trains - Component cooling water and service water pump trains System level reliability - On-site emergency ac power - Auxiliary feedwater - PWR high pressure injection - BWR high pressure coolant systems - Component cooling water and service water
		Shutdown/ Refueling	Mitigation system availability (future)	Train level reliability and availability - Emergency diesel generators - Reactor vessel inventory control (e.g., high and low pressure injection) - Residual heat removal - Component cooling water and service water
	Barriers	Power	Reactor coolant system specific activity Reactor coolant system identified leak rate	Train level reliability and availability - Containment spray system trains - Containment cooling system trains - Containment isolation system trains
2	Mitigating Systems	Power	None	Plant-specific availability
	Barriers	Shutdown/ Refueling	Reactor coolant system specific activity Reactor coolant system identified leak rate	Reliability and availability - Containment spray system trains - Containment isolation components (e.g., equipment hatches)
	Integrated	Power	None	Core damage frequency + barrier integrity
		Shutdown	None	Core damage frequency + barrier integrity
	Improvements to Phase 1 indicators (e.g., fire and shutdown) based on advances in the state of the art models, methods and data			

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APPENDIX H

RISK-BASED PERFORMANCE INDICATOR DEFINITIONS, DATA, AND CALCULATIONAL PROCEDURES

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Figures

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Appendix H: Risk-Based Performance Indicator Definitions, Data, and Calculational Procedures

H.1 Introduction

This appendix documents the risk-based performance indicator (RBPI) definitions, data, and calculational procedures. The appendix covers full power internal event (Level 1) RBPIs. RBPIs for fire, containment, and external events have not been developed to the same level as the internal event Level 1 RBPIs because suitable models and data are not available. Also, shutdown RBPIs are not included because performance data are not presently being collected.

The overall process for RBPI calculation and comparison with thresholds is illustrated in Figure H-1. Section H.2 of this report describes the definition of the RBPIs. These definitions are the starting point in the first block of Figure H-1. This section contains simplified drawings of mitigating systems that show the portions of the systems that were included in the definition of mitigating system trains. Section H.3 describes the process for setting the baseline values for these RBPIs and presents the results of that analysis. It includes the distribution parameters used for the Bayesian update process for calculating the performance indicators based on operating experience data. Section H.4 provides a table that contains simplified equations (derived from the SPAR Rev. 3i models) for calculating train failure probabilities. The terms from the drawings in Section H.2 correspond to the terms in these equations. It also describes how data for the components that make up these equations are used in a Bayesian update process to calculate the train level indicators. Section H.5 describes the process for the Bayesian updates based on the available data for the components that make up each train. Section H.6 describes the data used in calculating the RBPIs and Section H.7 gives some examples of how data for representative cases were produced.

H.2 RBPI Definitions

There are four types of full power internal event (Level 1) RBPIs: initiating event frequency, mitigating system train unavailability, mitigating system train unreliability, and component class unreliability. A list of the RBPIs is presented in Table H-1.

H.2.1 Initiating Events

Initiating-event-frequency RBPIs are expressed in units of events per calendar year, where the calendar year is defined as one involving 7000 critical hours of operation. The general transient (GT) RBPI is defined in Appendix A of the report *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 – 1995* (Ref. 1). In that report, the GT category is denoted by "Q". The GT category includes automatic or manual reactor trips where the capability of the systems that remove decay heat (safety systems or balance-of-plant systems) is not affected. For example,

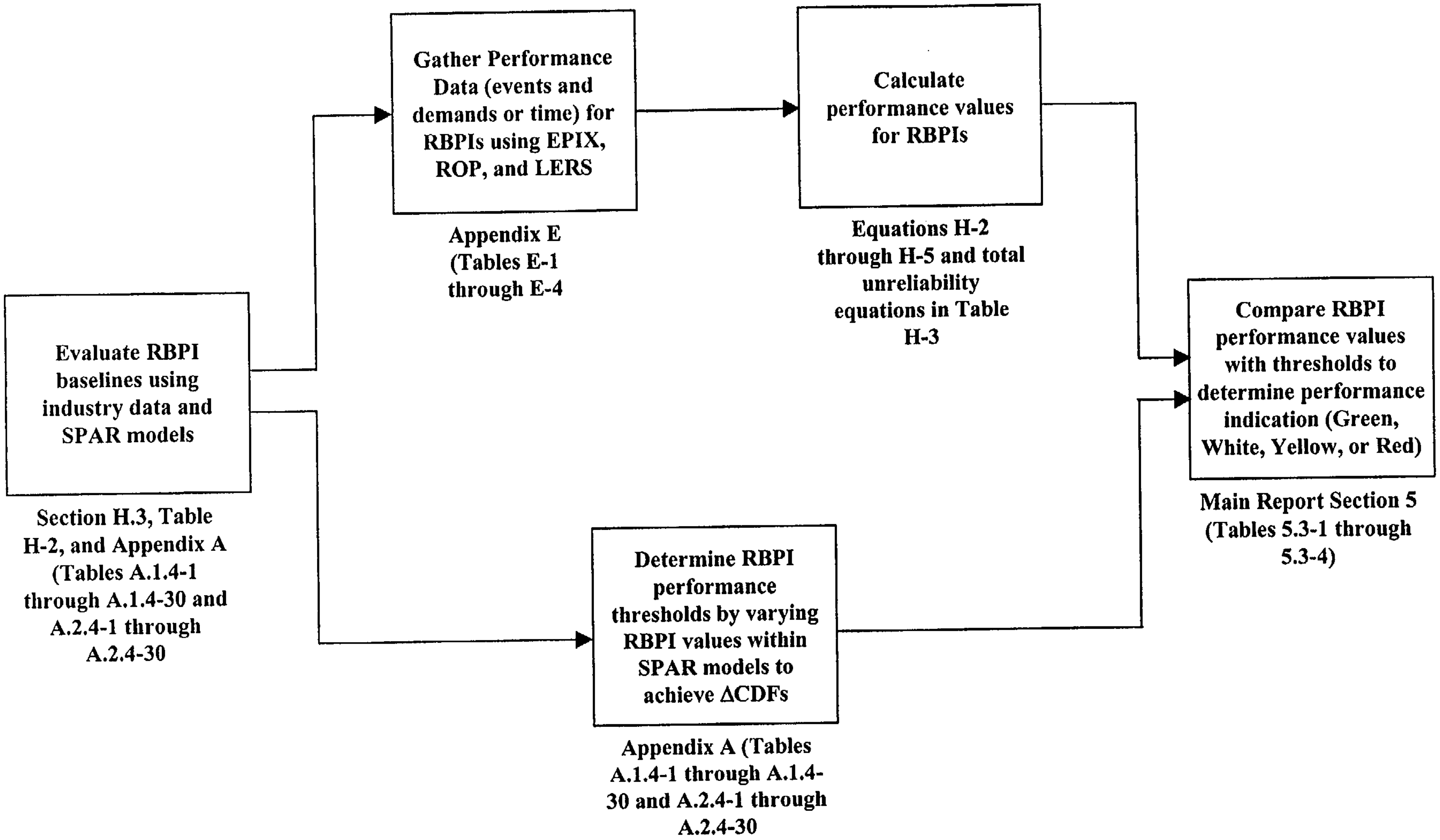


Figure H-1
Overall Process for RBPI Calculation (Full Power, Internal Events)

Table H-1 Full Power Internal Event (Level 1) RBPIs

RBPI Type	RBPI	RBPI Description	BWR/PWR
Initiating event	GT	General transient	Both
	LOHS	Loss of heat sink	Both
	LOFW	Loss of feedwater	Both
Mitigating system	EPS-UA/UR	Emergency power system (diesel generator) train unavailability and unreliability	Both
	HPSI-UA/UR	High-pressure safety injection train unavailability and unreliability	PWR
	SI-UA/UR	Safety injection train unavailability and unreliability	PWR
	CVC-UA/UR	Chemical volume and control system high-pressure injection train unavailability and unreliability	PWR
	HPCI-UA/UR	High-pressure coolant injection train unavailability and unreliability	BWR
	HPCS-UA/UR	High-pressure core spray train unavailability and unreliability	BWR
	AFW-MDP-UA/UR	Auxiliary feedwater motor-driven pump train unavailability and unreliability	PWR
	AFW-TDP-UA/UR	Auxiliary feedwater turbine-driven pump train unavailability and unreliability	PWR
	AFW-DDP-UA/UR	Auxiliary feedwater diesel-driven pump train unavailability and unreliability	PWR
	RCIC-UA/UR	Reactor core isolation cooling train unavailability and unreliability	BWR
Mitigating system	RHR-UA/UR	Residual heat removal train unavailability and unreliability	Both
	PORV-UR	Power-operated relief valve system unreliability	PWR
	CCW-UA/UR	Component cooling water system train unavailability and unreliability	PWR
	SWS-UA/UR	Service water system train unavailability and unreliability	Both
Component class	AOV-UR	Air-operated valve unreliability	Both
	MOV-UR	Motor-operated valve unreliability	Both
	MDP-UR	Motor-driven pump unreliability	Both

the LOFW initiator is not a GT because it affects the ability of the plant to remove decay heat using the main feedwater system. Similarly, LOHS or LOOP affect the ability of removing decay heat and are not included in the GT category. For comparison purposes, the ROP unplanned scrams performance indicator (PI) is similar to the GT RBPI (Ref. 2). However, the unplanned scram PI includes scrams where the capability of one or more mitigating systems is affected, so that PI includes more scrams than the GT RBPI.

Also defined in Appendix A of Ref. 2 are the loss of heat sink (LOHS) and loss of feedwater (LOFW) initiators. The LOHS functional category is termed “total loss of condenser heat sink” in that appendix and is denoted by “L”. Included are automatic or manual reactor trips that involve one or more of the following: complete closure of at least one main steam isolation valve in each main steam line, loss of condenser vacuum, or turbine bypass failure. LOFW is termed “total loss of feedwater flow” and is denoted by “P” in that appendix. Losses of offsite power events are not included in either of these categories. For comparison purposes, the ROP scrams with loss of normal heat removal PI includes both the LOHS and LOFW RBPIs, as well as other contributors such as LOOP.

H.2.2 Mitigating Systems

H.2.2.1 System Boundaries

Similar to the ROP, the mitigating system RBPIs include the emergency AC power system (EPS), high-pressure injection system, heat removal system, and residual heat removal system (RHR). The boundaries for these are similar for the ROP and the RBPI programs. Both include support systems necessary for mitigating system operation, except that the RBPI program includes component cooling water (CCW) as a separate system and includes various service water systems (SWSs) as separate systems. Also, the RBPI program includes the power-operated relief valves (PORVs) as a separate system.

Representative system diagrams are presented in Figures H-2 through H-10. No diagrams are presented for RHR, CCW, SWS, and PORVs because of their plant-specific variability. The diagrams indicate the groupings of components from the SPAR Rev. 3i models that were used to calculate the train level RBPIs. Section H.3 contains a table that has simplified equations of the trains from the SPAR Rev. 3i models that these groupings of components correspond to.

H.2.2.2 Train Unavailability

Train unavailability is defined as the number of hours the train was unavailable (while the plant was at power) divided by the number of hours the train was required to be available (while at power). For RBPI evaluation, trains are defined by the pumps in each fluid system, along with associated active components that must change state to fulfill the risk-significant function upon demand. For the emergency power system, a train is defined as the engine, generator, and output breaker.

Support system unavailability affecting a train is included, unless the support system is already included as a separate RBPI. Planned outage hours (including planned overhaul outages while at power) and unplanned outage hours are included in the RBPI unavailability. Fault exposure hours may or may not be included. If a fault exposure event is the result of a demand fault, then the hours are not included in the unavailability calculation. Other types of fault exposure events are included.

If more than one train exists for a system, then average train unavailability is determined using only trains with similar pumps and operating characteristics. For example, the AFW RBPIs are separated into MDP, TDP, and DDP RBPIs. Also, the SI and CVC systems are separated because of the differences in operating characteristics. The SI system is standby, while the CVC system contains pumps that may be operated continuously while the plant is at power.

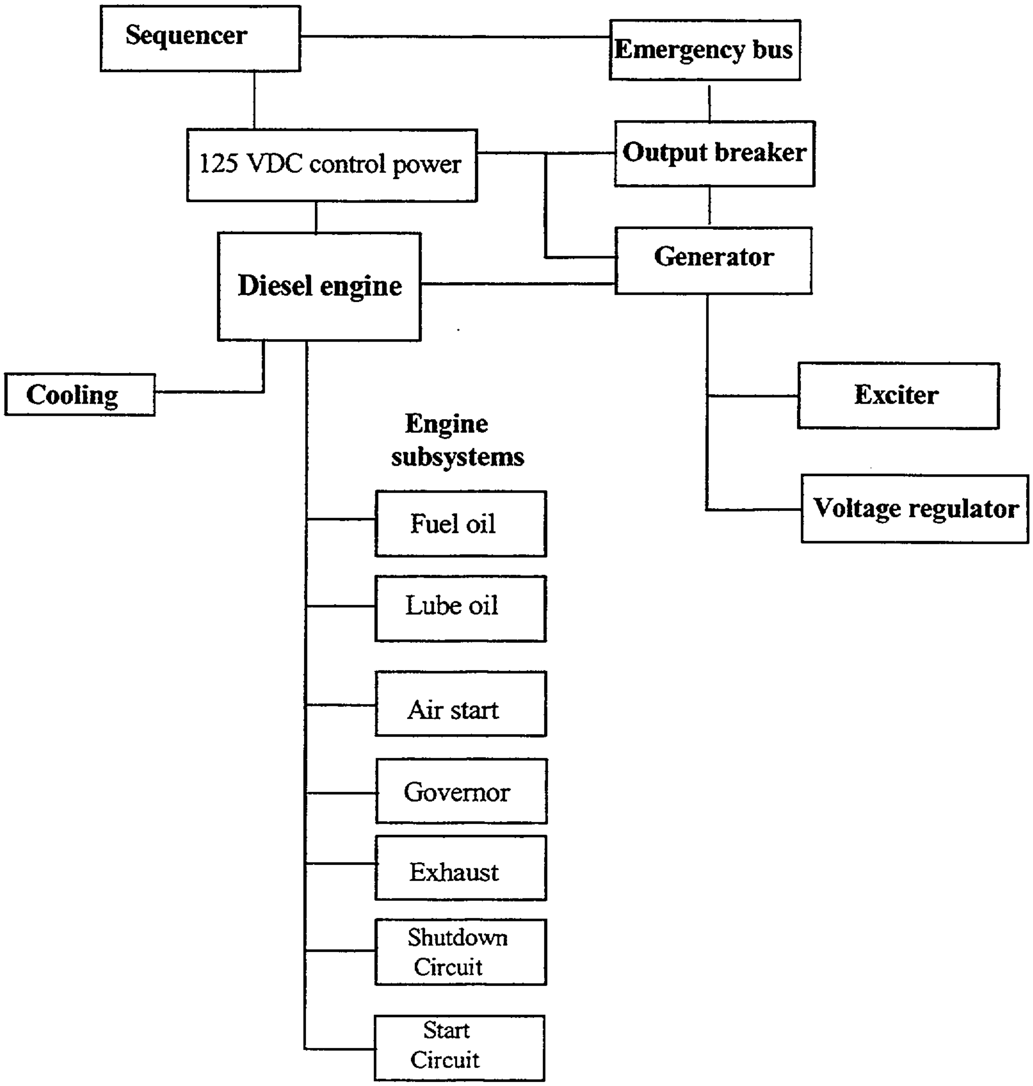


Figure H-2 Simplified Diagram for EDG Train

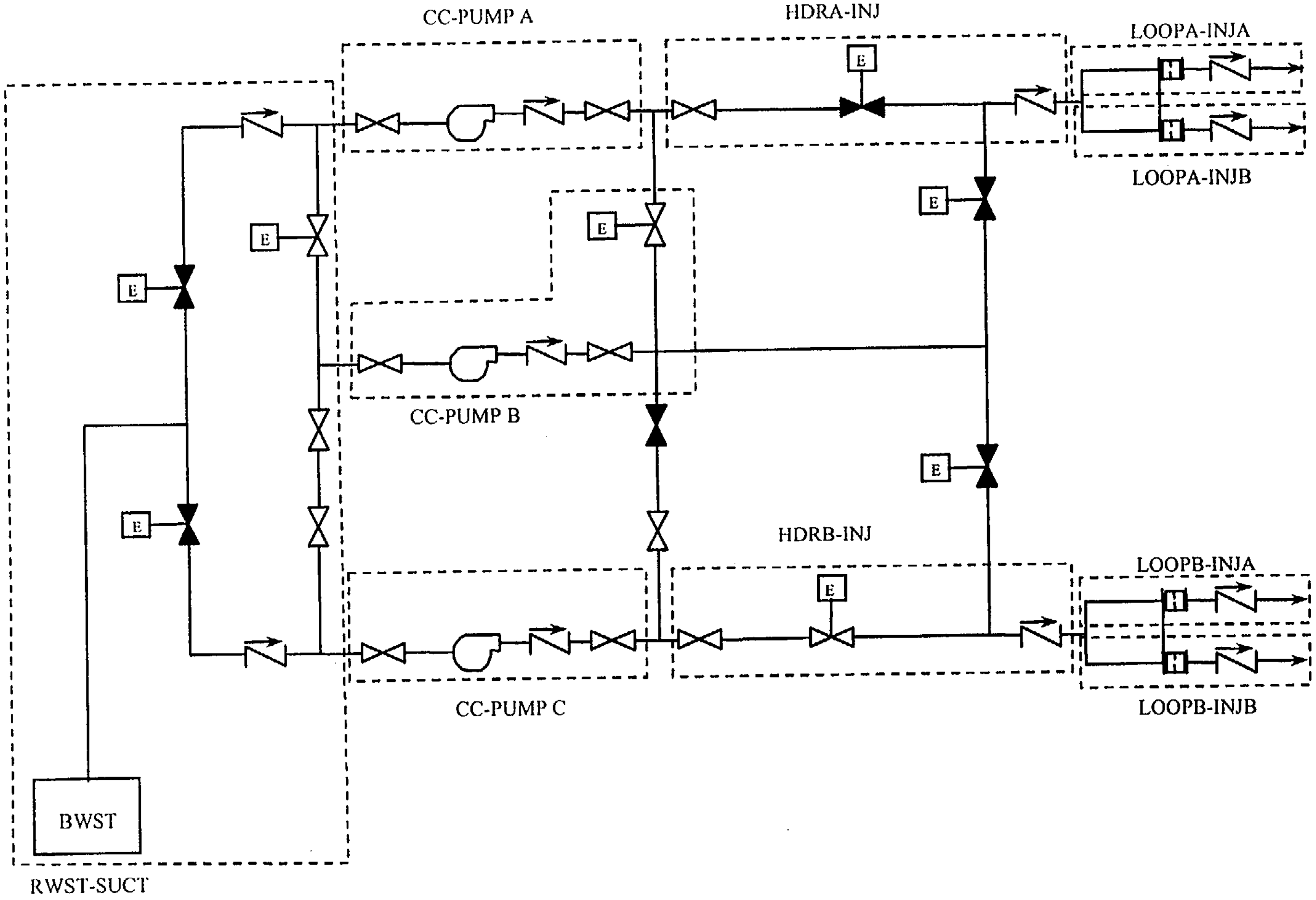


Figure H-3 Simplified Diagram for HPI Design Class 2

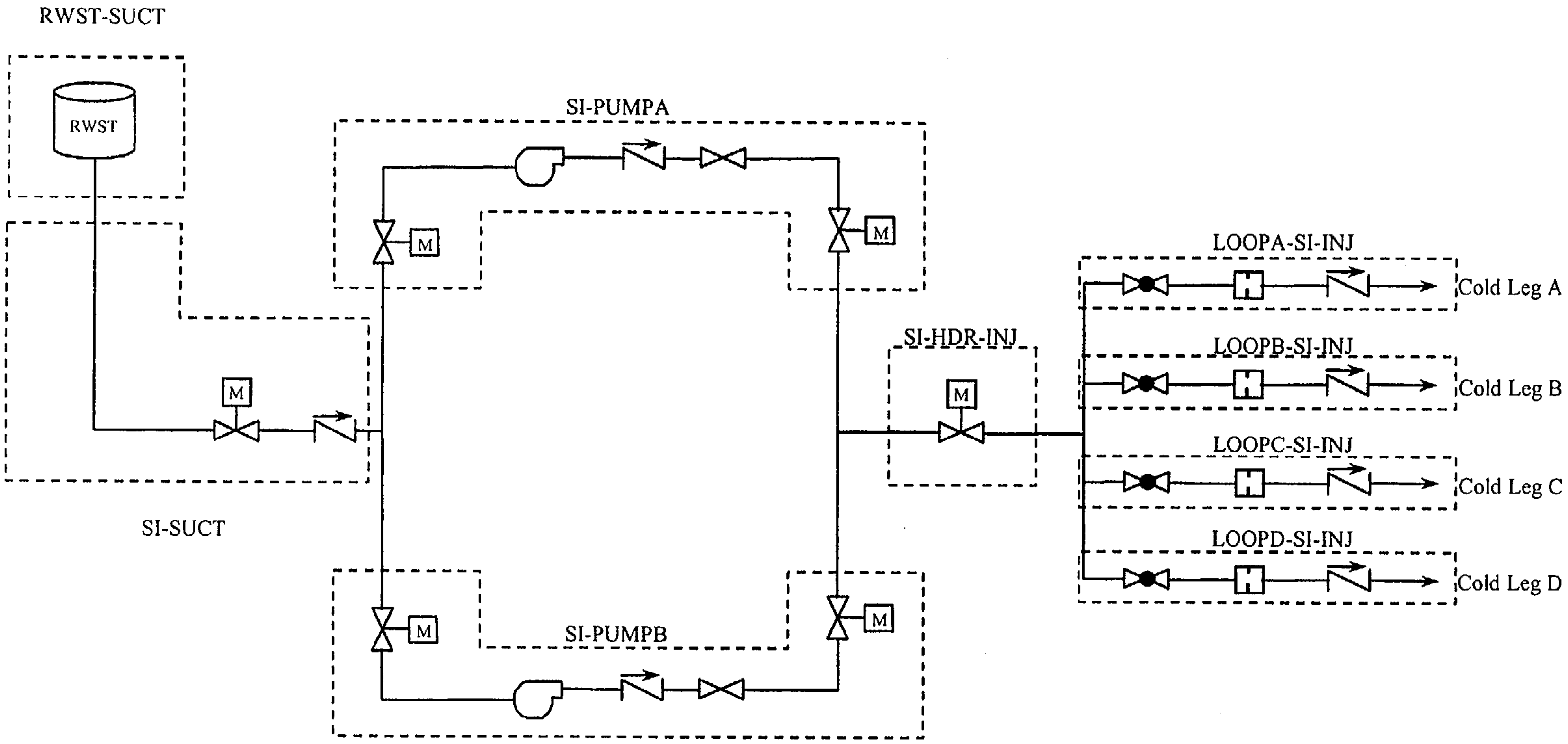


Figure H-4 Simplified Diagram for SI Design Class 6

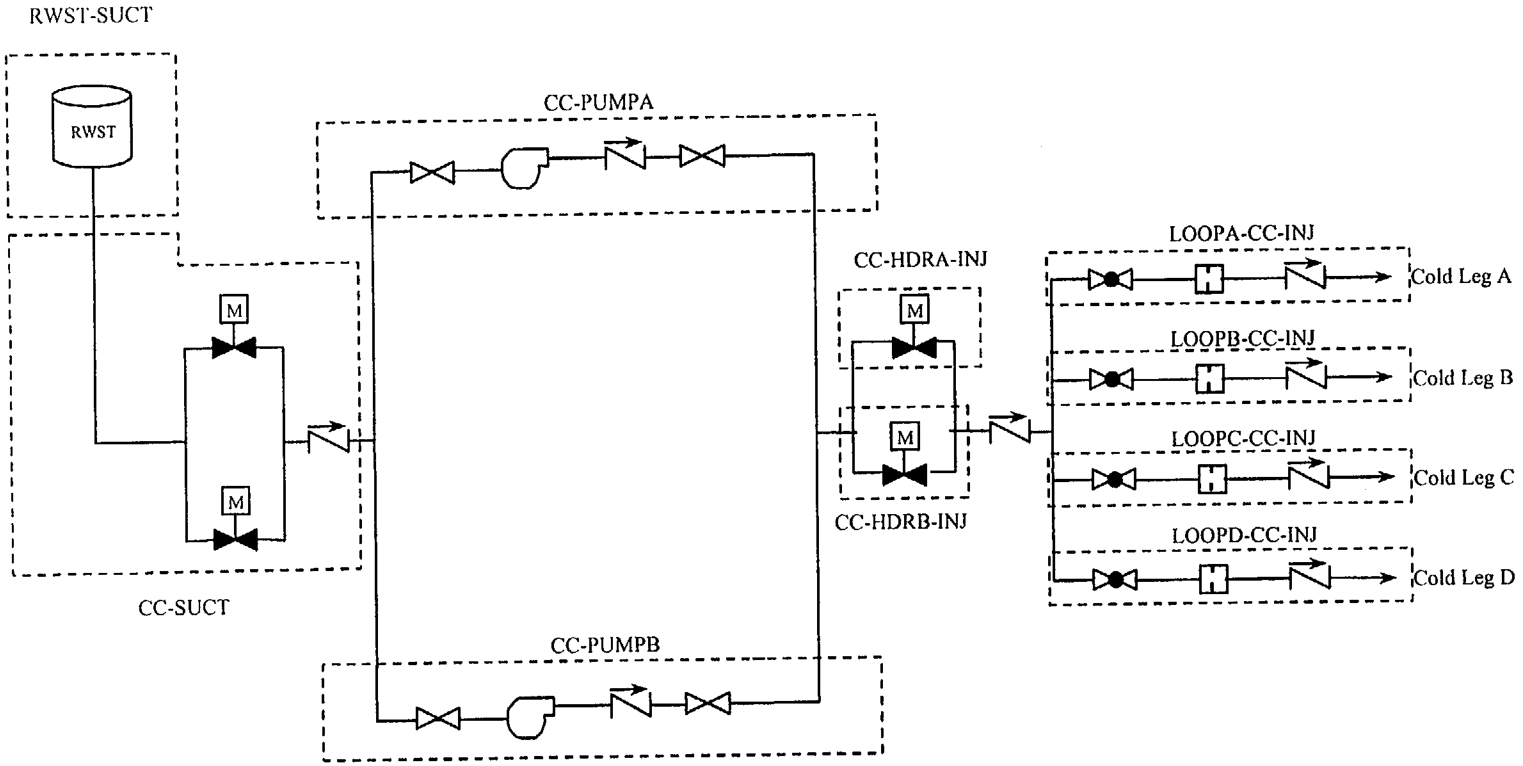


Figure H-5 Simplified Diagram for CVC Design Class 6

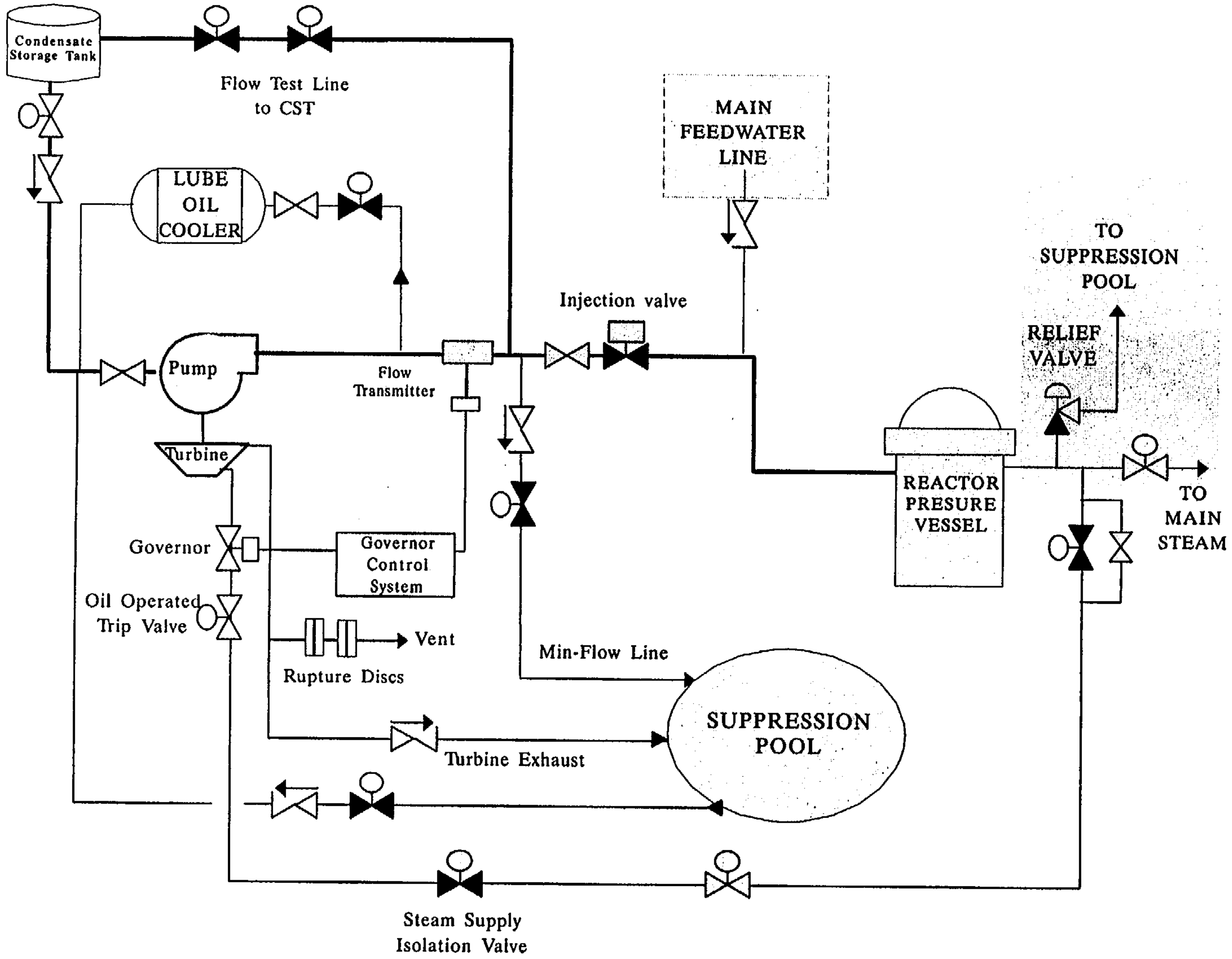
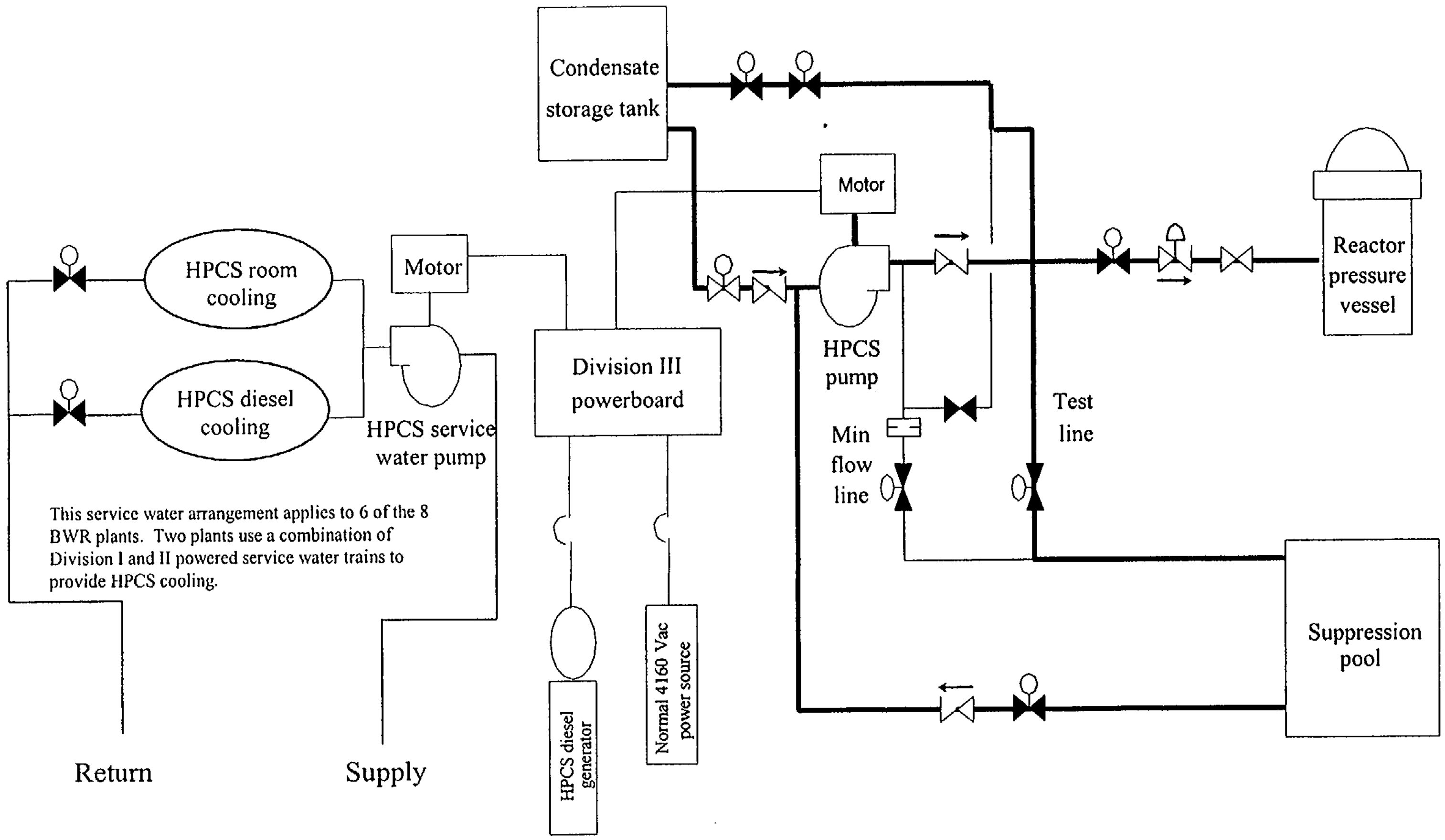


Figure H-6 Simplified Diagram for HPCI



This service water arrangement applies to 6 of the 8 BWR plants. Two plants use a combination of Division I and II powered service water trains to provide HPCS cooling.

Figure H-7 Simplified Diagram for HPCS

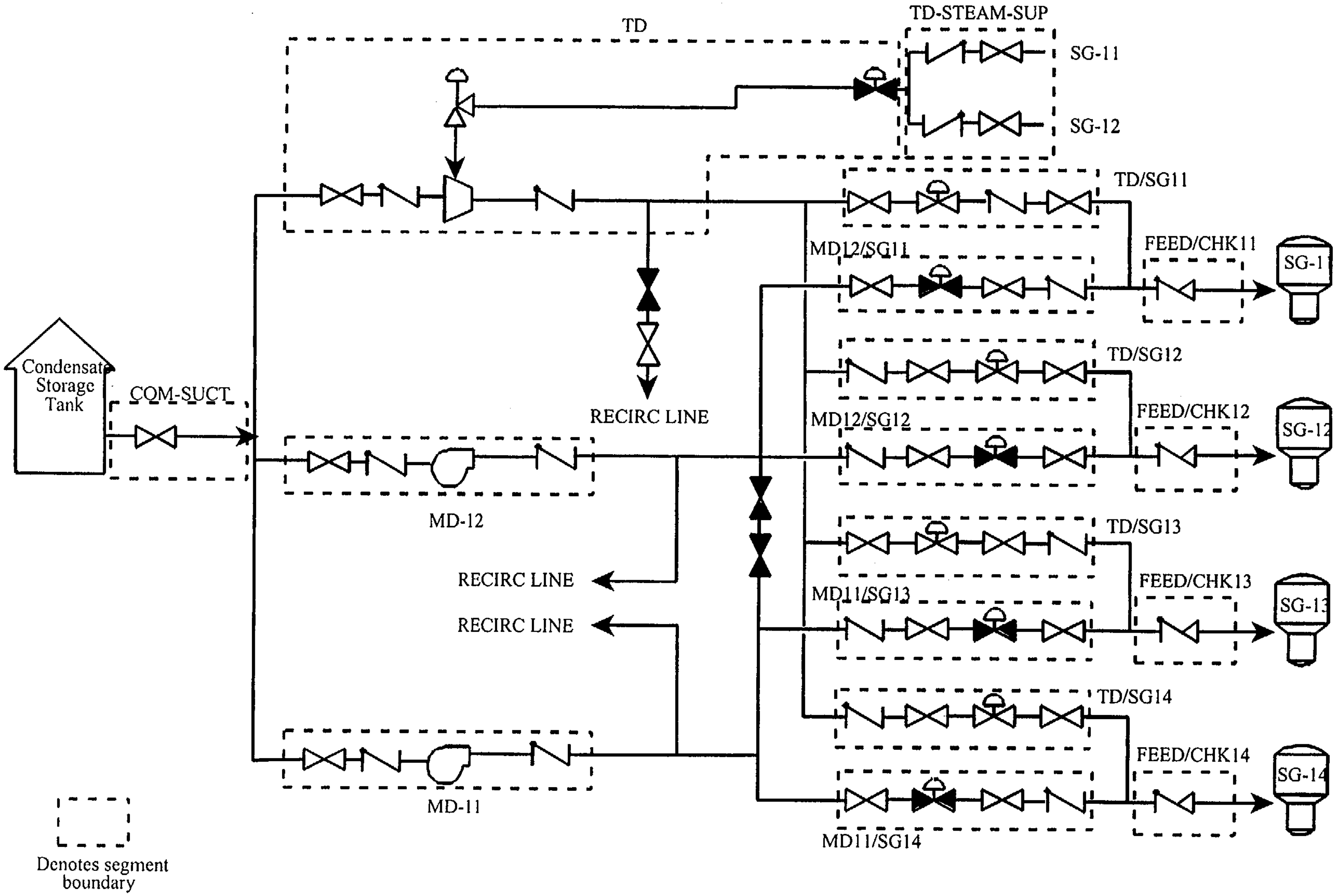


Figure H-8 Simplified Diagram for AFW Design Class 10

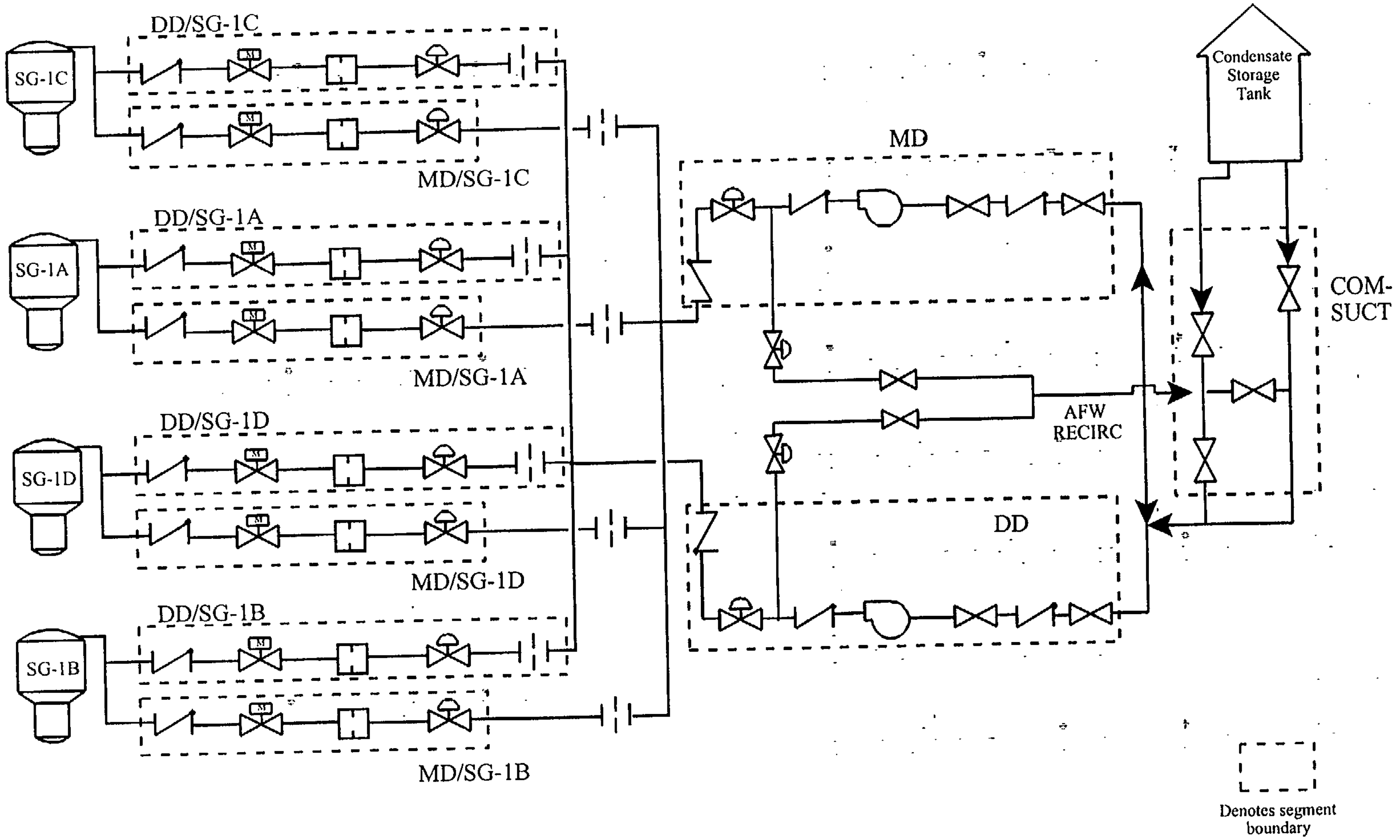


Figure H-9 Simplified Diagram for AFW Design Class 7

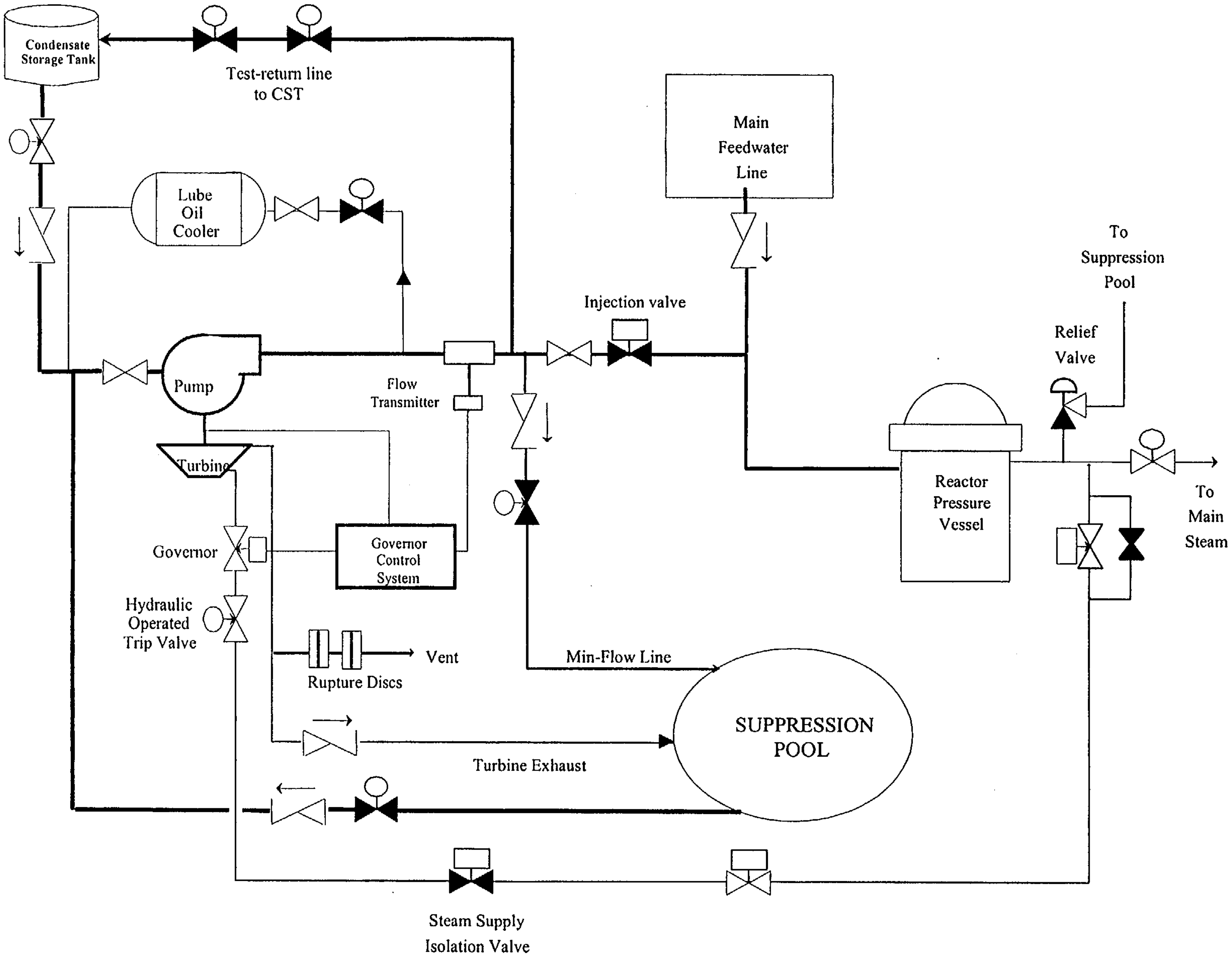


Figure H-10 Simplified Diagram for RCIC

For comparison purposes, the ROP definition of unavailability is similar. However, the ROP does not include planned overhaul outages in planned outage hours, includes all fault exposure times, and includes contributions to unavailability when the plant is shutdown (for systems required to be available during that time) (Ref. 2, Section 2.2 Mitigating Systems Cornerstone, Safety System Unavailability, Clarifying Notes). Also, the ROP averages unavailability across all trains within a system, even if the trains contain dissimilar pumps or operating characteristics.

H.2.2.3 Train or System Unreliability

Mitigating system unreliability at the train or system level is derived from a reliability logic model at the component level. Only active components that must change state upon actuation are explicitly included in the reliability models. Components that must start and run for a specified period, such as pumps or diesel generators, have both failure upon demand (failure to start) and failure to run contributions to unreliability. For such components, unreliability is defined as the following:

$$UR_{component} = P + \lambda T \qquad \text{(Eq. H-1)}$$

where $UR_{component}$ = component unreliability (failure to start and run)
P = component failure to start probability
λ = component failure to run (rate)
T = mission time.

Valves that need to change state (open or close) have only a failure upon demand (failure to open or close) contribution to unreliability.

Failure upon demand, P, is expressed as the number of failures divided by the number of demands. Failure to run, λ, is expressed as the number of failures divided by the run time.

RBPI train or system unreliability is defined as the total probability of failure to perform its risk-significant safety function (both unavailability and unreliability) for the train or system, as evaluated using the appropriate train or system fault tree in the SPAR Rev. 3i model. The train or system fault tree contains component contributions to unreliability. Unavailability is included at its baseline value in the calculation merely for the ease of manipulating the SPAR Rev. 3i models. It is kept constant in all threshold determinations and performance calculations, so that only changes in the unreliability portion affect the outcome.

At present the ROP does not have an unreliability PI. However, fault exposure time is included in the unavailability PIs as an approximate way to incorporate unreliability caused outage hours.

H.2.3 Component Classes

Component class RBPIs include air-operated valves (AOVs), motor-operated valves (MOVs), and MDPs in risk-significant systems. For the AOVs and MOVs, unreliability is defined as the failure to open or close. For MDPs, unreliability includes both failure to start and failure to run contributions. The scopes for these component classes include components within risk-significant systems as outlined in the U.S. Nuclear Regulatory Commission (NRC) component study reports (Refs. 3 through 6). The component boundaries are also specified in these references. AOVs include the valve body and pneumatic operator subcomponents (including the solenoid valve). MOVs include the valve body and motor-operator subcomponents (excluding the circuit breaker). Finally, the MDPs include the pump, motor, and circuit breaker subcomponents.

H.3 Baseline Determination

The SPAR Rev. 3i models are used as the baselines for plants. These baselines are needed to calculate plant-specific RBPI thresholds and to evaluate train (and system) unreliabilities. However, some changes to those models were made to create baselines that were more appropriate for the RBPI program. These changes were made to establish baselines that reflected (as closely as possible) 1996 industry performance. For initiating events, Reference 1 was used to determine industry (or PWR/BWR) average frequencies for the GT, LOHS, and LOFW RBPIs. (That report covered initiating event data through 1995, so the results for 1995 were used as representative of 1996 performance.) Mitigating system train unavailabilities were calculated using the World Association of Nuclear Operators (WANO, Ref. 8) unavailability data for the last quarter of 1995 and all of 1996 (planned and unplanned outage hours only). Industry average values were calculated, rather than plant-specific values. Finally, where available, unreliability information was obtained from the various system study reports (Refs. 9 through 14 and 18). This information typically included pump or EDG failure to start and failure to run data and selected valve failure to operate data. Recovery probabilities reported in these reports are reflected in the SPAR Rev. 3i models. The baseline values for initiating events, mitigating system train unavailabilities, and component unreliabilities are presented in Table H-2.

H.4 Mitigating System Unavailability and Unreliability Equations

Mitigating system unavailability and unreliability RBPIs are defined at the train level, rather than at the component level. The following subsections present the train-level equations.

H.4.1 Train Unavailability Equation

The equation for estimating train unavailability is the following:

$$UA = (PLAN + UNPL + FLT)/(RQRD) \qquad \text{(Eq. H-2)}$$

where UA = train unavailability

PLAN = train outage hours due to planned maintenance (while train is required for service)

UNPL = train outage hours due to unplanned maintenance (while train is required for service)

FLT = train outage hours due to fault exposure time (while train is required for service). Note that this term is used only if the fault exposure event is not covered in the unreliability RBPI.

RQRD = total hours train is required for service.

Table H-2 RBPI Baseline Values

RBPI	Industry Mean	Bayesian Update Parameters[a]		Notes[b]	Source
		a	b		
Initiating Events GT PWR	1.2/year	0.5	4.2E-1		NUREG/CR-5750 (1995)
LOHS PWR	2.3E-1/year	0.5	2.2		NUREG/CR-5750 (1995)
LOFW	6.8E-2/year	0.5	7.4		NUREG/CR-5750 (1995)
GT BWR	9.6E-1/year	0.5	5.2E-1		NUREG/CR-5750 (1995) (Ref. 1)
LOHS BWR	9.6E-2/year	0.5	5.2		NUREG/CR-5750 (1995)
Mitigating System Train Unavailability EPS	9.3E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c] (Ref. 8)
HPI	4.2E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
SI	4.2E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
CVC	5.4E-2	NA	NA	No Bayesian update is used for unavailability data.	SPAR generic database (average of IPE values) (Ref. 19)
AFW MDP	1.1E-3	NA	NA	No Bayesian update is used for unavailability data. Includes recovery.	NUREG/CR-5500, Vol. 1 (Ref. 13)
AFW TDP	4.6E-3	NA	NA	No Bayesian update is used for unavailability data. Includes recovery.	NUREG/CR-5500, Vol. 1
AFW DDP	1.5E-2	NA	NA	No Bayesian update is used for unavailability data.	SPAR generic database (average of IPE values)
RHR PWR	7.3E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
CCW	Range of train unavailability values used, depending upon design (1.1E-2 to 4.4E-2)	NA	NA	No Bayesian update is used for unavailability data.	SPAR generic database (based on IPE values)

Table H-2 (Continued)

RBPI	Industry Mean	Bayesian Update Parameters[a]		Notes[b]	Source
		a	b		
SWS	Range of train unavailability values used, depending upon design (5.9E-3 to 5.5E-2)	NA	NA	No Bayesian update is used for unavailability data.	SPAR generic database (based on IPE values)
HPCI	9.7E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
HPCS	3.4E-3	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
RCIC	1.3E-2	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
RHR BWR	1.0E-2	NA	NA	No Bayesian update is used for unavailability data.	WANO[c]
Mitigating System Component Unreliability					
EDG FTS	1.2E-2	4.8E-1	4.0E+1	Recovery not included, because it is included in the SPAR ac power recovery model.	NUREG/CR-5500, Vol. 5 (Ref. 12)
EDG FTLR	1.3E-2	4.8E-1	3.5E+1	Obtained from source by using the expression $(FTR_{0\ \mathrm{to}\ 0.5h})$*0.5h + $(FTR_{0.5\ \mathrm{to}\ 14h})$*0.5h. Recovery not included, because it is included in the SPAR ac power recovery model.	NUREG/CR-5500, Vol. 5
EDG FTR	1.8E-3/h	5.0E-1	4.6E+2	Obtained from source by using $FTR_{0.5\ \mathrm{to}\ 14h}$. Recovery not included, because it is included in the SPAR ac power recovery model.	NUREG/CR-5500, Vol. 5
HPI MDP FTS	3.0E-3	4.9E-1	1.6E+2	Recovery included	NUREG/CR-5500, Vol. 9 (Ref. 18)

Table H-2 (Continued)

RBPI	Industry Mean	Bayesian Update Parameters[a]		Notes[b]	Source
		a	b		
HPI MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1 (Ref. 20)
SI MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
SI MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1
CVC MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
CVC MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1
AFW MDP FTS	8.1E-4	5.0E-1	6.2E+2	Recovery included	NUREG/CR-5500, Vol. 1
AFW MDP FTR	2.4E-4/h	5.0E-1	2.1E+3	Recovery included	NUREG/CR-5500, Vol. 1
AFW TDP FTS	1.4E-2	4.8E-1	3.4E+1	Recovery included	NUREG/CR-5500, Vol. 1
AFW TDP FTR	8.2E-3/h	5.0E-1	6.1E+1	Recovery included	NUREG/CR-5500, Vol. 1
AFW DDP FTS	5.7E-3	4.9E-1	8.6E+1	Recovery included	NUREG/CR-5500, Vol. 1
AFW DDP FTR	8.0E-4/h	5.0E-1	6.3E+2		NUREG/CR-4550, Vol. 1
RHR MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
RHR MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1
PORV FTO	6.3E-3	4.9E-1	7.7E+1		NUREG/CR-4550, Vol. 1
CCW MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
CCW MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1
SWS MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
SWS MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1
HPCI TDP FTS	5.0E-3	4.9E-1	9.8E+1	Recovery included	NUREG/CR-5500, Vol. 4 (Ref. 11)
HPCI TDP FTR	1.1E-3/h	5.0E-1	4.6E+2	Recovery included	NUREG/CR-5500, Vol. 4
HPCI Injection MOV FTO	2.1E-3	4.9E-1	2.3E+2	Recovery included	NUREG/CR-5500, Vol. 4
HPCS MDP FTS	5.0E-3	4.9E-1	9.8E+1	Not enough data in source to model recovery	NUREG/CR-5500, Vol. 8 (Ref. 14)
HPCS MDP FTR	1.7E-3/h	5.0E-1	2.9E+2	Not enough data in source to model recovery	NUREG/CR-5500, Vol. 8
HPCS Injection MOV FTO	2.0E-2	4.7E-1	2.3E+1	Not enough data in source to model recovery	NUREG/CR-5500, Vol. 8

Table H-2 (Continued)

RBPI	Industry Mean	Bayesian Update Parameters[a]		Notes[b]	Source
		a	b		
RCIC TDP FTS	2.1E-2	4.7E-1	2.2E+1	Recovery included	NUREG/CR-5500, Vol. 7 (Ref. 10)
RCIC TDP FTR	2.5E-4/h	5.0E-1	2.0E+3	Recovery included	NUREG/CR-5500, Vol. 7
RCIC Injection MOV FTO	3.9E-3	4.9E-1	1.3E+2	Recovery included	NUREG/CR-5500, Vol. 7
Component Class Unreliability					
AOV FTO/FTC	1.0E-3	5.0E-1	5.0E+2		NUREG/CR-4550, Vol. 1
MOV FTO/C	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
MDP FTS	3.0E-3	4.9E-1	1.6E+2		NUREG/CR-4550, Vol. 1
MDP FTR	3.0E-5/h	5.0E-1	1.7E+4		NUREG/CR-4550, Vol. 1

Acronyms: Components [AOV – air-operated valve, CKV – check valve, DDP – diesel- or engine-driven pump, EDG – emergency diesel generator, MDP – motor-driven pump, MOV – motor-operated valve, TDP – turbine-driven pump]; failure modes [FTC – fail to close, FTLR – fail to load and run for one hour (only for EDGs), FTO – fail to open, FTR – fail to run, FTS – fail to start].

a. A constrained, noninformative Bayesian update is used.

b. "Recovery included" indicates that the baseline value listed includes the failure rate multiplied by the failure to recover probability. For example, in the NRC system studies listed as sources, a pump train has a failure to start probability and a failure to recover from failure to start probability. The baseline value presented in this table is the product of the failure to start value and the failure to recover from failure to start value.

c. The RBPI baseline values were selected to be representative of 1996 industry performance. Because ROP data on train unavailability were not available for that period, WANO data for the last quarter of 1995 and all of 1996 were used.

This train unavailability equation is similar to the one used in the ROP, except that the fault exposure time (FLT) contribution is included only if the FLT event is not associated with a demand fault. Train definitions for unavailability are similar for the RBPI and ROP programs. However, the RBPI program averages unavailability data only across trains with similar pumps and operating characteristics. In contrast, the ROP program averages unavailability across all trains within a system, even if the pump types and/or operating characteristics differ.

H.4.2 Train Unreliability Equations

As indicated in Section H.3, RBPI train unreliability is defined as the total unreliability (both unavailability and unreliability) for the train, as evaluated using the appropriate train fault tree in the SPAR Rev. 3i model. Presented in Table H-3 are equations for the RBPI train total unreliabilities (including unavailability), developed from the simplified system diagrams presented in Figures H-2 through H-10. These train total unreliability equations model only major components (pumps, diesel generators, and valves) that must change state upon demand, along with train unavailability. Changes of state during the mission time for valves that initially successfully changed state upon demand are not included. Baseline train unavailability is included in order to avoid making substantial changes to the SPAR models. It is treated as a constant term (at its baseline value) for the unreliability calculations for both threshold determination and performance evaluation. Therefore, only changes in the unreliability parameters affect the RBPI comparison of performance data with the thresholds.

H.5 RBPI Parameter Estimation

H.5.1 Initiating Events

Initiating event RBPIs are calculated using a Bayesian update procedure. The Bayesian update uses a constrained, noninformative prior (Ref. 7) and plant-specific data. As discussed in Appendix F, the constrained, noninformative prior had the best false positive/false negative characteristics. The Bayesian update equation is the following:

$$\lambda_{\text{posterior mean, ie}} = (a + n)/[b + t] \qquad \text{(Eq. H-3)}$$

where $\lambda_{\text{posterior mean,ie}}$ = RBPI initiating event frequency for the plant in question (per calendar year)

n = number of events for the plant in question over the time period of interest

a = 0.5

b = $a/\lambda_{\text{prior mean, ie}}$

$\lambda_{\text{prior mean,ie}}$ = baseline initiating event frequency (per 7000 hours of critical operation)

t = number of years (critical hours divided by 7000 hours).

The data collection periods are one year for GT and three years for LOHS and LOFW.

Table H-3 Equations for Mitigating System Train Unreliability

RBPI Train Unreliability	Equation for Train Total Unreliability [a, b]	Notes
EPS	EDG FTS + EDG FTLR + EDG FTR*(T – 1.0) + EDG Baseline Train Unavailability	Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 4 hours. Mission time reduced by 1.0 hour because the first hour of operation is covered under FTLR. EDG system is shown in Figure H-2.
HPI	(Suction MOV FTO*Suction MOV FTO) + (MDP FTS + MDP FTR*T) + Injection MOV FTO + (Isolation CKV FTO* Isolation CKV FTO) + HPI Baseline Train Unavailability	NUREG/CR-5500, Vol. 9 lists six plant design classes for HPI/SI/CVC. Equation is for design class 2 (Figure H-3). Other design classes would have different simplified unreliability equations. Mission time T taken from SPAR Rev. 3I model for plant in question. Typically T is 24 hours.
SI	(MDP FTS + MDP FTR*T) + 4*(Isolation CKV FTO*Isolation CKV FTO*Isolation CKV FTO) + SI Baseline Train Unavailability	NUREG/CR-5500, Vol. 9 lists six plant design classes for HPSI/SI/CVC. Equation is for design class 6 (Figure H-4). Success criterion for the injection lines is 2 of 4. Other design classes would have different simplified unreliability equations. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.
CVC	(Suction MOV FTO*Suction MOV FTO) + (MDP FTS + MDP FTR*T) + (Outlet MOV FTO*Outlet MOV FTO) + 4*(Isolation CKV FTO*Isolation CKV FTO*Isolation CKV FTO) + CVC Baseline Train Unavailability	NUREG/CR-5500, Vol. 9 lists six plant design classes for HPSI/SI/CVC. Equation is for design class 6 (Figure H-5). Success criterion for the injection lines is 2 of 4. Other design classes would have different simplified unreliability equations. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.
AFW MDP	(MDP FTS + MDP FTR*T) + (Injection MOV FTO + Isolation CKV FTO)*(Injection MOV FTO + Isolation CKV FTO) + AFW MDP Baseline Train Unavailability	NUREG/CR-5500, Vol. 1 lists 11 plant design classes. Equation is for design class 10 (Figure H-8). Success criterion for the injection lines is 2 of 4. If the other MDP and TDP trains fail, then the injection MOV portion of the equation changes to 2*(Injection MOV FTO + Isolation CKV FTO). Other design classes would have different simplified unreliability equations. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.

Table H-3 (Continued)

RBPI Train Unreliability	Simplified Equation for Train Total Unreliability[a]	Notes
AFW TDP	(TDP FTS + TDP FTR*T) + 4*(Isolation CKV FTO*Isolation CKV FTO*Isolation CKV FTO) + AFW TDP Baseline Train Unavailability	NUREG/CR-5500, Vol. 1 lists 11 plant design classes. Equation is for design class 10 (Figure H-8). Success criterion for the injection lines is 2 of 4. Other design classes would have different simplified unreliability equations. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically 24 hours.
AFW DDP	(DDP FTS + DDP FTR*T) + (Isolation CKV FTO*Isolation CKV FTO*Isolation CKV FTO*Isolation CKV FTO) + AFW DDP Baseline Train Unavailability	NUREG/CR-5500, Vol. 1 lists 11 plant design classes. Equation is for design class 7 (Figure H-9). Success criterion for the injection lines is 1 of 4. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically 24 hours.
RHR	MDP FTS + MDP FTR*T + RHR Baseline Train Unavailability	There is no NRC system study for the RHR system. Because plants vary significantly in RHR design, only the MDP is presented. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.
CCW	MDP FTS + MDP FTR*T + CCW Baseline Train Unavailability	There is no NRC system study for the CCW system. Plants vary with respect to cooling loads modeled in the SPAR models. Only the MDP is presented. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.
SWS	MDP FTS + MDP FTR*T + SWS Baseline Train Unavailability	There is no NRC system study for the SWS. Because plants vary significantly in SWS designs and the cooling loads modeled in the SPAR models, only the MDP is presented. Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.
PORV	PORV FTO	
HPCI	(TDP FTS + TDP FTR*T) + Injection MOV FTO + Steam Supply Isolation MOV FTO + HPCI Baseline Train Unavailability	Equation is for simplified diagram from NUREG/CR-5500, Vol. 4 (Figure H-6). Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.

Table H-3 (Continued)

RBPI Train Unreliability	Simplified Equation for Train Total Unreliability[a]	Notes
HPCS	MDP FTS + MDP FTR*T + Injection MOV FTO + EDG FTS + EDG FTLR + EDG FTR (T – 1.0) + HPCS Baseline Train Unavailability	Equation is for simplified diagram from NUREG/CR-5500, Vol. 7 (Figure H-8). Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours. Mission time for EDG FTR reduced by 1.0 hour because the first hour of operation is covered under FTLR.
RCIC	(TDP FTS + TDP FTR*T) + Injection MOV FTO + Isolation CKV FTO + Steam Supply Isolation MOV FTO + RCIC Baseline Train Unavailability	Equation is for simplified diagram from NUREG/CR-5500, Vol. 7 (Figure H-10). Mission time T taken from SPAR Rev. 3i model for plant in question. Typically 24 hours.
AOV	AOV FTO or FTC	
MOV	MOV FTO or FTC	
MDP	MDP FTS + MDP FTR*T	Mission time T taken from SPAR Rev. 3i model for plant in question. Typically T is 24 hours.

Acronyms: Components [AOV – air-operated valve, CKV – check valve, DDP – diesel- or engine-driven pump, EDG – emergency diesel generator, MDP – motor-driven pump, MOV – motor-operated valve, TDP – turbine-driven pump]; failure modes [FTC – fail to close, FTLR – fail to load and run for one hour (only for EDGs), FTO – fail to open, FTR – fail to run, FTS – fail to start].

a. The train total unreliability equations model only major components (pumps, diesel generators, and valves) that must change state upon demand and train unavailability. Changes of state during the mission time for valves that initially successfully changed state upon demand are not included.

b. Baseline train unavailability is included in order to avoid making substantial changes to the SPAR models. It is treated as a constant term (at its baseline value) for the unreliability calculations for both threshold determination and performance evaluation. Therefore, only changes in the unreliability parameters affect the RBPI comparison of performance data with the thresholds.

H.5.2 Mitigating System Unavailabilities

Data for unavailability are presently collected at the train level, and not at the component level. The train-level unavailability equation is presented in Section H.4.1. No Bayesian update is used for unavailability. As indicated in Appendix F, no such update procedure was identified for unavailability data in the form presented in the ROP. The data collection period for mitigating system train unavailability is one year, as discussed in Appendix F.

H.5.3 Mitigating System Unreliabilities

The equation for estimating the component unreliability contribution from failure upon demand is the following:

$$P_{\text{posterior mean}} = (a + n)/[a + b + D] \qquad \text{(Eq. H-4)}$$

where $P_{\text{posterior mean}}$ = component demand failure probability
n = number of demand failures over the time period of interest (3 years)
a = value ranging from 0.32 to 0.5 (function of $P_{\text{prior mean}}$, Table 1, column "moment-matching α" in Ref. 7)
b = $(a)(1-P_{\text{prior mean}})/(P_{\text{prior mean}})$
$P_{\text{prior mean}}$ = baseline demand failure probability (mean)
D = number of demands over the time period of interest.

The equation for component failure to run (rate) is the following:

$$\lambda_{\text{posterior mean,ur}} = (a + n)/[b + t] \qquad \text{(Eq. H-5)}$$

where $\lambda_{\text{posterior mean,ur}}$ = component failure rate (per hour)
n = number of run failures over the time period of interest (3 years)
a = 0.5
b = $a/\lambda_{\text{prior mean,ur}}$
$\lambda_{\text{prior mean,ur}}$ = baseline component failure rate (per hour)
t = number of run hours over the time period of interest.

When this rate is multiplied by the mission time, T, the result is the component failure to run contribution to component unreliability. The data collection period for unreliability is three years.

As discussed in Section H.2.2.3, individual component unreliabilities must be input to a fault tree model or to the unreliability equations in Table H-3 to evaluate train unreliability.

H.5.4 Component Class Unreliabilities

Component class unreliabilities are estimated using Equations H-4 and H-5. For motor-driven pumps, the mission time is assumed to be 24 hours. The data collection period for unreliability is three years.

H.6 Performance Data

For initiating event RBPI data, the RBPI program proposes to use the data and methods presented in the initiating event study, NUREG/CR-5750 (Ref. 1). At present, that effort has categorized initiating events at U.S. nuclear power plants through 1998. NRC plans to update the initiating event study yearly, starting in 2002. However, the review of LERs and categorization of scrams will be performed quarterly. Therefore, starting in 2002, all of the data required to quantify the initiating event RBPIs (GT, LOHS, and LOFW) will be available quarterly. There will be no industry burden other than to continue to report LERs as required. For the GT RBPI, one year of data is required. For LOHS and LOFW, three years of data are required.

To produce the initiating event RBPI results presented in Appendix E, 1997 and 1998 plant-specific data for LOHS and LOFW were obtained from the unpublished update to the initiating events study (Ref. 15). Because 1999 data were not available from that source, the ROP data for unplanned scrams and scrams with loss of normal heat removal were used for 1999. For the GT RBPI, the unplanned scram data were used (with loss of normal heat removal events removed). For the LOHS RBPI, scrams with loss of normal heat removal were used. It is recognized that these ROP events include both LOHS and LOFW events, but descriptions of the events were not available to determine which loss of normal heat removal events were LOHS and which were LOFW.

For mitigating system unavailability RBPI data, the RBPI program proposes to use the Equipment Performance and Information Exchange (EPIX) database (Ref. 16). However, at present EPIX does not include sufficient unavailability data (only unplanned outage hours are required to be reported). Changes will be required to the EPIX data reporting requirements to support the needs of the RBPI program. It should be noted that only unavailabilities associated with the risk-significant functions (as included in the SPAR Rev. 3i models) should be included. Unavailabilities associated with design basis functions (but during which the SPAR functions could still be accomplished) would not be included, or would be included only for those SPAR accident sequences involving design basis events. One year of unavailability data is required.

To produce the RBPI unavailability results presented in Appendix E, the ROP data for 1999 were used. However, train average unavailability was calculated only across trains with similar pumps and operating characteristics. Also, each fault exposure time entry was reviewed to determine whether a corresponding failure had been reported in EPIX. If the corresponding failure existed in EPIX, then the fault exposure time was not included in the unavailability calculation. (In such a case, the failure event is covered by the unreliability RBPI.) If no corresponding failure was in EPIX, then the fault exposure time was included in the unavailability calculation.

For mitigating system and component class unreliability data, the RBPI program proposes to use the EPIX database. That database was used as is to generate the unreliability data for 1997 through 1999 presented in Appendix E. The NRC-developed software Reliability and Availability Database System (RADS, Ref. 17) was used to search for component failures and to determine the associated demands or operating hours (based on data contained within EPIX). Note that EPIX contains many component "failure" events that are not failures with respect to the risk-based SPAR Rev. 3i models. Only events that are classified as "PRA failures" in EPIX were used. Three years of unreliability data are required.

For the mitigating system unreliability RBPIs, only major components within a train were included in the EPIX database search for component failures. These major components were defined as EDGs, pumps, and valves that must change state given a demand. All of these components are included within the scope of the existing EPIX database.

For the component class unreliability RBPIs, a subset of such components within EPIX was used. The subset is defined in the RADS data loading procedure, and includes EDGs, pumps, valves, and circuit breakers within most systems important to safety.

H.7 Example Calculations

H.7.1 Initiating Events

The formula for calculating initiating event RBPIs is presented in Section H.5.1, Equation H-3. As a sample calculation, consider GT for B&W Plant 5. Appendix E, Table E-1, indicates that the plant had four GT events in 7530 hours of critical operation (during 1999). Therefore, n = 4, and T = 7530/7000 = 1.08 calendar years. The prior mean (baseline) for GT for PWRs is obtained from Reference 2, Table 3-1 (entry Q for PWRs, 1.2/critical year of operation). Because the RBPI program uses calendar years (assuming 7000 critical hours of operation per year), that value must be multiplied by 7000/8760 = 0.8 to obtain calendar years. Therefore, the prior mean is (1.2)(0.8) = 0.96/calendar year. The resulting posterior mean for GT using Equation H-1 is then 2.8/calendar year (shown in Table 5.3-1, Section 5). Comparing this value with the thresholds for this plant (Table A.1.4-16, Appendix A), 2.8/calendar year is above the white/yellow threshold but below the yellow/red threshold. Therefore, the plant's performance band for GT is yellow.

As another example, look at LOHS for the same plant. Appendix E, Table E-1 indicates one LOHS in 21,562 critical hours of operation (during 1997 through 1999). The critical hours of operation translate to 21,562/7000 = 3.08 calendar years. The prior mean from Reference 2, Table 3-1 (entry L for PWRs, 0.12/critical year of operation) is then (0.12)(0.8) = 0.096/calendar year. Again, using Equation H-1, the resulting posterior mean for LOHS is 0.18/calendar year. Using the plant-specific thresholds (Table A.1.4-16, Appendix A), the plant's performance band for LOHS is white.

H.7.2 Mitigating System Unavailabilities

As discussed previously in Section H.4.1, average train unavailability includes contributions from planned outage hours, unplanned outage hours, and (sometimes) fault exposure hours. These outages are while the plant is at power. Also required for the unavailability calculation are the hours the train is required to be operable while the plant is at power. A single year of unavailability data is used.

As an example, consider CE Plant 5 AFW MDP trains. The total unavailable hours for 1999 for both MDP trains are 54.1, as indicated in Table E-2 in Appendix E. This is the sum of planned and unplanned outage hours for both trains, as indicated in the 1999 ROP data. (No fault exposure time was listed for these trains.) Also, the total hours of required operability (sum of both trains) are 11,154. Therefore, the average unavailability for the AFW MDP trains is (54.1)/11154) = 4.9E-3 (Table 5.3-2, Section 5 of the main report). Comparing this result with the CE Plant 5 thresholds (Table A.2.4-21, Appendix A), the plant performance band is white.

H.7.3 Mitigating System Unreliabilities

EPIX data for three years are collected for major components within the train or system. Resulting data include failures and associated demands or failures and associated run hours. Given data for these components, updated component failure rates are calculated as discussed in Section H.5.3. These updated values are then inserted into the equation for train total unreliability. Components, for which there are no (or inadequate) performance data, are left at the baseline values as was done for the train unavailability value. The updated train total unreliability is then compared with the values required to reach the white, yellow, and red thresholds. (Tables A.2.4-1 through A.2.4-30 in Appendix A indicate the total unreliability required to reach each threshold.)

To simplify the data collection for testing the unreliability RBPIs, only a subset of components listed in Table H-3 was considered. Specifically, suction MOVs, isolation CKVs, outlet MOVs, and steam supply isolation MOVs were excluded from the data collection task. (In general, most of these components require multiple failures in order to fail the train.) The actual components covered in the data collection and their associated data are presented in Appendix E of this report.

Consider the WE 4-Lp Plant 23 AFW MDP trains. The RADS search of EPIX data for 1997 through 1999 resulted in no MDP failures to start in 79 demands and one MDP failure to run in 494.0 hours of operation (Table E-3, Appendix E). The MDP failure to start baseline mean probability is 8.1E-4 (Table H-2). Therefore, the updated failure to start probability using Equation H-4 is 7.2E-4. (The parameters a and b come from Table H-2, while n = 0 and D = 79.) The MDP baseline failure to run rate is 2.4E-4/hour (Table H-2). Using Equation H-5, the updated failure to run rate is 5.8E-4/hour. (Again, the parameters a and b come from Table H-2, while n = 1 and t = 494.0 hours.) The total unreliability equation in Table H-3 is used to estimate the updated total unreliability. Because no data were collected for the MOV and CKV, they remain at their baseline values of 3.0E-3 and 1.0E-4, respectively. Also, the unavailability remains at the baseline value of 1.1E-3. The resulting total unreliability is 1.6E-2 (Table 5.3-3, Section 5 of the main report). This results in a plant performance band of white (Table A.2.4-29, Appendix A).

H.7.4 Component Class Unreliabilities

Unreliability data for the component class RBPIs (AOV, MOV, and MDP) was obtained from the EPIX database using the RADS software. For MDPs, RADS was used to search for failures to start or run among all MDPs included in the RADS data load of the EPIX data for the plant in question. Then any MDP data already included in other unreliability RBPIs (such as AFW MDP, HPSI MDP, etc.) were removed. The remaining data were used in Bayesian updates to obtain a new failure to start probability (Eq. H-4) and failure to run rate (Eq. H-5). To calculate the MDP unreliability, the failure to start probability was combined with the failure to run rate multiplied by a 24-hour mission time. A similar procedure was used for the AOVs and MOVs. However, in those cases, only failure to open or close was considered.

To illustrate the calculational procedure, consider MOVs for CE Plant 12. The RADS data search of EPIX resulted in four failures to open or close in 839 demands over the period 1997 through 1999 (Table E-4, Appendix E). Because no MOV data were used in any other unreliability RBPIs, all of these data were used. The baseline failure to open or close probability is 3.0E-3 (Table H-2). Using Equation H-4, the updated MOV unreliability is 4.5E-3, which is 1.5 times the baseline unreliability (Table 5.3-4, Section 5 of the main report). Comparing this increase with the thresholds for the plant (Table A.2.4-23, Appendix A), the plant performance band is white.

H.8 References

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APPENDIX I

SUMMARY OF MAJOR INDUSTRY AND ACRS COMMENTS ON DRAFT REPORT

Contents

Tables

Appendix I: Summary of Major Industry and ACRS Comments On Draft Report

I.1 Background

The Nuclear Regulatory Commission announced the availability of a draft of the present report for review and comment by external stakeholders in a document published in the February 1, 2001 Federal Register (66 *Fed. Reg.* 8606). As a result of comments received during a February 21, 2001 meeting at NRC headquarters, the NRC extended the comment period to allow the industry to incorporate insights from an April 24, 2001 public meeting into their written comments.

The following written comments were received:

> Letter, Stephen D. Floyd (NEI) to Michael T. Lesar (NRC), Subject: Comments on "Risk-Based Performance Indicators: Results of Phase-1 Development," May 12, 2001.
>
> Letter, Mark J. Burzynski (TVA) to "Gentlemen" (Chief, Rules and Directives Branch, NRC), "Nuclear Regulatory Commission (NRC) – Risk-Based Performance Indicators: Results of Phase 1 Development (Vol. 66 *Federal Register* 22)," March 9, 2001.
>
> Letter, J. M. Kenny (BWROG) to Michael T. Lesar (NRC), Subject: BWROG Comments on Risk-Based Performance Indicators: Results of Phase-1 Development, May 11, 2001.
>
> Letter, R. M. Krich (Exelon) to Chief, Rules and Directives Branch (NRC), Subject: Response to Request for Public Comments on Risk-Based Performance Indicators: Results of Phase-1 Development, May 14, 2001.

In addition to the above, the ACRS provided conclusions and recommendations in

> Letter, George E. Apostolakis (ACRS) to William D. Travers (NRC), Subject: Risk-Based Performance Indicators: Phase-1 Report, June 19, 2001.

Section I.2 summarizes key comments from these sources, and provides summary responses to those comments. Section I.3 provides a verbatim presentation of individual comments, and more detailed responses.

I.2 Summary of Major Comments and Responses

Initiation of Pilot Plans

Industry Comment: This activity has the potential to develop beneficial changes to the reactor oversight process (ROP). These include improvements in addressing fault exposure time (by addressing unreliability appropriately), defining availability appropriately (to address risk function as opposed to design basis function), and defining the G/W threshold in terms of risk change rather than 95th percentile. NEI also believes that a power level transient PI has value and that physical security should receive additional attention.

ACRS Comment: It is premature to initiate a pilot program for RBPIs.

Response: The Phase-1 report provides information on the feasibility of RBPIs for potential use in the ROP. Since the comment period closed, industry and the NRC are now planning a pilot activity for using unreliability and unavailability concepts from the RBPI Phase-1 report in accordance with the IMC-0608 process. The pilot activity will cover the potential improvement to the six SSUPIs of the ROP mitigating cornerstone.

Shutdown RBPIs

Industry Comments: The indicators, especially the shutdown indicators, have the potential to influence operations unduly and adversely.

- Shutdown indicators in particular (but not ONLY the shutdown indicators) could encourage unsafe haste in evolutions of plant configuration.
- The indicator scheme essentially tells the plant how to run an outage (and may be sub-optimal).

Numerous issues of detail are raised with respect to quantification of shutdown RBPIs.

- Not clear what credit is given to NUMARC 91-06
- No clear basis for baseline performance values
- Not clear why short periods incur relatively large risk increase

ACRS Comment: The staff does not have the up-to-date risk information needed to develop RBPIs for shutdown operations; therefore, the staff's work should focus on full-power operations until such information is developed.

Response: The following have been undertaken as part of the Phase-1 development, and reflected in the report:

- Verification of baseline values by examining additional data available for recent shutdown activities.
- Checking the validity of performance thresholds.
- Providing additional explanation in the report on how NUMARC 91-06 guidelines were incorporated for compensatory measures.
- Clarifying in the report that shutdown RBPIs are different from at-power RBPIs in that they provide a condition assessment over a short time period instead of a long-term monitoring of performance like the at-power indicators.
- Clarifying in the report that the shutdown work is mainly intended to demonstrate the process rather than defining absolute values for thresholds.

In addition to these activities, the NRC has concluded that the concepts embodied in this feasibility effort may be more appropriately used as part of the Significance Determination Process of the ROP for evaluating off-normal plant conditions. RES will be initiating a technology transfer activity to NRR to assist in this effort.

Alternative RBPIs

Industry Comment: Objections are raised to the "alternative approach" indicators that roll up lower-level indicators to assess the integrated effect of performance changes on plant response capability.

- Roll-ups don't change data burden
- Roll-ups are more abstract and not easy to understand

ACRS Comment: The staff should continue to explore "alternative" RBPIs.

Response: Section 6.5 has been added to the Phase-1 report to explain the general nature of alternative RBPIs and the results of preliminary work. Section 6.1 indicates that this work will be further investigated in follow-on activities.

Other Technical Comments

Industry: It is not possible to understand the capability of RBPIs to assess performance appropriately without knowing definitions and methodology for computing RBPIs.

Clear definitions of how to collect data and calculate PIs are needed for implementation. Current ROP experience indicates that this is difficult. Use of 50.9 is potentially a significant burden issue.

Response: A new appendix (Appendix H) has been added to the Phase-1 report, which includes definitions, data collection methods, and performance indicator parameter calculation guidelines. Burden issues for any proposed use of RBPIs will be addressed as part of the IMC-0608 process.

ACRS: The Phase 1 report states that the green/white thresholds used in the current ROP correspond to changes in CDF (ΔCDF) that vary by more than an order of magnitude among plants. The green/white thresholds in the ROP should be reevaluated.

Response: The interpretation by the ACRS of the report statement on pages A-10 and A-16 of the Draft Phase-1 report is correct. In general, the staff agrees with the ACRS that the green/white thresholds can be refined using risk information. However, this may only be possible for the indicators in the initiating events and mitigating systems cornerstones, and may not be possible for the other cornerstones where comparable risk information is not available for setting performance thresholds. As discussed with the ACRS, the staff initially developed the green/white thresholds using historical information on the performance of plants, and anticipated refining them as improved risk models were developed. The staff will decide on the appropriate extent of this effort as part of any follow-on development efforts for the RBPI program, and would incorporate any changes to the current PIs using the change process in IMC-0608.

Implementation Issues

Industry: The Phase-I report merely identifies candidate RBPIs; it does not address the tradeoff between increased benefit and increased burden associated with additional indicators, or address the general question of development of an optimal combination of indicators and baseline inspections, or discuss how the action matrix would work with the RBPIs added into the existing suite of indicators.

ACRS: The staff should develop methods for assessing tradeoffs between introducing new PIs versus reducing baseline inspections.

The staff should continue to develop RBPIs as part of the ongoing effort to make the ROP more objective and scrutable.

Response: This effort identifies feasible RBPIs for consideration under the ROP change process. Any changes to the current performance indicators in the ROP will be incorporated using the change process described in IMC-0608, which addresses issues of burden as well as technical benefit to the process. This is clarified in the main body of the report.

Peer Review of SAPHIRE and SPAR Models

ACRS: There should be a publicly available peer review of the SAPHIRE code and, eventually, the Standardized Plant Analysis Risk (SPAR) models.

Response: The SAPHIRE code has undergone extensive reviews and the information is publically available (NUREG/CR-6688, October 2000). We believe that this review is sufficient to establish confidence that the code's calculational functions are performed correctly. We have concluded that resources that would be used for a peer review of the SAPHIRE code would be better allocated to other NRC projects. However, we agree that the Revision 3i SPAR models should undergo peer review to establish confidence in the models by stakeholders.

I.3 Detailed Responses to Individual Comments

Table I.1 presents detailed responses to the written comments received from external stakeholders listed in Section I.1, as well as the ACRS conclusions and recommendations.

Table I.1 Disposition of Comments Received on "Risk-Based Performance Indicators - Results of Phase-1 Development," Draft Report Dated January 2001

Comment No.	Comment/Response	Report Change?
NEI I1	We believe it is appropriate for NRC to pursue improvements to the Reactor Oversight Program (ROP) performance indicators. Improvements are necessary, and the Office of Research has been pursuing purely risk-based alternatives and additions. The initial results described in the Phase 1 Development report appear to provide some opportunities for improvement, particularly in the area of replacing start and demand fault exposure unavailability with unreliability indicators.	
Response	We agree with this comment. We plan to pilot unreliability indicators in early 2002.	No
NEI I2	In addition to the problems with fault exposure, the distinction between design basis availability and risk basis availability must be resolved.	
Response	In the RBPI program, risk-significant functions are utilized. As part of the Safety System Unavailability Performance Indicators (SSUPI) working group, design-basis functions are considered for replacement by risk-significant functions.	No
NEI 1	It is essential that there be an overall plan for how the RBPIs are integrated with current regulations. Currently, technical specifications provide allowed outage times and configuration control requirements which are based primarily on design basis requirements. Alternatively, maintenance rule implementation requires out of service target times and configuration management activities based more on risk insights. This situation is already creating conflicts and problems at plants. Without a well-thought out strategy for integrating these requirements and the RBPIs, licensees will be facing a third set of potentially conflicting performance targets. This is an unacceptable outcome.	
Response	This concern is valid, and we are working with NEI to establish commonality through the SSUPI working group. Any changes to the risk-informed inspection program would be made using the change process in IMC-0608.	No
NEI 2	RBPIs, while they may be technically feasible, must prove themselves through the MC 0608 Change Management Process for performance indicators. This change management process requires that any change to performance indicators add value to the process as it currently exists. The change must provide additional risk-significant insights not being gathered through the current process (of performance indicators and inspection findings), avoid unnecessary regulatory burden, and reduce inspection activity. The Phase 1 report may show that there are additional indicators, which could be reported; however, it does not address the key question of whether these indicators even have the potential to pass the MC 0608 tests. A key policy issue which needs to be addressed is: What is NRC's policy regarding reductions in inspection resources should additional performance indicators be added?	
Response	This is recognized as an important implementation issue. This would be assessed in a pilot program conducted as part of the change process in IMC-0608 prior to implementation. Also, see the response to comment NEI 6a.	No
NEI 3a	There may be significant unintended safety consequences from several of the proposed indicators. In particular, the shutdown indicator is suspecting in this regard. For example, while time spent in mid-loop operation should be limited, one does not want to rush through evolutions to avoid crossing performance thresholds of very short duration.	
Response	The potential for unintended adverse consequences of performance indicators is recognized as an important issue. If these PIs are considered for incorporation in the ROP, this issue will be assessed as part of the change process in IMC-0608. This issue was discussed in Section 6 of the Phase-1 report.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI 3b	We believe that part of the problem with the indicator thresholds may be that little or no credit has been given for NUMARC 91-06 compensatory measures.	
Response	In one respect, credit was given for NUMARC 91-06 compensatory measures. Specifically, the non-zero baseline allowance for entry into early reduced-inventory configurations is predicated on compensatory measures; otherwise the configuration is considered "high" risk significant, a category whose baseline allowance is zero. Because the indicator thresholds are based on available models, which do not fully address NUMARC 91-06 compensatory measures, it was difficult to explicitly reflect compensatory measures in threshold determinations. Available models can address two aspects of NUMARC guidance: (1) hardware defense in depth, and (2) crew readiness to respond to initiating events within available time. Aspect (1) is captured in available models and is already reflected in thresholds. Implementation of NUMARC guidance will minimize dwell times in configurations that have tight thresholds. Aspect (2) is not explicitly treated in available models, which do not model a distinction between standard practice and enhanced human performance resulting from adherence to 91-06 ("Personnel who may be required to implement a CONTINGENCY PLAN should be identified and familiar with the plan."). Quantifying such credit would require additional modeling. This could be undertaken but is not currently planned. A paragraph was added to the shutdown section of the Phase-1 report to explain how NUMARC 91-06 guidelines were considered for compensatory measures. Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes
NEI 3c	There is also a scarcity of data on baseline periods of time in the configurations discussed in the proposed indicator. We believe that this indicator is far from ready for recommendation even as a potential indicator to be piloted.	
Response	The shutdown work in this report is mainly intended to demonstrate the process rather than to define absolute values for performance thresholds during shutdown. This point was clarified in the report. In response to industry comments on shutdown RBPIs, the following actions were also taken: – More shutdown data were reviewed to adjust baseline performance values as necessary. – The validity of configurational CCDFs (and associated thresholds) was rechecked. – It was also clarified in the shutdown section of the report that shutdown RBPIs are different in character from at-power RBPIs, in that the at-power RBPIs are sensitive to changes in CDF, while the shutdown RBPIs measure contributions to CDP from particular evolutions. Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI 4	Another question which must be addressed to determine the potential viability of these RBPIs is, how are they to be calculated? To be implemented in the program, indicators must be relatively simple to collect and to calculate. It is not clear from the Phase 1 report how the RBPIs are defined and calculated. A majority of the burden associated with the current PIs has to do with definitions and clarifying notes. The calculation methodology and definitions are not addressed in sufficient detail to determine if they can pass this crucial test.	
Response	A new appendix (Appendix H) was added to the report to clearly outline the RBPI definitions, scope, and calculations. Also, comparisons with the existing ROP PI definitions were presented in that appendix. Data collection issues will be assessed using the change process described in IMC-0608.	Yes
NEI 5a	The use of risk-based, plant specific thresholds has much to recommend it; however, there may be problems in adhering too strictly to pure risk numbers. For example, it appears that the green-white threshold for a loss of heat sink performance indicator for one of the plants would be 0.72 over a three-year period – in effect a "threshold" of zero.	
Response	The example cited reflects a partial misunderstanding of the approach. For the case in question, the green-white threshold is 0.24/year (Table A.1.4-15 in Appendix A). To determine how many events are required in three years to reach this threshold, the plant data for three years must be processed through the Bayesian update outlined in Appendices E and F. This method was developed in order to damp out small-statistics variations in a way that reduces the false-positive and false-negative probabilities. Applying this method for the case in question, if one event occurs in three years (21,000 critical hours of operation), the resulting RBPI value is 0.18/year, which is below the green-white threshold. Therefore, for this plant, two events in three years are required to degrade to white performance. Therefore, it is not necessarily true that a single transient crosses a threshold, just because the threshold's value is less than unity.	No
NEI 5b	Another example is the wide variance between plants in the green-white threshold for general transients, which varied between 1.2 and 8.2 per year. It is hard to believe that the public and industry would understand or support such a wide variance for the green-white threshold for supplemental inspection for this indicator.	
Response	We agree that plant-specific thresholds must be clearly explained to maintain public confidence. This variance is a straightforward consequence of the plant-specific performance thresholds based on plant-specific models that reflect variations in plant design and operation. This issue would be assessed during the implementation phase using the change process in IMC-0608.	No
NEI 6a	If the proposed RBPIs can meet all of the concerns expressed above, and show their indicative value through piloting, there remains the important issue of how they are used in the assessment process, i.e., the action matrix. If there are to be additional performance indicators, there must be a strategy for how this will affect NRC supplemental inspection activities.	
Response	We agree with this comment. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI 6b	Rolling up the performance indicators to a higher level does not solve the problem of additional burden in collecting, reporting and exposure to inspection verification. In addition, there are problems in rolling up system train information to higher levels of abstraction, which are not actionable or easily understood by the public. The simplicity of the current system of indicators, which directly measure performance outcomes, should not become too abstract and model driven.	
Response	The pros and cons of the "alternative approaches" (higher-level RBPIs) will be investigated further in follow-on activities. Issues relating to simplicity and public understanding will be considered during the potential implementation phase, if a decision is made to pursue them.	No
NEI 6c	We also believe that a power level transient PI provides leading indication of potential plant problems and should be included, although enhancements are needed to the current indicator to address NRC and industry concerns. The physical security area should receive additional attention once the proposed rulemaking makes clear what potential targets of opportunity exist. (Of course, it will be difficult to use purely risk-based approaches in this area.)	
Response	Currently, there are no risk models and tools available that could support the development of risk-based thresholds for power-level transient PIs or physical security.	No
NEI 6d	*Do the data sources for the RBPIs exist and have sufficient quality for use in the ROP?* Data sources exist for the initiating event PIs. Data quality for the additional mitigating system PIs and for unreliability data is problematic. This statement is based on our experience with the rollout of the current mitigating system PIs. Prior to being included in the regulatory arena, the data was good enough for management and control; however, in the regulatory arena, additional scrutiny is necessary to avoid violations for data inaccuracy. There is virtually no reliable data for the shutdown indicator.	
Response	This is recognized as an important implementation issue, which will be further investigated during the implementation phase using the change process in IMC-0608 and the proposed pilot activity for 2002.	No
NEI FRN 1	*The RBPIs are compatible with, and complementary to, the risk-informed inspection activities of the oversight process.* In order to be compatible with, and complementary to, the risk-informed inspection activities of the reactor oversight process, any additional PI would need to provide additional value to the current scheme of PIs and inspection activities. That is to say, an addition to the current PIs would need to provide better understanding of licensee performance such that inspection activity could be decreased. Or, alternatively, the value could be provided by replacing a current PI with one which better assessed licensee performance, with the same, or less, licensee and NRC resource burden. An example of the first type of improvement would be reducing maintenance inspection activities based on the addition of a PI. An example of the second type of improvement would be to replace the fault exposure term in the unavailability PI with a unreliability PI (if such a PI could be derived which was easy to compute, easily understood, and not subject to aleatory problems). It does not appear that this type of assessment has been undertaken in the Phase I development report. This is unfortunate, because these are key considerations for new PIs as part of the ROP.	
Response	We agree that inspections must be considered when assessing whether to introduce additional PIs into the ROP. Also, see the response to comment NEI 6a.	No.

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI FRN 2a	*The RBPIs cover all modes of plant operation.* It is appropriate to attempt to cover all modes of plant operation. The current PIs and the proposed RBPIs would cover operational modes.	
Response	We agree with this comment.	No
NEI FRN 2b	The indicator proposed to assess performance while the plant is in a shutdown mode, however, is at a rudimentary stage and appears to have several weaknesses: (1) The indicator does not appear to be consistent with maintenance rule, technical specifications, and shutdown procedures in place;	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
NEI FRN 2c	(2) The short time periods used for performance thresholds will encourage licensees to rush through maintenance and surveillance procedures to avoid exceeding thresholds - this is not an appropriate use of a performance indicator.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
NEI FRN 2d	It is also questionable whether a shutdown indicator is appropriate. The reason is that shutdowns are now relatively short and receive significant inspection coverage which would not likely be decreased if there were a shutdown PI in place.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
NEI FRN 2e	Also, the risk profiles used allow very little time between thresholds (e.g., 2 hours), so one could easily move from green to yellow or red while performing actions in a prudent and compliant manner.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
NEI FRN 2f	There are also very few plant specific models such that it would be hard to set plant specific thresholds.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
NEI FRN 2g	In addition, it does not appear that credit for the compensatory measures established in NUMARC 91-06 was taken into consideration in the risk analysis.	
Response	See the response to comment NEI 3b.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI FRN 3a	*Within each mode, the RBPIs cover risk-important SSCs to the extent practicable.* The purpose of the PIs in the reactor oversight process is to assess licensee performance and assist NRC in determining what level of resource above the baseline level are necessary to assure safety. The purpose is NOT to cover all risk-important SSCs. The proposed scheme covers some additional systems, and therefore some additional aspects of total plant risk. While covering additional SSCs, the additional RBPIs must provide additional value to the ROP, as stated above.	
Response	See the response to comment NEI FRN 1 and NEI 6a.	No
NEI FRN 3b	Addition of classes of components does not appear to meet the test of reducing inspection resources and it will add resource reporting burden to licensees.	
Response	See the response to comment NEI FRN 1 and NEI 6a.	No
NEI FRN 3c	Another aspect of this question is: the RBPIs are generic (i.e., are the same for all BWRs and PWRs) and therefore do not necessarily cover the most risk significant SSCs at each plant. This situation is necessary in order to be able to compare plants across industry and illuminates another difference between PIs that are useful for reactor oversight, as opposed to PIs that are constructed to maximize determination of total plant risk. The PIs used in the ROP must be chosen to meet both criteria.	
Response	The Phase-1 RBPI development program considered only performance areas that were found to be risk-significant at a majority of PWRs or BWRs. It is recognized that this does not include all risk-significant SSCs at all plants but it does constitute a reasonable sample of risk important systems for each plant.	No
NEI FRN 4	*To the extent practicable, the RBPIs identify declining performance before performance becomes unacceptable without incorrectly identifying normal variations as degradations.* It is not possible to understand the capability of the RBPIs to assess performance appropriately without knowing the definitions and methodology for computing the RBPIs. It is also not possible to answer this question without a benchmarking of the historical data against the chosen thresholds and a rigorous pilot program. Some of the thresholds chosen based solely on the methodology of decades to incremental risk do not appear to be reasonable operational goals. For example, setting a green/white threshold for loss of heat removal at 0.24 per year, or 0.72 over a three year period, does not even allow the plant one transient in three years without exceeding the threshold. It is also unlikely that the industry or public would understand thresholds which allowed one plant to have 1.2 general transients a year and another 8.2. This is what the methodology forces, but it does not pass the common sense and common acceptability needs of the ROP.	
Response	A new appendix (Appendix H) was added to the report to clearly outline the RBPI definitions, scope, and calculations. Also, comparisons with the existing ROP PI definitions were presented in that appendix. Data collection issues will be assessed using the change process described in IMC-0608. Also see the responses to comments NEI 5a, 5b, and 6a.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI FRN 5	*The RBPIs are capable of implementation without excessive burdens to licensees or NRC in the areas of data collection and quantification.* Once again, without knowing the definitions and methodology used to calculate the RBPIs, it is difficult to answer this question. The initiating event PIs appear to be capable of implementation without excessive burden. The shutdown PI and the mitigating PIs are not clear without more definition. The need to report so much additional data will put a burden on licensees because of the need to ensure accuracy in reporting to the NRC. The NRC will also have to devote more effort in reviewing the additional data. What will be the offsetting benefit in terms of improved inspection coverage and resource savings?	
Response	A new appendix (Appendix H) was added to the report to clearly outline the RBPI definitions, scope, and calculations. Also, comparisons with the existing ROP PI definitions were presented in that appendix. Data collection issues will be assessed using the change process described in IMC-0608. Also see response to comment NEI 6a.	Yes
NEI FRN 6	*The RBPIs are amenable to establishment of plant-specific thresholds consistent with the ROP.* Theoretically, plant specific thresholds can be developed, however, there are implementation issues which must be addressed: (1) Plant specific thresholds that vary too much from plant to plant will not be understood by the public and will be viewed as unfair and arbitrary by licensees. (For example, the General Transient PI green/white threshold varies from 1.2 to 8.2); (2) Mitigating system green/white PI threshold should not be inconsistent with technical specifications, allowed outage times, and maintenance rule action levels; (3) shutdown PIs that could force inappropriate actions to avoid exceeding tight thresholds and increase risk rather than managing it.	
Response	Regarding (1): see response to comment NEI 5b. Regarding (2): see response to comment NEI 1. Regarding (3): see responses to comments NEI FRN 2b and 2c.	No
NEI FRN 7a	*Are any additional performance indicators needed to enhance the ROP?* Once again, the answer for the ROP PIs is whether they provide additional value in determining the appropriate level of NRC inspection resources. The current level of resource expenditure is essentially the same as prior to the new program, and the current PIs assist NRC in redistributing them.	
Response	See the response to comment NEI 6a.	No
NEI FRN 7b	The RBPIs do not appear to be capable of enhancing that resource distribution without significant additional burden.	
Response	See the response to comment NEI 2.	No
NEI FRN 7c	We do believe that the mitigating system PIs need to be enhanced to resolve difficulties associated with fault exposure (the solution of adding unreliability to unavailability (less fault exposure) is well worth pursuing). As stated above, we do not believe the addition of component classes or shutdown PIs adds value to the ROP. Similarly, if a support system is added, there should be a reduction in inspection levels.	
Response	The program will continue to pursue the unreliability indicator development. The unreliability indicators are being considered for early evaluation through a pilot program using the IMC-0608 process. Also, see responses to comments NEI 2, NEI 6a, NEI FRN 1, and NEI FRN 2d.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
NEI FRN 7d	We also believe that a power level transient PI provides leading indication of potential plant problems and should be included, although enhancements are needed to the current indicator to address NRC and industry concerns.	
Response	See the response to comment NEI 6c.	No
NEI FRN 7e	The physical security area should receive additional attention once the proposed rulemaking makes clear what potential targets of opportunity exist. (Of course, it will be difficult to use purely risk-based approaches in this area.)	
Response	RBPIs are predicated on models, baseline data, and continuing performance data which do not currently exist to address this arena.	No
NEI FRN 8	*Is the number of potential new indicators appropriate? Which of the proposed indicators would be most beneficial?* The number of potential new indicators appears too high based on the minimal additional value they add to the ROP. The most beneficial change would be to restructure the mitigating systems into unavailability and unreliability, if this can be achieved without excessive burden, including false positives. Obviously, the action matrix would need to be reviewed based on the total number of indicators in a cornerstone. Aggregating PIs to some higher level does not take away the burden associated with collecting and reporting them.	
Response	See the responses to comments NEI 6a and NEI FRN 7c.	No
NEI FRN 9	*Will SPAR Revision 3i models be available for setting plant-specific thresholds for all plants?* NRC must answer this question itself.	
Response	The current plan is to complete SPAR Revision 3i models by the end of 2002. QA of the models will be completed in 2004.	No
NEI FRN 10	*Will LERF models be available for setting thresholds for mitigating and containment systems?* NRC must answer this question itself.	
Response	SPAR LERF models are expected to be completed in FY 2004.	No
TVA ES1	TVA appreciates the opportunity to comment on the subject draft report published in the *Federal Register* on February 1, 2001. TVA supports NRC's continuing efforts to improve the performance indicators. We also recognize the challenge in developing effective risk-based performance indicators without adding unnecessary burden. In general, the indicators proposed in this draft report would probably result in only a nominal improvement in the predictive or assessment capability over the current indicators used in the reactor oversight process. However, we believe that adopting such a set of indicators would result in a significant increase in the data collection and verification burden imposed on the licensee.	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Response	This is recognized as an important implementation issue. This would be assessed in a pilot program conducted as part of the change process in IMC-0608 prior to implementation. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No
TVA 1	Assuming that system reliability would be monitored as a separate indicator than availability, the proposed list of risk-based performance indicators (PIs) would number between 20 and 25 versus the current number of 11 for the three safety cornerstones addressed in this phase of the study. The collection and verification of the data elements for the proposed number of PIs would result in significant additional burden on the licensee. How this additional burden will be compensated for in reduced baseline inspection has not been addressed.	
Response	Most of the data required to evaluate the proposed RBPIs are already being reported in EPIX, for the ROP, or as Licensee Event Reports. However, the level of verification for EPIX data to support the RBPIs is not addressed in the Phase-1 report. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No
TVA 2a	Support of the reliability indicators would require data collection of component failures currently beyond that being done for the current PIs. In addition, this collection effort will be beyond the data currently being collected for maintenance rule for several of the proposed systems. If the PIs are to be true measures of reliability that relates the number of failures to the number of actual demands, an even more significant increase in the data collection requirements of licensees would result. For many of the components being considered for reliability monitors, especially for air-and motor-operated valves, the demand component of the calculation is not readily obtainable, and significant new data calculation procedures would have to be developed to collect this information.	
Response	This is recognized as an important implementation issue. This would be assessed in a pilot program conducted as part of the change process in IMC-0608 prior to implementation. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
TVA 2b	If the reliability indicators were to only track the number of failures (as is currently being done for safety system functional failures), thresholds set based on acceptable risk levels would have to be very site-specific considering the design of the system as well as the accident impact of a specific components failure. This would result in increased issues with uneven playing fields between sites and be a source of additional confusion to our public stakeholders.	
Response	The RBPIs are intended to have plant-specific performance thresholds. We agree that plant-specific thresholds must be clearly explained to maintain public confidence. This variance is a straightforward consequence of the plant-specific performance thresholds based on plant-specific models that reflect variations in plant design and operation. This issue would be assessed during the implementation phase using the change process in IMC-0608.	No
TVA 3	With the significant difference in plant design, the development of a consistent scope definition of the PIs for air-operated valves, motor-operated valves, and motor-driven pumps will be a substantial challenge. The concern of ensuring an even playing field would likely require the calculation formula to contain a normalizing factor or the use of a variety of thresholds. This would add significant complexity to the additional confusion for our public stakeholders who try to compare performance between sites.	
Response	We agree that development of component class RBPIs is a challenging task, but models and tools already exist to accomplish this development. More explanation was added to the report in Section 3.1.2 and Appendix H to clarify the intention of the component class indicators.	Yes
TVA 4	The shutdown monitor of time in high/medium/low-risk significant configurations would be a lagging indicator. It would take several refueling outages to obtain a notable trend for a licensee or site, if at all possible. On the other hand, the high/medium/low conditions are very dependent on the specific outage work plan and would likely change significantly from one outage to the next. This information could be easily captured in an outage inspection module and compared across the industry annually as an industry norm and trend. This would provide more timely feedback to specific licensees that are outliers.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
TVA 5	The monitoring of actual fire suppression system availability and reliability would be extremely burdensome. The definition of unavailable would be very complex and subject to considerable controversy. With the extreme variety between licensees on the methods and designs used to provide fire suppression, an even playing field would be nearly impossible to achieve. System performance might be bettered monitored in a manner similar to how security is currently being monitored with the hours in compensatory fire watches for an out of service sector of suppression being the desired comparison component between licensees. While not a true availability or reliability, the use of this type of monitor for security has successfully raised licensee awareness of the system status and performance.	
Response	We appreciate this suggestion. This approach would not be "risk-based" as defined in this program, and therefore has not been pursued.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG ES1	At the outset, we want to recognize that substantial work was applied to develop the risk-based performance indicators (RBPIs) methodology, to exercise the methodology, and to document the results in the subject report. This work has provided the basis for discussion of the future direction of the revised reactor oversight program. It is, however, not clear to the BWROG that the performance indicators provide a tool which will add sufficient value to outweigh the additional burden to implement the program.	No
Response	This is recognized as an important implementation issue. This would be assessed in a pilot program conducted as part of the change process in IMC-0608 prior to implementation. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	
BWROG ES2	The BWROG believes that consideration of the unintended consequences of the suggested RBPIs be evaluated. Such unintended consequences include, but is not restricted to, redefining Technical Specification AOTs, redefining Maintenance Rule implementation, and impacting plant operations.	No
Response	We agree. The potential for unintended adverse consequences of performance indicators is recognized as an important issue. If these PIs are considered for incorporation in the ROP, this issue will be assessed as part of the change process in IMC-0608. This issue was discussed in Section 6 of the Phase-1 report.	
BWROG G1	The RBPIs must be consistent with and take credit for other risk informed initiatives. If the RBPIs are not integrated with existing risk informed regulations such as technical specifications, then they will in effect become another layer of regulation.	No
Response	We agree with this comment. This is an implementation issue and will be considered during the implementation phase using the process in IMC-0608.	
BWROG G2	Table 3.1.2-1, Candidate Mitigating Systems RBPIs, includes MOVs and AOVs as component classes. Component failures that are not PRA functional failure should not be included in the calculation of unreliability.	Yes
Response	We agree with this comment. The intention of the RBPI development is consistent with this comment. A paragraph was added to the report to clarify that RBPIs and their associated thresholds are based on risk-significant functions. The data for MOVs' and AOVs' unavailability comes from those MOVs and AOVs in risk-important systems, as noted in NUREG-1715, Vol.3, "Component Performance Study - Air-Operated Valves, 1987-1998," and NUREG-1715, Vol. 4, "Component Performance Study - Motor-Operated Valves, 1987 - 1998."	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG G3	The unavailability indicator at the train/system level is not relevant because plant configuration is controlled by other means such as 10 CFR50.65 (a)(4). It is the high risk combinations of equipment that are most important to risk, not planned unavailability of a single train. The actual risk of equipment unavailability due to planned maintenance is generally less than calculated because contingency actions are usually not credited in performance indicator calculations of risk.	No
Response	Train unavailabilities of systems important to safety are typical elements in the IPE and SPAR risk models. These train unavailabilities may or may not be significant contributors to risk at baseline values. However, in the SPAR model work performed to date, the plant-specific threshold determinations (green-white, white-yellow, and yellow-red) for unavailability RBPIs indicate that (for some systems) small changes in train unavailability can result in changes in core damage frequency greater than 1E-6/y. It is true that the available models only eliminate disallowed configurations, and do not otherwise credit configuration management or contingency actions. It is true that 10CFR50.65 (a)(4) helps to minimize risk significant combinations of concurrent unavailabilities. At present, the RBPI development program is not attempting to monitor such concurrent unavailabilities at full power, except as individual train unavailability information. Such conditions are addressed by the SDP process for cases where technical specifications or maintenance rule requirements are violated.	
BWROG G4	A single event should not cause multiple indicators to change color which could result in one event leading to degraded cornerstones. One event at a plant should not impact a performance indicator (PI) and at the same time have a significant determination process (SDP) performed for the event.	No
Response	Regarding the one-event-leading-to-degraded-cornerstones: In the RBPI development, one single event does not cause multiple indicators to change color because RBPIs are developed for front-line systems as well as support systems based on their risk significance and available data. Regarding operational event impacting a PI and being evaluated under the SDP: The staff conducts a supplemental inspection for PIs that cross the green/white threshold. Normally, PI input data are not processed through the SDP. Should additional issues be identified, the staff evaluates the inspection findings using the SDP.	
BWROG G5	We agree with other stakeholder comments stating that additional PIs should result in less inspections. But it is not clear from the subject report how the inspection scope identified in document, as being impacted by the new RBPIs, will be reduced.	No
Response	We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	
BWROG G6	We agree with previous stakeholder comments stating that the action matrix will need to be revised if additional PIs are added.	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Response	We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No
BWROG G7	The discussion in Section 2 regarding risk and NRC safety goals is a good discussion that places the risk associated with nuclear reactors in perspective compared to other societal risk. An implication of this discussion is that there will be no need to reduce any thresholds in future.	
Response	Currently, there is no plan to reduce the performance thresholds.	No
BWROG G8	It is important that the benefit should be weighed against additional data collection effort for each RBPI that is added to the reactor oversight program.	
Response	This is recognized as an important implementation issue. This would be assessed in a pilot program conducted as part of the change process in IMC-0608 prior to implementation. We intend to follow the change process for PIs discussed in IMC-0608. This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection programs. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment.	No
BWROG G9	The BWROG endorses switching the green to white threshold basis from the 95th percentile to the recommended 1E-6 delta CDF contingent upon reasonable calculation and uncertainty of parameter being monitored.	
Response	In general, we agree with this recommendation. However, this may only be possible for the indicators in the initiating events and mitigating systems cornerstones. We initially developed the green/white thresholds using historical information on the performance of plants, and anticipated refining them as improved risk models were developed. We will decide on the appropriate extent of this effort as part of any follow-on development efforts for the RBPI program and would incorporate any changes to the current PIs using the change process in IMC-0608.	No
BWROG G10	The review of this document would have been much more convenient if the Appendices would have been available electronically. The confusion in how to obtain copies of the appendices has resulted in very limited time for the BWROG to review the appendices,	
Response	We recognize that electronic versions would have been useful, and will make the final Phase-1 report and its appendices available electronically to all members of the public.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG P1	It appears that BWR General Transient (GT) & Loss of Heat Sink Conditional Core Damage Probability are at least an order of magnitude too high in Table 3.1.1-1, Initiating Event RBPIs. For example, using the numbers in the table, it appears that the CCDP of GT for BWR Plant 18 is about 1.5E-6. It also seems like there is an inconsistency between the General Transients for BWRs and PWRs. The baseline frequencies are 1.3 (BWR) and 1.0 (PWR).	
Response	The reviewer is correct in estimating that the conditional core damage probability (CCDP) given a general transient (GT) is approximately 1.5E-6/y. (The exact calculation is 1.0E-6 divided by the difference between the GT green-white threshold value of 2.0 and the GT baseline value of 1.3. Therefore, (1.0E-6)/0.7 = 1.43E-6.) The green-white threshold value of 2.0/y was determined using the Standardized Plant Analysis Risk (SPAR) Rev. 3i model for this plant. A review of the results for other plants (Tables A.1.4-1 through 15 in Appendix A of the draft report) indicates that this CCDP is not unusual for GT. The baseline frequencies for GT are 1.2/y for BWRs (increased to 1.3/y in the SPAR model to correctly model GT, LOHS, and LOFW) and 0.96/y for PWRs (increased to 1.0/y in the SPAR model). These frequencies represent industry-wide experience for 1995 (broken down into BWR and PWR groups), as indicated in the report *Rates of Initiating Events at U.S. Nuclear Power Plants: 1987 – 1995* (NUREG/CR-5750, February 1999). The frequencies from Table 3-1 of that report, 1.5/critical year (BWRs) and 1.2/critical year (PWRs), were multiplied by 0.8 to convert to calendar years (assuming a plant is critical 80%, or 7000 hours, of each year). Therefore, (1.5)(0.8) = 1.2/y (BWRs) and (1.2)(0.8) = 0.96/y (PWRs). A new appendix (Appendix H) was added to the report to clearly outline the RBPI definitions, scope, and calculations.	Yes
BWROG P2	The data in Table 3.1.2-2, BWR Mitigating System RBPIs, does not look realistic for majority of BWR's. Also, the green to white threshold for emergency AC power reliability is a change of 5%. This small change does not seem reasonable to monitor against, i.e., it is within the uncertainty range of the number being calculated.	
Response	We agree that in cases where the green-white threshold RBPI value is close to the baseline value, the probability of false positive indications or false negative indications is higher. Statistical analyses presented in Appendix F address the issue of false positives (declaring an RBPI white when it is actually at its baseline value). For unreliability RBPIs, when a white is indicated, the corresponding probability of this false positive is also presented. See Tables 5.3-3 (AFW for WE 4-Loop Plant 23) and 5.3-4 (MOVs for CE Plant 12 and MDPs for WE 2-Loop Plant 6).	No
BWROG P3	Regarding the data in Table 3.1.2-2, it is not clear what the basis is of the assumed number of demands for these systems/components or from where the values came. There may be discrepancies between the number of estimated demands and the actual number of demands. Actual demands are typically greater than estimated demands.	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Response	The demand estimates are generated automatically by the Reliability and Availability Database System (RADS) software, using demand information (test and non-test) from the Equipment Performance and Information Exchange (EPIX) database. For most of the RBPI systems, EPIX requires a plant to report an estimate of test demands per train (typically determined by reviewing an 18-month or 36-month period and actually counting the test demands), and to report on a quarterly basis the actual non-test demands. Given this information, RADS generates the total demands for the period of interest. Based on the EPIX reporting requirements, it is believed that the demand estimates generated by RADS should be reasonably accurate. The accuracy of data reported to EPIX was not verified as part of the Phase-1 RBPI development effort. This is a potential implementation issue, which will be addressed using the change process described in IMC-0608	No
BWROG P5	It is the position of the BWROG that there should be no Level 2 PI. The basis for this position is to maintain consistency with the ASME PRA standard and other risk informed initiatives that allow simplified LERF calculations.	
Response	An attempt was made in the Phase 1 RBPI report to develop RBPIs for containment performance based on simplified LERF calculations because containment performance is part of the barrier integrity cornerstone of safety under the current ROP. However, current models and data were inadequate to do so.	No
BWROG S1	It is the position of the BWROG that the shutdown indicators should be delayed until more experience is gained with the on-line RBPIs. The remaining comments regarding shutdown are given for use when the decision is made to go ahead with the shutdown RBPIs.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
BWROG S2	An unintended consequence of the level of detail in Tables 3.2.2-2 and 3.2.2-4 is that they in effect tell the plant how to run an outage. Although a plant might be able to show that a given configuration is low risk after putting in place contingency actions, the plant management may feel obligated to follow the table and avoid the configuration even though it is a safe configuration. The tables should be constructed at a higher level such as at the level of key safety functions. The current level of detail is not consistent with NEI 91-06.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes
BWROG S3	Regarding Table 3.2.2-1 and Table 3.2.2-2, the basis for the numbers is not clear. It is also not clear why there is such a large difference between the PWR and BWR durations. Some of the durations appear to be short, e.g., the duration allowed for emergency diesel generator out of service is less than allowed by typical BWR Technical Specification. This would have the unintended consequence of redefining Technical Specification AOTs.	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Response	The baseline and thresholds were derived from the risk study in the report cited. PWR/BWR differences were due to the relative contribution to CDF from the models cited in the report. The threshold values for each category represent the same delta time over the baseline values for BWRs or PWRs. The absolute values of a particular threshold are generally lower for BWRs because they generally spend less time in the low, medium, or high configurations as part of their baseline. Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes
BWROG S4	Guidance on implementation for Table 3.2.2-2 should address taking credit for contingencies. It also should allow for a SDP Phase 3 type of plant specific evaluation to be used when the simplified table gives an overly conservative result.	
Response	The table is intended to take credit for all equipment invoked in a comprehensive risk model, and for human performance at the level modeled. Credit for additional capability due to contingency plans when the configuration is known to be risk-significant has been credited for nominal periods in the ERI-V case in the Phase-1 report but not in other cases. Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes
BWROG EE1	External events RBPIs at the plant specific level will have little value and should not be developed. Seismic events can not be predicted and would not have a higher probability of occurring for reasons that under control of the plant.	
Response	For the initiating events cornerstone, this comment is correct. For the mitigating systems cornerstone, there are areas that could be considered for performance monitoring in follow-on work (for example, fire suppression performance). However, we agree that mitigating system performance for seismic events is unlikely to yield an RBPI based on current model and data availability.	No
BWROG EE2	It is recognized that fire events can be prevented and a frequent occurrence of small fires or single occurrence of fire sufficient to result in loss of safety function or plant scram may indicate degradation in reactor safety due to reduction of fire prevention/mitigation capability. However, fires of risk significant consequence would generally result in an increase in an indicator of safety systems or at the plant level, thus fire is captured already in existing PI and need not be developed independently. Also plant administrative procedures require compensatory actions when mitigation equipment is unavailable, so the position applies even if there is "hot" work being performed.	
Response	Indicators are intended to identify adverse performance trends before risk-significant events occur, rather than afterwards. We agree that a fire of risk significant consequence would be assessed using the SDP. Existing indicators do not address unreliability and unavailability of fire detection and mitigation systems, and the development described in the report was intended to assess the viability and desirability of doing so. Credit for compensatory actions would affect RBPI thresholds for fire detection and mitigation systems. Unfortunately, this area is not modeled well enough in available models to address this point adequately within the RBPI program. This was clarified in the report.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG RPT1	Important information that is required to understand the PIs and their thresholds is not included in the body of the report, but is buried in footnotes in the appendices. Sometimes the footnote directly contradicts the information presented in the text. The following are some examples of this: – Table A.1.1.1-1 - The footnote indicates that BWR general transients do not meet the 1E-6 CCDP criterion for being included in the risk based initiators but are included anyway because their frequency is high. This goes against the text that explains the criteria for including initiating events. This type of information should be included in the text rather than being buried in a footnote in an appendix. – Page A-9 - A footnote indicates the LOFW and LOHS initiators include loss of offsite power events. This information needs to be included in the body of the report. Loss of offsite power events have very different CCDPs and impact than LOFW and LOHS events with power available. By combining these initiators, it effectively applies a LOOP CCDP to LOFW and LOHS initiator frequencies. This information should be incorporated into the review of the main document. – Table A.1.4 series of tables - These table contain footnotes that indicate general transients include the LOHS and LOFW events. Once again, this effectively applies the higher CCDP from LOHS and LOFW to the higher initiating event frequency of a general transient. This information is essential for the review of the main document. The thresholds in the tables do not make sense without this information. – Table A.2.4 series of tables contain important information in the footnotes. It states that the unreliability value also includes unavailability. These should not be combined, because these two parameters have different affects on model results. This information is necessary to understand the tables in the main part of the report.	

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Response	First item: We added several sentences in the main text to highlight this exception. Second item: The footnote is incorrect. Losses of offsite power are not included in the LOHS and LOFW counts (based on definitions of events contained in Appendix A of NUREG/CR-5750). The footnote was removed. Third item: All of the initiating event tables (Tables A.1.4-1 through 15) were modified to indicate the GT baselines and thresholds before modification for use within the SPAR models. The LOHS and LOFW values do not require any changes. Fourth item: The inclusion of unavailability (at its baseline value) in the unreliability thresholds was done merely for convenience and does not affect how component failure data (failures to start or run, failures to open or close, etc.) relate to changes in core damage frequency. Unavailability impacts on core damage frequency were handled separately. Several sentences were added to the main text to more clearly explain what the unreliability thresholds represent. Also, a footnote was added to Tables 3.1.2-2 and 3. In order to work directly with SPAR Rev. 3i models, it was decided to present train unreliability results directly from the SPAR system fault tree models. Unreliability at the train level in the fault trees typically also includes the train unavailability event. The baseline unreliability values presented in Tables A.2.4-1 through 15 were obtained from the fault trees (at the train level) using baseline data for each basic event in the fault tree. To obtain threshold train unreliabilities, only the unreliability portion of the fault tree (at the train level) was allowed to increase. The train unavailability event was held constant at its baseline value. Therefore, the train unavailability (at its baseline value) is included only for presentation purposes and for convenience.	Yes
BWROG RPT2	On page A-51, one of the LERF multipliers is stated to be 10. This can't be correct since the multipliers must range from 0 to 1.	
Response	This was corrected in the report.	Yes
BWROG RPT3	Table A.3.1-1 contains two BWR Mark I rows.	
Response	The second entry in the table was changed to refer to Mark II.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG RPT4	On page A-58, the author provides a "reformulation" of LERF. This should not be done in this paper. The reformulation introduces a "large" definition that is different than is typically used at BWRs. Most BWRs use 10% of the CsI released to the environment as the threshold for "large." It is also different than the definition in the ASME Standard (draft) on PRA applications for both "large" and "early." The standard defines "early" as prior to effective offsite actions. The definition of "early" in this appendix would indicate that TW sequences are early releases. This is not typical. The definition needs to be left to the standard and not reformulated for the PIs.	
Response	This definition was used in the Phase 1 development in order to make use of IPE insights. The ASME Standard cited in the comment is a draft currently undergoing review. Its definition will be considered in follow-on work.	No
BWROG RPT5	Section B totally mischaracterizes the shutdown risk contributors for BWRs. The risk is high in the first two days of cold shutdown because decay heat is high and the model probably did not credit steam driven systems. It is not directly a result of POS 5 (cold shutdown with the head on). In fact, risk follows decay heat level. If the head is replaced later in the outage, CDF is extremely low due to the long time to boil. Also, if steam driven systems are not properly credited in the model, CDF has a high contribution from loss of AC power events (other initiators tend to be lower). In LOOP events, the reactor can re-pressurize so that high pressure systems can be used for injection. It is suggested that the shutdown PIs be deferred until the risk drivers during shutdowns are properly understood and can be reflected appropriately in performance indicators.	
Response	We agree that POS 5 can occur both early and late in an outage and that the risk is significantly lower due to reduced decay heat loads later in the outage. We also agree that steam-driven system can provide injection following a LOOP in POS 5. Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process, and will transfer this technology to the NRR staff for use in developing shutdown SDP.	No
BWROG RPT6	In the section of fire events, there is an inconsistency with the way plants treat fire mitigating system impairments. Most plants put compensatory measures in place when detection/suppression systems are impaired. In nearly all cases, these measures are just as reliable as the automatic systems, so unavailability has very little meaning as a PI. In addition, many plants' fire systems are only licensed for automatic containment of the fire, rather than suppression. Manual suppression means are typically required even if the automatic systems are available.	
Response	We agree with the thrust of this comment. However, the current formulation is based on the available modeling information such as the IPEEE studies. The available fire risk studies in the IPEEE reports do not have data and models required to support the suggested improvements to the potential RBPIs for fire. The discussion in the report was modified to acknowledge these issues. We will consider them in any potential follow-on work.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG RPT7	In many of the sections in Appendix F, the reader is referred to F.6 for the calculation that was performed. F.6 only contains the calculation for one of the PIs. It then says that a later table will cover the others. We could not find this "later" table.	
Response	The references to Section F.6 were modified to indicate that F.6 presents only a sample calculation (Table F.6) and a summary of all calculations performed (Table 8). The statement in Section F.6 referring to a "later table" is referring to Table F.8. As indicated in that statement, only conclusions from the analyses are presented (recommended prior distributions and data collection intervals). The text below Table F-7 should have been included under the "Summary" portion of Section F.6, and this probably added to the confusion. This text was moved to the "Summary" section.	Yes
BWROG RPT8	The process that was used in Appendix F to create data to validate the thresholds is not valid. Duplicating and recombining existing data points does not create any new information, and cannot be used to increase the statistical significance of that data set. This evaluation needs to be performed by identifying plants that have both good and bad performance, and then taking actual data from those plants.	
Response	The comment refers to the unavailability methodology outlined in Section F.3.2. We believe that this methodology is valid for the intended purpose, which is to characterize variability in unavailability, not to increase the statistical significance of the data set. However, other methods could have been used. Text was added to indicate that this approach is one of several that might have been used. Follow-on work may include an investigation of alternative approaches.	Yes
BWROG RPT9	Abbreviations and Acronyms - page xix - LPI and LPR are both defined as Low Pressure Injection.	
Response	The definition for LPR in the report was changed to "Low Pressure Recirculation."	Yes
BWROG RPT10	Page 2-8 - Fourth paragraph in Step 4, first sentence - It seems like the sentence should read "Some elements under the initiating events cornerstone and mitigating systems cornerstone affect <u>CDF</u> as well as <u>LERF</u>."	
Response	The sentence was changed to make its intention clearer.	Yes
BWROG RPT12	Paragraph 3.2.2 - Without the benefit of having Appendix B, the methodology in the subject paragraph seems somewhat suspect.	
Response	Appendix B is now available.	No
BWROG RPT13	The method uses time in a configuration in excess of the baseline as metric of risk. The numerator in the cited equation is ΔCDP threshold. This paragraph states that the thresholds are the standard thresholds for G/W, W/Y, and Y/R. However, the threshold established in Section 2 is based on core damage frequencies per year not changes in core damage probabilities.	
Response	It is agreed that the numerator in the cited equation is a ΔCDP threshold, while the threshold established in Section 2 is based on core damage frequencies. The report was changed to reflect this. The report has also been changed to provide a broader discussion of the differences between the shutdown RBPIs and the full-power RBPIs.	Yes

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
BWROG RPT14a	Configuration CCDF, is assumed to be calculated for each plant. The frequency of the CCDF expressed here is per day. If one assumes the average CDF for operation, 1E-5 per year, the CDF per day is 2.7E-8. This means the outage configuration needs to be 36 times more likely to yield core damage than the normal operating configuration just to have a CCDF of 1E-6, which is low. Using the listed thresholds and CCDFs the thresholds Δt's will range from .01 to 100 days. Hence, a color change can occur when .01 of a day is exceeded and when, 0.1 of a day is exceeded, etc. Having short time limits is relatively meaningless since outage delays typically will exceed 2.4 hours.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	Yes
BWROG RPT14b	Section 5 Validation and Verification: It appears that V&V is for the data (failure rates) being used. It seems more appropriate to pick a plant with declining performance and apply the RBPI methodology to it to determine if the indicators would predict declining performance.	
Response	The V&V discussed in the report is a test of the RBPI definitions, data collection, RBPI evaluation processes, and subsequent performance band determinations. The present V&V does not include choosing plants based on their past performance, and determining whether the RBPIs properly indicate declining performance.	Yes
Exelon ES1	The NRC Reactor Oversight Process (ROP) is seen as an improvement over the previous process in that the new approach is objective, safety-focused, predictable and more transparent to the industry and the public. This approach provides objective measurements of performance, avoids unnecessary regulatory burden, focuses NRC and licensee resources on risk significant issues, standardizes NRC response to performance issues based on safety significance, and it gives the public and industry a timely and understandable assessment of a plant's performance. Even though this process is much improved, enhancements that reflect the lessons learned from the initial year of implementation and the insights from the subject report provide a useful basis for discussion of the future direction of the ROP.	
Response	We agree with this comment.	No
Exelon ES2	Industry and the NRC must continue to properly prioritize and pursue the ROP process improvements, such as performance indicator changes, within the context of the entire regulatory framework and industry initiatives to standardize and streamline industry performance indicator (PI) information. These process improvements must be compatible with existing regulations, risk-informed initiatives and plant Technical Specifications and add value to the process as it currently exists. The viability of proposed changes to the ROP performance indicators must be proven using the rigorous change management process defined in NRC Inspection Manual Chapter 0608, "Performance Indicator Program."	
Response	We agree with this comment and intend to use the change process described in IMC-0608 for any potential changes to the current ROP.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
Exelon ES3	Changes to the ROP performance indicators, particularly the Safety System Unavailability PIs and associated performance thresholds are needed to sharpen the focus on risk significant conditions, reduce unnecessary burden associated with overly complex and differing definitions for similar PIs and Address perceived concerns on unintended consequences. The subject report appears to provide some opportunities for improvement in the area of replacing safety system start and demand fault exposure unavailability with unreliability indicators. As the report suggests, consideration of plant specific risk-insights in the establishment of performance indicator thresholds is an improvement. However, wide variances in the green/white threshold should be carefully considered to avoid unintended consequences on public confidence and understandability.	
Response	We agree that plant-specific thresholds must be clearly explained to maintain public confidence. This variance is a straightforward consequence of the plant-specific performance thresholds based on plant-specific models that reflect variations in plant design and operation. This issue would be assessed during the implementation phase using the change process in IMC-0608.	No
ACRS 1	A rational framework has been established for evaluating RBPIs and handling the relevant aleatory and epistemic uncertainties in evaluating PIs from available data.	
Response	We agree with this conclusion.	No
ACRS 2	The staff should continue to develop RBPIs as part of the ongoing effort to make the reactor oversight process (ROP) more objective and scrutable.	
Response	We agree with this recommendation. After reviewing all of the comments received from stakeholders on the draft Phase-1 RBPI report in two public meetings and written comments in response to a *Federal Register* Notice, NRR and RES will decide on specific future development efforts for RBPIs.	No
ACRS 3	The staff should develop methods for assessing tradeoffs between introducing new PIs versus reducing baseline inspections.	
Response	We intend to follow the change process for PIs discussed in Inspection Manual Chapter 0608, "Performance Indicator Program." This change process includes a decision as to whether the new PIs are justified based on their feasibility and the information regarding attributes not currently monitored, solicitation of input from stakeholders, and consideration of the incremental burden on licensees and possible adjustments to the baseline inspection program. If justified, these issues are then examined as part of a pilot program with a concurrent opportunity for additional public comment. Any changes to the risk-informed baseline inspection program would be made as described in IMC 0040, "Preparing, Revising, and Issuing Documents for the NRC Inspection Manual." The RBPI Phase 1 Report provides an assessment of attributes of plant performance monitored by the RBPIs. The staff intends to consider this assessment and any potential adjustments to the baseline inspection program as part of the change process.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
ACRS 4 **Response**	The staff should investigate establishing thresholds that depend on the baseline core damage frequency (CDF) of the plant. We do not agree that the thresholds for performance indicators (potential RBPIs or current ROP indicators) should be dependent on the baseline plant CDF. The sliding scale of Regulatory Guide 1.174 was based on acceptable values for permanent changes in plant performance. The ROP philosophy is to monitor temporary performance degradations that must be corrected to bring plant performance back to the existing acceptable baseline performance. The degree of NRC inspection, enforcement, and oversight are dependent on the magnitude of those changes in risk. We intend to continue using the ROP approach for the RBPI threshold development.	No
ACRS 5 **Response**	The Phase 1 report states that the green/white thresholds used in the current ROP correspond to changes in CDF (ΔCDF) that vary by more than an order of magnitude among plants. The green/white thresholds in the ROP should be reevaluated. The interpretation by the ACRS of the report statement on pages A-10 and A-16 of the Phase-1 report is correct. In general, we agree with the ACRS that the green/white thresholds can be refined using risk information. However, this may only be possible for the indicators in the initiating events and mitigating systems cornerstones, and may not be possible for the other cornerstones where comparable risk information is not available for setting performance thresholds. As discussed with the ACRS, we initially developed the green/white thresholds using historical information on the performance of plants, and anticipated refining them as improved risk models were developed. The staff will decide on the appropriate extent of this effort as part of any follow-on work for the RBPI program, and would incorporate any changes to the current PIs using the change process in IMC-0608.	No
ACRS 6 **Response**	The derivations of decision rules (thresholds for RBPIs) given in Appendix F to the RBPI Phase 1 report should be expanded to include plant- or design-specific prior distributions. The generic prior distributions developed from operating experience included the plant-to-plant variability in the calculation. The use of the constrained non-informative prior based on that calculation provided the optimum false positive/false negative performance indication for RBPIs. We will investigate whether the plant-specific or design-specific priors would be of more value in a follow-on project.	No
ACRS 7 **Response**	The staff should continue to explore "alternative" RBPIs. We will consider investigating alternative RBPIs that represent performance at a system, function, or cornerstone level in a follow-on project.	No
ACRS 8 **Response**	The potential for unintended impacts of RBPIs on plant performance is a concern and should be carefully considered in the development of the RBPIs. We agree with this recommendation. This issue has also been raised by external stakeholders, and will be assessed as part of the change process in IMC-0608.	No

Table I.1 (Continued)

Comment No.	Comment/Response	Report Change?
ACRS 9	The staff does not have the up-to-date risk information needed to develop RBPIs for shutdown operations; therefore, the staff's work should focus on full-power operations until such information is developed.	
Response	Following review of internal and external stakeholder comments, we have decided that the shutdown indicator work more appropriately supports an SDP process and will transfer this technology to the NRR staff for use in developing the shutdown SDP.	No
ACRS 10	There should be a publicly available peer review of the SAPHIRE code and, eventually, the Standardized Plant Analysis Risk (SPAR) models.	
Response	The SAPHIRE code has undergone extensive reviews and the information is publically available (NUREG/CR-6688, October 2000). We believe that this review is sufficient to establish confidence that the code's calculational functions are performed correctly. As such, we have concluded that resources that would be used for a peer review of the SAPHIRE code would be better allocated to other NRC projects. However, we agree that the Revision 3i SPAR models should undergo peer review to establish confidence in the models by stakeholders. The QA process established for the Level 1, Revision 3i SPAR models meets the intent of the proposed ASME Standard on PRA to the extent required, commensurate with the level of detail in the models and their intended purpose. The Revision 3i SPAR model QA process consists of two parts, an independent, internal QA review of each model by the contractor, Idaho National Engineering and Environmental Laboratory, and an external QA process comprised of an onsite QA review of the SPAR model for each plant against the licensee's plant PRA. The onsite QA review is conducted in conjunction with the benchmarking of the SDP Notebooks conducted by NRR. During this review, the event tree structure, the systems success criteria, dependency matrix, equipment failure probabilities, and human error probabilities in the Revision 3i SPAR model are compared with those in the licensee's model. In addition, the results for the baseline CDF and various sensitivity runs obtained using the Revision 3i SPAR model are compared to the results obtained using the licensee's PRA model. Significant differences in the two sets of results are discussed with the licensee in an effort to understand the reason for such differences. Based on the results of this onsite review, appropriate changes are then made to the SPAR model where justified. The purpose of this review is to ensure that the SPAR model adequately reflects plant responses to various accident initiators. To date, 44 Revision 3i SPAR models have been produced; 3 of these have received the detailed onsite QA review described herein. We plan to complete the onsite QA reviews of the remainder of the 70 SPAR models as they are produced over the next several years.	No
ACRS 11	It is premature to initiate a pilot program for RBPIs.	
Response	We agree that it is premature to initiate a pilot program for the complete set of RBPIs. As stated previously, implementation of the RBPIs would follow the change process for the ROP PIs described in IMC-0608. There are several key issues that must be addressed prior to implementation. They are summarized in the RBPI Report, and include verification of the risk models by licensees and verification of the data used to establish performance measures. However, the industry has recently expressed an interest to pilot some of the at-power RBPIs in an effort to enhance the current safety system unavailability performance indicators in the ROP. This selected subset of the RBPIs may be considered for early evaluation using the IMC-0608 process.	No

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10. SUPPLEMENTARY NOTES

11. ABSTRACT *(200 words or less)*

This report presents the results of the Phase 1 development of risk-based performance indicators (RBPIs) to potentially enhance the Reactor Oversight Process (ROP). SECY-99-007 recognized that improved performance indicators may be developed as part of the evolution of the ROP. RBPIs reflect changes in licensee performance that are logically related to risk and associated models. To the extent practical, the RBPIs identify declining performance before performance becomes unacceptable, without incorrectly identifying normal variations as degradations (i.e., avoid false-positive and false-negative indications). Phase 1 of the RBPI development includes performance indicators that are related to the initiating events cornerstone, mitigating systems cornerstone, and the containment portion of the barrier integrity cornerstone.

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