

Component Performance Studies

Motor-Operated Valves

1987–2004

This report presents a performance evaluation of the motor-operated valves (MOVs) at United States commercial reactors. The evaluation is based on the operating experience from 1987 through 2004, 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 4*, updating data, availability estimates, trends, and figures.

1 LATEST UNAVAILABILITY VALUES AND TRENDS

1.1 Overall Unavailability

The industry-wide unavailability of MOVs has been calculated from the operating experience for failure on demand, failure-to-open (FO), and failure-to-close (FC). The estimates are based on failures that occurred during unplanned demands, and cyclic and quarterly surveillance tests.

[Table 1](#) shows overall results for the MOV. Three failure modes were identified. Failure probability estimates for the resulting failure modes 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 1987-2004.

Component	Estimated Number of Demands	Failure Mode	Number of Failures	Failure Probability		
				Lower Bound	MLE	Upper Bound
Motor-operated valve	269698	Failure to close	126	1.84E-06	4.67E-04	1.79E-03
	269700	Failure to open	199	2.90E-06	7.38E-04	2.83E-03
	269704	Failure on demand	403	5.88E-06	1.49E-03	5.74E-03

1.2 Unavailability Trend

An extremely statistically significant¹ decreasing trend within the industry estimates of MOV failure on demand on a per fiscal year basis was identified. [Figure 1](#) displays the trend by

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

fiscal year of the MOV failure on demand unavailability calculated from the 1987–2004 experience. Table 2 shows the data points for Figure 1.

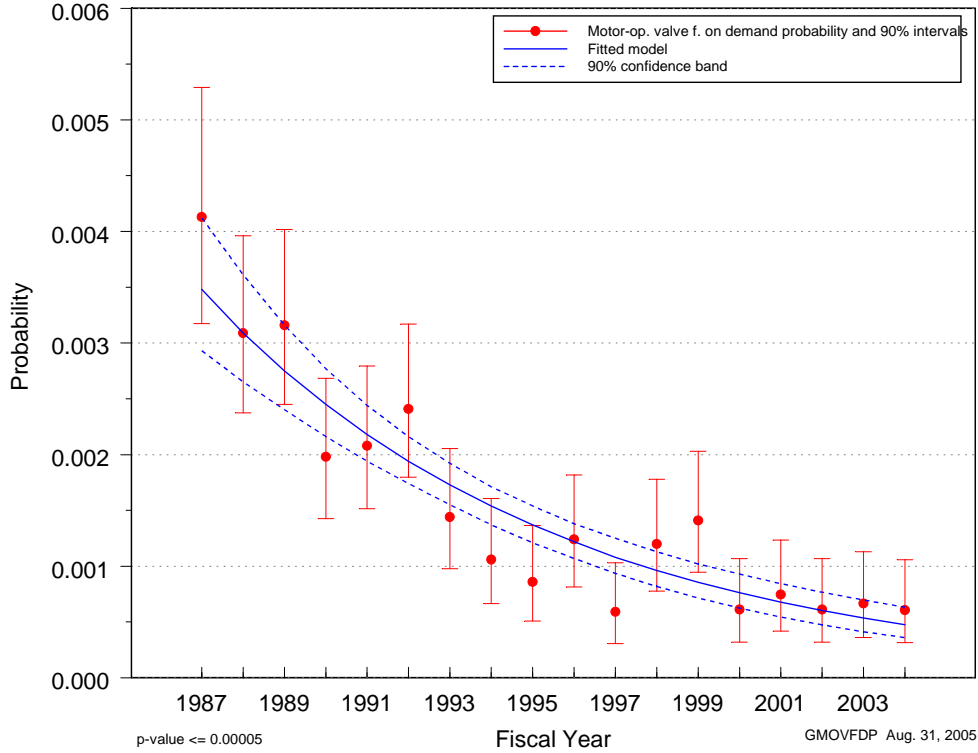


Figure 1. Motor-operated valves failure on demand.

An extremely statistically significant decreasing trend within the industry estimates of MOV FO on a per fiscal year basis was identified. Figure 2 displays the trend by fiscal year of the MOV FO unavailability calculated from the 1987–2004 experience. 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).

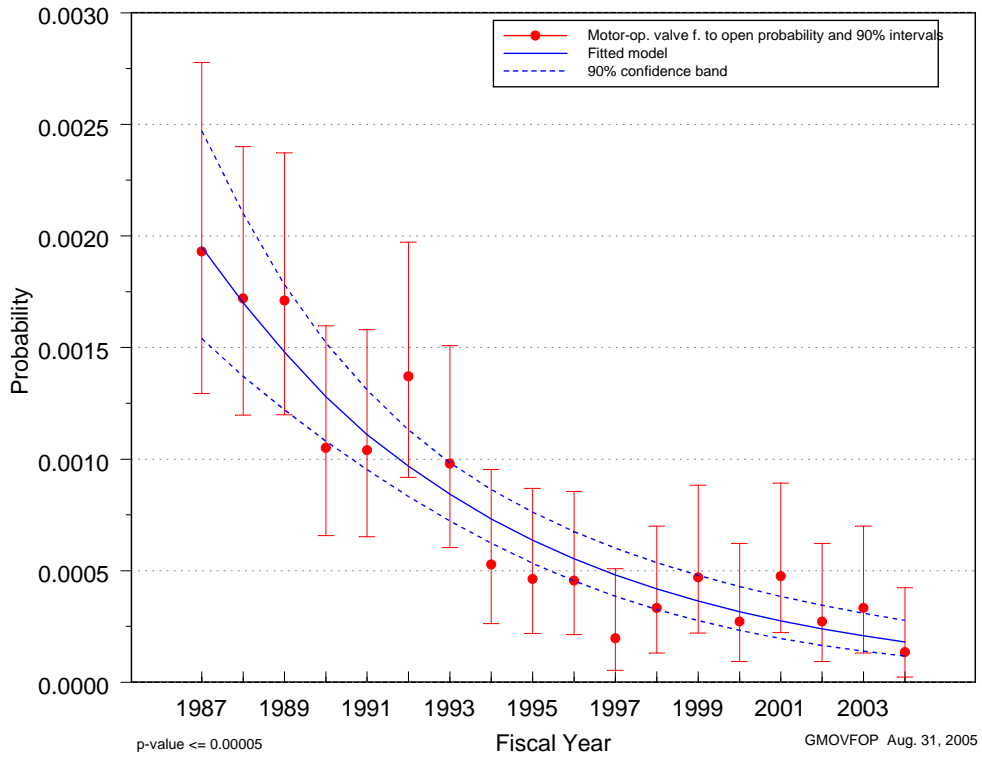


Figure 2. Motor-operated valves fail-to-open.

A statistically significant decreasing trend within the industry estimates of MOV FC unavailability on a per fiscal year basis was identified. Figure 3 shows the trend in the MOV FC unavailability. Table 4 shows the data points for Figure 3. Each figure is annotated with the p-value.

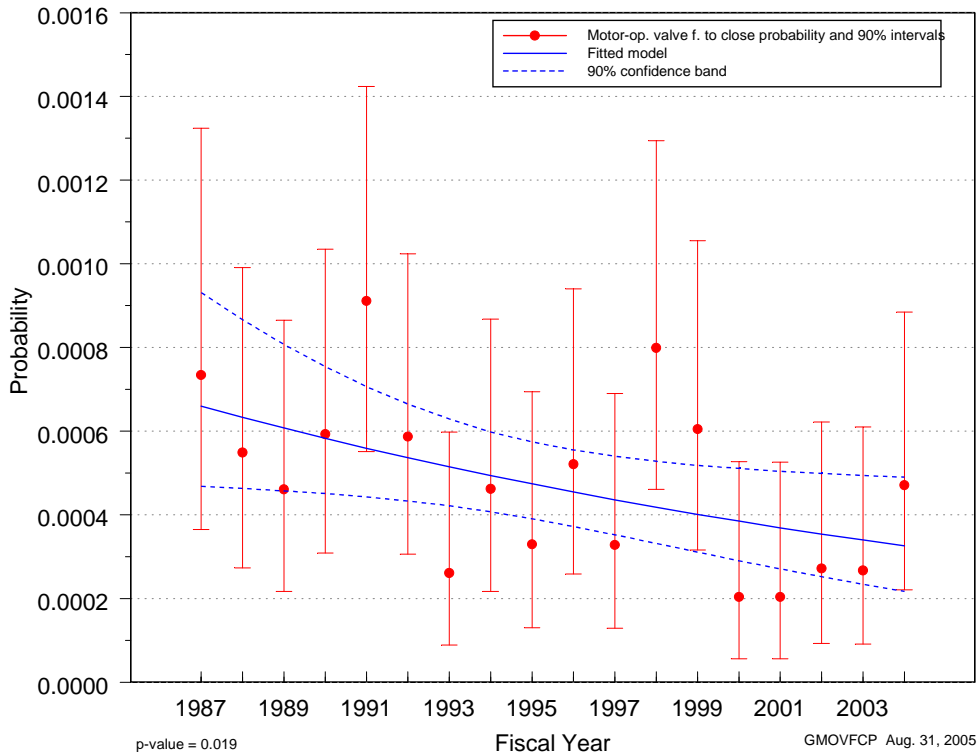


Figure 3. Motor-operated valves fail-to-close.

1.3 Unplanned Demand Trend

Trends were identified in the frequency of MOV unplanned demands [Figure 4](#). When modeled as a function of fiscal year, the unplanned demand frequency exhibited an extremely statistically significant decreasing trend. [Table 5](#) shows the plot data.

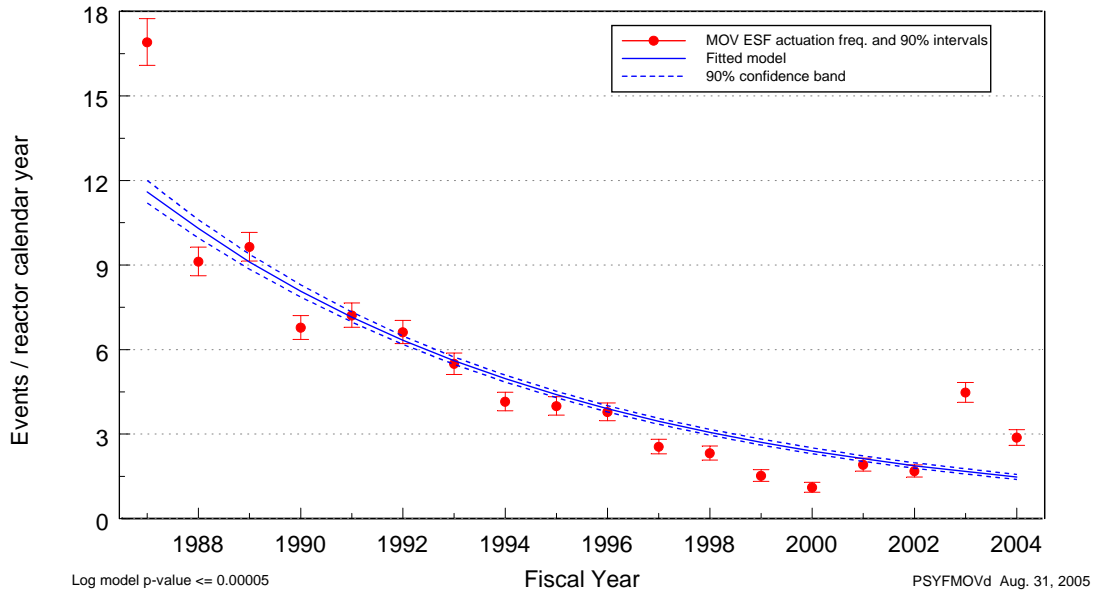


Figure 4. Frequency (events per operating year) of unplanned demands, as a function of fiscal year.

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, an extremely statistically significant decreasing trend was identified. The fitted frequency is plotted against fiscal year in [Figure 5](#). Trends for MOV failures are plotted without regard to method of detection (the trend excludes maintenance out of service and support system failures). [Table 6](#) shows the plot data.

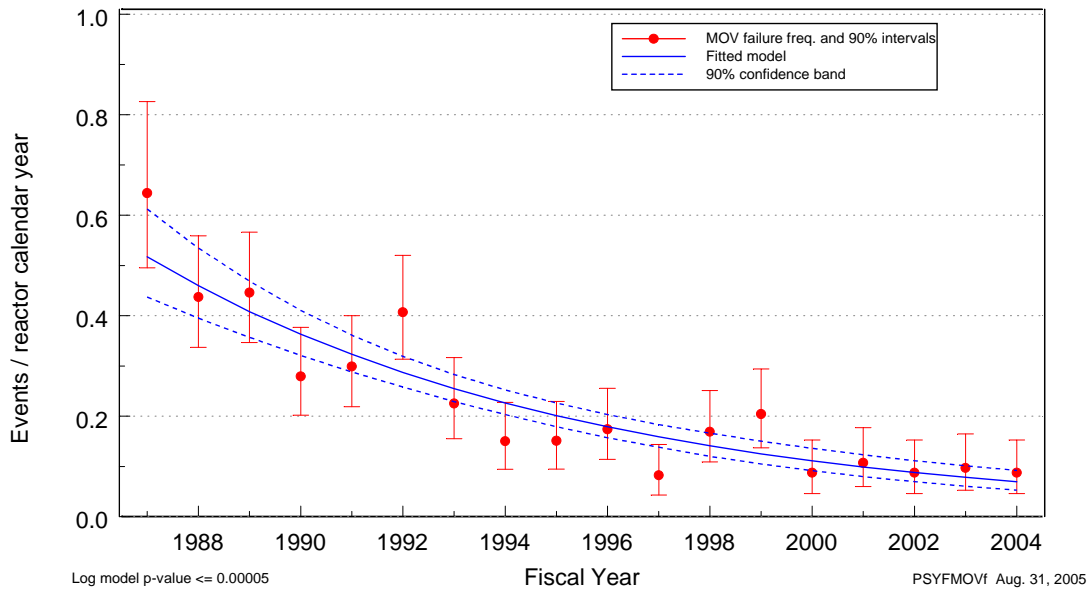


Figure 5. Frequency (events per operating year) of failures, as a function of fiscal year.

1.5 Major Contributors to Component Unreliability and Unavailability

1.5.1 Leading Component Failures.

The valve operator had the most failures in the motor-operated valve data. [Figure 6](#) shows the distribution of sub-component failures.

1.5.2 Leading Systems.

[Figure 7](#) shows the distribution of systems.

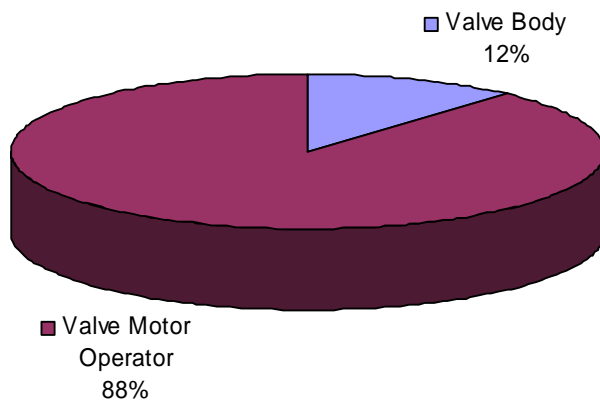


Figure 6. MOV sub-component failure distribution

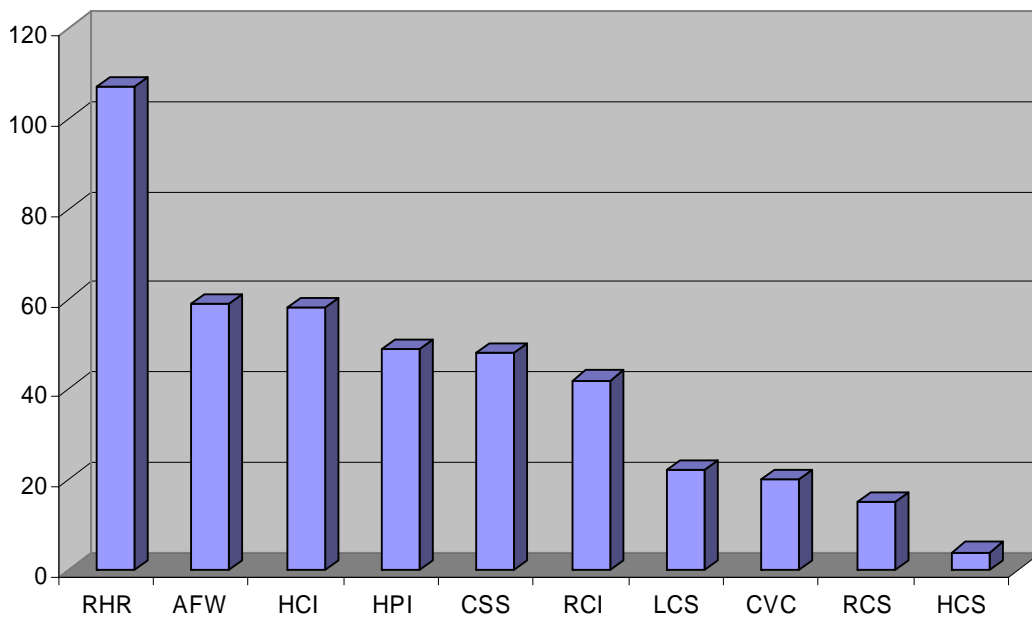


Figure 7. MOV system failures distribution

2 DATA TABLES

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

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

Fiscal Year	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	2.48E-03	3.23E-03	4.13E-03	2.75E-03	3.26E-03	3.86E-03
1988	2.37E-03	3.09E-03	3.96E-03	2.51E-03	2.92E-03	3.40E-03
1989	2.45E-03	3.16E-03	4.02E-03	2.28E-03	2.62E-03	3.00E-03
1990	1.42E-03	1.98E-03	2.68E-03	2.07E-03	2.34E-03	2.65E-03
1991	1.52E-03	2.08E-03	2.80E-03	1.87E-03	2.10E-03	2.35E-03
1992	1.80E-03	2.41E-03	3.17E-03	1.69E-03	1.88E-03	2.10E-03
1993	9.73E-04	1.44E-03	2.05E-03	1.51E-03	1.68E-03	1.87E-03
1994	6.63E-04	1.06E-03	1.60E-03	1.35E-03	1.51E-03	1.69E-03
1995	5.08E-04	8.59E-04	1.37E-03	1.20E-03	1.35E-03	1.52E-03
1996	8.10E-04	1.24E-03	1.81E-03	1.06E-03	1.21E-03	1.38E-03
1997	3.08E-04	5.91E-04	1.03E-03	9.39E-04	1.08E-03	1.25E-03
1998	7.74E-04	1.20E-03	1.78E-03	8.28E-04	9.72E-04	1.14E-03
1999	9.45E-04	1.41E-03	2.03E-03	7.29E-04	8.71E-04	1.04E-03
2000	3.19E-04	6.12E-04	1.07E-03	6.41E-04	7.80E-04	9.49E-04
2001	4.19E-04	7.46E-04	1.23E-03	5.63E-04	6.99E-04	8.67E-04
2002	3.19E-04	6.12E-04	1.07E-03	4.94E-04	6.26E-04	7.92E-04
2003	3.62E-04	6.66E-04	1.13E-03	4.34E-04	5.61E-04	7.25E-04
2004	3.16E-04	6.06E-04	1.06E-03	3.80E-04	5.02E-04	6.63E-04

Table 3. Plot data table for MOV fail-to-open. Figure 2

Fiscal Year	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.01E-03	1.51E-03	2.17E-03	1.44E-03	1.82E-03	2.30E-03
1988	1.19E-03	1.72E-03	2.40E-03	1.29E-03	1.60E-03	1.97E-03
1989	1.20E-03	1.71E-03	2.37E-03	1.16E-03	1.40E-03	1.69E-03
1990	6.62E-04	1.05E-03	1.60E-03	1.03E-03	1.22E-03	1.45E-03
1991	6.53E-04	1.04E-03	1.58E-03	9.16E-04	1.07E-03	1.26E-03
1992	9.18E-04	1.37E-03	1.97E-03	8.07E-04	9.39E-04	1.09E-03
1993	6.04E-04	9.80E-04	1.51E-03	7.06E-04	8.23E-04	9.60E-04
1994	2.63E-04	5.28E-04	9.53E-04	6.13E-04	7.21E-04	8.48E-04
1995	2.17E-04	4.63E-04	8.69E-04	5.29E-04	6.32E-04	7.54E-04
1996	2.14E-04	4.55E-04	8.55E-04	4.54E-04	5.53E-04	6.74E-04
1997	5.37E-05	1.97E-04	5.09E-04	3.89E-04	4.85E-04	6.04E-04
1998	1.31E-04	3.33E-04	6.99E-04	3.32E-04	4.24E-04	5.42E-04
1999	2.21E-04	4.70E-04	8.83E-04	2.83E-04	3.72E-04	4.88E-04
2000	9.29E-05	2.72E-04	6.22E-04	2.41E-04	3.26E-04	4.40E-04
2001	2.23E-04	4.75E-04	8.92E-04	2.05E-04	2.85E-04	3.97E-04
2002	9.29E-05	2.72E-04	6.22E-04	1.74E-04	2.50E-04	3.58E-04
2003	1.31E-04	3.33E-04	7.01E-04	1.48E-04	2.19E-04	3.24E-04
2004	2.39E-05	1.35E-04	4.24E-04	1.26E-04	1.92E-04	2.93E-04

Table 4. Plot data table for MOV fail-to-close. Figure 3

Fiscal Year	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	2.85E-04	5.73E-04	1.03E-03	4.46E-04	6.28E-04	8.83E-04
1988	2.73E-04	5.49E-04	9.91E-04	4.43E-04	6.05E-04	8.26E-04
1989	2.16E-04	4.61E-04	8.65E-04	4.40E-04	5.83E-04	7.73E-04
1990	3.10E-04	5.93E-04	1.03E-03	4.35E-04	5.62E-04	7.26E-04
1991	5.51E-04	9.11E-04	1.42E-03	4.29E-04	5.42E-04	6.84E-04
1992	3.06E-04	5.87E-04	1.02E-03	4.22E-04	5.22E-04	6.46E-04
1993	8.93E-05	2.61E-04	5.98E-04	4.12E-04	5.03E-04	6.14E-04
1994	2.17E-04	4.62E-04	8.68E-04	4.00E-04	4.85E-04	5.88E-04
1995	1.30E-04	3.30E-04	6.94E-04	3.86E-04	4.67E-04	5.66E-04
1996	2.59E-04	5.21E-04	9.39E-04	3.69E-04	4.51E-04	5.50E-04
1997	1.29E-04	3.28E-04	6.90E-04	3.51E-04	4.34E-04	5.37E-04
1998	4.61E-04	7.99E-04	1.29E-03	3.32E-04	4.19E-04	5.27E-04
1999	3.15E-04	6.05E-04	1.05E-03	3.13E-04	4.03E-04	5.20E-04
2000	5.56E-05	2.04E-04	5.27E-04	2.94E-04	3.89E-04	5.15E-04
2001	5.55E-05	2.04E-04	5.27E-04	2.75E-04	3.75E-04	5.10E-04
2002	9.29E-05	2.72E-04	6.22E-04	2.57E-04	3.61E-04	5.07E-04
2003	9.11E-05	2.67E-04	6.10E-04	2.40E-04	3.48E-04	5.04E-04
2004	2.21E-04	4.71E-04	8.85E-04	2.24E-04	3.36E-04	5.02E-04

Table 5. Plot data for demand trend. Figure 4

Fiscal Year	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	1.21E+01	1.27E+01	1.33E+01	1.04E+01	1.08E+01	1.12E+01
1988	8.62E+00	9.12E+00	9.64E+00	9.33E+00	9.64E+00	9.96E+00
1989	9.14E+00	9.64E+00	1.02E+01	8.36E+00	8.61E+00	8.86E+00
1990	6.36E+00	6.77E+00	7.21E+00	7.48E+00	7.68E+00	7.89E+00
1991	6.78E+00	7.21E+00	7.65E+00	6.69E+00	6.86E+00	7.03E+00
1992	6.20E+00	6.61E+00	7.03E+00	5.98E+00	6.12E+00	6.26E+00
1993	5.12E+00	5.49E+00	5.88E+00	5.34E+00	5.46E+00	5.59E+00
1994	3.83E+00	4.15E+00	4.49E+00	4.76E+00	4.88E+00	4.99E+00
1995	3.68E+00	3.99E+00	4.32E+00	4.25E+00	4.35E+00	4.46E+00
1996	3.47E+00	3.78E+00	4.10E+00	3.78E+00	3.89E+00	4.00E+00
1997	2.30E+00	2.55E+00	2.82E+00	3.36E+00	3.47E+00	3.58E+00
1998	2.08E+00	2.32E+00	2.58E+00	2.99E+00	3.10E+00	3.20E+00
1999	1.33E+00	1.52E+00	1.74E+00	2.66E+00	2.76E+00	2.87E+00
2000	9.33E-01	1.10E+00	1.28E+00	2.37E+00	2.47E+00	2.57E+00
2001	1.69E+00	1.91E+00	2.15E+00	2.10E+00	2.20E+00	2.31E+00
2002	1.48E+00	1.68E+00	1.91E+00	1.87E+00	1.97E+00	2.07E+00
2003	4.13E+00	4.47E+00	4.82E+00	1.66E+00	1.76E+00	1.85E+00
2004	2.60E+00	2.87E+00	3.16E+00	1.48E+00	1.57E+00	1.66E+00

Table 6. Plot data for failure trend. Figure 5

Fiscal Year	Plot Trend Error Bar Points			Regression Curve Data Points		
	Lower (5%)	Mean	Upper (95%)	Lower (5%)	Mean	Upper (95%)
1987	3.71E-01	4.83E-01	6.19E-01	4.08E-01	4.82E-01	5.69E-01
1988	3.37E-01	4.37E-01	5.59E-01	3.72E-01	4.32E-01	5.01E-01
1989	3.47E-01	4.46E-01	5.66E-01	3.38E-01	3.86E-01	4.42E-01
1990	2.02E-01	2.79E-01	3.77E-01	3.06E-01	3.46E-01	3.91E-01
1991	2.19E-01	2.99E-01	4.00E-01	2.77E-01	3.10E-01	3.46E-01
1992	3.14E-01	4.07E-01	5.20E-01	2.49E-01	2.77E-01	3.08E-01
1993	1.55E-01	2.25E-01	3.17E-01	2.24E-01	2.48E-01	2.76E-01
1994	9.38E-02	1.50E-01	2.27E-01	1.99E-01	2.22E-01	2.48E-01
1995	9.47E-02	1.51E-01	2.29E-01	1.77E-01	1.99E-01	2.23E-01
1996	1.14E-01	1.74E-01	2.55E-01	1.57E-01	1.78E-01	2.02E-01
1997	4.30E-02	8.24E-02	1.44E-01	1.38E-01	1.59E-01	1.84E-01
1998	1.10E-01	1.69E-01	2.51E-01	1.22E-01	1.43E-01	1.67E-01
1999	1.37E-01	2.04E-01	2.94E-01	1.07E-01	1.28E-01	1.52E-01
2000	4.56E-02	8.74E-02	1.52E-01	9.42E-02	1.14E-01	1.39E-01
2001	5.99E-02	1.07E-01	1.77E-01	8.27E-02	1.02E-01	1.27E-01
2002	4.56E-02	8.74E-02	1.52E-01	7.26E-02	9.17E-02	1.16E-01
2003	5.27E-02	9.71E-02	1.65E-01	6.37E-02	8.21E-02	1.06E-01
2004	4.56E-02	8.74E-02	1.52E-01	5.58E-02	7.35E-02	9.66E-02

3 COMPONENT DESCRIPTIONS AND BOUNDARIES

3.1 MOV Assembly Description and Boundaries

A MOV assembly consists of a valve body and motor-operated sub-components (excludes the circuit breaker). The valve body is generally a gate type. The motor-operator is generally a Limitorque or a Rotork ac or dc motor actuator.

The MOV component boundaries are the MOV assembly, its sub-components described above, and the piece-parts of the sub-components. The piece-parts of the valve body are the stem, packing, and internals. The motor-operator piece-parts include the torque switch, spring pack, limit switch, wiring/contacts, and motor internal and mechanical devices.