

Component Performance Study

Motor-Operated Valves

1998–2009

1 INTRODUCTION

This report presents a performance evaluation of motor-operated valves (MOVs) at U.S. commercial nuclear power plants. This report does not estimate values for use in probabilistic risk assessments (PRAs), but does evaluate component performance over time. Reference 1 ([NUREG/CR-6928](#)) reports MOV unreliability estimates using Equipment Performance and Information Exchange (EPIX) data from 1998–2002 for use in PRAs.

The trend evaluations in this study are based on the operating experience failure reports from fiscal year (FY) 1998 through FY 2009 for the component reliability as reported in EPIX. The MOV failure modes considered are failure-to-open/close (failure to operate) (FTOC) and spurious operation (SO).

Previously, the study relied on operating experience obtained from licensee event reports, Nuclear Plant Reliability Data System (NPRDS), and EPIX. The EPIX database (which includes as a subset the Mitigating Systems Performance Index (MSPI) designated devices) has matured to the point where component availability and reliability can be estimated with a higher degree of assurance of accuracy. In addition, the population of data is much larger than the population used in the previous study.

The objective of the effort for the updated component performance studies is to obtain annual performance trends of failure rates and probabilities. An overview of the trending methods, glossary of terms, and abbreviations can be found in the [Overview and Reference](#) document on the Reactor Operational Experience Results and Databases web page.

2 SUMMARY OF FINDINGS

The results of this study are summarized in this section. Of particular interest is the existence of any statistically significant¹ increasing trends. In this update, no statistically significant increasing trends were identified in the MOV results. Statistically significant decreasing trends were identified in the MOV results for the following:

- All systems, industry-wide MOV FTOC trend MOVs with ≤ 20 demands per year. (see Figure 1)
- All systems, industry-wide MOV FTOC trend MOVs with > 20 demands per year. (see Figure 2)

¹ Statistical significance 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).

- Frequency (demands per reactor year) of MOV operation demands, ≤ 20 demands per year. (see Figure 5)
- Frequency (failures per reactor year) of MOV FTOC events ≤ 20 demands per year. (see Figure 7)
- Frequency (failures per reactor year) of MOV FTOC events > 20 demands per year. (see Figure 8)

Considering the low-demand MOVs; Table 3 shows that 77% of the MOV FTOC failures occurred in eight systems. Similarly, Table 4 shows that 87% of the MOV SO failures occurred in seven systems. And considering the high-demand MOVs; Table 5 shows that 81% of the MOV FTOC failures occurred in five systems. Similarly, Table 6 shows that 100% of the MOV SO failures occurred in five systems.

3 FAILURE PROBABILITIES AND FAILURE RATES

3.1 Overview

Trends of industry-wide failure probabilities and failure rates of MOVs have been calculated from the operating experience for the FTOC and SO failure modes. The MOV data set obtained from EPIX was segregated to MOVs with ≤ 20 demands/year (d/yr) and MOVs with > 20 d/yr and includes MOVs in the systems listed in Table 1. [NUREG/CR-6928](#) lists the industry failure data for MOVs with ≤ 20 d/yr. Table 2 shows industry-wide failure probability and failure rate results for the MOV with ≤ 20 d/yr from Reference 1.

The MOVs are assumed to operate both when the reactor is critical and during shutdown periods. The number of valves in operation is assumed to be constant throughout the study period. All demand types are considered—testing, non-testing, and, as applicable, emergency safeguard feature (ESF) demands.

Table 1. MOV systems.

System	Description	MOV Component Count			System	Description	MOV Component Count		
		Total	≤ 20 d/yr	> 20 d/yr			Total	≤ 20 d/yr	> 20 d/yr
AFW	Auxiliary feedwater	571	457	114	HVC	Heating ventilation and air conditioning	28	24	4
CCW	Component cooling water	837	691	146	IAS	Instrument air	15	14	1
CHW	Chilled water system	46	46		ISO	Isolation condenser	20	16	4
CIS	Containment isolation system	430	399	31	LCS	Low pressure core spray	235	207	28
CRD	Control rod drive	25	15	10	MFW	Main feedwater	332	319	13
CSR	Containment spray recirculation	339	321	18	MSS	Main steam	179	171	8
CTS	Condensate transfer system	6	6		RCI	Reactor core isolation	320	290	30
CVC	Chemical and volume control	572	531	41	RCS	Reactor coolant	162	155	7
HCI	High pressure coolant injection	262	237	25	RHR	Residual heat removal	2061	1773	288
HCS	High pressure core spray	43	28	15	SLC	Standby liquid control	23	23	
HPI	High pressure injection	1030	947	83	SWN	Emergency service water (Standby)	964	706	258
					SWS	Standby service water	275	188	87
					VSS	Vapor suppression	21	19	2
					Total		8796	7583	1213

Table 2. Industry-wide distributions of p (failure probability) and λ (hourly rate) for MOVs.

Failure Mode	5%	Median	Mean	95%	Distribution		
					Type	α	β
FTOC	8.0E-05	7.0E-04	1.0E-03	3.0E-03	Beta	1.20	1.20E+03
SO	1.5E-10	2.0E-08	4.0E-08	1.5E-07	Gamma	0.50	1.25E+07

3.2 MOV Failure Probability and Failure Rate Trends

Trends in failure probabilities and failure rates are shown in Figure 1, Figure 2, Figure 3, and Figure 4. The data for the trend plots are contained in Table 7, Table 8, Table 9, and Table 10, respectively.

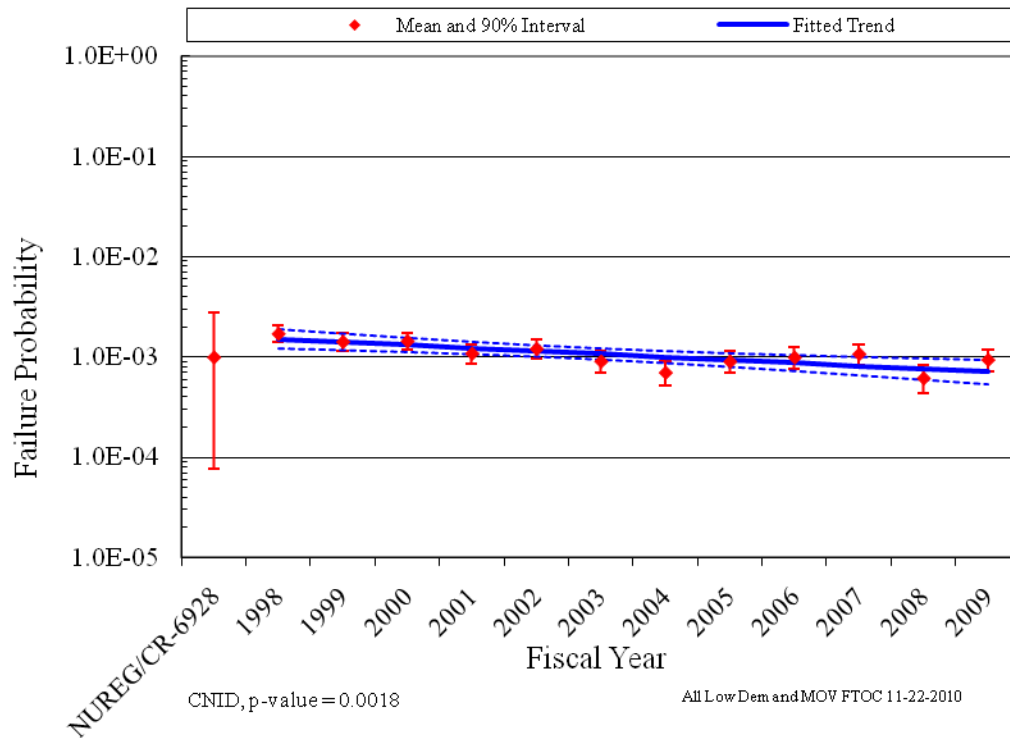


Figure 1. All systems, industry-wide MOV FTOC trend MOVs with ≤ 20 demands per year.

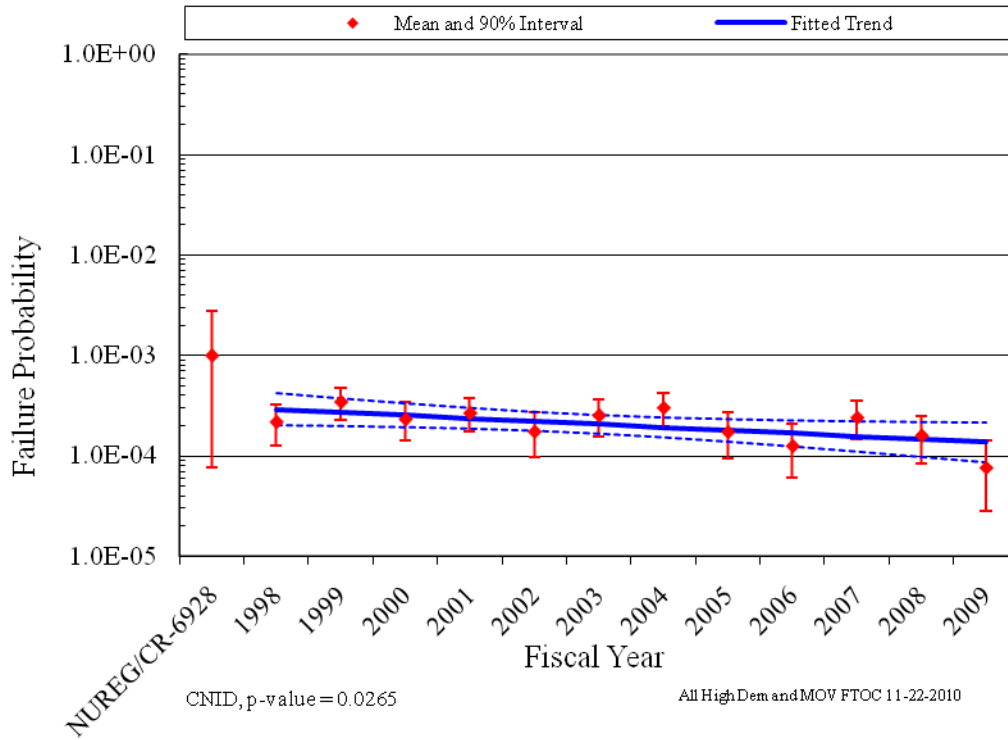


Figure 2. All systems, industry-wide MOV FTOC trend MOVs with > 20 demands per year.

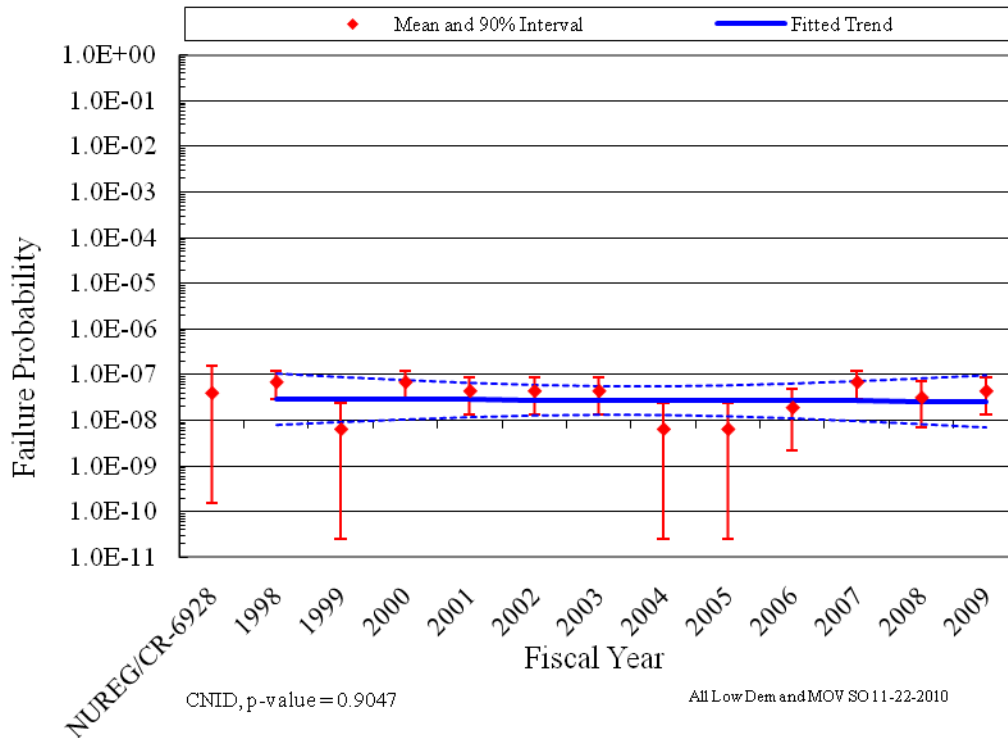


Figure 3. All systems, industry-wide MOV SO trend with ≤ 20 demands per year.

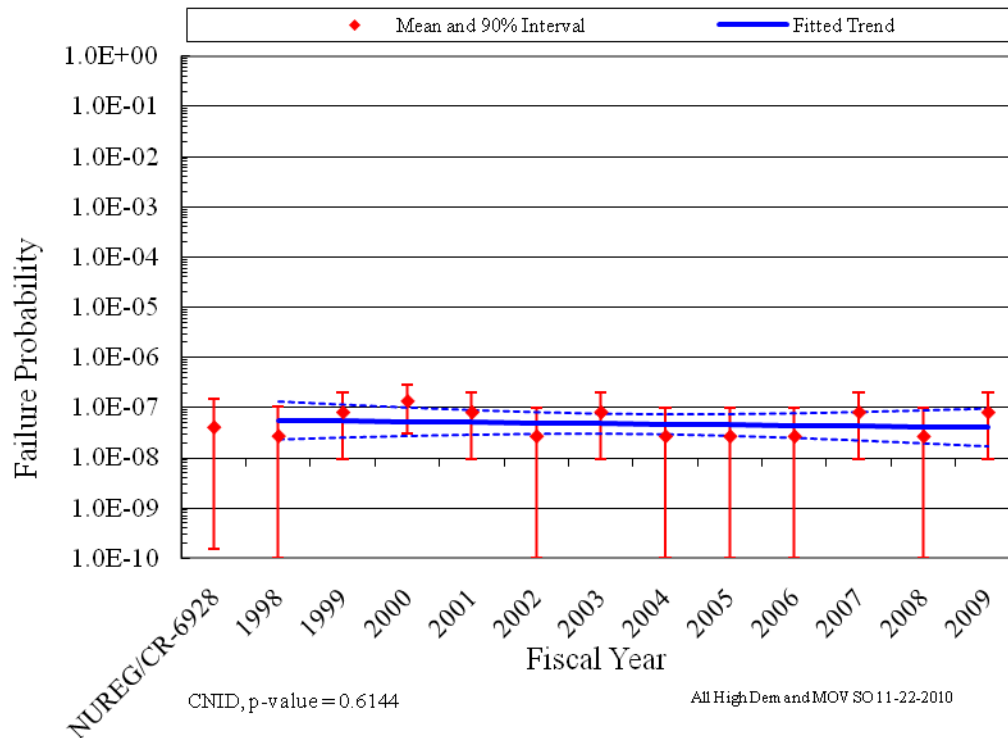


Figure 4. All systems, industry-wide MOV SO trend with > 20 demands per year.

In the plots, the means of the posterior distributions from the Bayesian update process were trended across the years. The posterior distributions were also used for the vertical bounds for each year. The 5th and 95th percentiles of these distributions give an indication of the relative variation from year to year in the data. When there are no failures, the interval is larger than the interval for years when there are one or more failures. The larger interval reflects the uncertainty that comes from having little information in that year's data. Such uncertainty intervals are determined by the prior distribution. In each plot, a relatively “flat” constrained noninformative prior distribution (CNID) is used, which has large bounds.

The horizontal curves plotted around the regression lines in the graphs form 90 percent simultaneous confidence bands for the fitted lines. The bounds are larger than ordinary confidence intervals for the trended values because they form a band that has a 90% probability of containing the entire line. In the lower left hand corner of the trend figures, the regression p-values are reported. They come from a statistical test on whether the slope of the regression line might be zero. Low p-values indicate that the slopes are not likely to be zero, and that trends exist. Further information on the trending methods is provided in Section 2 of the [Overview and Reference](#) document. A final feature of the trend graphs is that the baseline industry values from Table 2 are shown for comparison.

4 ENGINEERING TRENDS

This section presents frequency trends for MOV failures and demands. The data are normalized by reactor year for plants that have the equipment being trended. Figure 5 shows the trend for MOV demands. Figure 7 shows the trend in failure events for FTOC mode, and Figure 9 shows the trend for the SO failure events. Table 3 and Table 5 summarize the failures by system, year, and the FTOC failure mode. The top five (and ties) contributing systems for the FTOC failure mode are AFW, HCI, HPI, RCI, RHR, and SWN. Table 4 and Table 6 summarize the failures by system, year, and the SO failure mode. The top five (and ties) contributing systems for the SO failure mode are AFW, CCW, HCI, LCS, RCI,

RHR, and SWS. Table 11, Table 12, Table 13, Table 14, Table 15, and Table 16 provide the frequency (per reactor year) of MOV demands, FTOC events, and SO events, respectively. The systems from Table 2 are trended together for each figure. The rate methods described in Section 2 of the [Overview and Reference](#) document are used.

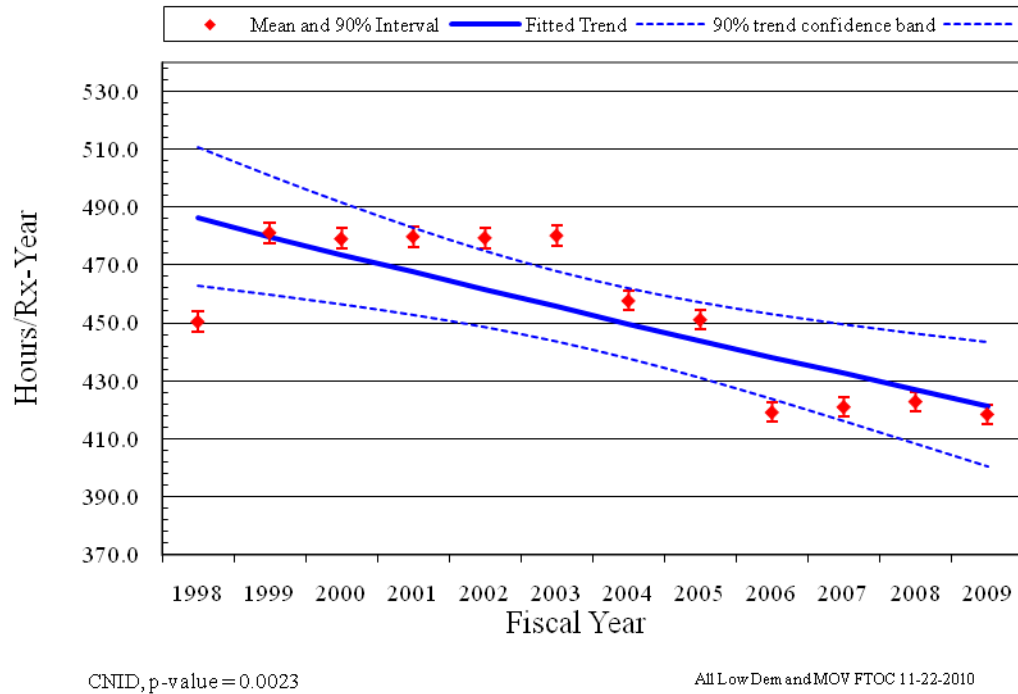
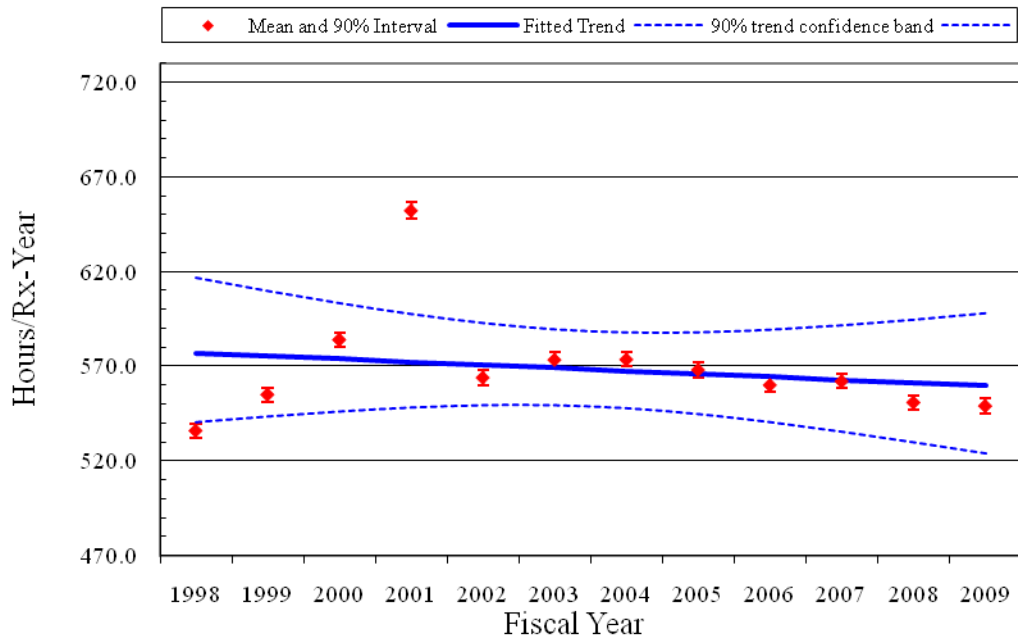


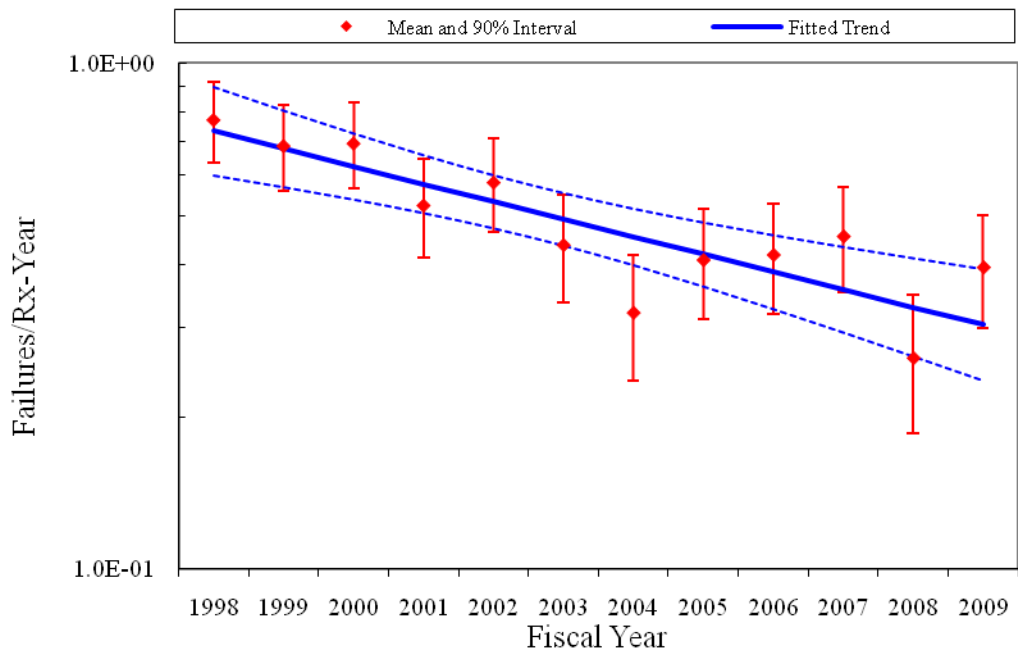
Figure 5. Frequency (demands per reactor year) of MOV operation demands, ≤ 20 demands per year.



CNID, p-value = 0.5227

All High Dem and MOV FTOC 11-22-2010

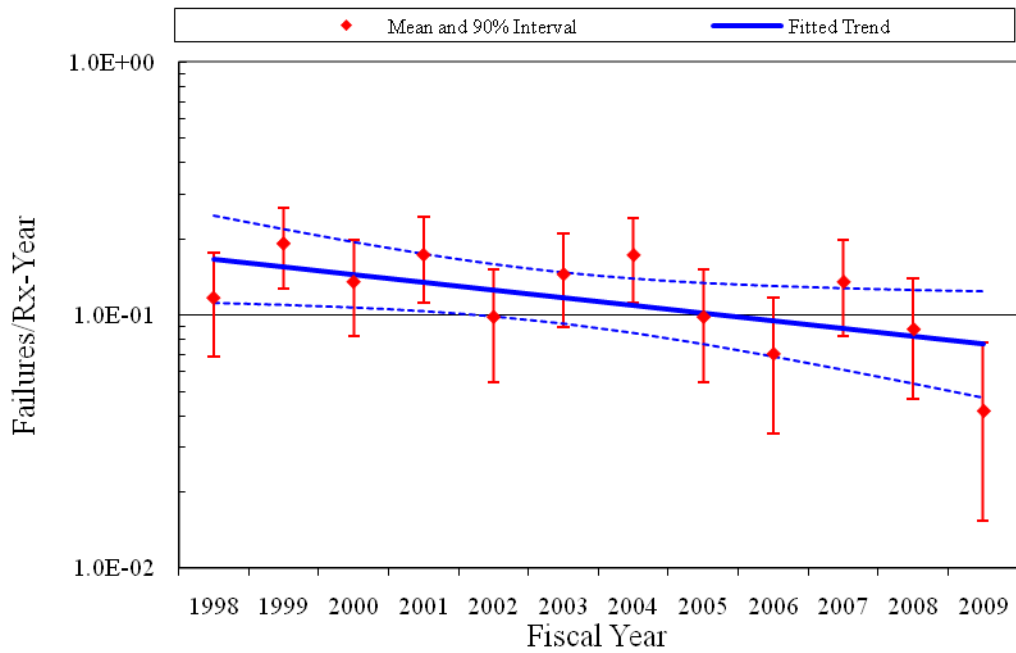
Figure 6. Frequency (demands per reactor year) of MOV operation demands, > 20 demands per year.



CNID, p-value = 0.0003

All Low Dem and MOV FTOC 11-22-2010

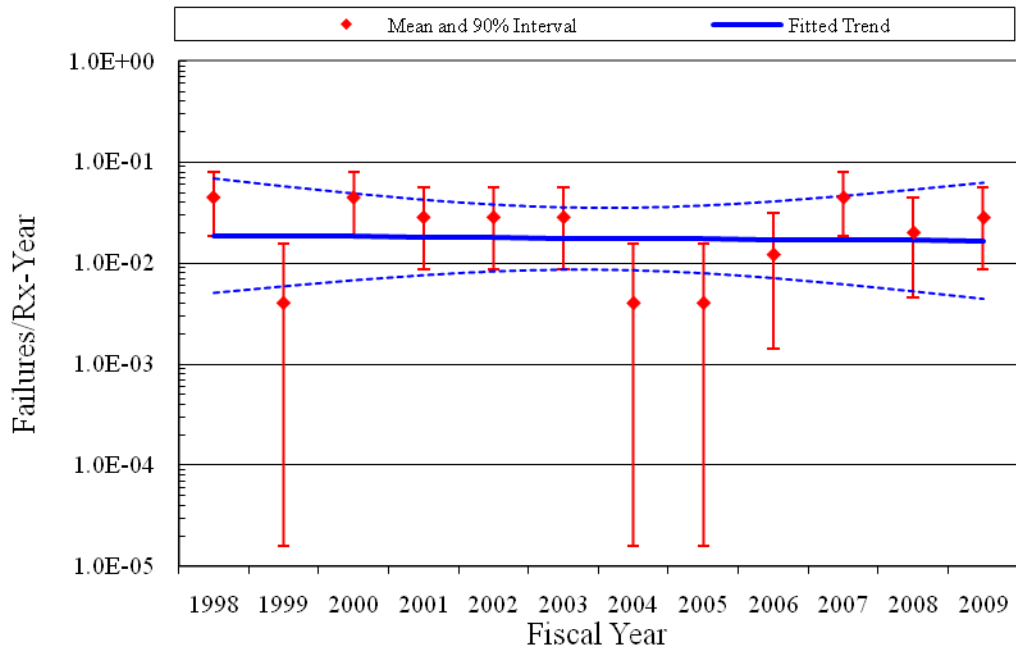
Figure 7. Frequency (failures per reactor year) of MOV FTOC events ≤ 20 demands per year.



CNID, p-value = 0.0304

All High Dem and MOV FTOC 11-22-2010

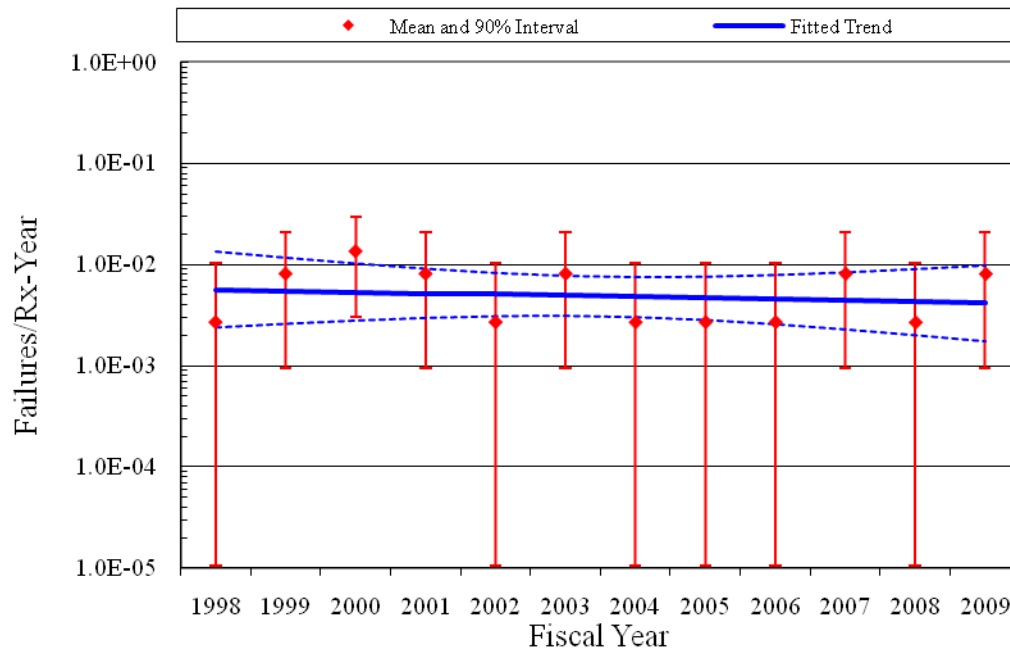
Figure 8. Frequency (failures per reactor year) of MOV FTOC events > 20 demands per year.



CNID, p-value = 0.9006

All Low Dem and MOV SO 11-22-2010

Figure 9. Frequency (failures per reactor year) of MOV SO events \leq 20 demands per year.



CNID, p-value = 0.6189

All High Dem and MOV SO 11-22-2010

Figure 10. Frequency (failures per reactor year) of MOV SO events > 20 demands per year.

Table 3. Summary of MOV failure counts for the FTOC failure mode over time by system ≤ 20 demands per year.

System Code	Valve Count	Valve Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	Total	Percent of Failures
AFW	457	6.1%	4	6	7	5	7	1	2	3	2	3	2	6	48	7.8%
CCW	691	9.2%	4	2	5	4	4	4	1	1	2	1		3	31	5.0%
CHW	46	0.6%		1					1						2	0.3%
CIS	399	5.3%	5	2	3	3	5	4		2	2		3	2	31	5.0%
CRD	15	0.2%		1											1	0.2%
CSR	321	4.3%	1	2	2		2	1	2		1		1	1	13	2.1%
CTS	6	0.1%		1											1	0.2%
CVC	531	7.0%	3	3	4		1	2			1	2	1	1	18	2.9%
HCI	237	3.1%	4	3	2	2	1	2	2	1	3	9		7	36	5.9%
HCS	28	0.4%		1	1										2	0.3%
HPI	947	12.5%	6	5	6	4	7	2	6	6	3	3	1	3	52	8.5%
HVC	24	0.3%	1	1			1								3	0.5%
ISO	16	0.2%		1	2	1			1	2					7	1.1%
LCS	207	2.7%	5	11	2	4	1	2			1	1			27	4.4%
MFW	319	4.2%	1			1		3	2	2	1	3	2	1	16	2.6%
MSS	171	2.3%		1	3	1	2	1	2	2		3	4	2	21	3.4%
RCI	290	3.8%	3	9	4	5	1	2	1	4	3	1	2	1	36	5.9%
RCS	155	2.1%				1			2	1	1				5	0.8%
RHR	1773	23.5%	20	17	22	10	23	11	9	15	17	18	7	9	178	28.9%
SWN	706	9.4%	9	4	8	11	3	7	2	2	6	1	4	4	61	9.9%
SWS	188	2.5%	14		1	2	1	1				1		1	21	3.4%
VSS	19	0.3%					1	2		1		1			5	0.8%
Total	7546	100.0%	80	71	72	54	60	45	33	42	43	47	27	41	615	100.0%

Table 4. Summary of MOV failure counts for the SO failure mode over time by system ≤ 20 demands per year.

System Code	Valve Count	Valve Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	Total	Percent of Failures
AFW	457	7.9%	1			1									2	6.7%
CCW	691	11.9%					1	1					2	2	6	20.0%
CIS	399	6.9%				1									1	3.3%
CSR	321	5.5%				1									1	3.3%
CVC	531	9.2%			1										1	3.3%
HCI	237	4.1%	1									1			2	6.7%
LCS	207	3.6%									1	4			5	16.7%
RCI	290	5.0%			2		1							1	4	13.3%
RHR	1773	30.6%	2		2			1							5	16.7%
SWN	706	12.2%					1								1	3.3%
SWS	188	3.2%	1					1							2	6.7%
Total	5800	100.0%	5	0	5	3	3	3	0	0	1	5	42	3	30	100.0%

Table 5. Summary of MOV failure counts for the FTOC failure mode over time by system > 20 demands per year.

System Code	Valve Count	Valve Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	Total	Percent of Failures
AFW	114	9.6%	1	2	3	2	1	8	4	1		4	1		27	17.9%
CCW	146	12.3%	1			1		2	2	1			1		8	5.3%
CIS	31	2.6%	1	2	1										4	2.6%
CSR	18	1.5%	1												1	0.7%
CVC	41	3.4%						1				1			2	1.3%
HCI	25	2.1%					1			1	1		1		4	2.6%
HCS	15	1.3%											1		1	0.7%
HPI	83	7.0%	1		1		1					1			4	2.6%
HVC	4	0.3%				1									1	0.7%
LCS	28	2.4%							1				1		2	1.3%
MFW	13	1.1%	1			2									3	2.0%
MSS	8	0.7%			1										1	0.7%
RCI	30	2.5%		1		1			2	2					6	4.0%
RHR	288	24.2%	4	8	7	4	2	2	2	4	2	6	2	3	46	30.5%
SWN	258	21.7%	2	7	1	5	2	1	5	1	3	1	1	1	30	19.9%
SWS	87	7.3%				2	3	1	2		1	1	1		11	7.3%
Total	1189	100.0%	12	20	14	18	10	15	18	10	7	14	9	4	151	100.0%

Table 6. Summary of MOV failure counts for the SO failure mode over time by system > 20 demands per year.

System Code	Valve Count	Valve Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08	FY 09	Total	Percent of Failures
CIS	31	5.0%			1										1	14.3%
MFW	13	2.1%				1									1	14.3%
RCI	30	4.8%			1										1	14.3%
RHR	288	46.5%										1		1	2	28.6%
SWN	258	41.6%		1				1							2	28.6%
Total	620	100.0%	0	1	2	1	0	1	0	0	0	1	13	1	7	100.0%

5 MOV ASSEMBLY DESCRIPTION

A MOV assembly consists of a valve body and motor-operated sub-components (includes 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 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.

6 DATA TABLES

Table 7. Plot data for industry-wide MOV FTOC trend with ≤ 20 demands per year. Figure 1

FY/ Source	Failures	Demands	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG /CR-6928						7.76E-05	2.81E-03	1.00E-03
1998	80	46396	1.51E-03	1.21E-03	1.90E-03	1.41E-03	2.04E-03	1.72E-03
1999	71	49564	1.41E-03	1.17E-03	1.72E-03	1.16E-03	1.72E-03	1.43E-03
2000	72	49483	1.32E-03	1.12E-03	1.56E-03	1.18E-03	1.74E-03	1.45E-03
2001	54	49426	1.23E-03	1.07E-03	1.43E-03	8.60E-04	1.35E-03	1.09E-03
2002	60	49382	1.15E-03	1.01E-03	1.32E-03	9.68E-04	1.48E-03	1.21E-03
2003	45	49463	1.08E-03	9.43E-04	1.23E-03	7.01E-04	1.14E-03	9.11E-04
2004	33	47271	1.01E-03	8.73E-04	1.16E-03	5.15E-04	9.12E-04	7.02E-04
2005	42	46466	9.39E-04	8.00E-04	1.10E-03	6.89E-04	1.14E-03	9.06E-04
2006	43	43167	8.77E-04	7.28E-04	1.06E-03	7.62E-04	1.26E-03	9.97E-04
2007	47	43511	8.19E-04	6.60E-04	1.02E-03	8.35E-04	1.35E-03	1.08E-03
2008	27	44093	7.65E-04	5.97E-04	9.79E-04	4.37E-04	8.22E-04	6.17E-04
2009	41	43518	7.14E-04	5.39E-04	9.46E-04	7.16E-04	1.20E-03	9.44E-04

Table 8. Plot data for industry-wide MOV FTOC trend with > 20 demands per year. Figure 2

FY/ Source	Failures	Demands	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG /CR-6928						7.76E-05	2.81E-03	1.00E-03
1998	12	55194	2.92E-04	2.02E-04	4.22E-04	1.27E-04	3.27E-04	2.17E-04
1999	20	57162	2.73E-04	1.98E-04	3.75E-04	2.30E-04	4.78E-04	3.45E-04
2000	14	60313	2.55E-04	1.93E-04	3.35E-04	1.41E-04	3.40E-04	2.31E-04
2001	18	67183	2.38E-04	1.87E-04	3.02E-04	1.73E-04	3.75E-04	2.66E-04
2002	10	58084	2.22E-04	1.78E-04	2.76E-04	9.59E-05	2.70E-04	1.74E-04
2003	15	59055	2.07E-04	1.67E-04	2.57E-04	1.57E-04	3.66E-04	2.53E-04
2004	18	59235	1.93E-04	1.53E-04	2.44E-04	1.95E-04	4.24E-04	3.01E-04
2005	10	58506	1.80E-04	1.39E-04	2.35E-04	9.53E-05	2.68E-04	1.73E-04
2006	7	57680	1.68E-04	1.24E-04	2.28E-04	6.05E-05	2.08E-04	1.25E-04
2007	14	58088	1.57E-04	1.11E-04	2.23E-04	1.47E-04	3.52E-04	2.40E-04
2008	9	57438	1.47E-04	9.79E-05	2.20E-04	8.46E-05	2.52E-04	1.59E-04
2009	4	57092	1.37E-04	8.64E-05	2.17E-04	2.80E-05	1.42E-04	7.57E-05

Table 9. Plot data for industry-wide MOV SO trend with ≤ 20 demands per year. Figure 3

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG /CR-6928						1.57E-10	1.54E-07	4.00E-08
1998	5	65848920	2.92E-08	7.87E-09	1.09E-07	2.90E-08	1.25E-07	6.98E-08
1999	0	66015360	2.89E-08	9.21E-09	9.10E-08	2.49E-11	2.43E-08	6.33E-09
2000	5	66032880	2.86E-08	1.06E-08	7.73E-08	2.89E-08	1.24E-07	6.96E-08
2001	3	66015360	2.84E-08	1.20E-08	6.71E-08	1.37E-08	8.90E-08	4.43E-08
2002	3	65989080	2.81E-08	1.31E-08	6.01E-08	1.37E-08	8.91E-08	4.43E-08
2003	3	66032880	2.78E-08	1.37E-08	5.65E-08	1.37E-08	8.90E-08	4.43E-08
2004	0	65989080	2.75E-08	1.35E-08	5.61E-08	2.49E-11	2.43E-08	6.33E-09
2005	0	66015360	2.72E-08	1.26E-08	5.89E-08	2.49E-11	2.43E-08	6.33E-09
2006	1	66059160	2.69E-08	1.12E-08	6.47E-08	2.23E-09	4.94E-08	1.90E-08
2007	5	66041640	2.66E-08	9.68E-09	7.33E-08	2.89E-08	1.24E-07	6.96E-08
2008	2	66102960	2.64E-08	8.20E-09	8.48E-08	7.24E-09	7.00E-08	3.16E-08
2009	3	66181800	2.61E-08	6.86E-09	9.93E-08	1.37E-08	8.88E-08	4.42E-08

Table 10. Plot data for industry-wide MOV SO trend, >20 demands per year. Figure 4

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG /CR-6928						1.57E-10	1.54E-07	4.00E-08
1998	0	10328040	5.59E-08	2.36E-08	1.32E-07	1.05E-10	1.02E-07	2.67E-08
1999	1	10494480	5.43E-08	2.56E-08	1.15E-07	9.30E-09	2.07E-07	7.93E-08
2000	2	10512000	5.28E-08	2.75E-08	1.01E-07	3.03E-08	2.93E-07	1.32E-07
2001	1	10494480	5.13E-08	2.91E-08	9.03E-08	9.30E-09	2.07E-07	7.93E-08
2002	0	10503240	4.98E-08	3.03E-08	8.21E-08	1.04E-10	1.02E-07	2.64E-08
2003	1	10512000	4.84E-08	3.05E-08	7.70E-08	9.30E-09	2.06E-07	7.93E-08
2004	0	10538280	4.71E-08	2.96E-08	7.48E-08	1.04E-10	1.01E-07	2.64E-08
2005	0	10538280	4.58E-08	2.78E-08	7.54E-08	1.04E-10	1.01E-07	2.64E-08
2006	0	10538280	4.45E-08	2.53E-08	7.83E-08	1.04E-10	1.01E-07	2.64E-08
2007	1	10538280	4.32E-08	2.25E-08	8.30E-08	9.28E-09	2.06E-07	7.92E-08
2008	0	10617120	4.20E-08	1.98E-08	8.91E-08	1.03E-10	1.01E-07	2.63E-08
2009	1	10555800	4.08E-08	1.73E-08	9.66E-08	9.27E-09	2.06E-07	7.91E-08

Table 11. Plot data for frequency (events per reactor year) of MOV operation demands with ≤ 20 demands per year. Figure 5

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	46396	103.0	4.86E+02	4.63E+02	5.11E+02	4.47E+02	4.54E+02	4.50E+02
1999	49564	103.0	4.80E+02	4.60E+02	5.01E+02	4.78E+02	4.85E+02	4.81E+02
2000	49483	103.3	4.74E+02	4.56E+02	4.92E+02	4.76E+02	4.83E+02	4.79E+02
2001	49426	103.0	4.68E+02	4.53E+02	4.83E+02	4.76E+02	4.83E+02	4.80E+02
2002	49382	103.0	4.62E+02	4.48E+02	4.75E+02	4.76E+02	4.83E+02	4.79E+02
2003	49463	103.0	4.56E+02	4.44E+02	4.68E+02	4.77E+02	4.84E+02	4.80E+02
2004	47271	103.3	4.50E+02	4.38E+02	4.62E+02	4.54E+02	4.61E+02	4.58E+02
2005	46466	103.0	4.44E+02	4.31E+02	4.57E+02	4.48E+02	4.55E+02	4.51E+02
2006	43167	103.0	4.38E+02	4.24E+02	4.53E+02	4.16E+02	4.22E+02	4.19E+02
2007	43511	103.4	4.33E+02	4.16E+02	4.50E+02	4.18E+02	4.24E+02	4.21E+02
2008	44093	104.3	4.27E+02	4.08E+02	4.46E+02	4.20E+02	4.26E+02	4.23E+02
2009	43518	104.0	4.21E+02	4.00E+02	4.44E+02	4.15E+02	4.22E+02	4.18E+02

Table 12. Plot data for frequency (events per reactor year) of MOV operation demands with > 20 demands per year. Figure 6

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	55194	103.0	5.77E+02	5.40E+02	6.17E+02	5.32E+02	5.40E+02	5.36E+02
1999	57162	103.0	5.75E+02	5.43E+02	6.10E+02	5.51E+02	5.59E+02	5.55E+02
2000	60313	103.3	5.74E+02	5.46E+02	6.03E+02	5.80E+02	5.88E+02	5.84E+02
2001	67183	103.0	5.72E+02	5.48E+02	5.98E+02	6.48E+02	6.56E+02	6.52E+02
2002	58084	103.0	5.71E+02	5.49E+02	5.93E+02	5.60E+02	5.68E+02	5.64E+02
2003	59055	103.0	5.69E+02	5.49E+02	5.90E+02	5.69E+02	5.77E+02	5.73E+02
2004	59235	103.3	5.68E+02	5.48E+02	5.88E+02	5.70E+02	5.77E+02	5.74E+02
2005	58506	103.0	5.66E+02	5.45E+02	5.88E+02	5.64E+02	5.72E+02	5.68E+02
2006	57680	103.0	5.64E+02	5.40E+02	5.90E+02	5.56E+02	5.64E+02	5.60E+02
2007	58088	103.4	5.63E+02	5.35E+02	5.92E+02	5.58E+02	5.66E+02	5.62E+02
2008	57438	104.3	5.61E+02	5.30E+02	5.95E+02	5.47E+02	5.55E+02	5.51E+02
2009	57092	104.0	5.60E+02	5.24E+02	5.98E+02	5.45E+02	5.53E+02	5.49E+02

Table 13. Plot data for frequency (events per reactor year) of MOV FTOC events with ≤ 20 demands per year. Figure 7

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	80	103.0	7.34E-01	6.01E-01	8.98E-01	6.38E-01	9.21E-01	7.74E-01
1999	71	103.0	6.78E-01	5.70E-01	8.06E-01	5.59E-01	8.26E-01	6.87E-01
2000	72	103.3	6.26E-01	5.38E-01	7.27E-01	5.67E-01	8.35E-01	6.95E-01
2001	54	103.0	5.77E-01	5.06E-01	6.59E-01	4.13E-01	6.46E-01	5.24E-01
2002	60	103.0	5.33E-01	4.72E-01	6.01E-01	4.64E-01	7.10E-01	5.82E-01
2003	45	103.0	4.92E-01	4.36E-01	5.55E-01	3.37E-01	5.49E-01	4.37E-01
2004	33	103.3	4.54E-01	3.99E-01	5.17E-01	2.36E-01	4.18E-01	3.21E-01
2005	42	103.0	4.19E-01	3.62E-01	4.85E-01	3.11E-01	5.17E-01	4.09E-01
2006	43	103.0	3.87E-01	3.26E-01	4.58E-01	3.20E-01	5.28E-01	4.18E-01
2007	47	103.4	3.57E-01	2.93E-01	4.34E-01	3.52E-01	5.69E-01	4.55E-01
2008	27	104.3	3.29E-01	2.63E-01	4.13E-01	1.85E-01	3.48E-01	2.61E-01
2009	41	104.0	3.04E-01	2.35E-01	3.93E-01	3.00E-01	5.01E-01	3.95E-01

Table 14. Plot data for frequency (events per reactor year) of MOV FTOC events with > 20 demands per year. Figure 8

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	12	103.0	1.67E-01	1.12E-01	2.48E-01	6.82E-02	1.76E-01	1.17E-01
1999	20	103.0	1.56E-01	1.10E-01	2.19E-01	1.28E-01	2.66E-01	1.91E-01
2000	14	103.3	1.45E-01	1.08E-01	1.95E-01	8.25E-02	1.98E-01	1.35E-01
2001	18	103.0	1.35E-01	1.04E-01	1.75E-01	1.12E-01	2.44E-01	1.73E-01
2002	10	103.0	1.26E-01	9.94E-02	1.60E-01	5.41E-02	1.53E-01	9.80E-02
2003	15	103.0	1.17E-01	9.31E-02	1.48E-01	9.00E-02	2.10E-01	1.45E-01
2004	18	103.3	1.09E-01	8.55E-02	1.40E-01	1.12E-01	2.43E-01	1.72E-01
2005	10	103.0	1.02E-01	7.72E-02	1.34E-01	5.41E-02	1.53E-01	9.80E-02
2006	7	103.0	9.49E-02	6.90E-02	1.31E-01	3.39E-02	1.17E-01	7.00E-02
2007	14	103.4	8.85E-02	6.11E-02	1.28E-01	8.24E-02	1.98E-01	1.35E-01
2008	9	104.3	8.24E-02	5.39E-02	1.26E-01	4.67E-02	1.39E-01	8.77E-02
2009	4	104.0	7.68E-02	4.74E-02	1.25E-01	1.54E-02	7.83E-02	4.16E-02

Table 15. Plot data for frequency (events per reactor year) of MOV SO events ≤ 20 demands per year.
Figure 9

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	5	103.0	1.88E-02	5.05E-03	6.96E-02	1.85E-02	7.98E-02	4.46E-02
1999	0	103.0	1.85E-02	5.91E-03	5.83E-02	1.59E-05	1.56E-02	4.05E-03
2000	5	103.3	1.84E-02	6.81E-03	4.95E-02	1.85E-02	7.96E-02	4.45E-02
2001	3	103.0	1.82E-02	7.68E-03	4.29E-02	8.79E-03	5.70E-02	2.84E-02
2002	3	103.0	1.80E-02	8.39E-03	3.85E-02	8.79E-03	5.70E-02	2.84E-02
2003	3	103.0	1.78E-02	8.74E-03	3.61E-02	8.79E-03	5.70E-02	2.84E-02
2004	0	103.3	1.76E-02	8.62E-03	3.58E-02	1.59E-05	1.55E-02	4.05E-03
2005	0	103.0	1.74E-02	8.03E-03	3.76E-02	1.59E-05	1.56E-02	4.05E-03
2006	1	103.0	1.72E-02	7.16E-03	4.13E-02	1.43E-03	3.17E-02	1.22E-02
2007	5	103.4	1.70E-02	6.19E-03	4.68E-02	1.85E-02	7.95E-02	4.45E-02
2008	2	104.3	1.68E-02	5.24E-03	5.40E-02	4.60E-03	4.44E-02	2.01E-02
2009	3	104.0	1.67E-02	4.38E-03	6.32E-02	8.72E-03	5.66E-02	2.82E-02

Table 16. Plot data for frequency (events per reactor year) of MOV SO events > 20 demands per year.
Figure 10

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	0	103.0	5.68E-03	2.40E-03	1.34E-02	1.06E-05	1.03E-02	2.69E-03
1999	1	103.0	5.52E-03	2.60E-03	1.17E-02	9.48E-04	2.11E-02	8.08E-03
2000	2	103.3	5.37E-03	2.80E-03	1.03E-02	3.08E-03	2.98E-02	1.34E-02
2001	1	103.0	5.22E-03	2.96E-03	9.18E-03	9.48E-04	2.11E-02	8.08E-03
2002	0	103.0	5.07E-03	3.08E-03	8.36E-03	1.06E-05	1.03E-02	2.69E-03
2003	1	103.0	4.93E-03	3.10E-03	7.83E-03	9.48E-04	2.11E-02	8.08E-03
2004	0	103.3	4.79E-03	3.02E-03	7.62E-03	1.06E-05	1.03E-02	2.69E-03
2005	0	103.0	4.66E-03	2.83E-03	7.68E-03	1.06E-05	1.03E-02	2.69E-03
2006	0	103.0	4.53E-03	2.57E-03	7.98E-03	1.06E-05	1.03E-02	2.69E-03
2007	1	103.4	4.41E-03	2.29E-03	8.46E-03	9.46E-04	2.10E-02	8.07E-03
2008	0	104.3	4.28E-03	2.02E-03	9.09E-03	1.05E-05	1.03E-02	2.68E-03
2009	1	104.0	4.17E-03	1.76E-03	9.86E-03	9.43E-04	2.09E-02	8.04E-03

7 REFERENCE

1. S.A. Eide, et al, *Industry-Average Performance for Components and Initiating Events at U.S. Commercial Nuclear Power Plants*, U.S. Nuclear Regulatory Commission, NUREG/CR-6928, February 2007.