Component Performance Study

Motor-Operated Valves

1998–2008

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 2008 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 significant[1] 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)
- Frequency (demands per reactor year) of MOV operation demands, <= 20 demands per year. (see Figure 5)

[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 (failures per reactor year) of MOV FTOC events <= 20 demands per year. (see Figure 7)

Table 3 shows that 80% of the MOV FTOC failures occurred in 9 systems. Similarly, Table 4 shows that 88% of the MOV SO failures occurred in 7 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.

		MOV Component Count		
System	Description	Total	<=20 d/yr	>20 d/yr
AFW	Auxiliary feedwater	566	496	70
CCW	Component cooling water	748	602	146
CHW	Chilled water system	46	46	
CIS	Containment isolation system	437	404	33
CRD	Control rod drive	21	7	14
CSR	Containment spray recirculation	342	328	14
CTS	Condensate transfer system	6	6	
CVC	Chemical and volume control	565	527	38
HCI	High pressure coolant injection	268	248	20
HCS	High pressure core spray	47	30	17
HPI	High pressure injection	1076	1008	68
HVC	Heating ventilation and air conditioning	27	23	4
IAS	Instrument air	14	14	
ISO	Isolation condenser	20	20	
LCS	Low pressure core spray	222	201	21
MFW	Main feedwater	318	304	14
MSS	Main steam	151	149	2
RCI	Reactor core isolation	326	294	32
RCS	Reactor coolant	165	159	6
RHR	Residual heat removal	2095	1837	258
SLC	Standby liquid control	17	17	
SWN	Emergency service water (Standby)	1020	755	265
SWS	Standby service water	265	195	70
VSS	Vapor suppression	21	19	2
	Total	8783	7689	1094

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.

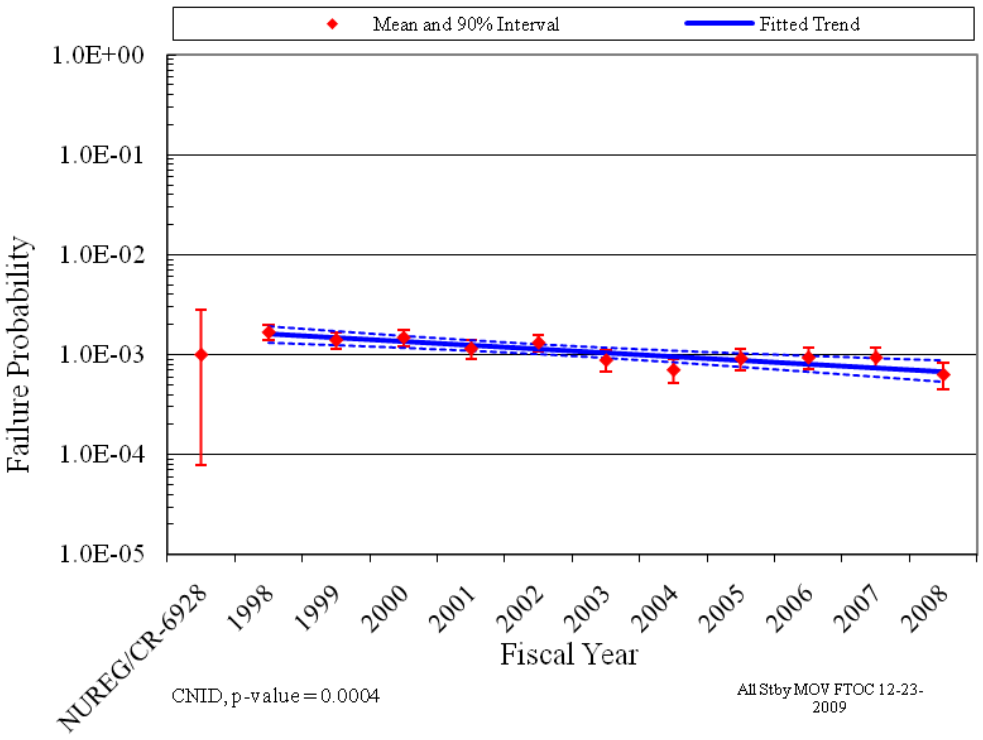

Figure 1. All systems, industry-wide MOV FTOC trend MOVs with <= 20 demands per year.

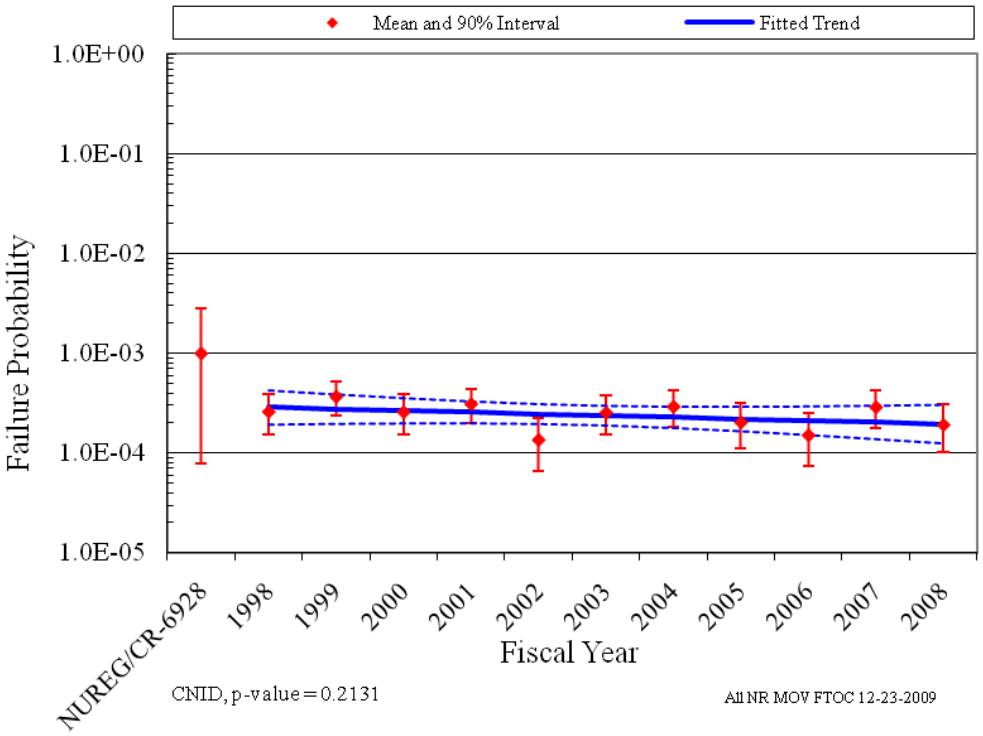

Figure 2. All systems, industry-wide MOV FTOC trend MOVs with > 20 demands per year.

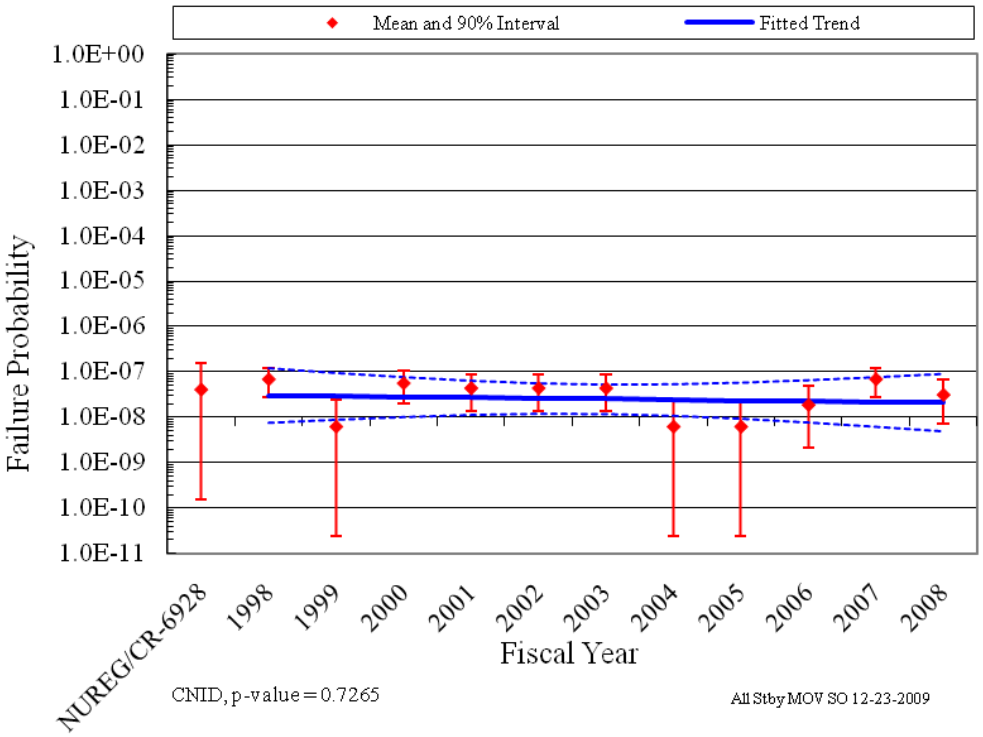

Figure 3. All systems, industry-wide MOV SO trend with <= 20 demands per year.

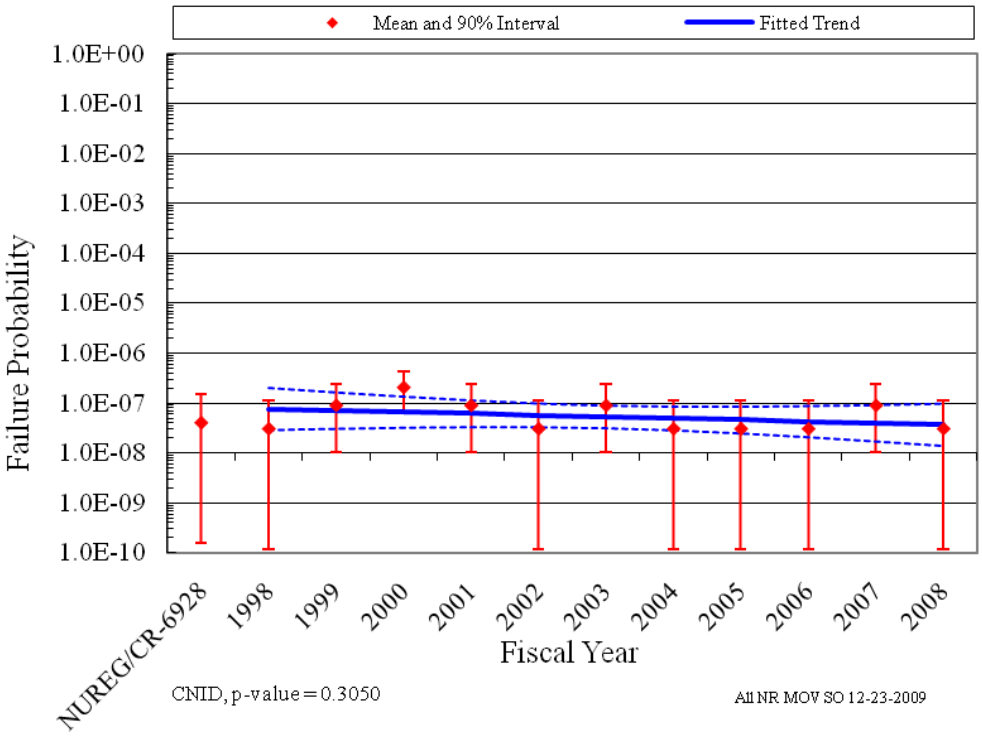

Figure 4. All systems, industry-wide MOV SO trend with > 20 demands per year.

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 major contributing systems for the FTOC failure mode are RHR, SWN, HPI, and RCI. Table 4 and Table 6 summarize the failures by system, year, and the SO failure mode. The major contributing systems for the SO failure mode are RHR, LCS, CCW, 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.

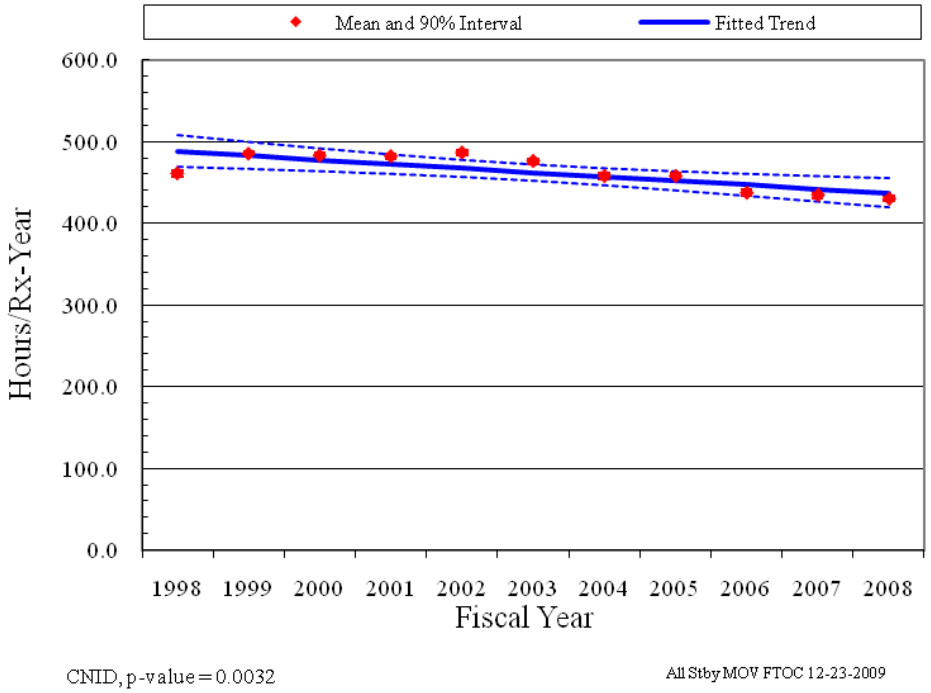

Figure 5. Frequency (demands per reactor year) of MOV operation demands, <= 20 demands per year.

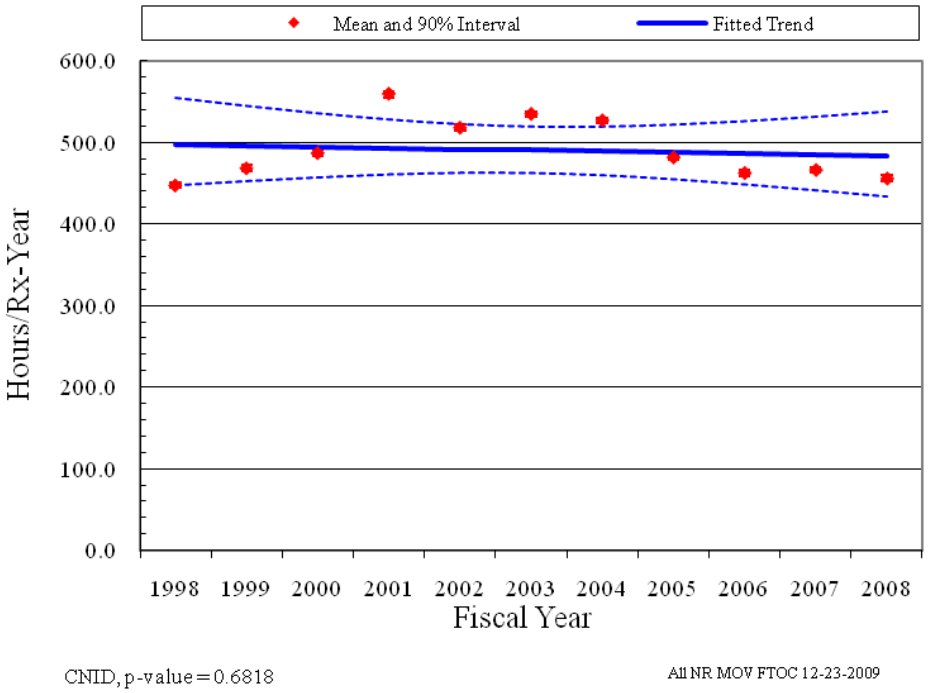

Figure 6. Frequency (demands per reactor year) of MOV operation demands, > 20 demands per year.

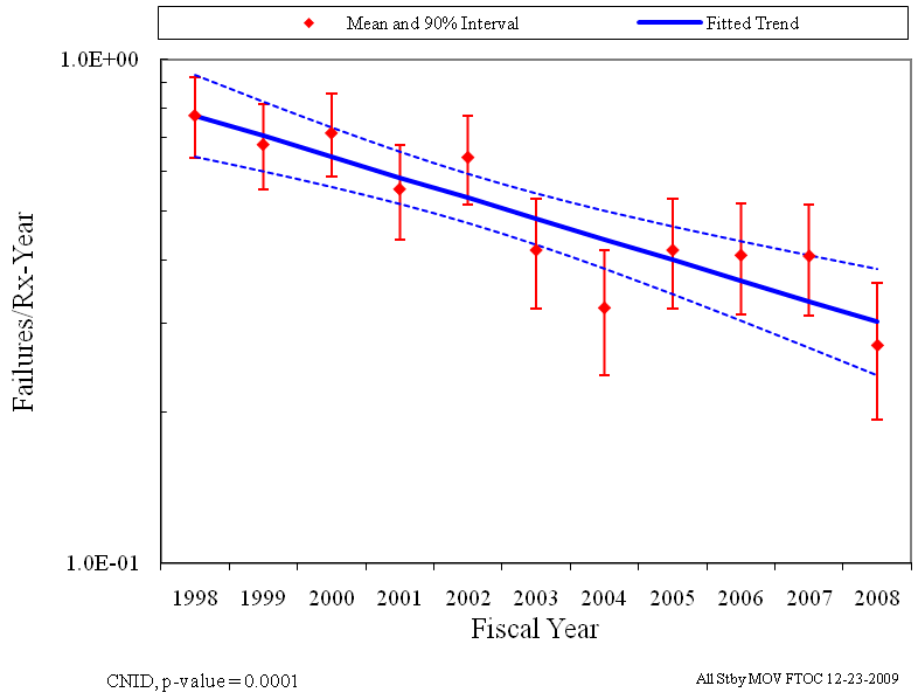

Figure 7. Frequency (failures per reactor year) of MOV FTOC events <= 20 demands per year.

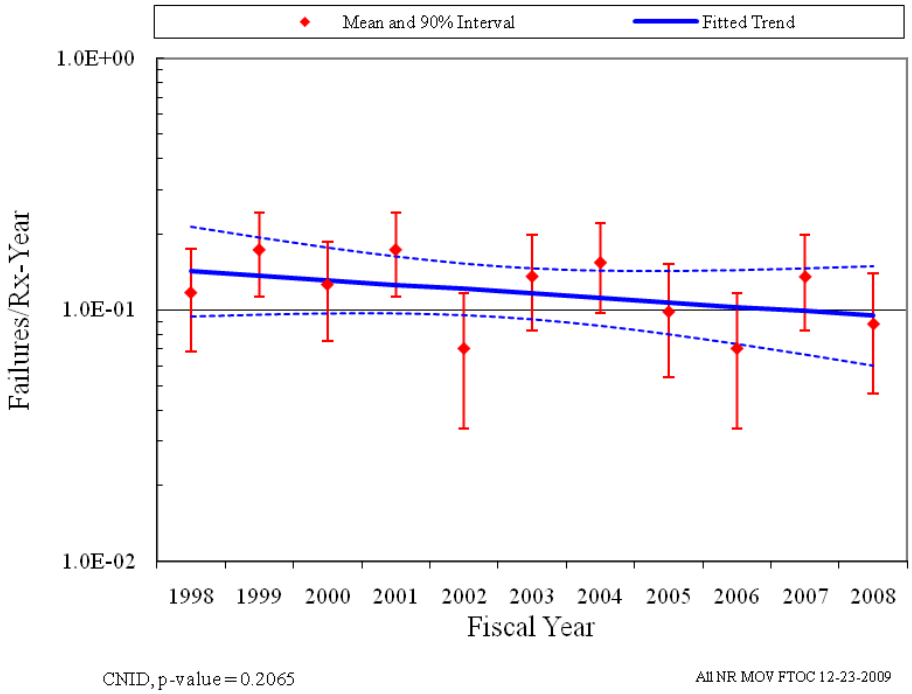

Figure 8. Frequency (failures per reactor year) of MOV FTOC events > 20 demands per year.

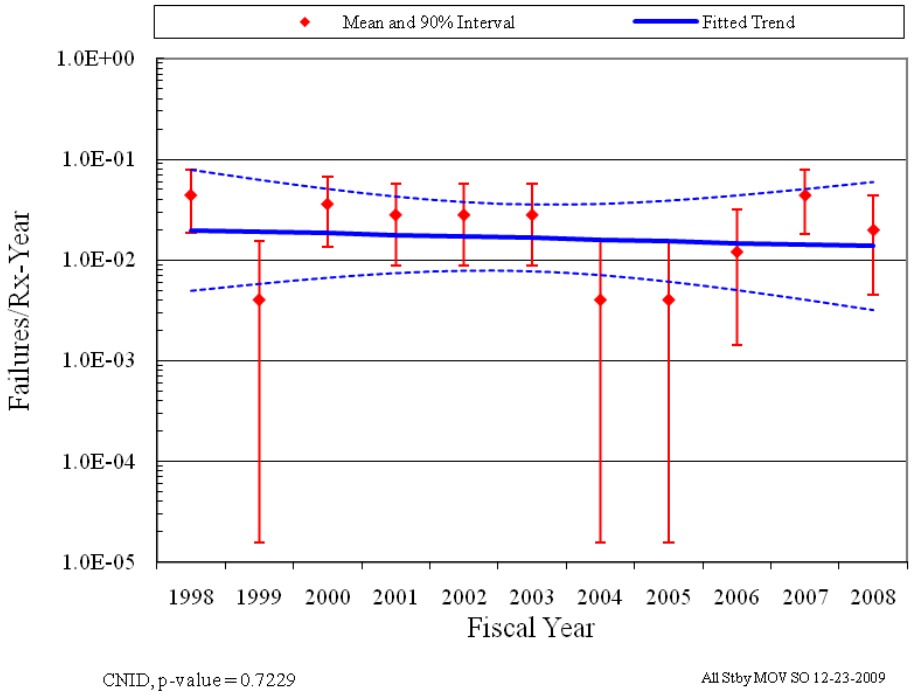

Figure 9. Frequency (failures per reactor year) of MOV SO events <= 20 demands per year.

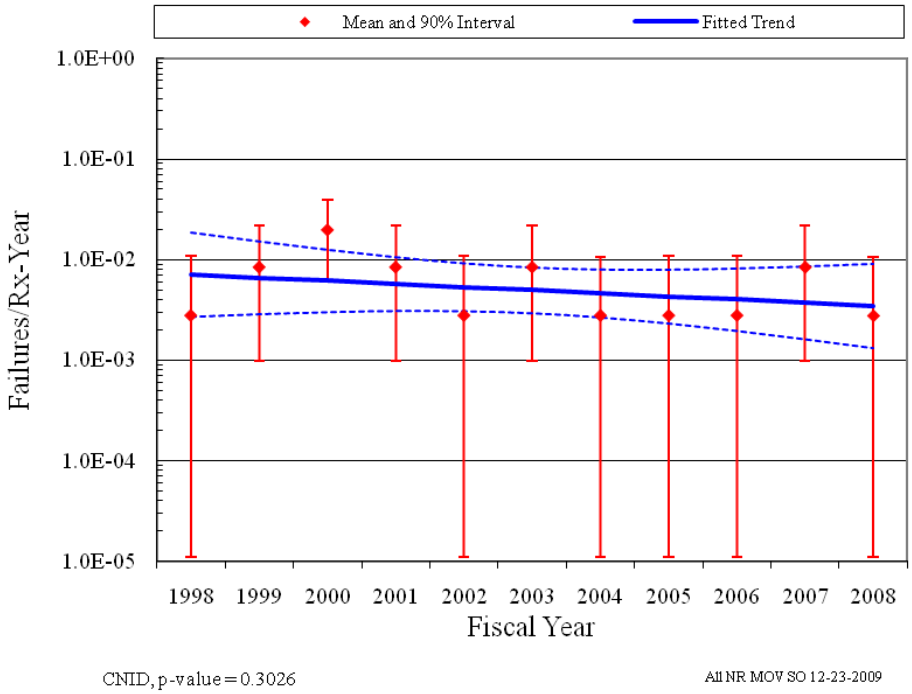

Figure 10. Frequency (failures per reactor year) of MOV SO events > 20 demands per year.

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*	*Total*	*Percent of Failures*
AFW	496	6.5%	4	5	7	5	7		2	3	2	2	2	39	6.7%
CCW	602	7.9%	4	1	4	5	4	3	1	1	2	1		26	4.5%
CHW	46	0.6%		1					1					2	0.3%
CIS	404	5.3%	6	2	2	3	5	4		2	2		3	29	5.0%
CRD	7	0.1%		1										1	0.2%
CSR	328	4.3%	2	2	2		2	1	2	1	1		1	14	2.4%
CTS	6	0.1%		1										1	0.2%
CVC	527	6.9%	3	3	5		1	2			1	2	1	18	3.1%
HCI	248	3.2%	4	3	2	3	2	2	2	2	3	9		32	5.5%
HCS	30	0.4%		1	1		1							3	0.5%
HPI	1008	13.2%	8	6	7	4	7	2	6	6	2	3	1	52	9.0%
HVC	23	0.3%	1	1			1							3	0.5%
ISO	20	0.3%		1	2	1			1	2				7	1.2%
LCS	201	2.6%	4	10	2	3	1	2			1	1		24	4.2%
MFW	304	4.0%	1	1		1		3	1	2	1	2	2	14	2.4%
MSS	149	1.9%		1	3	1	2	1	2	2		1	3	16	2.8%
RCI	294	3.8%	3	9	5	5	3	2	2	4	3	1	3	40	6.9%
RCS	159	2.1%				1			2	1	1			5	0.9%
RHR	1837	24.0%	18	16	22	11	23	11	9	14	16	18	8	166	28.7%
SWN	755	9.9%	8	5	8	12	4	7	2	2	7	1	4	60	10.4%
SWS	195	2.5%	14		2	2	2	1						21	3.6%
VSS	19	0.2%					1	2		1		1		5	0.9%
Total	7658	100.0%	80	70	74	57	66	43	33	43	42	42	28	578	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*	*Total*	*Percent of Failures*
AFW	496	8.4%	1			1								2	7.7%
CCW	602	10.2%					1	1					2	4	15.4%
CIS	404	6.9%				1								1	3.8%
CSR	328	5.6%				1								1	3.8%
CVC	527	9.0%			1									1	3.8%
HCI	248	4.2%	1									1		2	7.7%
LCS	201	3.4%									1	4		5	19.2%
RCI	294	5.0%			1		1							2	7.7%
RHR	1837	31.2%	2		2			1						5	19.2%
SWN	755	12.8%					1							1	3.8%
SWS	195	3.3%	1					1						2	7.7%
Total	5887	100.0%	5	0	4	3	3	3	0	0	1	5	2	26	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*	*Total*	*Percent of Failures*
AFW	70	6.5%	1	1	4	2	2	8	4	1		3	2	28	7.9%
CCW	146	13.5%	2	4	5	1		3	2	3			1	21	5.9%
CIS	33	3.1%	1	9	3	4	3	3	5	4	2	1	1	36	10.2%
CSR	14	1.3%		1		1		1		1		2	1	7	2.0%
CVC	38	3.5%		1	1	2		1			1	1		7	2.0%
HCI	20	1.9%					1			1	1		1	4	1.1%
HCS	17	1.6%			2	1							1	4	1.1%
HPI	68	6.3%	2		2	1	1	2	1			1		10	2.8%
HVC	4	0.4%	1	3	3	2	5	1			2	5	4	26	7.4%
LCS	21	1.9%	2	1	2	3	1	1	1		1		2	14	4.0%
MFW	14	1.3%	2	2	4	2	2		1	3	1	3	2	22	6.2%
MSS	2	0.2%	2	3	4	4	5	1	2	1		4		26	7.4%
RCI	32	3.0%	3	2		1			1	4			1	12	3.4%
RCS	6	0.6%	1		1	1	1			1				5	1.4%
RHR	258	23.9%	4	13	7	3	3	2	4	5	1	6	4	52	14.7%
SWN	265	24.5%	6	14	3	6	2	1	7	3	4	5	5	56	15.9%
SWS	70	6.5%	5		2	2	2	1	3	2	1	3	1	22	6.2%
VSS	2	0.2%											1	1	0.3%
Total	1080	100.0%	32	54	43	36	28	25	31	29	14	34	27	353	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*	*Total*	*Percent of Failures*
AFW	70	9.3%				1								1	5.3%
CIS	33	4.4%	1		1	1								3	15.8%
HVC	4	0.5%										1		1	5.3%
MFW	14	1.9%				1								1	5.3%
MSS	2	0.3%	1				1	1						3	15.8%
RCI	32	4.2%		1	2							1		4	21.1%
RCS	6	0.8%		1										1	5.3%
RHR	258	34.2%										1		1	5.3%
SWN	265	35.1%		1				1				1		3	15.8%
SWS	70	9.3%						1						1	5.3%
Total	0	100.0%	2	3	3	3	1	3	0	0	0	4	0	19	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	47450	1.60E-03	1.32E-03	1.94E-03	1.38E-03	2.00E-03	1.68E-03
1999	70	49898	1.47E-03	1.24E-03	1.73E-03	1.14E-03	1.68E-03	1.40E-03
2000	74	49808	1.35E-03	1.17E-03	1.55E-03	1.21E-03	1.77E-03	1.48E-03
2001	57	49584	1.24E-03	1.10E-03	1.40E-03	9.11E-04	1.41E-03	1.15E-03
2002	66	50049	1.14E-03	1.01E-03	1.27E-03	1.06E-03	1.59E-03	1.32E-03
2003	43	48993	1.04E-03	9.26E-04	1.18E-03	6.72E-04	1.11E-03	8.80E-04
2004	33	47242	9.59E-04	8.38E-04	1.10E-03	5.15E-04	9.12E-04	7.02E-04
2005	43	47109	8.81E-04	7.52E-04	1.03E-03	6.98E-04	1.15E-03	9.15E-04
2006	42	45024	8.09E-04	6.72E-04	9.74E-04	7.11E-04	1.18E-03	9.35E-04
2007	42	44913	7.43E-04	5.99E-04	9.22E-04	7.13E-04	1.18E-03	9.37E-04
2008	28	44829	6.82E-04	5.32E-04	8.75E-04	4.49E-04	8.34E-04	6.29E-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	46066	2.89E-04	1.94E-04	4.30E-04	1.52E-04	3.91E-04	2.60E-04
1999	18	48218	2.78E-04	1.97E-04	3.91E-04	2.40E-04	5.19E-04	3.68E-04
2000	13	50262	2.67E-04	1.99E-04	3.57E-04	1.54E-04	3.84E-04	2.58E-04
2001	18	57565	2.57E-04	2.00E-04	3.30E-04	2.02E-04	4.38E-04	3.11E-04
2002	7	53306	2.47E-04	1.97E-04	3.09E-04	6.56E-05	2.26E-04	1.36E-04
2003	14	55040	2.37E-04	1.90E-04	2.96E-04	1.55E-04	3.73E-04	2.54E-04
2004	16	54378	2.28E-04	1.79E-04	2.90E-04	1.85E-04	4.20E-04	2.93E-04
2005	10	49592	2.19E-04	1.66E-04	2.90E-04	1.12E-04	3.16E-04	2.03E-04
2006	7	47628	2.11E-04	1.52E-04	2.92E-04	7.31E-05	2.52E-04	1.51E-04
2007	14	48183	2.03E-04	1.38E-04	2.97E-04	1.76E-04	4.24E-04	2.89E-04
2008	9	47523	1.95E-04	1.25E-04	3.04E-04	1.02E-04	3.04E-04	1.92E-04

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	67425720	3.01E-08	7.57E-09	1.20E-07	2.81E-08	1.21E-07	6.76E-08
1999	0	67355640	2.91E-08	8.86E-09	9.54E-08	2.42E-11	2.36E-08	6.15E-09
2000	4	67355640	2.81E-08	1.02E-08	7.75E-08	2.04E-08	1.04E-07	5.53E-08
2001	3	67355640	2.71E-08	1.13E-08	6.50E-08	1.33E-08	8.65E-08	4.30E-08
2002	3	67355640	2.62E-08	1.19E-08	5.73E-08	1.33E-08	8.65E-08	4.30E-08
2003	3	67355640	2.52E-08	1.18E-08	5.40E-08	1.33E-08	8.65E-08	4.30E-08
2004	0	67355640	2.44E-08	1.08E-08	5.49E-08	2.42E-11	2.36E-08	6.15E-09
2005	0	67355640	2.35E-08	9.34E-09	5.93E-08	2.42E-11	2.36E-08	6.15E-09
2006	1	67355640	2.27E-08	7.72E-09	6.68E-08	2.16E-09	4.80E-08	1.84E-08
2007	5	67355640	2.19E-08	6.21E-09	7.74E-08	2.81E-08	1.21E-07	6.76E-08
2008	2	67355640	2.12E-08	4.91E-09	9.11E-08	7.04E-09	6.81E-08	3.07E-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	9583440	7.67E-08	2.94E-08	2.01E-07	1.18E-10	1.16E-07	3.01E-08
1999	1	9583440	7.14E-08	3.12E-08	1.63E-07	1.06E-08	2.35E-07	9.03E-08
2000	3	9583440	6.64E-08	3.27E-08	1.35E-07	6.52E-08	4.23E-07	2.11E-07
2001	1	9583440	6.18E-08	3.36E-08	1.14E-07	1.06E-08	2.35E-07	9.03E-08
2002	0	9583440	5.75E-08	3.35E-08	9.88E-08	1.18E-10	1.16E-07	3.01E-08
2003	1	9583440	5.35E-08	3.19E-08	8.97E-08	1.06E-08	2.35E-07	9.03E-08
2004	0	9583440	4.98E-08	2.90E-08	8.56E-08	1.18E-10	1.16E-07	3.01E-08
2005	0	9583440	4.63E-08	2.52E-08	8.53E-08	1.18E-10	1.16E-07	3.01E-08
2006	0	9583440	4.31E-08	2.12E-08	8.78E-08	1.18E-10	1.16E-07	3.01E-08
2007	1	9583440	4.01E-08	1.75E-08	9.21E-08	1.06E-08	2.35E-07	9.03E-08
2008	0	9583440	3.73E-08	1.42E-08	9.78E-08	1.18E-10	1.16E-07	3.01E-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	47450	103.0	4.88E+02	4.69E+02	5.08E+02	4.57E+02	4.64E+02	4.61E+02
1999	49898	103.0	4.83E+02	4.67E+02	5.00E+02	4.81E+02	4.88E+02	4.84E+02
2000	49808	103.3	4.78E+02	4.64E+02	4.92E+02	4.79E+02	4.86E+02	4.82E+02
2001	49584	103.0	4.72E+02	4.61E+02	4.84E+02	4.78E+02	4.85E+02	4.81E+02
2002	50049	103.0	4.67E+02	4.57E+02	4.78E+02	4.82E+02	4.89E+02	4.86E+02
2003	48993	103.0	4.62E+02	4.52E+02	4.72E+02	4.72E+02	4.79E+02	4.76E+02
2004	47242	103.3	4.57E+02	4.47E+02	4.67E+02	4.54E+02	4.61E+02	4.57E+02
2005	47109	103.0	4.52E+02	4.40E+02	4.64E+02	4.54E+02	4.61E+02	4.57E+02
2006	45024	103.0	4.47E+02	4.34E+02	4.61E+02	4.34E+02	4.41E+02	4.37E+02
2007	44913	103.4	4.42E+02	4.27E+02	4.58E+02	4.31E+02	4.38E+02	4.35E+02
2008	44829	104.3	4.37E+02	4.20E+02	4.55E+02	4.27E+02	4.33E+02	4.30E+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	46066	103.0	4.98E+02	4.47E+02	5.54E+02	4.44E+02	4.51E+02	4.47E+02
1999	48218	103.0	4.96E+02	4.53E+02	5.44E+02	4.65E+02	4.72E+02	4.68E+02
2000	50262	103.3	4.95E+02	4.57E+02	5.35E+02	4.83E+02	4.90E+02	4.87E+02
2001	57565	103.0	4.93E+02	4.61E+02	5.28E+02	5.55E+02	5.63E+02	5.59E+02
2002	53306	103.0	4.92E+02	4.63E+02	5.22E+02	5.14E+02	5.21E+02	5.18E+02
2003	55040	103.0	4.90E+02	4.63E+02	5.19E+02	5.31E+02	5.38E+02	5.34E+02
2004	54378	103.3	4.89E+02	4.60E+02	5.19E+02	5.23E+02	5.30E+02	5.27E+02
2005	49592	103.0	4.87E+02	4.55E+02	5.21E+02	4.78E+02	4.85E+02	4.81E+02
2006	47628	103.0	4.86E+02	4.49E+02	5.26E+02	4.59E+02	4.66E+02	4.62E+02
2007	48183	103.4	4.84E+02	4.41E+02	5.31E+02	4.63E+02	4.70E+02	4.66E+02
2008	47523	104.3	4.83E+02	4.33E+02	5.37E+02	4.52E+02	4.59E+02	4.56E+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	7.74E-01	6.42E-01	9.34E-01	6.38E-01	9.21E-01	7.74E-01
1999	70	103.0	7.04E-01	6.01E-01	8.26E-01	5.51E-01	8.16E-01	6.78E-01
2000	74	103.3	6.41E-01	5.59E-01	7.35E-01	5.84E-01	8.56E-01	7.15E-01
2001	57	103.0	5.83E-01	5.18E-01	6.57E-01	4.39E-01	6.78E-01	5.53E-01
2002	66	103.0	5.31E-01	4.74E-01	5.94E-01	5.16E-01	7.74E-01	6.40E-01
2003	43	103.0	4.83E-01	4.29E-01	5.43E-01	3.20E-01	5.28E-01	4.18E-01
2004	33	103.3	4.39E-01	3.85E-01	5.02E-01	2.36E-01	4.18E-01	3.21E-01
2005	43	103.0	4.00E-01	3.43E-01	4.67E-01	3.20E-01	5.28E-01	4.18E-01
2006	42	103.0	3.64E-01	3.03E-01	4.36E-01	3.11E-01	5.17E-01	4.09E-01
2007	42	103.4	3.31E-01	2.68E-01	4.09E-01	3.10E-01	5.15E-01	4.07E-01
2008	28	104.3	3.01E-01	2.36E-01	3.84E-01	1.93E-01	3.59E-01	2.71E-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	1.42E-01	9.45E-02	2.14E-01	6.82E-02	1.76E-01	1.17E-01
1999	18	103.0	1.37E-01	9.61E-02	1.94E-01	1.12E-01	2.44E-01	1.73E-01
2000	13	103.3	1.31E-01	9.72E-02	1.77E-01	7.52E-02	1.87E-01	1.26E-01
2001	18	103.0	1.26E-01	9.72E-02	1.63E-01	1.12E-01	2.44E-01	1.73E-01
2002	7	103.0	1.21E-01	9.56E-02	1.53E-01	3.39E-02	1.17E-01	7.00E-02
2003	14	103.0	1.16E-01	9.21E-02	1.46E-01	8.27E-02	1.99E-01	1.35E-01
2004	16	103.3	1.12E-01	8.68E-02	1.43E-01	9.72E-02	2.21E-01	1.54E-01
2005	10	103.0	1.07E-01	8.03E-02	1.43E-01	5.41E-02	1.53E-01	9.80E-02
2006	7	103.0	1.03E-01	7.34E-02	1.44E-01	3.39E-02	1.17E-01	7.00E-02
2007	14	103.4	9.87E-02	6.66E-02	1.46E-01	8.24E-02	1.98E-01	1.35E-01
2008	9	104.3	9.48E-02	6.02E-02	1.49E-01	4.67E-02	1.39E-01	8.77E-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	1.97E-02	4.96E-03	7.84E-02	1.84E-02	7.91E-02	4.42E-02
1999	0	103.0	1.90E-02	5.80E-03	6.24E-02	1.58E-05	1.54E-02	4.02E-03
2000	4	103.3	1.84E-02	6.65E-03	5.06E-02	1.33E-02	6.78E-02	3.61E-02
2001	3	103.0	1.77E-02	7.39E-03	4.24E-02	8.71E-03	5.65E-02	2.81E-02
2002	3	103.0	1.71E-02	7.81E-03	3.74E-02	8.71E-03	5.65E-02	2.81E-02
2003	3	103.0	1.65E-02	7.71E-03	3.53E-02	8.71E-03	5.65E-02	2.81E-02
2004	0	103.3	1.59E-02	7.07E-03	3.58E-02	1.58E-05	1.54E-02	4.01E-03
2005	0	103.0	1.53E-02	6.09E-03	3.86E-02	1.58E-05	1.54E-02	4.02E-03
2006	1	103.0	1.48E-02	5.04E-03	4.35E-02	1.41E-03	3.14E-02	1.21E-02
2007	5	103.4	1.43E-02	4.05E-03	5.04E-02	1.83E-02	7.88E-02	4.41E-02
2008	2	104.3	1.38E-02	3.20E-03	5.93E-02	4.56E-03	4.40E-02	1.99E-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	7.14E-03	2.73E-03	1.87E-02	1.10E-05	1.07E-02	2.80E-03
1999	1	103.0	6.64E-03	2.90E-03	1.52E-02	9.85E-04	2.19E-02	8.39E-03
2000	3	103.3	6.18E-03	3.04E-03	1.25E-02	6.06E-03	3.93E-02	1.96E-02
2001	1	103.0	5.75E-03	3.13E-03	1.06E-02	9.85E-04	2.19E-02	8.39E-03
2002	0	103.0	5.34E-03	3.11E-03	9.17E-03	1.10E-05	1.07E-02	2.80E-03
2003	1	103.0	4.97E-03	2.97E-03	8.33E-03	9.85E-04	2.19E-02	8.39E-03
2004	0	103.3	4.62E-03	2.69E-03	7.95E-03	1.10E-05	1.07E-02	2.79E-03
2005	0	103.0	4.30E-03	2.34E-03	7.92E-03	1.10E-05	1.07E-02	2.80E-03
2006	0	103.0	4.00E-03	1.97E-03	8.14E-03	1.10E-05	1.07E-02	2.80E-03
2007	1	103.4	3.72E-03	1.62E-03	8.54E-03	9.83E-04	2.18E-02	8.38E-03
2008	0	104.3	3.46E-03	1.32E-03	9.07E-03	1.09E-05	1.07E-02	2.78E-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.