Reliability Study Update

Isolation Condenser

1987–2005

This report presents a performance evaluation of the isolation condenser (IC) system at five U.S. commercial boiling water reactors (BWRs). The evaluation is based on the operating experience from fiscal year 1987 through 2005, as reported in Licensee Event Reports (LERs). This is the latest update to NUREG/CR 5500 Volume 6, updating data, reliability estimates, trends, and figures.

This report calculates one basic model for the IC system that operates and has sufficient make-up capabilities to continue to operate for 8 hours. See the IC Fault Tree Description document for more detail.

1 LATEST UNRELIABILITY VALUES AND TREND

1.1 Industry-Wide Unreliability

The industry-wide unreliability of the IC system has been calculated from the operating experience, see Table 1. The estimate is based on failures that occurred during unplanned demands five-year testing.

Table 1. Industry-wide values.

Model	Lower (5%)	Mean	Upper (95%)
Unreliability (operate and makeup)	2.60E-03	2.64E-02	7.04E-02

1.2 Unreliability Results

Individual plant unreliability, for currently operating plants, has been calculated. The estimates of IC system unreliability using operating experience from LERs and fault tree analyses are plotted in Figure 1 (unreliability) and the data table is shown in Table 2.

No statistically significant[1] trend within the industry estimates of IC system unreliability on a per fiscal year basis was identified. Figure 2 displays the trend by fiscal year of the IC system unreliability calculated from the 1987–2005 experience. Table 6 shows the data points for Figure 2. Individual plant result unreliability has not been calculated for the IC system unreliability due to the small amount of data.

[1] Statistically significant is defined in terms of the 'p-value.' A p-value is a probability indicating whether to accept or reject the null hypothesis that there is no trend in the data. P-values of less than or equal to 0.05 indicate that we are 95% confident that there is a trend in the data (reject the null hypothesis of no trend.) By convention, we use the "Michelin Guide" scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

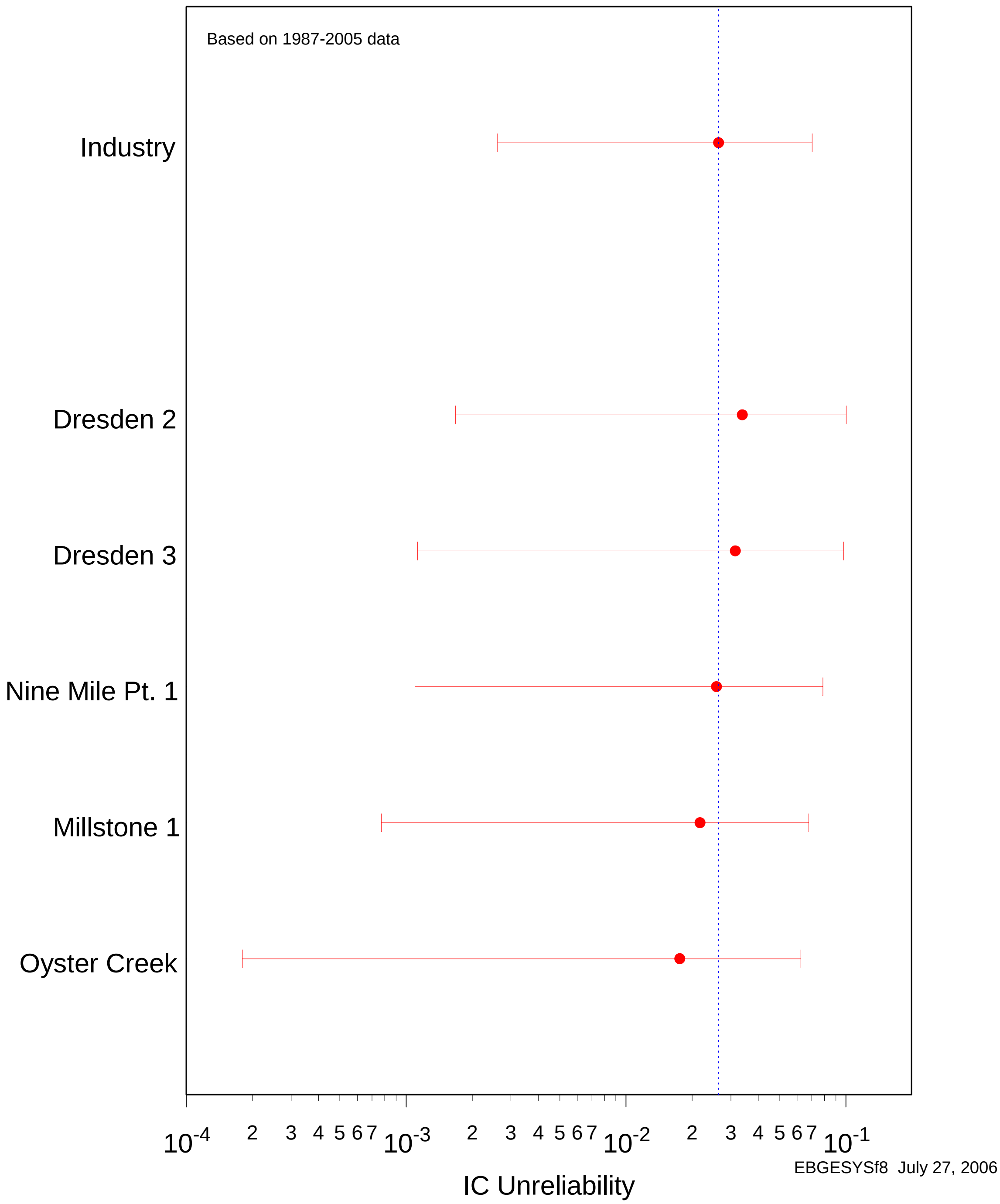

Figure 1. Plant-specific estimates of IC system unreliability.

Table 2. IC plant unreliability data.

Plant	Lower (5%)	Mean	Upper (95%)
Industry	2.60E-03	2.64E-02	7.04E-02
Dresden 2	1.68E-03	3.38E-02	1.00E-01
Dresden 3	1.12E-03	3.15E-02	9.77E-02
Nine Mile Pt. 1	1.09E-03	2.58E-02	7.85E-02
Millstone 1	7.74E-04	2.18E-02	6.78E-02
Oyster Creek	1.83E-04	1.76E-02	6.24E-02

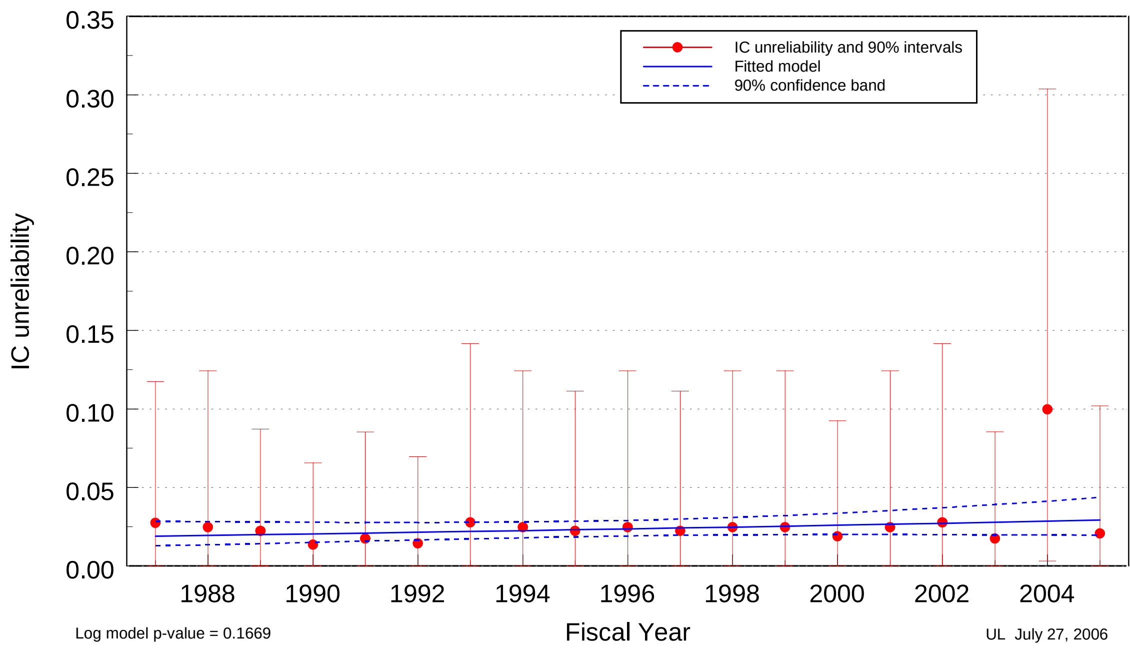

Figure 2. Trend of IC system unreliability (operate and makeup), as a function of fiscal year.

The leading contributor to IC system short-term unreliability is the failure of the system to operate. Figure 3 shows the distribution of segment failure contributions.

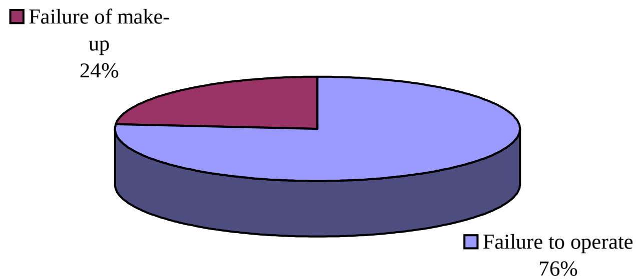

Figure 3. Segment failure distribution, 8-hour mission.

2 DATA TRENDS

2.1 Unplanned Demand Trend

Trends were identified in the frequency of IC unplanned demands (Figure 4). When modeled as a function of fiscal year, the unplanned demand frequency exhibited a highly statistically significant decreasing trend. Table 7 shows the LERs that are represented in the figure.

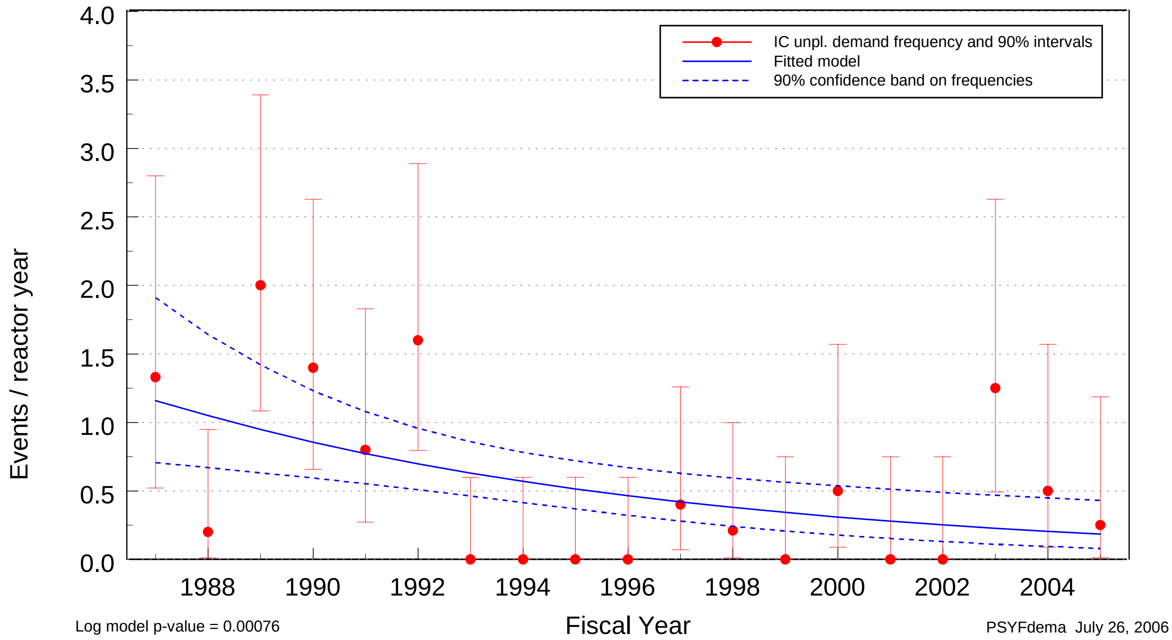

Figure 4. Frequency (events per reactor year) of unplanned demands, as a function of fiscal year.

2.2 Failure Trend

The frequency of all failures (unplanned demands, surveillance tests, inspections, etc.) resulting in train unreliability identified in the experience was analyzed to determine trends. When modeled as a function of fiscal year, a highly statistically significant decreasing trend was identified. The fitted frequency is plotted against fiscal year in Figure 5. Trends for IC failures are plotted without regard to method of detection. Table 8 shows the LERs that are represented in the figure.

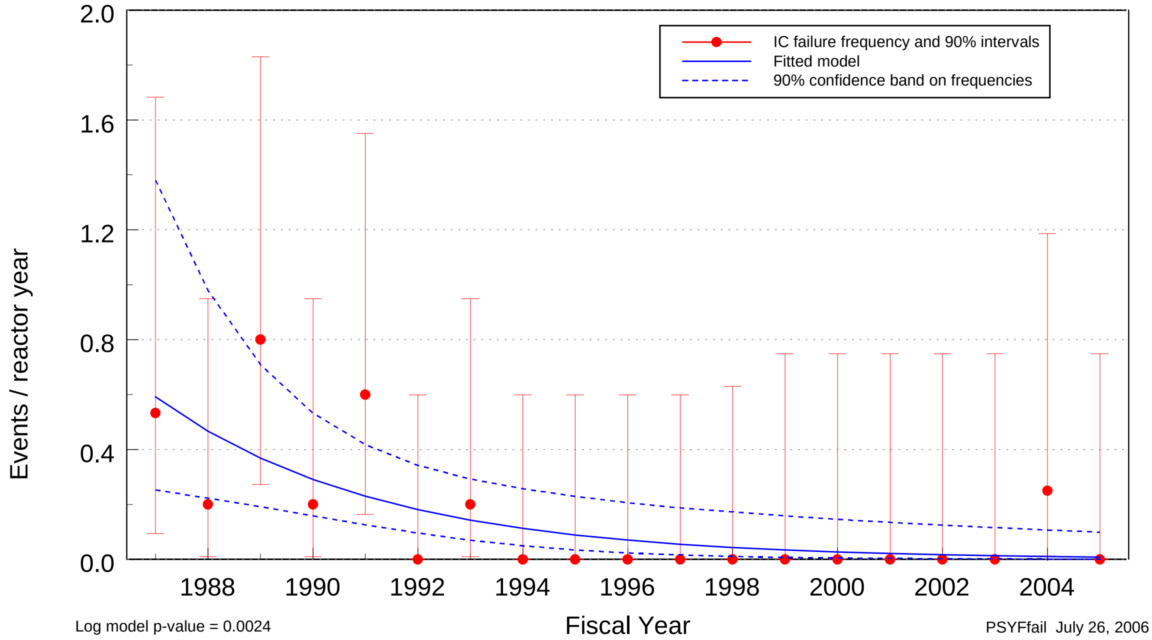

Figure 5. Frequency (events per reactor year) of failures, as a function of fiscal year.

2.3 Failure Cause and Discovery Method Summary

The raw failure data were sliced to show the distribution of the failure causes and the discovery methods by the affected segment.

2.3.1 Leading Segment Failures.

One component group contributed approximately two-thirds of all IC system failures: the isolation logic circuitry. Seventy-five percent of these were recovered after a spurious isolation. See Table 3.

2.3.2 Leading Discovery Methods

Observation (54%) was the most likely method of discovery for failures in the isolation condenser. Actuation (31%) was the next most likely method of discovery. See Table 3.

Table 3. Failed components compared to the discovery method. [2]

Description	Periodic surveillance on system	Observation	Actual/ unplanned demand	Total	Percent
Actuation Circuitry	1			1	8%
Condensate Return Valve		1		1	8%
Isolation Logic	1	5	2	8	62%

[2] The discovery method is the activity that is ongoing at the time of the failure.

Description	Periodic surveillance on system	Observation	Actual/ unplanned demand	Total	Percent
Makeup Valve			1	1	8%
Steam MOV			1	1	8%
Vent Valve		1		1	8%
Total	2	7	4	13	100%
Percent	15%	54%	31%	100%	

Table 4. Discovery method description.

Discovery Method	Description	Used in the Failure Calculations
Actuation	The demand for the system was ESF, inadvertent. If the demand was inadvertent, the demand should mimic an ESF demand.	✓
Test	Normally scheduled surveillance. These surveillances are to satisfy scheduled Technical Specification requirements.	✓
Observation	The failure was discovered during operator duties such as walk downs, inspections, etc.	

2.3.3 Leading Causes of Failure.

Forty-six percent of the failures of the IC system observed in the experience were attributed to hardware-related problems. Personnel problems caused 38% of all IC system failures, with the personnel error leading to an isolation being the most likely. See Table 5.

Table 5. Failed components compared to the failure cause. [3]

Description	Design	Hardware	Personnel	Procedure	Total	Percent
Actuation Circuitry			1		1	8%
Condensate Return Valve		1			1	8%
Isolation Logic		5	3		8	62%
Makeup Valve	1				1	8%
Steam MOV				1	1	8%
Vent Valve			1		1	8%
Total	1	6	5	1	13	100%
Percent	8%	46%	38%	8%	100%	

- Design–The failure was the result of a flawed design.
- Hardware–The failure was the result of some aspect of the equipment. Typically, this is used for normal wear of the component.
- Personnel–The failure was the result of personnel error, by either commission or omission.
- Procedure–The failure was the result of an incorrect procedure.

[3] The cause of the failure is assigned to a broadly defined cause classification. The cause classifications are design, environment, hardware (e.g., aging, wear, manufacturing defects), personnel, and procedure. The cause classification assigned is based on the immediate cause of the failure and not the root cause. Generally, root cause is only determined through a detailed investigation and analysis of the failure. Specifically, the mechanism that actually resulted in the failure of the segment or component is captured as the cause.

3 DATA TABLES

3.1 Data Tables for Unreliability Trend

Table 6. Plot data table for IC system unreliability. Figure 2

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.30E-05	2.74E-02	1.18E-01	0.00E+00	1.63E-02	3.42E-02
1988	9.93E-08	2.47E-02	1.24E-01	9.33E-04	1.74E-02	3.39E-02
1989	6.34E-05	2.24E-02	8.72E-02	3.42E-03	1.85E-02	3.36E-02
1990	2.67E-07	1.36E-02	6.57E-02	5.83E-03	1.96E-02	3.35E-02
1991	2.18E-07	1.74E-02	8.53E-02	8.14E-03	2.08E-02	3.34E-02
1992	2.59E-07	1.44E-02	6.96E-02	1.03E-02	2.19E-02	3.34E-02
1993	6.01E-08	2.77E-02	1.42E-01	1.24E-02	2.30E-02	3.36E-02
1994	9.93E-08	2.47E-02	1.24E-01	1.42E-02	2.41E-02	3.40E-02
1995	1.37E-07	2.23E-02	1.11E-01	1.57E-02	2.52E-02	3.47E-02
1996	9.93E-08	2.47E-02	1.24E-01	1.70E-02	2.63E-02	3.56E-02
1997	1.37E-07	2.23E-02	1.11E-01	1.80E-02	2.74E-02	3.69E-02
1998	9.93E-08	2.47E-02	1.24E-01	1.86E-02	2.85E-02	3.85E-02
1999	9.93E-08	2.47E-02	1.24E-01	1.90E-02	2.97E-02	4.03E-02
2000	1.97E-07	1.88E-02	9.24E-02	1.92E-02	3.08E-02	4.23E-02
2001	9.93E-08	2.47E-02	1.24E-01	1.93E-02	3.19E-02	4.45E-02
2002	6.01E-08	2.77E-02	1.42E-01	1.92E-02	3.30E-02	4.68E-02
2003	2.21E-07	1.75E-02	8.54E-02	1.90E-02	3.41E-02	4.92E-02
2004	3.19E-03	9.97E-02	3.04E-01	1.87E-02	3.52E-02	5.17E-02
2005	1.84E-07	2.07E-02	1.02E-01	1.84E-02	3.63E-02	5.42E-02

Table 7. LER listing for demand trend figure. Figure 4

FY	Plant Name	LER	Event Date
1988	Dresden 2	2371987032	10/20/1987
1989	Dresden 2	2371989012	3/4/1989
1990	Dresden 2	2371990001	1/5/1990
1990	Dresden 2	2371990002	1/16/1990
2004	Dresden 2	2372004002	4/24/2004
2005	Dresden 2	2372005002	3/24/2005
1987	Dresden 3	2491987013	8/7/1987
1989	Dresden 3	2491989001	3/25/1989
1990	Dresden 3	2491990005	3/10/1990
1998	Dresden 3	2491998003	4/9/1998
2004	Dresden 3	2492004003	5/5/2004
1987	Millstone 1	2451987007	3/22/1987
1991	Millstone 1	2451991008	4/7/1991
2003	Nine Mile Pt. 1	2202003002	8/14/2003
1987	Oyster Creek	2191987011	2/14/1987
1989	Oyster Creek	2191989015	5/18/1989
1989	Oyster Creek	2191989016	6/25/1989
1989	Oyster Creek	2191989021	9/22/1989
1991	Oyster Creek	2191991005	8/22/1991
1992	Oyster Creek	2191992005	5/3/1992
1992	Oyster Creek	2191992009	8/22/1992
1997	Oyster Creek	2191997010	8/1/1997
2000	Oyster Creek	2192000003	3/1/2000
2003	Oyster Creek	2192003003	8/14/2003
2003	Oyster Creek	2192003004	8/22/2003

Table 8. LER listing for failure trend figure. Figure 5

FY	Plant Name	LER	Event Date
1989	Dresden 2	2371989012	3/4/1989
1989	Dresden 2	2371989021	8/9/1989
1990	Dresden 2	2371990005	7/30/1990
2004	Dresden 2	2372004002	4/24/2004
1987	Dresden 3	2491987013	8/7/1987
1987	Dresden 3	2491987014	9/5/1987
1989	Dresden 3	2491989001	3/25/1989
1991	Dresden 3	2491991008	8/30/1991
1993	Dresden 3	2491993009	5/12/1993
1991	Millstone 1	2451991008	4/7/1991
1991	Nine Mile Pt. 1	2201991010	9/9/1991
1988	Oyster Creek	2191988019	9/2/1988
1989	Oyster Creek	2191989013	5/8/1989