

Component Performance Studies

Motor-Driven Pumps

1987–2005

This report presents a performance evaluation of the motor-driven pumps (MDPs) at United States commercial reactors. The evaluation is based on the operating experience from fiscal year 1987 through 2005, as reported in Licensee Event Reports (LERs), Nuclear Plant Reliability Data System (NPRDS), and Equipment Performance and Information Exchange (EPIX). This is the latest update to *NUREG-1715, Volume 2*, updating data, availability estimates, trends, and figures.

1 LATEST UNAVAILABILITY VALUES AND TRENDS

1.1 Overall Unavailability

The industry-wide unavailability of MDPs has been calculated from the operating experience for failure on demand¹ and failure-to-start (FTS). The estimates are based on failures that occurred during unplanned demands, and cyclic and quarterly surveillance tests.

Table 1 shows overall results for the MDP. Two primary failure modes were identified. Failure probability estimates for the resulting failure modes combinations are given in the table. Both ESF actuations and surveillance tests were treated as opportunities to observe possible failures.

Table 1. Component performance data from fiscal year 1987-2005.

Component	Estimated Number of Demands	Failure Mode	Number of Failures	Failure Probability		
				Lower Bound	MLE	Upper Bound
Motor-driven pump	214924	Fail on demand	346	6.33E-06	1.61E-03	6.18E-03
	214923	Fail to start	295	5.40E-06	1.37E-03	5.27E-03

1.2 Unavailability Trend

No statistically significant² increasing trend within the industry estimates of MDP failure on demand on a per fiscal year basis was identified. Figure 1 displays the trend by fiscal year of

¹ The term “failure on demand” is used to denote the combined failure to start and the failure to run failure modes. The failure to run portion is a probability the pump succeeds with the run phase and is not correlated with a specific failure rate per hour.

² 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

the MDP failure on demand calculated from the 1987–2005 experience. [Table 2](#) shows the data points for [Figure 1](#).

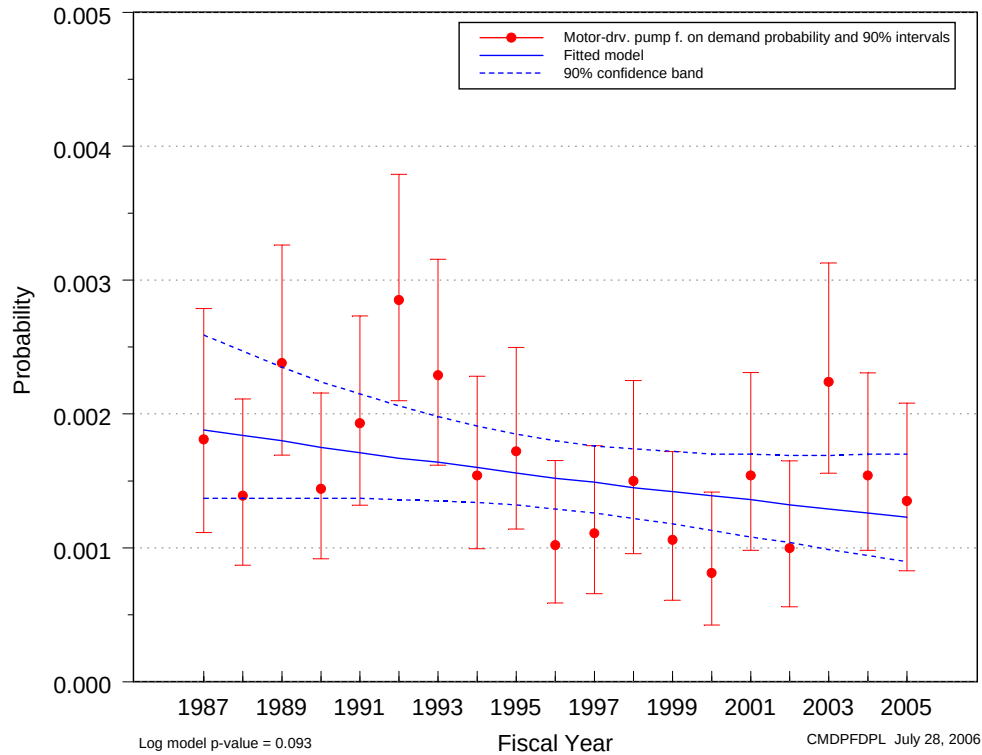


Figure 1. Motor-driven pump failure on demand.

A statistically significant decreasing trend within the industry estimates of MDP FTS on a per fiscal year basis was identified. [Figure 2](#) shows the trend in the FTS unavailability. [Table 3](#) shows the data points for [Figure 2](#).

"Michelin Guide" scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

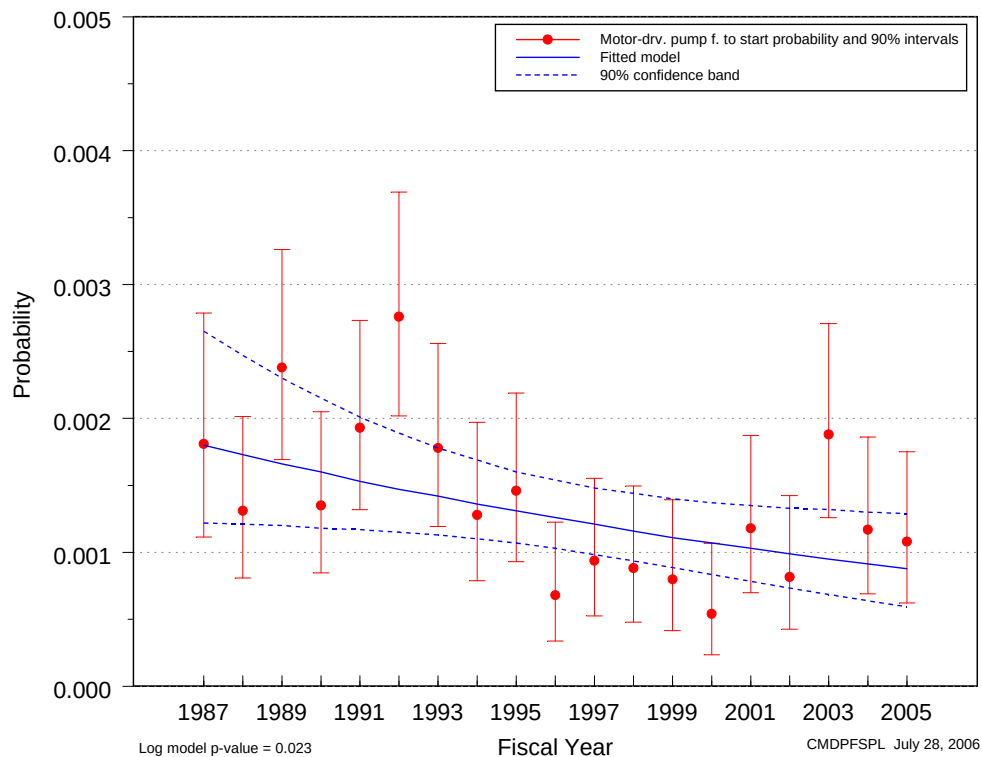


Figure 2. Motor-driven pump fail-to-start.

1.3 Unplanned Demand Trend

Trends were identified in the frequency of MDP unplanned demands [Figure 3](#). When modeled as a function of fiscal year, the unplanned demand frequency exhibited an extremely statistically significant decreasing trend. The noticeable increase in MDP 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. [Table 4](#) shows the plot data.

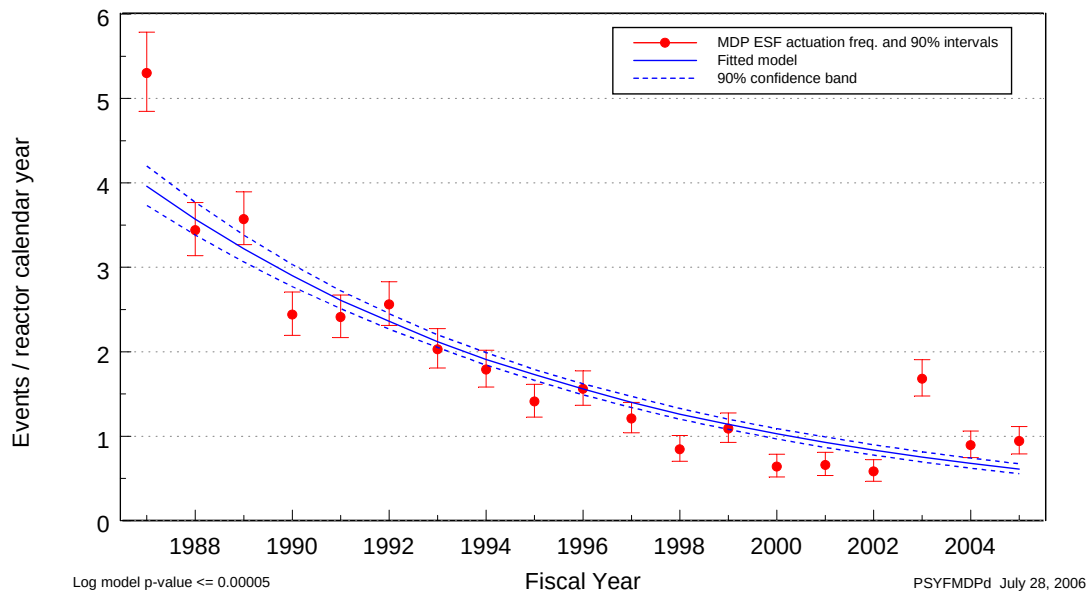


Figure 3. Frequency (events per operating year) of unplanned demands, as a function of fiscal year.

1.4 Failure Trend

The frequency of all failures (unplanned demands, surveillance tests, inspections, etc.) resulting in component unavailability 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 MDP failures are plotted without regard to method of detection (the trend excludes maintenance out of service and support system failures). [Table 5](#) shows the plot data.

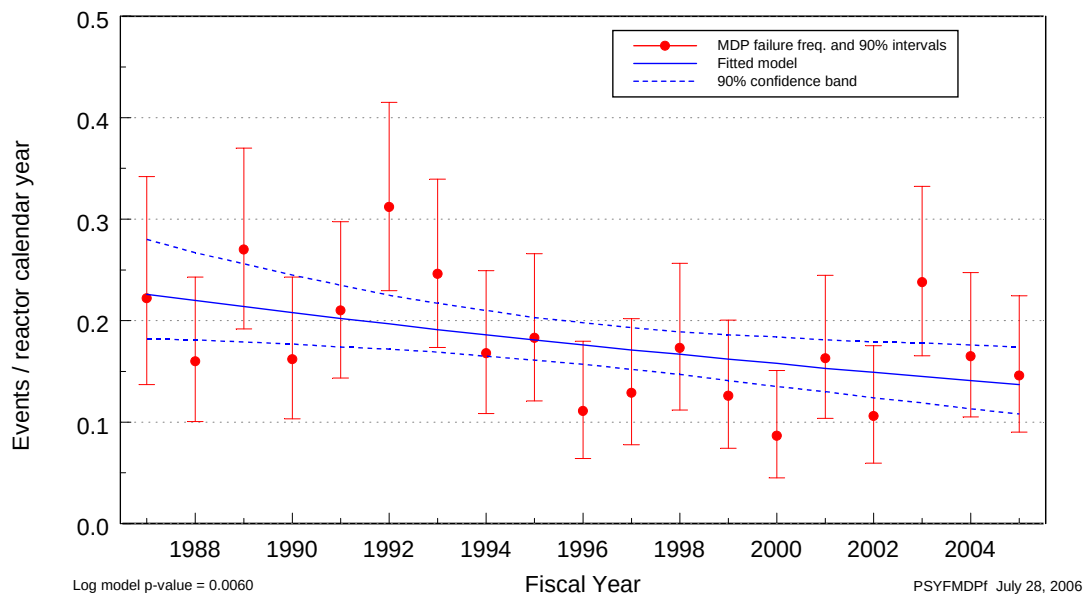


Figure 4. Frequency (events per operating year) of failures, as a function of fiscal year.

1.5 Major Contributors to Component Unreliability and Unavailability

1.5.1 Leading Component Failures.

The circuit breaker had the most failures in the motor-driven pump data. [Figure 5](#) shows the distribution of sub-component failures.

1.5.2 Leading Systems.

[Figure 6](#) shows the distribution of MDP failures by system and by the fiscal year they occurred in.

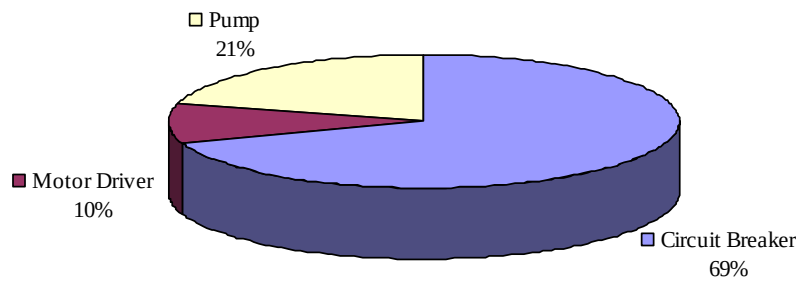


Figure 5. MDP sub-component failure distribution

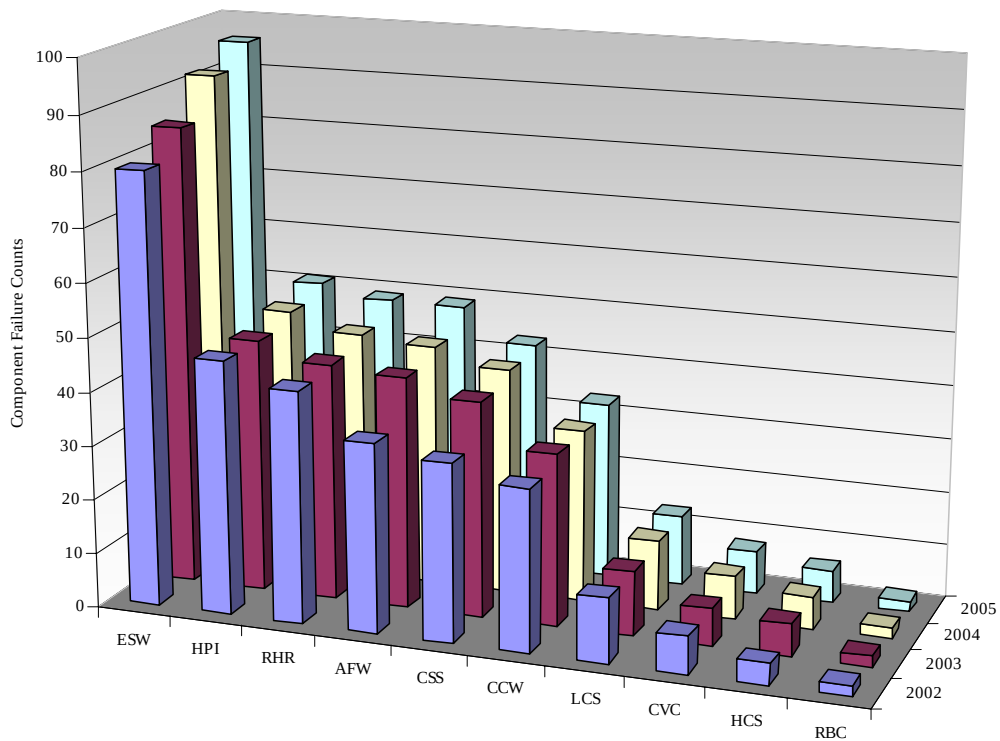


Figure 6. MDP system failures distribution

2 DATA TABLES

This section contains the data tables that support the charts in the first sections.

Table 2. Plot data table for MDP failure on demand. Figure 1

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.12E-03	1.81E-03	2.79E-03	1.37E-03	1.88E-03	2.59E-03
1988	8.74E-04	1.39E-03	2.12E-03	1.37E-03	1.84E-03	2.47E-03
1989	1.69E-03	2.38E-03	3.26E-03	1.37E-03	1.80E-03	2.35E-03
1990	9.15E-04	1.44E-03	2.15E-03	1.37E-03	1.75E-03	2.24E-03
1991	1.32E-03	1.93E-03	2.73E-03	1.37E-03	1.71E-03	2.15E-03
1992	2.09E-03	2.85E-03	3.79E-03	1.36E-03	1.67E-03	2.06E-03
1993	1.61E-03	2.29E-03	3.15E-03	1.35E-03	1.64E-03	1.98E-03
1994	9.96E-04	1.54E-03	2.28E-03	1.34E-03	1.60E-03	1.91E-03
1995	1.14E-03	1.72E-03	2.50E-03	1.32E-03	1.56E-03	1.85E-03
1996	5.89E-04	1.02E-03	1.65E-03	1.29E-03	1.52E-03	1.80E-03
1997	6.56E-04	1.11E-03	1.76E-03	1.26E-03	1.49E-03	1.76E-03
1998	9.56E-04	1.50E-03	2.25E-03	1.22E-03	1.45E-03	1.74E-03
1999	6.14E-04	1.06E-03	1.72E-03	1.18E-03	1.42E-03	1.72E-03
2000	4.24E-04	8.12E-04	1.42E-03	1.13E-03	1.39E-03	1.70E-03
2001	9.81E-04	1.54E-03	2.31E-03	1.08E-03	1.36E-03	1.70E-03
2002	5.59E-04	9.97E-04	1.65E-03	1.04E-03	1.32E-03	1.69E-03
2003	1.56E-03	2.24E-03	3.13E-03	9.88E-04	1.29E-03	1.69E-03
2004	9.79E-04	1.54E-03	2.30E-03	9.42E-04	1.26E-03	1.70E-03
2005	8.35E-04	1.35E-03	2.09E-03	8.97E-04	1.23E-03	1.70E-03

Table 3. Plot data table for MDP fail-to-start. Figure 2

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.12E-03	1.79E-03	2.60E-03	1.34E-03	1.85E-03	2.36E-03
1988	8.14E-04	1.31E-03	1.90E-03	1.32E-03	1.79E-03	2.26E-03
1989	1.67E-03	2.35E-03	3.11E-03	1.31E-03	1.74E-03	2.17E-03
1990	8.55E-04	1.35E-03	1.94E-03	1.29E-03	1.69E-03	2.08E-03
1991	1.31E-03	1.91E-03	2.61E-03	1.28E-03	1.64E-03	2.00E-03
1992	2.00E-03	2.72E-03	3.54E-03	1.25E-03	1.58E-03	1.91E-03
1993	1.19E-03	1.77E-03	2.43E-03	1.23E-03	1.53E-03	1.83E-03
1994	8.00E-04	1.29E-03	1.87E-03	1.19E-03	1.48E-03	1.76E-03
1995	9.36E-04	1.46E-03	2.07E-03	1.15E-03	1.42E-03	1.69E-03
1996	3.57E-04	7.01E-04	1.14E-03	1.10E-03	1.37E-03	1.64E-03
1997	5.42E-04	9.51E-04	1.45E-03	1.05E-03	1.32E-03	1.59E-03
1998	4.95E-04	8.97E-04	1.40E-03	9.82E-04	1.26E-03	1.55E-03
1999	4.35E-04	8.16E-04	1.29E-03	9.09E-04	1.21E-03	1.51E-03
2000	2.57E-04	5.68E-04	9.76E-04	8.29E-04	1.16E-03	1.49E-03
2001	7.08E-04	1.18E-03	1.76E-03	7.46E-04	1.11E-03	1.47E-03
2002	4.44E-04	8.33E-04	1.32E-03	6.58E-04	1.05E-03	1.45E-03
2003	1.26E-03	1.87E-03	2.57E-03	5.68E-04	1.00E-03	1.43E-03
2004	7.07E-04	1.18E-03	1.75E-03	4.76E-04	9.47E-04	1.42E-03
2005	6.39E-04	1.09E-03	1.65E-03	3.82E-04	8.94E-04	1.40E-03

Table 4. Plot data for demand trend. Figure 3

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	4.85E+00	5.30E+00	5.79E+00	3.72E+00	3.95E+00	4.20E+00
1988	3.13E+00	3.44E+00	3.76E+00	3.38E+00	3.57E+00	3.76E+00
1989	3.27E+00	3.57E+00	3.89E+00	3.06E+00	3.21E+00	3.38E+00
1990	2.19E+00	2.44E+00	2.71E+00	2.77E+00	2.90E+00	3.03E+00
1991	2.17E+00	2.41E+00	2.68E+00	2.51E+00	2.61E+00	2.72E+00
1992	2.31E+00	2.56E+00	2.83E+00	2.27E+00	2.36E+00	2.45E+00
1993	1.80E+00	2.03E+00	2.27E+00	2.05E+00	2.12E+00	2.20E+00
1994	1.58E+00	1.79E+00	2.02E+00	1.85E+00	1.92E+00	1.99E+00
1995	1.22E+00	1.41E+00	1.61E+00	1.66E+00	1.73E+00	1.79E+00
1996	1.36E+00	1.56E+00	1.77E+00	1.49E+00	1.56E+00	1.62E+00
1997	1.04E+00	1.21E+00	1.40E+00	1.34E+00	1.40E+00	1.47E+00
1998	7.02E-01	8.44E-01	1.01E+00	1.20E+00	1.27E+00	1.33E+00
1999	9.24E-01	1.09E+00	1.27E+00	1.08E+00	1.14E+00	1.21E+00
2000	5.17E-01	6.41E-01	7.86E-01	9.68E-01	1.03E+00	1.09E+00
2001	5.34E-01	6.60E-01	8.08E-01	8.67E-01	9.28E-01	9.93E-01
2002	4.82E-01	6.02E-01	7.44E-01	7.77E-01	8.37E-01	9.01E-01
2003	1.48E+00	1.68E+00	1.91E+00	6.96E-01	7.54E-01	8.17E-01
2004	7.46E-01	8.93E-01	1.06E+00	6.23E-01	6.80E-01	7.42E-01
2005	7.90E-01	9.42E-01	1.11E+00	5.58E-01	6.13E-01	6.74E-01

Table 5. Plot data for failure trend. Figure 4

FY	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.37E-01	2.22E-01	3.41E-01	1.82E-01	2.26E-01	2.80E-01
1988	1.00E-01	1.60E-01	2.43E-01	1.81E-01	2.20E-01	2.67E-01
1989	1.92E-01	2.70E-01	3.70E-01	1.79E-01	2.14E-01	2.56E-01
1990	1.03E-01	1.62E-01	2.43E-01	1.77E-01	2.08E-01	2.45E-01
1991	1.44E-01	2.10E-01	2.98E-01	1.74E-01	2.02E-01	2.35E-01
1992	2.29E-01	3.12E-01	4.15E-01	1.72E-01	1.97E-01	2.25E-01
1993	1.74E-01	2.46E-01	3.40E-01	1.69E-01	1.91E-01	2.17E-01
1994	1.09E-01	1.68E-01	2.49E-01	1.65E-01	1.86E-01	2.10E-01
1995	1.22E-01	1.83E-01	2.67E-01	1.61E-01	1.81E-01	2.03E-01
1996	6.39E-02	1.11E-01	1.80E-01	1.57E-01	1.76E-01	1.98E-01
1997	7.82E-02	1.29E-01	2.02E-01	1.52E-01	1.71E-01	1.93E-01
1998	1.12E-01	1.73E-01	2.56E-01	1.47E-01	1.67E-01	1.89E-01
1999	7.47E-02	1.26E-01	2.01E-01	1.41E-01	1.62E-01	1.86E-01
2000	4.51E-02	8.65E-02	1.51E-01	1.35E-01	1.58E-01	1.84E-01
2001	1.04E-01	1.63E-01	2.45E-01	1.30E-01	1.53E-01	1.81E-01
2002	5.93E-02	1.06E-01	1.75E-01	1.24E-01	1.49E-01	1.79E-01
2003	1.66E-01	2.38E-01	3.33E-01	1.19E-01	1.45E-01	1.78E-01
2004	1.05E-01	1.65E-01	2.48E-01	1.13E-01	1.41E-01	1.76E-01
2005	8.98E-02	1.46E-01	2.24E-01	1.08E-01	1.37E-01	1.74E-01

3 COMPONENT DESCRIPTIONS AND BOUNDARIES

3.1 MDP Assembly Description and Boundaries

The MDP consists of the pump, motor-driver, and circuit breaker sub-components. All of the pumps are centrifugal, but can be different configurations. The drivers are medium or large ac motors. For most PWRs, the MDP assembly includes a speed increaser, which is treated as a sub-component.

The component boundaries are the MDP assembly, its sub-component, and piece-parts described above, that are supplied as part of the MDP assembly. Other system components, such as pump suction and discharge valves, flow instrumentation and controls, and remote electrical controls, are considered outside the component boundary for the MDP study.

