# Reliability Study Update

# High Pressure Coolant Injection System

# 1987–2005

This report presents a performance evaluation of the high-pressure coolant injection (HPCI) system at 24 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 4, updating data, availability and reliability estimates, trends, and figures.

This report calculates two basic models for the HPCI system. The FTS model includes the start and recovery of the pump and the initial opening of the injection valve. The 8-hour mission model includes the HPCI system start and operation for 8 hours. Restart of the HPCI turbine, multiple injections, transfer of the suction from the condensate storage tank (CST) to the suppression pool, and recovery actions are included. Both models include failures due to the unavailability while in maintenance. See the HPCI Fault Tree Description document for more detail.

## 1 LATEST VALUES AND TRENDS

### 1.1 Industry-Wide Unavailability and Unreliability

The industry-wide unavailability and unreliability of the HPCI system have been estimated from operating experience. A failure to start (FTS) unavailability and an 8-hour mission unreliability were evaluated, see Table 1. The estimates are 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%) |
|---|---|---|---|
| Failure-to-Start (Unavailability) | 4.75E-03 | 1.97E-02 | 4.29E-02 |
| 8-hour Mission (Unreliability) | 1.76E-02 | 4.72E-02 | 8.75E-02 |

### 1.2 Fail to Start Model Results

The estimates of HPCI system unavailability using operating experience from LERs and fault tree analyses show no statistically significant difference between plants. Plant system differences are computed based on plant differences seen in the segment failure data. When there are no statistically significant differences observed in the segment failure data, any update to show system unavailability results in the same values for all plants. Therefore, no data are plotted.

An extremely statistically significant[1] decreasing trend within the industry estimates of HPCI system unavailability (FTS) on a per fiscal year basis was identified. Figure 1 shows the trend in the FTS model unavailability. Table 6 shows the data points for Figure 1.

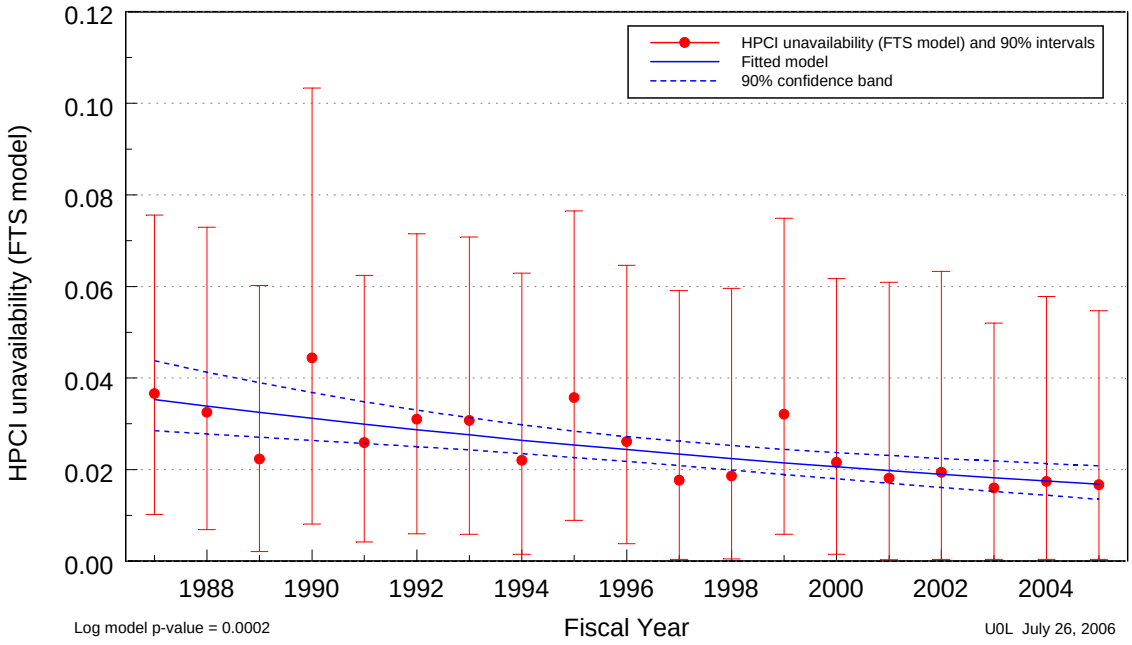


**Figure 1. Trend of HPCI system unavailability (FTS model), as a function of fiscal year.**

[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).

The leading contributor to HPCI system short-term unavailability, after maintenance out of service, is the failure of the turbine to start. Figure 2 shows the distribution of segment failure contributions for the FTS model.

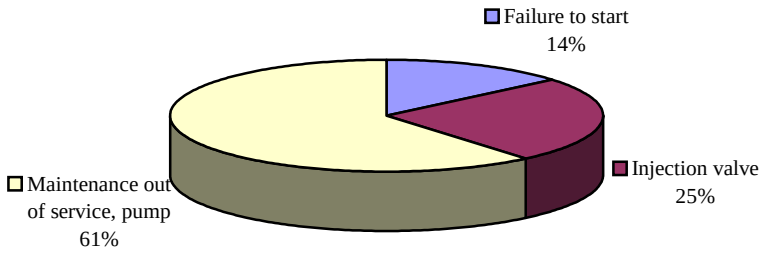


**Figure 2. Segment failure distribution, FTS model.**

## 1.3 Fail to Operate for 8-Hour Model Results

Individual plant result unreliability has been calculated for the 8-hour model. The estimates of HPCI system unreliability using operating experience from LERs and fault tree analyses are plotted in Figure 3 (8-hour model). Table 2 shows the data points for Figure 3.

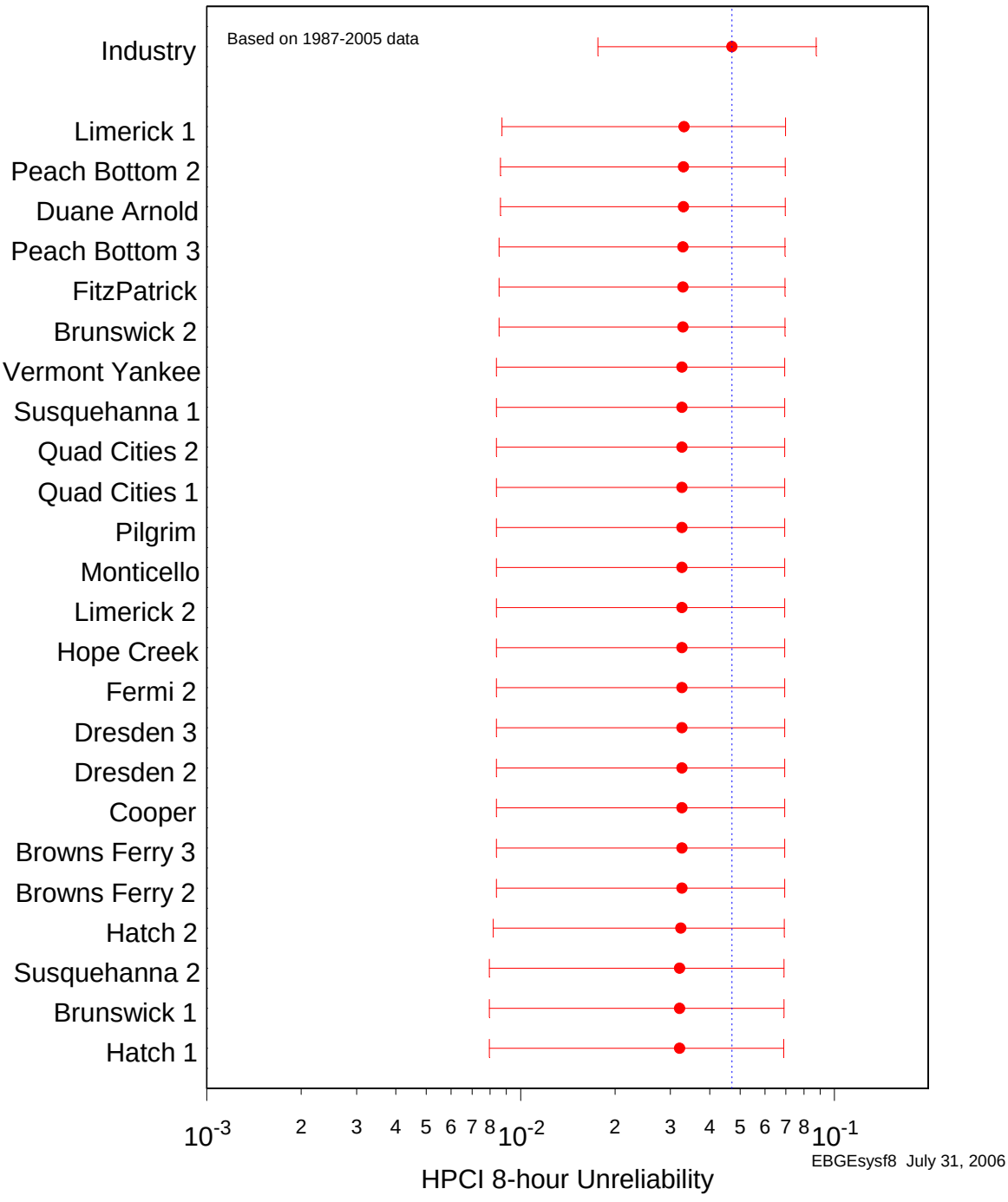


**Figure 3. Plant-specific estimates of HPCI system unreliability (8-hour mission).**

**Table 2. HPCI plant unreliability (8-hour mission).**

| Plant | Lower (5%) | Mean | Upper (95%) |
|---|---|---|---|
| Industry | 1.76E-02 | 4.72E-02 | 8.75E-02 |
| Limerick 1 | 8.73E-03 | 3.32E-02 | 6.99E-02 |
| Duane Arnold | 8.62E-03 | 3.30E-02 | 6.97E-02 |
| Peach Bottom 2 | 8.62E-03 | 3.30E-02 | 6.97E-02 |
| Brunswick 2 | 8.53E-03 | 3.29E-02 | 6.96E-02 |
| FitzPatrick | 8.53E-03 | 3.29E-02 | 6.96E-02 |
| Peach Bottom 3 | 8.53E-03 | 3.29E-02 | 6.96E-02 |
| Browns Ferry 2 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Browns Ferry 3 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Cooper | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Dresden 2 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Dresden 3 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Fermi 2 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Hope Creek | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Limerick 2 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Monticello | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Pilgrim | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Quad Cities 1 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Quad Cities 2 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Susquehanna 1 | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Vermont Yankee | 8.36E-03 | 3.27E-02 | 6.94E-02 |
| Hatch 2 | 8.18E-03 | 3.24E-02 | 6.92E-02 |
| Brunswick 1 | 7.95E-03 | 3.21E-02 | 6.90E-02 |
| Susquehanna 2 | 7.95E-03 | 3.21E-02 | 6.90E-02 |
| Hatch 1 | 7.95E-03 | 3.21E-02 | 6.89E-02 |

A highly statistically significant trend within the industry estimates of HPCI system unreliability (8-hour mission) on a per fiscal year basis was identified. Figure 4 displays the trend by fiscal year of the HPCI system unreliability calculated from the 1987–2005 experience. Table 7 shows the data points for Figure 4.

The leading contributors to HPCI system long-term unreliability are the failure to run and the failure of the injection valve to reopen. Figure 5 shows the distribution of segment failures for the 8-hour mission.

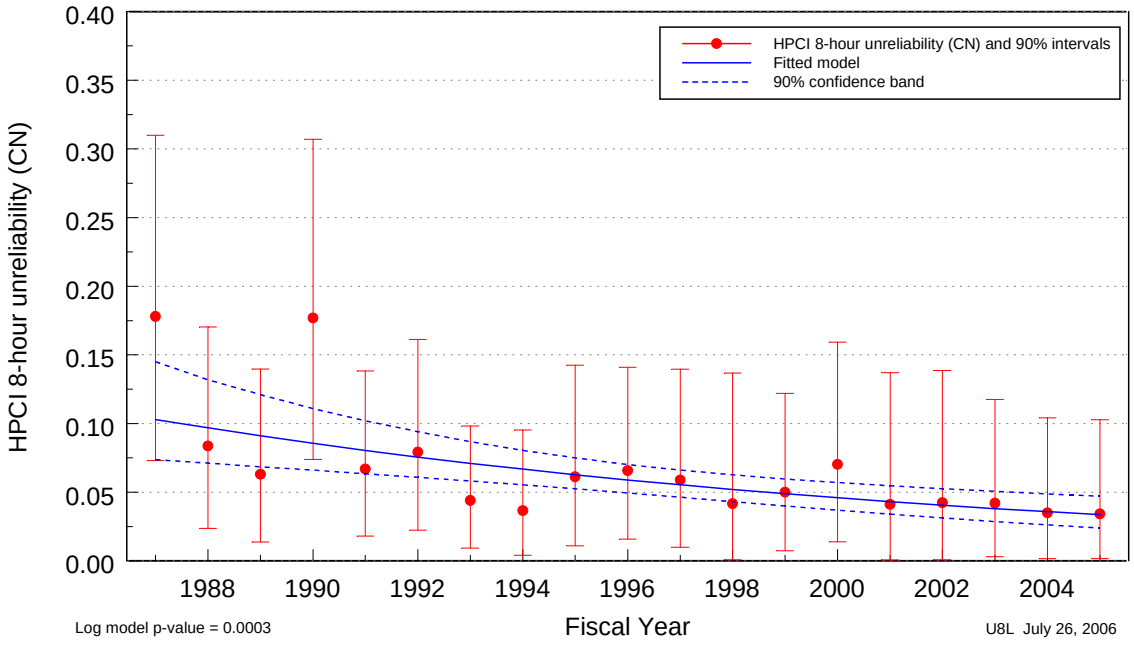


**Figure 4. Trend of HPCI system unreliability (8-hour mission), as a function of fiscal year.**

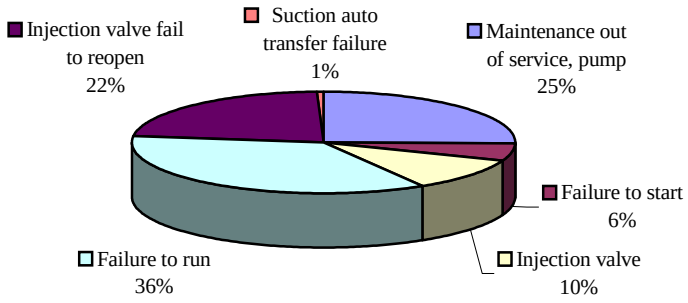


**Figure 5. Segment failure distribution, 8-hour mission.**

# 2 DATA TRENDS

The raw actuation and failure data were trended for event counts over time.

## 2.1 Unplanned Demand Trend

Trends were identified in the frequency of HPCI unplanned demands (Figure 6). When modeled as a function of fiscal year, the unplanned demand frequency exhibited an extremely statistically significant decreasing trend. Table 8 shows the LERs that are represented in the figure. The noticeable increase in HPCI unplanned demands in FY-2003 through FY-2005 is related to the significant increase in scrams and ECCS actuations in FY-2003 to FY-2005 compared to recent history.

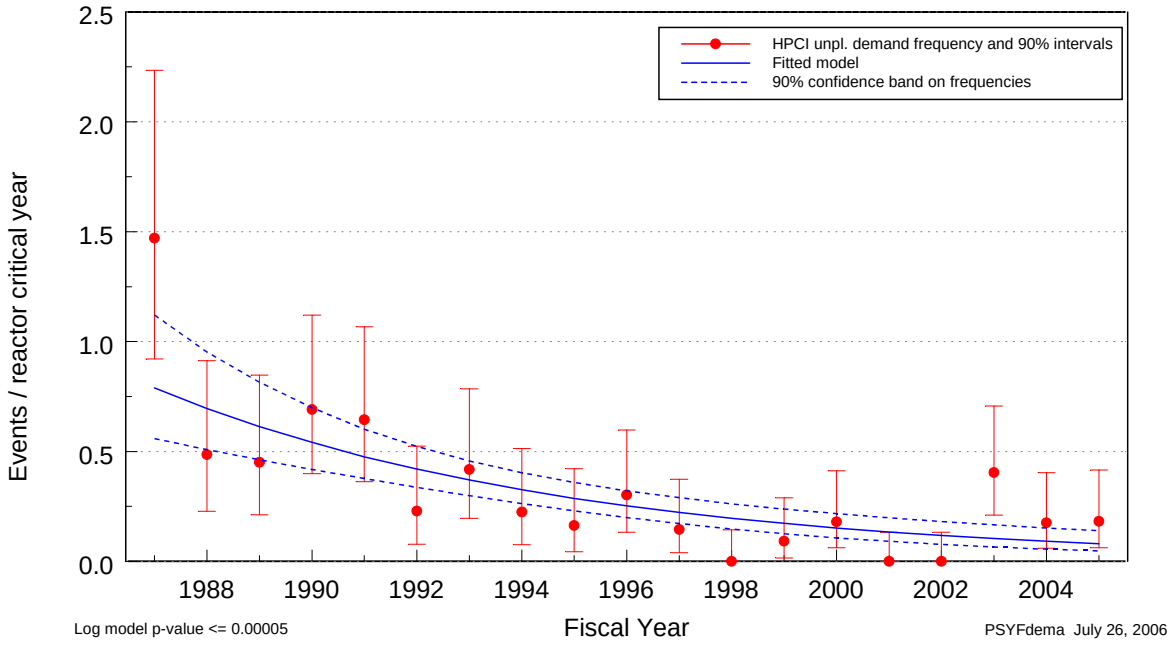


**Figure 6. Frequency (events per operating year) of unplanned demands, as a function of fiscal year.**

## 2.2 Failure Trend

The frequency of all failures (unplanned demands, surveillance tests, inspections, etc.) resulting in train unavailability identified in the experience was analyzed to determine trends. When modeled as a function of fiscal year, an extremely statistically significant decreasing trend was identified. The fitted frequency is plotted against fiscal year in Figure 7. Trends for HPCI failures are plotted without regard to method of detection (the trend excludes maintenance out of service and support system failures). Table 9 shows the LERs that are represented in the figure.

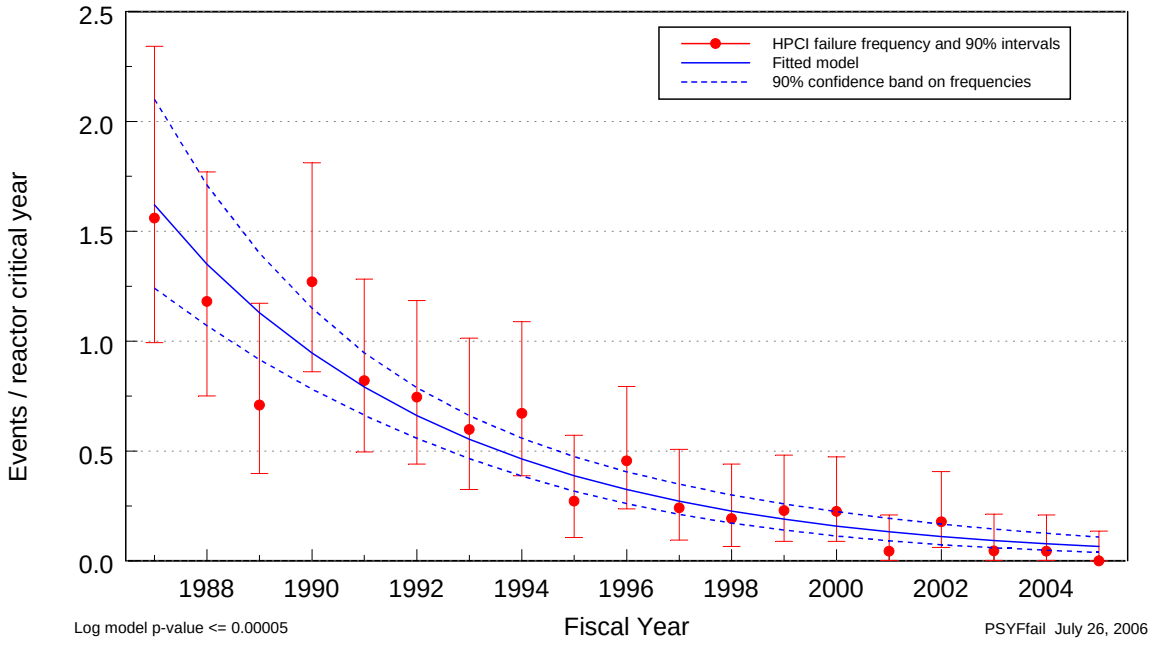


**Figure 7. Frequency (events per operating year) of failures, as a function of fiscal year.**

## 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.

The turbine (48%) and the instrumentation and control (15%) were the leading segment failures identified in the database. See Table 3.

### 2.3.2 Leading Discovery Methods

Periodic surveillance (52%) and alarms and indication (22%) were the leading methods of discovery. See Table 3.

### 2.3.3 Leading Causes of Failure.

Seventy-two percent of the HPCI system failures that were observed in the experience are attributed to hardware-related problems. Personnel errors caused 13% of all HPCI system failures. See Table 5

**Table 3. Comparison of failed segment with the method of discovery.[2]**

| Segment | Actual/ unplanned demand | Alarm/ indicator | I&C functional test | Inspection/ review | Maintenance on system | Periodic surveillance on system | Post-maintenance testing | Total | Percent |
|---|---|---|---|---|---|---|---|---|---|
| I&C | | 9 | 3 | 2 | | 10 | | 24 | 15% |
| Injection | 4 | | | 3 | | 8 | 1 | 16 | 10% |
| Pump | 1 | 4 | | 2 | 1 | 13 | 1 | 22 | 14% |
| Support | 1 | 12 | | 4 | | 2 | | 19 | 12% |
| Turbine | 3 | 10 | 2 | 7 | | 48 | 5 | 75 | 48% |
| Total | 9 | 35 | 5 | 18 | 1 | 81 | 7 | 156 | 100% |
| Percent | 6% | 22% | 3% | 12% | 1% | 52% | 4% | 100% | |

**Table 4. Discovery method description.**

| Discovery Method | Description | Used in the Failure Calculations |
|---|---|---|
| Actual/unplanned demand | The demand for the system was ESF, inadvertent. If the demand was inadvertent, the demand should mimic an ESF demand. | ✓ |
| Design review | Because of a design review, a deficiency was noted in the system. | |
| Periodic surveillance on subject system | Normally scheduled surveillance. These surveillances are to satisfy scheduled Technical Specification requirements. | ✓ |
| Maintenance on subject system | The failed condition was discovered during maintenance on the system. These include latent failures as well as maintenance-induced failures. | |
| Inspection/review | The failure was discovered during operator duties such as walk downs, inspections, etc. | |
| Alarm/indicator | The failure was evidenced by an alarm or by other indications. | |
| I&C functional test | The failure was discovered during testing of the instrumentation and control system for the subject system or another system. | |
| Post-maintenance testing | Failed condition was discovered during post-maintenance testing. The technical specification surveillance tests can be used for this testing, but cannot be counted. | |

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

| Discovery Method | Description | Used in the Failure Calculations |
|---|---|---|
| Unscheduled TS required surveillance | Failed condition was discovered during technical specification required testing. Tests are performed to show system operability per the technical specifications and are not scheduled. The technical specification surveillance tests can be used for this testing, but cannot be counted. | |
| Other (not counted) surveillance test | All others discovered by testing. | |

**Table 5. Comparison of failed segment and failure cause.[3]**

| Segment | Contamination | Design | Hardware | Personnel | Procedure | Total | Percent |
|---|---|---|---|---|---|---|---|
| I&C | | | 17 | 4 | 3 | 24 | 15% |
| Injection | | 2 | 12 | 1 | 1 | 16 | 10% |
| Pump | 4 | 1 | 11 | 5 | 1 | 22 | 14% |
| Support | | | 13 | 5 | 1 | 19 | 12% |
| Turbine | 1 | 4 | 60 | 6 | 4 | 75 | 48% |
| Total | 5 | 7 | 113 | 21 | 10 | 156 | 100% |
| Percent | 3% | 4% | 72% | 13% | 6% | 100% | |

- Contamination–The failure was the result of foreign material affecting the component.
- 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 and Unavailability Trends

**Table 6. Plot data table for HPCI system unavailability, FTS model. Figure 1.**

| FY | Plot Trend Error Bar Points | | | Regression Curve Data Points | | |
|---|---|---|---|---|---|---|
| | Lower (5%) | Mean | Upper (95%) | Lower (5%) | Mean | Upper (95%) |
| 1987 | 1.02E-02 | 3.66E-02 | 7.56E-02 | 2.85E-02 | 3.53E-02 | 4.38E-02 |
| 1988 | 6.89E-03 | 3.25E-02 | 7.29E-02 | 2.78E-02 | 3.39E-02 | 4.13E-02 |
| 1989 | 2.11E-03 | 2.23E-02 | 6.02E-02 | 2.71E-02 | 3.25E-02 | 3.90E-02 |
| 1990 | 8.14E-03 | 4.44E-02 | 1.03E-01 | 2.64E-02 | 3.12E-02 | 3.68E-02 |
| 1991 | 4.18E-03 | 2.59E-02 | 6.23E-02 | 2.57E-02 | 2.99E-02 | 3.48E-02 |
| 1992 | 5.91E-03 | 3.10E-02 | 7.15E-02 | 2.50E-02 | 2.87E-02 | 3.30E-02 |
| 1993 | 5.90E-03 | 3.07E-02 | 7.09E-02 | 2.43E-02 | 2.76E-02 | 3.13E-02 |
| 1994 | 1.45E-03 | 2.20E-02 | 6.29E-02 | 2.35E-02 | 2.64E-02 | 2.98E-02 |
| 1995 | 8.89E-03 | 3.57E-02 | 7.65E-02 | 2.26E-02 | 2.54E-02 | 2.84E-02 |
| 1996 | 3.74E-03 | 2.61E-02 | 6.46E-02 | 2.18E-02 | 2.44E-02 | 2.72E-02 |
| 1997 | 3.47E-04 | 1.77E-02 | 5.91E-02 | 2.09E-02 | 2.34E-02 | 2.62E-02 |
| 1998 | 5.27E-04 | 1.86E-02 | 5.96E-02 | 1.99E-02 | 2.24E-02 | 2.53E-02 |
| 1999 | 5.90E-03 | 3.21E-02 | 7.50E-02 | 1.89E-02 | 2.15E-02 | 2.44E-02 |
| 2000 | 1.44E-03 | 2.16E-02 | 6.16E-02 | 1.80E-02 | 2.06E-02 | 2.37E-02 |
| 2001 | 3.34E-04 | 1.81E-02 | 6.09E-02 | 1.70E-02 | 1.98E-02 | 2.31E-02 |
| 2002 | 4.80E-04 | 1.94E-02 | 6.33E-02 | 1.61E-02 | 1.90E-02 | 2.24E-02 |
| 2003 | 4.10E-04 | 1.60E-02 | 5.20E-02 | 1.52E-02 | 1.82E-02 | 2.19E-02 |
| 2004 | 3.59E-04 | 1.74E-02 | 5.78E-02 | 1.44E-02 | 1.75E-02 | 2.13E-02 |
| 2005 | 3.89E-04 | 1.67E-02 | 5.46E-02 | 1.35E-02 | 1.68E-02 | 2.08E-02 |

**Table 7. Plot data table for HPCI system unreliability, 8-hour mission. Figure 4**

| FY | Plot Trend Error Bar Points | | | Regression Curve Data Points | | |
|---|---|---|---|---|---|---|
| | Lower (5%) | Mean | Upper (95%) | Lower (5%) | Mean | Upper (95%) |
| 1987 | 7.38E-02 | 1.78E-01 | 3.11E-01 | 7.37E-02 | 1.03E-01 | 1.45E-01 |
| 1988 | 2.37E-02 | 8.37E-02 | 1.70E-01 | 7.12E-02 | 9.70E-02 | 1.32E-01 |
| 1989 | 1.36E-02 | 6.31E-02 | 1.40E-01 | 6.86E-02 | 9.12E-02 | 1.21E-01 |
| 1990 | 7.38E-02 | 1.77E-01 | 3.07E-01 | 6.61E-02 | 8.57E-02 | 1.11E-01 |
| 1991 | 1.82E-02 | 6.68E-02 | 1.38E-01 | 6.35E-02 | 8.05E-02 | 1.02E-01 |
| 1992 | 2.25E-02 | 7.92E-02 | 1.61E-01 | 6.09E-02 | 7.56E-02 | 9.40E-02 |
| 1993 | 9.43E-03 | 4.40E-02 | 9.82E-02 | 5.82E-02 | 7.11E-02 | 8.68E-02 |
| 1994 | 4.03E-03 | 3.66E-02 | 9.52E-02 | 5.54E-02 | 6.68E-02 | 8.05E-02 |
| 1995 | 1.10E-02 | 6.13E-02 | 1.42E-01 | 5.25E-02 | 6.27E-02 | 7.50E-02 |
| 1996 | 1.60E-02 | 6.58E-02 | 1.41E-01 | 4.95E-02 | 5.90E-02 | 7.02E-02 |
| 1997 | 9.93E-03 | 5.90E-02 | 1.40E-01 | 4.64E-02 | 5.54E-02 | 6.62E-02 |
| 1998 | 8.76E-04 | 4.17E-02 | 1.37E-01 | 4.32E-02 | 5.21E-02 | 6.27E-02 |
| 1999 | 7.47E-03 | 5.01E-02 | 1.22E-01 | 4.01E-02 | 4.89E-02 | 5.97E-02 |
| 2000 | 1.39E-02 | 7.04E-02 | 1.59E-01 | 3.70E-02 | 4.60E-02 | 5.71E-02 |
| 2001 | 7.52E-04 | 4.12E-02 | 1.37E-01 | 3.41E-02 | 4.32E-02 | 5.47E-02 |
| 2002 | 9.41E-04 | 4.25E-02 | 1.39E-01 | 3.13E-02 | 4.06E-02 | 5.26E-02 |
| 2003 | 3.10E-03 | 4.21E-02 | 1.18E-01 | 2.87E-02 | 3.81E-02 | 5.07E-02 |
| 2004 | 1.65E-03 | 3.49E-02 | 1.04E-01 | 2.63E-02 | 3.58E-02 | 4.88E-02 |
| 2005 | 1.61E-03 | 3.43E-02 | 1.03E-01 | 2.40E-02 | 3.37E-02 | 4.71E-02 |

## 3.2 Data Tables for Failure and Demand Trends

**Table 8. LER listing for demand trend figure. Figure 6**

| FY | Plant Name | LER | Event Date |
|---|---|---|---|
| 1996 | Browns Ferry 2 | 2601996005 | 5/10/1996 |
| 1997 | Browns Ferry 2 | 2601997001 | 4/24/1997 |
| 2005 | Browns Ferry 2 | 2602005007 | 8/5/2005 |
| 1996 | Browns Ferry 3 | 2961996002 | 4/21/1996 |
| 1996 | Browns Ferry 3 | 2961996003 | 5/1/1996 |
| 2000 | Browns Ferry 3 | 2962000001 | 4/15/2000 |
| 2000 | Browns Ferry 3 | 2962000005 | 5/24/2000 |
| 1991 | Brunswick 1 | 3251991018 | 7/18/1991 |
| 1992 | Brunswick 1 | 3251992003 | 1/17/1992 |
| 1995 | Brunswick 1 | 3251995015 | 7/13/1995 |
| 2004 | Brunswick 1 | 3252004002 | 8/14/2004 |
| 1987 | Brunswick 2 | 3241987001 | 1/5/1987 |
| 1987 | Brunswick 2 | 3241987004 | 3/11/1987 |
| 1989 | Brunswick 2 | 3241988018 | 11/16/1988 |
| 1990 | Brunswick 2 | 3241990008 | 8/16/1990 |
| 1990 | Brunswick 2 | 3241990009 | 8/19/1990 |
| 1990 | Brunswick 2 | 3241990015 | 9/27/1990 |
| 1991 | Brunswick 2 | 3241990016 | 10/12/1990 |
| 1991 | Brunswick 2 | 3241991001 | 1/25/1991 |
| 1992 | Brunswick 2 | 3241991021 | 12/17/1991 |
| 2004 | Brunswick 2 | 3242003004 | 11/4/2003 |
| 1987 | Cooper | 2981987003 | 1/7/1987 |
| 1987 | Cooper | 2981987009 | 2/18/1987 |
| 1988 | Cooper | 2981988021 | 8/25/1988 |
| 1990 | Cooper | 2981989026 | 11/25/1989 |
| 1991 | Cooper | 2981990011 | 10/17/1990 |
| 1994 | Cooper | 2981993038 | 12/14/1993 |
| 1994 | Cooper | 2981994004 | 3/2/1994 |
| 2003 | Cooper | 2982003004 | 5/26/2003 |
| 2004 | Cooper | 2982003007 | 11/26/2003 |
| 2005 | Cooper | 2982005001 | 4/15/2005 |
| 1989 | Dresden 3 | 2491989001 | 3/25/1989 |
| 1996 | Dresden 3 | 2491996004 | 5/15/1996 |
| 2004 | Dresden 3 | 2492004003 | 5/5/2004 |
| 1989 | Duane Arnold | 3311989008 | 3/5/1989 |
| 1989 | Duane Arnold | 3311989011 | 8/26/1989 |
| 1988 | Fermi 2 | 3411988004 | 1/10/1988 |
| 1993 | Fermi 2 | 3411992012 | 11/18/1992 |
| 1993 | Fermi 2 | 3411993010 | 8/13/1993 |
| 2003 | Fermi 2 | 3412003002 | 8/14/2003 |
| 1990 | FitzPatrick | 3331990009 | 3/19/1990 |
| 1993 | FitzPatrick | 3331993009 | 4/20/1993 |
| 1995 | FitzPatrick | 3331995013 | 9/5/1995 |
| 1996 | FitzPatrick | 3331996010 | 9/16/1996 |
| 2003 | FitzPatrick | 3332003001 | 8/14/2003 |
| 1987 | Hatch 1 | 3211987011 | 7/23/1987 |
| 1987 | Hatch 1 | 3211987013 | 8/3/1987 |
| 1988 | Hatch 1 | 3211988013 | 9/4/1988 |
| 1989 | Hatch 1 | 3211988018 | 12/17/1988 |
| 1990 | Hatch 1 | 3211990013 | 6/20/1990 |
| 1991 | Hatch 1 | 3211991001 | 1/18/1991 |
| 1991 | Hatch 1 | 3211991007 | 2/27/1991 |
| 1991 | Hatch 1 | 3211991017 | 9/11/1991 |
| 1992 | Hatch 1 | 3211992021 | 8/27/1992 |
| 1994 | Hatch 1 | 3211993013 | 10/22/1993 |
| 2000 | Hatch 1 | 3212000002 | 1/26/2000 |
| 2000 | Hatch 1 | 3212000011 | 9/29/2000 |
| 1987 | Hatch 2 | 3661987003 | 1/26/1987 |
| 1987 | Hatch 2 | 3661987006 | 7/26/1987 |
| 1987 | Hatch 2 | 3661987008 | 4/22/1987 |
| 1987 | Hatch 2 | 3661987009 | 8/3/1987 |
| 1988 | Hatch 2 | 3661988017 | 5/27/1988 |
| 1988 | Hatch 2 | 3661988020 | 8/5/1988 |
| 1990 | Hatch 2 | 3661990001 | 1/12/1990 |
| 1992 | Hatch 2 | 3661992009 | 6/25/1992 |
| 1994 | Hatch 2 | 3661994007 | 8/30/1994 |
| 1995 | Hatch 2 | 3661995001 | 4/11/1995 |
| 1997 | Hatch 2 | 3661997007 | 4/22/1997 |
| 1987 | Hope Creek | 3541987017 | 2/24/1987 |
| 1987 | Hope Creek | 3541987034 | 7/30/1987 |
| 1987 | Hope Creek | 3541987037 | 8/16/1987 |
| 1987 | Hope Creek | 3541987039 | 8/29/1987 |
| 1988 | Hope Creek | 3541988012 | 4/30/1988 |
| 1988 | Hope Creek | 3541988022 | 8/26/1988 |
| 1989 | Hope Creek | 3541988027 | 10/15/1988 |
| 1989 | Hope Creek | 3541988029 | 11/1/1988 |
| 1990 | Hope Creek | 3541990003 | 3/19/1990 |
| 1991 | Hope Creek | 3541990029 | 11/26/1990 |
| 1999 | Limerick 1 | 3521999003 | 4/20/1999 |
| 2003 | Limerick 1 | 3522003003 | 4/23/2003 |
| 1987 | Monticello | 2631987009 | 4/3/1987 |
| 1991 | Monticello | 2631991019 | 8/25/1991 |
| 1990 | Peach Bottom 2 | 2771989033 | 12/20/1989 |
| 1993 | Peach Bottom 2 | 2771993004 | 3/2/1993 |
| 2003 | Peach Bottom 2 | 2772002001 | 12/21/2002 |
| 2003 | Peach Bottom 2 | 2772003003 | 7/22/2003 |
| 2003 | Peach Bottom 2 | 2772003004 | 9/15/2003 |
| 2005 | Peach Bottom 2 | 2772004003 | 12/22/2004 |
| 2003 | Peach Bottom 3 | 2772003004 | 9/15/2003 |
| 1990 | Peach Bottom 3 | 2781990002 | 1/28/1990 |
| 1990 | Peach Bottom 3 | 2781990008 | 7/27/1990 |
| 1993 | Peach Bottom 3 | 2781992008 | 10/15/1992 |
| 1993 | Peach Bottom 3 | 2781993004 | 7/30/1993 |
| 1990 | Pilgrim | 2931990013 | 9/2/1990 |
| 1997 | Quad Cities 2 | 2651997001 | 2/27/1997 |
| 1991 | Susquehanna 1 | 3871991008 | 7/31/1991 |
| 1999 | Susquehanna 1 | 3871999003 | 7/1/1999 |
| 2003 | Susquehanna 1 | 3872003006 | 9/24/2003 |
| 1987 | Susquehanna 2 | 3881987006 | 4/16/1987 |
| 1996 | Susquehanna 2 | 3881996004 | 7/14/1996 |
| 1991 | Vermont Yankee | 2711991009 | 4/23/1991 |
| 2005 | Vermont Yankee | 2712005001 | 7/25/2005 |

**Table 9. LER listing for failure trend figure. Figure 7**

| FY | Plant Name | LER | Event Date |
|---|---|---|---|
| 1991 | Browns Ferry 2 | 2601991015 | 7/31/1991 |
| 1994 | Browns Ferry 2 | 2601994001 | 2/14/1994 |
| 1995 | Browns Ferry 2 | 2601995005 | 6/7/1995 |
| 2000 | Browns Ferry 2 | 2601999011 | 11/18/1999 |
| 2003 | Browns Ferry 3 | 2962002004 | 10/22/2002 |

| FY | Plant Name | LER | Event Date |
|---|---|---|---|
| 1987 | Brunswick 1 | 3251987001 | 1/26/1987 |
| 1988 | Brunswick 1 | 3251987023 | 12/31/1987 |
| 1988 | Brunswick 1 | 3251988011 | 4/20/1988 |
| 1988 | Brunswick 1 | 3251988012 | 5/28/1988 |
| 1988 | Brunswick 1 | 3251988017 | 7/1/1988 |
| 1988 | Brunswick 1 | 3251988018 | 7/13/1988 |
| 1990 | Brunswick 1 | 3251989020 | 10/11/1989 |
| 1990 | Brunswick 1 | 3251990001 | 1/2/1990 |
| 1990 | Brunswick 1 | 3251990003 | 3/2/1990 |
| 1991 | Brunswick 1 | 3251991018 | 7/18/1991 |
| 1994 | Brunswick 1 | 3251994009 | 5/13/1994 |
| 1994 | Brunswick 1 | 3251994012 | 9/22/1994 |
| 1996 | Brunswick 1 | 3251996007 | 5/9/1996 |
| 1987 | Brunswick 2 | 3241987001 | 1/5/1987 |
| 1987 | Brunswick 2 | 3241987004 | 3/11/1987 |
| 1989 | Brunswick 2 | 3241988018 | 11/16/1988 |
| 1989 | Brunswick 2 | 3241989013 | 9/9/1989 |
| 1990 | Brunswick 2 | 3241990008 | 8/16/1990 |
| 1990 | Brunswick 2 | 3241990013 | 9/6/1990 |
| 1992 | Brunswick 2 | 3241991020 | 12/14/1991 |
| 1995 | Brunswick 2 | 3241995002 | 5/10/1995 |
| 1992 | Cooper | 2981992014 | 7/31/1992 |
| 1993 | Cooper | 2981993031 | 8/30/1993 |
| 1999 | Cooper | 2981998011 | 12/18/1998 |
| 1999 | Cooper | 2981998012 | 12/17/1998 |
| 2002 | Cooper | 2982001005 | 10/17/2001 |
| 2002 | Cooper | 2982002001 | 9/18/2002 |
| 1987 | Dresden 2 | 2371987012 | 4/22/1987 |
| 1987 | Dresden 2 | 2371987018 | 6/6/1987 |
| 1988 | Dresden 2 | 2371988013 | 7/8/1988 |
| 1994 | Dresden 2 | 2371994020 | 7/15/1994 |
| 1994 | Dresden 2 | 2371994021 | 8/4/1994 |
| 1998 | Dresden 2 | 2371998003 | 1/28/1998 |
| 1987 | Dresden 3 | 2491987002 | 2/25/1987 |
| 1993 | Dresden 3 | 2491993013 | 8/9/1993 |
| 1994 | Dresden 3 | 2491993019 | 12/14/1993 |
| 1987 | Duane Arnold | 3311987023 | 7/14/1987 |
| 1988 | Duane Arnold | 3311988002 | 4/11/1988 |
| 1989 | Duane Arnold | 3311989002 | 1/26/1989 |
| 1996 | Duane Arnold | 3311995012 | 12/12/1995 |
| 2001 | Duane Arnold | 3312001004 | 9/2/2001 |
| 1988 | Fermi 2 | 3411988028 | 7/26/1988 |
| 1990 | Fermi 2 | 3411990008 | 9/5/1990 |
| 1991 | Fermi 2 | 3411990012 | 10/16/1990 |
| 1992 | Fermi 2 | 3411991020 | 11/20/1991 |
| 1993 | Fermi 2 | 3411993001 | 1/4/1993 |
| 1993 | Fermi 2 | 3411993002 | 1/14/1993 |
| 1997 | Fermi 2 | 3411997002 | 2/16/1997 |
| 1987 | FitzPatrick | 3331987010 | 7/23/1987 |
| 1988 | FitzPatrick | 3331988001 | 3/10/1988 |
| 1989 | FitzPatrick | 3331989005 | 4/12/1989 |
| 1990 | FitzPatrick | 3331989018 | 10/8/1989 |
| 1990 | FitzPatrick | 3331989025 | 11/30/1989 |
| 1991 | FitzPatrick | 3331991019 | 9/17/1991 |
| 1995 | FitzPatrick | 3331995008 | 3/26/1995 |
| 1996 | FitzPatrick | 3331996008 | 9/6/1996 |
| 1998 | FitzPatrick | 3331997013 | 12/16/1997 |
| 1998 | FitzPatrick | 3331998007 | 7/31/1998 |
| 2000 | FitzPatrick | 3331999010 | 10/14/1999 |
| 1988 | Hatch 1 | 3211988012 | 8/26/1988 |
| 1988 | Hatch 1 | 3211988013 | 9/4/1988 |
| 1989 | Hatch 1 | 3211989006 | 3/29/1989 |
| 1990 | Hatch 1 | 3211990001 | 1/4/1990 |
| 1990 | Hatch 1 | 3211990015 | 7/30/1990 |
| 1991 | Hatch 1 | 3211991001 | 1/18/1991 |
| 1992 | Hatch 1 | 3211991033 | 12/30/1991 |
| 1992 | Hatch 1 | 3211992006 | 2/26/1992 |
| 1996 | Hatch 1 | 3211996010 | 6/29/1996 |
| 2000 | Hatch 1 | 3212000005 | 8/16/2000 |
| 1987 | Hatch 2 | 3661987004 | 6/16/1987 |
| 1987 | Hatch 2 | 3661987009 | 8/3/1987 |
| 1988 | Hatch 2 | 3661987017 | 11/19/1987 |
| 1988 | Hatch 2 | 3661988001 | 1/6/1988 |
| 1990 | Hatch 2 | 3661990001 | 1/12/1990 |
| 1990 | Hatch 2 | 3661990005 | 7/19/1990 |
| 1994 | Hatch 2 | 3661993008 | 11/3/1993 |
| 1994 | Hatch 2 | 3661994002 | 3/1/1994 |
| 1996 | Hatch 2 | 3661996002 | 6/26/1996 |
| 1997 | Hatch 2 | 3661997001 | 1/25/1997 |
| 1997 | Hatch 2 | 3661997008 | 8/18/1997 |
| 2000 | Hatch 2 | 3662000001 | 2/27/2000 |
| 1988 | Hope Creek | 3541988010 | 4/14/1988 |
| 1989 | Hope Creek | 3541989009 | 4/14/1989 |
| 1989 | Hope Creek | 3541989012 | 6/7/1989 |
| 1990 | Hope Creek | 3541990009 | 6/7/1990 |
| 1996 | Hope Creek | 3541995025 | 10/24/1995 |
| 1998 | Hope Creek | 3541997032 | 12/5/1997 |
| 1999 | Hope Creek | 3541999011 | 9/19/1999 |
| 1987 | Limerick 1 | 3521987015 | 5/14/1987 |
| 1988 | Limerick 1 | 3521987066 | 12/8/1987 |
| 1992 | Limerick 1 | 3521991028 | 12/10/1991 |
| 1992 | Limerick 1 | 3521992002 | 3/11/1992 |
| 1992 | Limerick 1 | 3521992015 | 7/7/1992 |
| 1996 | Limerick 1 | 3521996018 | 9/25/1996 |
| 1999 | Limerick 1 | 3521999008 | 6/23/1999 |
| 1990 | Limerick 2 | 3531989010 | 10/13/1989 |
| 1990 | Limerick 2 | 3531990004 | 3/8/1990 |
| 1991 | Limerick 2 | 3531991015 | 9/12/1991 |
| 1992 | Limerick 2 | 3531991017 | 11/15/1991 |
| 1992 | Limerick 2 | 3531992004 | 2/21/1992 |
| 1987 | Peach Bottom 2 | 2771987020 | 9/4/1987 |
| 1989 | Peach Bottom 2 | 2771989009 | 5/5/1989 |
| 1990 | Peach Bottom 2 | 2771990017 | 7/24/1990 |
| 1993 | Peach Bottom 2 | 2771993003 | 1/31/1993 |
| 1994 | Peach Bottom 2 | 2771994004 | 7/18/1994 |
| 1997 | Peach Bottom 2 | 2771996009 | 10/1/1996 |
| 1997 | Peach Bottom 2 | 2771997003 | 6/1/1997 |
| 1999 | Peach Bottom 2 | 2771999001 | 1/19/1999 |
| 1987 | Peach Bottom 3 | 2781987007 | 8/29/1987 |
| 1990 | Peach Bottom 3 | 2781989009 | 12/7/1989 |
| 1990 | Peach Bottom 3 | 2781990010 | 8/4/1990 |
| 1990 | Peach Bottom 3 | 2781990011 | 9/10/1990 |
| 1991 | Peach Bottom 3 | 2781991005 | 4/10/1991 |
| 1991 | Peach Bottom 3 | 2781991014 | 9/5/1991 |
| 1993 | Peach Bottom 3 | 2781992009 | 11/28/1992 |
| 1993 | Peach Bottom 3 | 2781993001 | 1/25/1993 |
| 1993 | Peach Bottom 3 | 2781993005 | 8/9/1993 |
| 1994 | Peach Bottom 3 | 2781993009 | 11/13/1993 |
| 1994 | Peach Bottom 3 | 2781994004 | 9/24/1994 |
| 1995 | Peach Bottom 3 | 2781995002 | 7/6/1995 |
| 1996 | Peach Bottom 3 | 2781996001 | 5/29/1996 |
| 2004 | Peach Bottom 3 | 2782004001 | 3/17/2004 |

| FY | Plant Name | LER | Event Date |
|---|---|---|---|
| 1989 | Pilgrim | 2931989013 | 3/24/1989 |
| 1989 | Pilgrim | 2931989028 | 9/7/1989 |
| 1991 | Pilgrim | 2931990017 | 10/9/1990 |
| 1994 | Pilgrim | 2931994002 | 3/9/1994 |
| 2002 | Pilgrim | 2932002001 | 7/7/2002 |
| 1990 | Quad Cities 1 | 2541989022 | 11/28/1989 |
| 1991 | Quad Cities 1 | 2541991012 | 5/7/1991 |
| 1992 | Quad Cities 1 | 2541992002 | 2/6/1992 |
| 1993 | Quad Cities 1 | 2541993005 | 6/9/1993 |
| 1993 | Quad Cities 1 | 2541993012 | 7/26/1993 |
| 1995 | Quad Cities 1 | 2541995004 | 3/29/1995 |
| 1987 | Quad Cities 2 | 2651987003 | 1/27/1987 |
| 1991 | Quad Cities 2 | 2651990012 | 11/24/1990 |
| 1991 | Quad Cities 2 | 2651991003 | 1/22/1991 |
| 2000 | Quad Cities 2 | 2652000005 | 2/11/2000 |

| FY | Plant Name | LER | Event Date |
|---|---|---|---|
| 1987 | Susquehanna 1 | 3871987008 | 2/23/1987 |
| 1988 | Susquehanna 1 | 3871988009 | 5/20/1988 |
| 1989 | Susquehanna 1 | 3871988022 | 11/4/1988 |
| 1990 | Susquehanna 1 | 3871990007 | 2/15/1990 |
| 1991 | Susquehanna 1 | 3871991002 | 2/7/1991 |
| 1996 | Susquehanna 1 | 3871995016 | 12/31/1995 |
| 2002 | Susquehanna 1 | 3872001004 | 11/11/2001 |
| 1987 | Susquehanna 2 | 3881987007 | 4/13/1987 |
| 1990 | Susquehanna 2 | 3881990001 | 2/16/1990 |
| 1992 | Susquehanna 2 | 3881991015 | 12/16/1991 |
| 1992 | Susquehanna 2 | 3881992002 | 4/22/1992 |
| 1988 | Vermont Yankee | 2711987016 | 11/5/1987 |