Reliability Study Update

Isolation Condenser

1987–2002

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 1987 through 2002, as reported in Licensee Event Reports (LERs). This is the latest update to NUREG/CR 5500 Volume 6.

This report calculates one basic model for the IC system. The 8-hour mission, models the IC system start and operation for 8 hours. Makeup to the system is included. 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 for an 8-hour mission, Table 1. The estimate is based on failures that occurred during unplanned demands, and cyclic and quarterly surveillance tests.

Table 1. Industry-wide values.

Model	Lower (5%)	Mean	Upper (95%)
8-hour Mission (Unreliability)	5.87E-04	1.50E-02	4.65E-02

1.2 Unreliability Results

No statistically significant[1] trend within the industry estimates of IC system unreliability on a per fiscal year basis was identified. Figure 1 displays the trend by fiscal year of the IC system unreliability calculated from the 1987–2002 experience. Table 5 shows the data points for Figure 1. Individual plant result unreliability has not been calculated for the IC system unreliability due to the small amount of data.

[1] The term “statistically significant” means that the data are too closely correlated to be attributed to chances and consequently have a systematic relationship. A p-value of less than 0.05 is generally considered to be statistically significant.

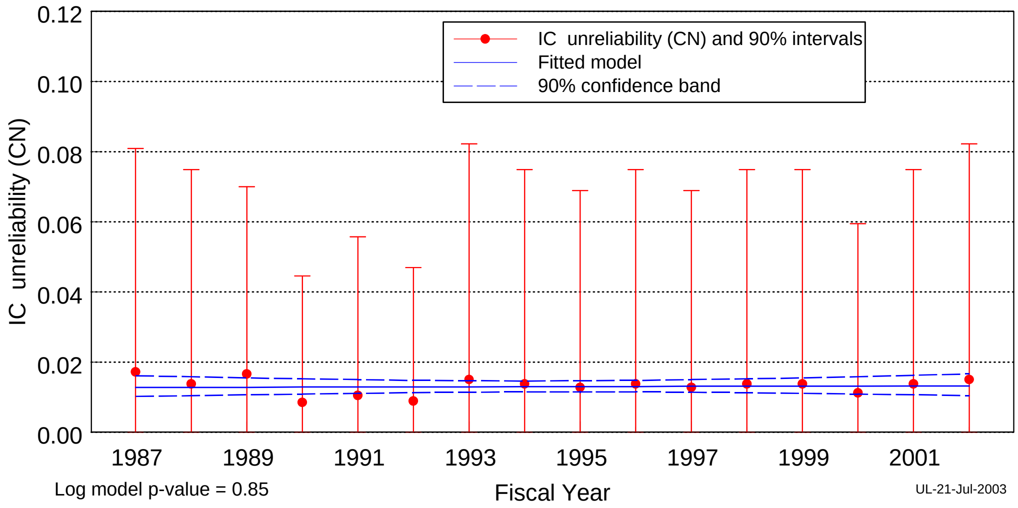

Figure 1. Trend of IC system unreliability (8-hour mission), as a function of fiscal year.

The leading contributor to IC system short-term unreliability is the failure of the system to operate. Figure 2 shows the distribution of segment failure contributions for the 8-hour model.

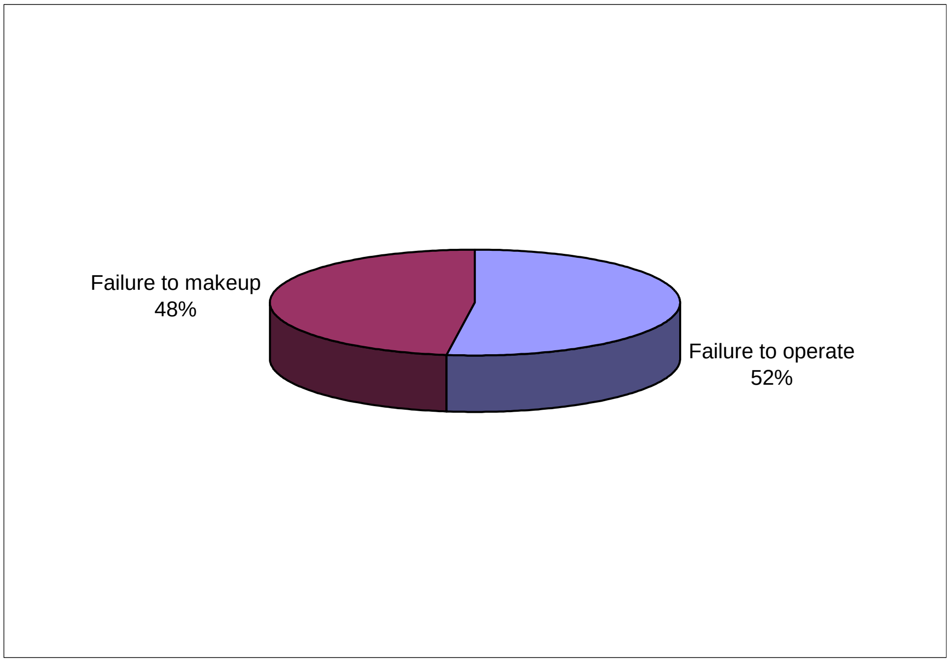

Figure 2. Segment failure distribution, 8-hour mission.

2 DATA TRENDS

2.1 Unplanned Demand Trend

Trends were identified in the frequency of IC unplanned demands (Figure 3). When modeled as a function of fiscal year, the unplanned demand frequency exhibited a highly statistically significant decreasing trend. Table 6 shows the LERs that are represented in the figure.

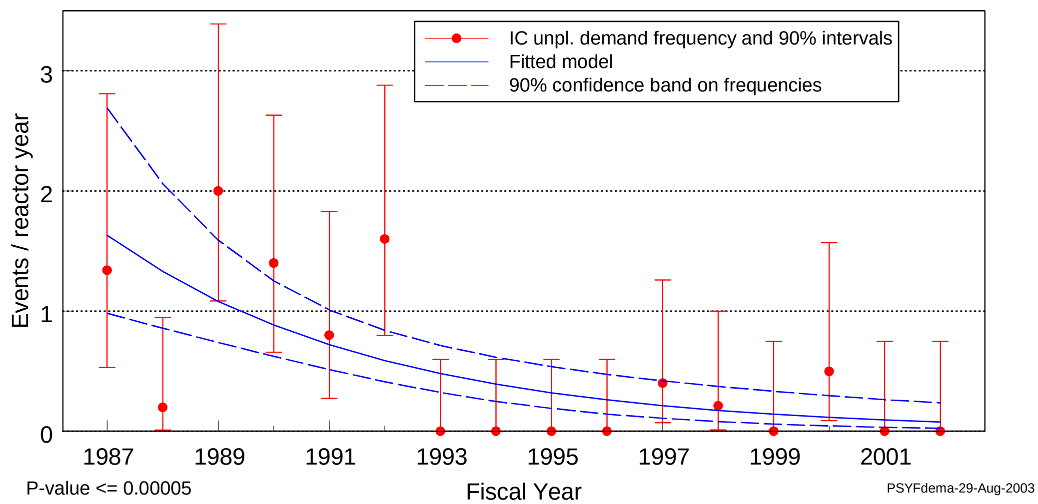

Figure 3. Frequency (events per operating year) of unplanned demands, as a function of fiscal year.

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 4. Trends for IC failures are plotted without regard to method of detection (the trend excludes maintenance out of service and support system failures). Table 7 shows the LERs that are represented in the figure.

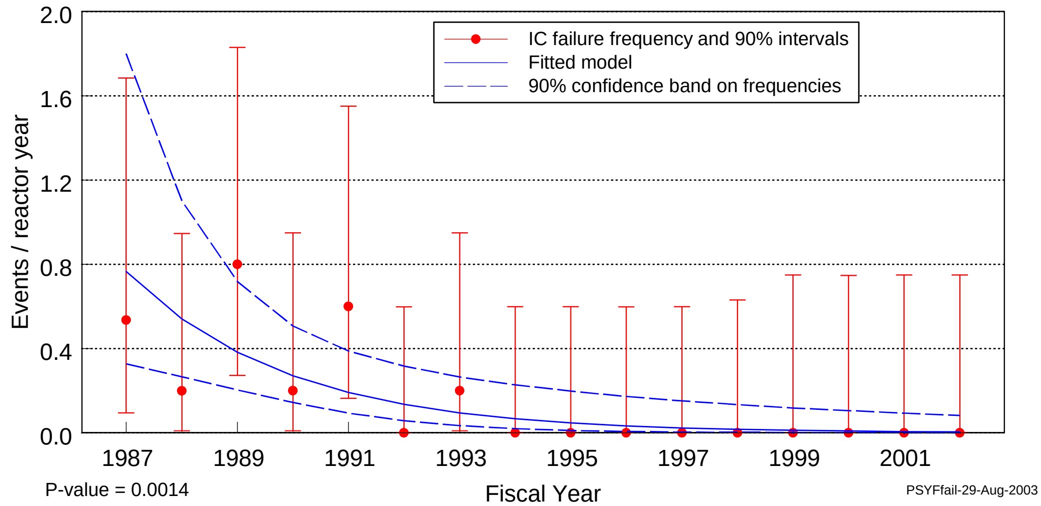

Figure 4. Frequency (events per operating year) of failures, as a function of fiscal year.

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 two-thirds of all IC system failures: the isolation logic circuitry. Seventy-five percent of these were recovered after a spurious isolation. See Table 2.

2.3.2 Leading Discovery Methods

Observation (58%) was the most likely method of discovery for failures in the isolation condenser. Actuation (25%) was the next most likely method of discovery. See Table 2.

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

Segment	Actuation	Observation	Test	Total	Percent
Actuation Circuitry			1	1	8%
Condensate Return Valve		1		1	8%
Isolation Logic	2	5	1	8	67%
Makeup Valve	1			1	8%
Vent Valve		1		1	8%
Total	3	7	2	12	100%
Percent	25%	58%	17%	100%	

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

Table 3. 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.

Fifty percent of the failures of the IC system observed in the experience were attributed to hardware-related problems. Personnel problems caused 42% of all IC system failures, with the personnel error leading to an isolation being the most likely. See Table 4.

Table 4. Failed components compared to the failure cause.[3]

Segment	Design	Hardware	Personnel	Total	Percent
Actuation Circuitry			1	1	8%
Condensate Return Valve		1		1	8%
Isolation Logic		5	3	8	67%
Makeup Valve	1			1	8%
Vent Valve			1	1	8%
Total	1	6	5	12	100%
Percent	8%	50%	42%	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 5. Plot data table for IC system unreliability. Figure 1

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	7.76E-07	1.72E-02	8.09E-02	1.02E-02	1.28E-02	1.61E-02
1988	1.13E-09	1.38E-02	7.49E-02	1.04E-02	1.28E-02	1.58E-02
1989	1.13E-05	1.66E-02	7.00E-02	1.07E-02	1.28E-02	1.55E-02
1990	3.98E-09	8.50E-03	4.46E-02	1.09E-02	1.29E-02	1.52E-02
1991	2.92E-09	1.05E-02	5.57E-02	1.11E-02	1.29E-02	1.50E-02
1992	3.79E-09	8.93E-03	4.69E-02	1.13E-02	1.29E-02	1.48E-02
1993	6.82E-10	1.50E-02	8.23E-02	1.14E-02	1.29E-02	1.47E-02
1994	1.13E-09	1.38E-02	7.49E-02	1.15E-02	1.30E-02	1.46E-02
1995	1.61E-09	1.28E-02	6.89E-02	1.15E-02	1.30E-02	1.47E-02
1996	1.13E-09	1.38E-02	7.49E-02	1.15E-02	1.30E-02	1.48E-02
1997	1.61E-09	1.28E-02	6.89E-02	1.14E-02	1.31E-02	1.50E-02
1998	1.13E-09	1.38E-02	7.49E-02	1.13E-02	1.31E-02	1.52E-02
1999	1.13E-09	1.38E-02	7.49E-02	1.11E-02	1.31E-02	1.55E-02
2000	2.53E-09	1.12E-02	5.94E-02	1.09E-02	1.31E-02	1.58E-02
2001	1.13E-09	1.38E-02	7.49E-02	1.07E-02	1.32E-02	1.62E-02
2002	6.82E-10	1.50E-02	8.23E-02	1.05E-02	1.32E-02	1.66E-02

Table 6. LER listing for demand trend figure. Figure 3

FY	Plant	Date	LER
1987	Dresden 3	8/7/1987	2491987013
1987	Millstone 1	3/22/1987	2451987007
1987	Oyster Creek	2/14/1987	2191987011
1988	Dresden 2	10/20/1987	2371987032
1989	Dresden 2	3/4/1989	2371989012
1989	Dresden 3	3/25/1989	2491989001
1989	Oyster Creek	5/18/1989	2191989015
1989	Oyster Creek	6/25/1989	2191989016
1989	Oyster Creek	9/22/1989	2191989021
1990	Dresden 2	1/5/1990	2371990001
1990	Dresden 2	1/16/1990	2371990002
1990	Dresden 3	3/10/1990	2491990005
1991	Millstone 1	4/7/1991	2451991008
1991	Oyster Creek	8/22/1991	2191991005
1992	Oyster Creek	5/3/1992	2191992005
1992	Oyster Creek	5/3/1992	2191992005
1992	Oyster Creek	8/22/1992	2191992009
1997	Oyster Creek	8/1/1997	2191997010
1998	Dresden 3	4/9/1998	2491998003

FY	Plant	Date	LER
2000	Oyster Creek	3/1/2000	2192000003

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

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