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Enhanced Component Performance Study: Motor-Operated Valves 1998–2014

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ABSTRACT

This report presents an enhanced performance evaluation of motor-operated valves (MOVs) at U.S. commercial nuclear power plants. The data used in this study are based on the operating experience failure reports from fiscal year 1998 through 2014 for the component reliability as reported in the Institute of Nuclear Power Operations (INPO) Consolidated Events Database (ICES). The MOV failure modes considered are failure to open/close, failure to operate or control, and spurious operation (SO). The component reliability estimates and the reliability data are trended for the most recent 10-year period while yearly estimates for reliability are provided for the entire active period. One extremely statistically significant decreasing trend was observed for the frequency of valve fail-to-open/close demands per reactor year for low demand valves. One highly statistically significant decreasing trend was observed for the failure frequency of valve fail-to-open/close events for low demand valves. Two statistically significant decreasing trends were observed in the data: The frequency of demands per reactor year for valves with fail-to-open/close failure modes, for valves high-demand valves, was found to be decreasing, and the failure probability estimate for valve fail-to-open/close for low-demand valves was found to be decreasing.

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ACRONYMS

AFW	Auxiliary feed water
CCW	component cooling water
CNID	constrained non-informative prior distribution
CRD	control rod drive
CSR	containment spray recirculation
CVC	chemical and volume control
EPS	emergency power supply
FTOC	failure-to-open/close (failure to operate)
FTOP	failure to operate or control
FY	fiscal year
GLM	generalized linear model
HCI	high-pressure coolant injection
HCS	high-pressure core spray
HPI	high-pressure injection
ICES	INPO Consolidated Events Database
INPO	Institute of Nuclear Power Operations
ISO	isolation condenser
LCS	low-pressure core spray
MOV	motor-operated valve
MSPI	Mitigating Systems Performance Index
OLS	ordinary least squares
PRA	probabilistic risk assessment
RCI	reactor core isolation
RCS	reactor coolant
RHR	residual heat removal
SO	spurious operation
SWN	normally running service water
SWS	standby service water
TDP	turbine-driven pump
UA	unavailability
VSS	vapor suppression

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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. The 2010 Component Reliability Update [1], which is an update to NUREG/CR-6928 [2], reports the MOV unreliability estimates using Institute of Nuclear Power Operations (INPO) Consolidated Events Database (ICES) data from 1998 through 2010 for use in PRAs [3].

Annual failure rate estimates are trended for the most recent 10-year period, similar to the NRC's Industry Trend Program [4]. Yearly estimates have been provided for the entire active period.

The data used in this study are based on the operating experience failure reports from fiscal year (FY) 1998 through FY 2014 for the component reliability as reported in ICES. The MOV failure modes considered are failure-to-open/close (FTOC), failure to operate or control (FTOP), and spurious operation (SO). The component reliability estimates and the reliability data are trended for the most recent 10-year period while yearly estimates for reliability are provided for the entire active period.

This study is modeled on the web page updates associated with the NUREG/CR-1715 series of reports [5], which were published around 2000. Those studies relied on operating experience obtained from licensee event reports, Nuclear Plant Reliability Data System, and ICES. The ICES database, which includes as a subset the Mitigating Systems Performance Index (MSPI) designated devices [6], 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, present an analysis of factors that could influence the system, provide component trends, annual performance trends of failure rates, and probabilities. Engineering analyses were performed with respect to time period and failure mode (Section 4.1). The factors analyzed are sub-component, failure cause, detection method, and recovery.

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 [7].

2. SUMMARY OF FINDINGS

The results of this study are summarized in this section. Of particular interest is the existence of any statistically significant[a] increasing trends. In this update one statistically significant trend was identified in the MOV data.

2.1 Increasing Trends

2.1.1 Extremely Statistically Significant

- None.

2.1.2 Highly Statistically Significant

- None.

2.1.3 Statistically Significant

- None.

2.2 Decreasing Trends

2.2.1 Extremely Statistically Significant

- The frequency of ≤ 20 MOV FTOC demands per reactor year (see Figure 7) was independently re-evaluated using a Poisson generalized linear model (GLM) rather than the iteratively re-weighted least squares routine currently built into the annual update software and was found to be extremely statistically significant.

2.2.2 Highly Statistically Significant

- The frequency (failures per reactor year) of MOV FTOC events where demands ≤ 20 per year. (see Figure 9) was independently re-evaluated using a Normal GLM instead of the iteratively re-weighted least squares routine currently built into the annual update software and was found to be highly statistically significant.

2.2.3 Statistically Significant

- The frequency of demands per reactor year for valves with fail-to-open/close failure modes, for valves with greater than twenty demands per year, was found to be decreasing (Figure 8).
- The failure probability estimate trend for MOV FTOC, all systems, industry-wide trend of MOVs with ≤ 20 demands per year (see Figure 1) was separately re-evaluated utilizing a Poisson GLM rather than the iteratively re-weighted least squares routine currently built into the annual update software and was found to be statistically significant.

a. 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).

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, FTOP, and SO failure modes. The MOV data set obtained from ICES was segregated for MOVs with ≤ 20 demands per year and MOVs with > 20 demands per year. The data set includes MOVs in the systems listed in Table 1. NUREG/CR-6928 lists the industry failure data for MOVs with ≤ 20 demands per year. Table 2 shows industry-wide failure probability and failure rate results for the MOV with ≤ 20 demands per year from [1]. No results are shown for > 20 demands per year MOVs because [1] does not present results for > 20 demands per year.

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, engineered safety feature demands.

Table 1. Summary of MOV counts in the systems in which they are found.

		MOV Count		
System	**Description**	**Total**	**≤ 20 demands/yr**	**> 20 demands/yr**
AFW	Auxiliary feed water	581	448	133
CCW	Component cooling water	836	675	161
CRD	Control rod drive	25	10	15
CSR	Containment spray recirculation	347	326	21
CVC	Chemical and volume control	13	13	0
HCI	High pressure coolant injection	270	247	23
HCS	High pressure core spray	47	28	19
HPI	High pressure injection	1079	963	116
ISO	Isolation condenser	20	14	6
LCS	Low pressure core spray	234	205	29
RCI	Reactor core isolation	335	303	32
RCS	Reactor coolant	109	102	7
RHR	Residual heat removal	2106	1807	299
SWN	Normally running service water	952	682	270
SWS	Standby service water	284	193	91
VSS	Vapor suppression	14	14	0
	Total	7252	6030	1222

Table 2. 2010 Update industry-wide distributions of p (failure probability) and λ (hourly rate) for MOVs with ≤ 20 demands per year [1].

					Distribution		
Failure Mode	**5%**	**Median**	**Mean**	**95%**	**Type**	α	β
FTOC	1.76E−04	8.12E−04	9.63E−04	2.27E−03	Beta	2.05	2.123E+03
FTOP	7.40E−09	5.18E−08	6.62E−08	1.74E−07	Gamma	1.46	2.205E+07
SO	2.54E−10	1.72E−08	3.39E−08	1.24E−07	Gamma	0.57	1.684E+07

3.2 MOV Failure Probability and Failure Rate Trends

Trends in failure probabilities and failure rates are shown in Figures 1–6. The data for the trend plots are contained in Tables 10–15, respectively.

The annual failure rate estimates in the plots were obtained from a Bayesian update process. The means from the posterior distributions were plotted for each year. The 5th and 95th percentiles from the posterior distributions are also provided and give an indication of the relative uncertainty in the estimated parameters from year to year. When there are no failures, the uncertainty interval tends to be 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 sometimes strongly influenced by the prior distribution. In each plot, a relatively "weak" constrained non-informative prior distribution (CNID) is used, which has large bounds. For probabilities, the posterior means for each year are calculated from)

$$mean = \frac{failures + 0.5}{demands + 1} \tag{1}$$

For rates, the posterior means for each year are calculated from

$$mean = \frac{failures + 0.5}{operting\ hours} \tag{2}$$

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 therefore could exist. A final feature of the trend graphs is that the baseline industry-average values recommended for PRA use (Table 2) are shown for comparison.

The regression methods are all based on "ordinary least squares" (OLS); which minimizes the square of the vertical distance between the annual estimate data points and the regression line. The p-values assume normal distributions for the data in each year, with a constant variance across the years. In the case where the data involve failure counts, the method of iterative reweighing accounts for the fact that count data are not expected to have a constant variance (for example, the variance for Poisson-distributed counts is equal to the expected number of counts). Further information on the trending methods is provided in Section 2 of the Overview and Reference document [7].

GLM regression is a trending method that accounts for the expected variance of the count data. The method is based on maximizing the likelihood of the observed data. It uses the actual data—counts and demands or time; no transformation of the input data are needed. It can also be applied to ordinary data that might be normally-distributed, in which case it gives the same result if the sample is large enough. In this study, the GLM method was applied using the R [8] and SAS [9] statistical packages for those cases where the p-value was less than or equal to 0.10. Instances have occurred where the p-value from OLS is less than 0.05 but the GLM p-value exceeds 0.05. In these instances, the GLM method is believed to be more reliable because it accounts for more of the features present in the data.

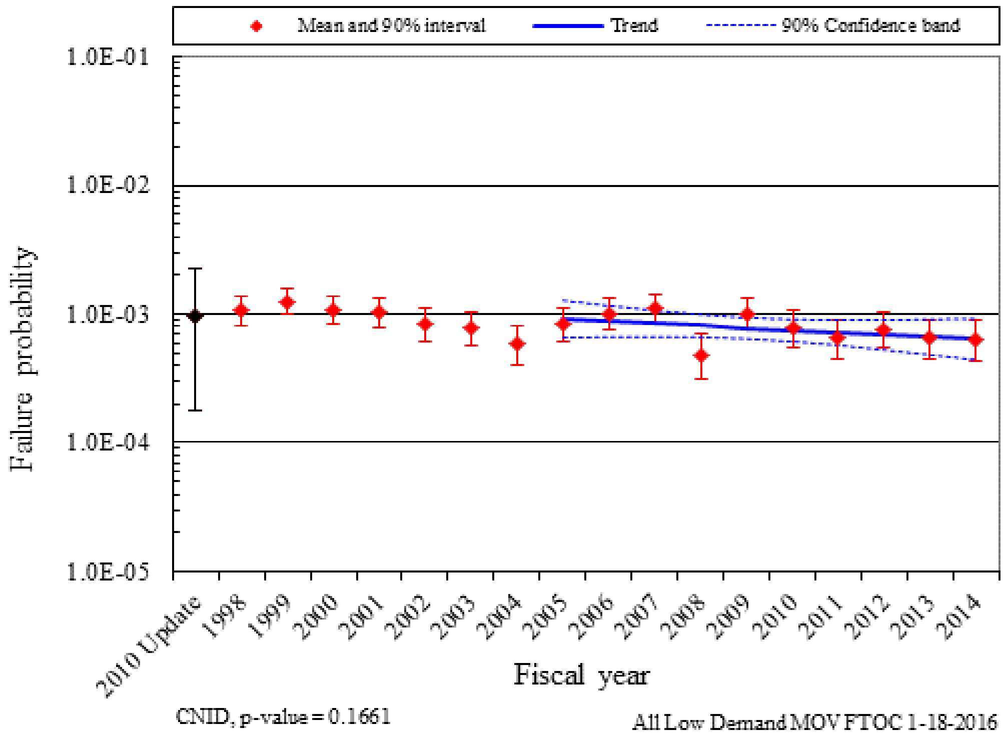

Figure 1. Failure probability estimate trend for MOV FTOC, all systems, industry-average trend of MOVs with ≤ 20 demands per a year.

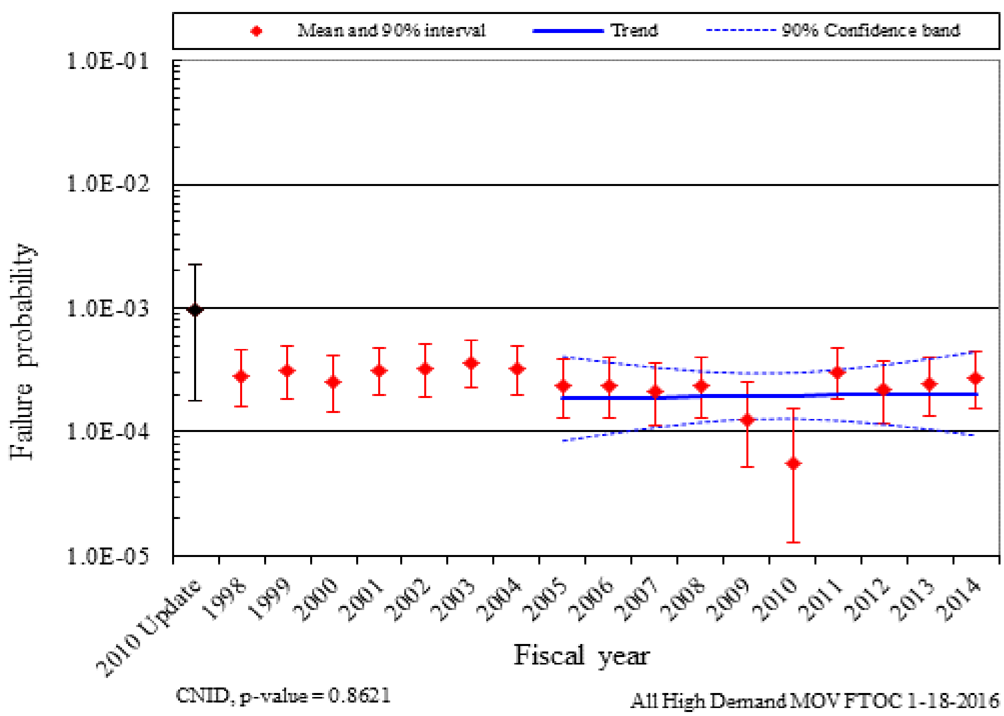

Figure 2. Failure probability estimate trend for MOV FTOC, all systems, industry-average trend of MOVs with > 20 demands per a year.

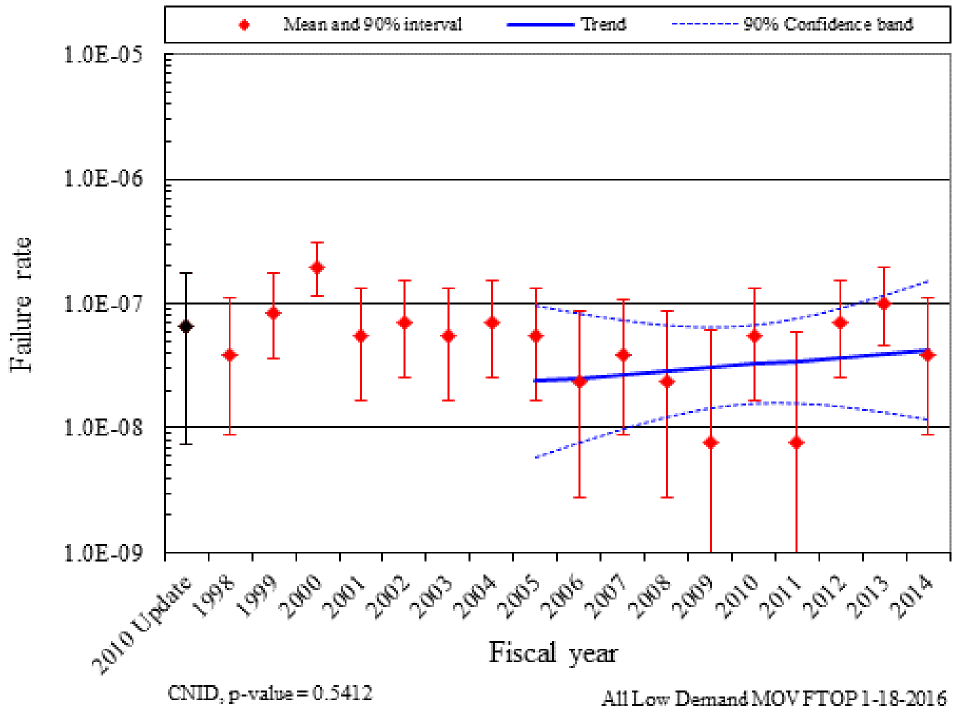

Figure 3. Failure rate estimate trend for MOV FTOP, all systems, industry-wide trend of MOVs with ≤ 20 demands per a year.

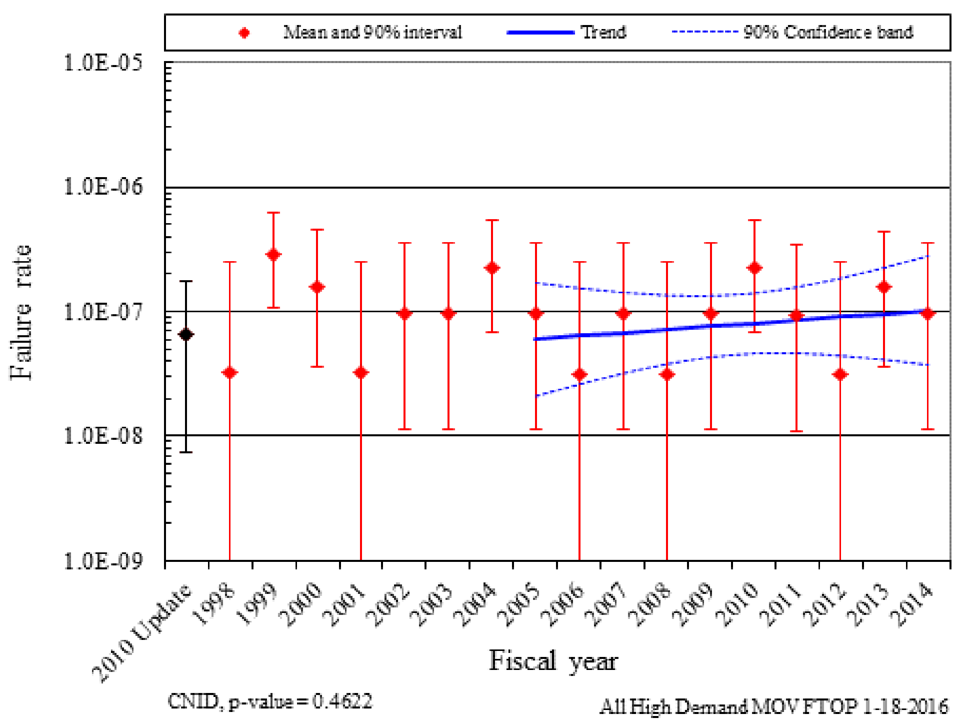

Figure 4. Failure rate estimate trend for MOV FTOP, all systems, industry-wide trend of MOVs with > 20 demands per year.

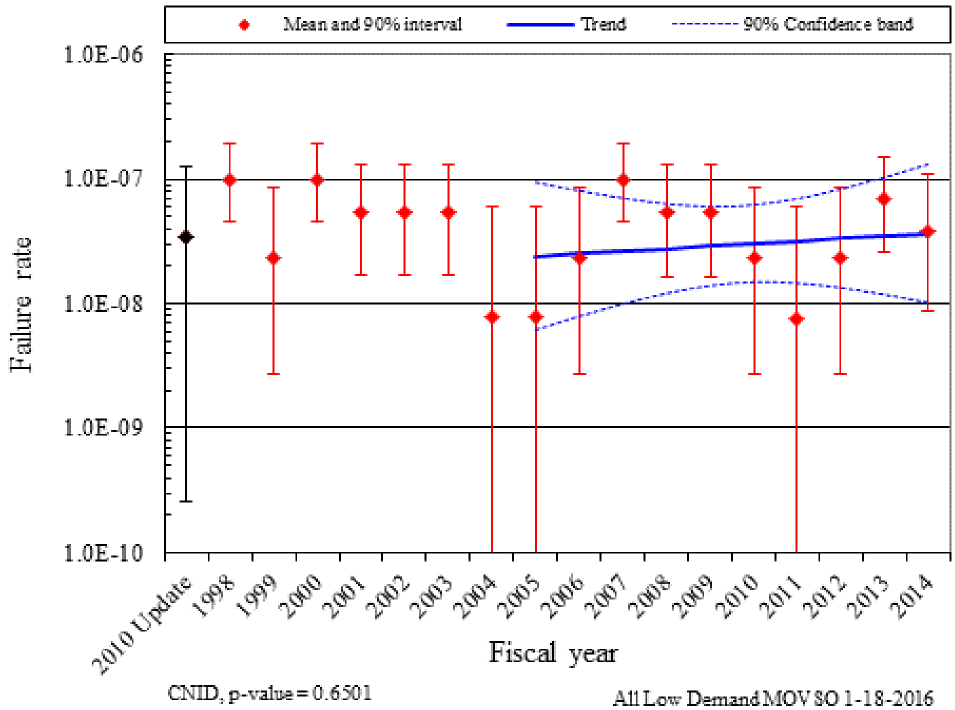

Figure 5. Failure rate estimate trend for MOV SO, all systems, industry-wide trend of MOVs with ≤ 20 demands per year.

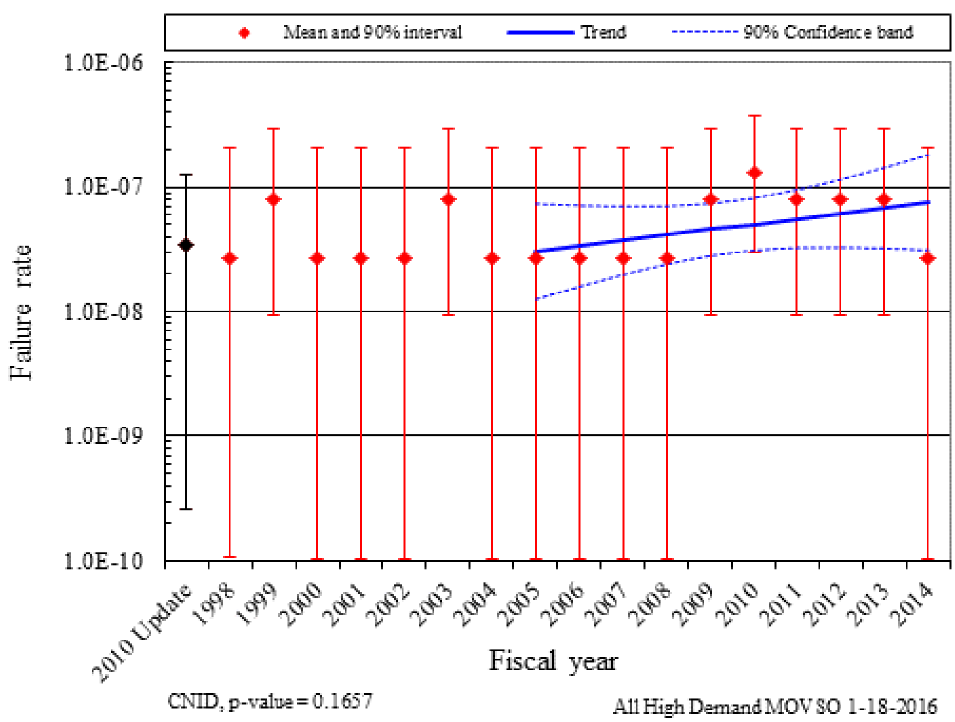

Figure 6. Failure rate estimate trend for MOV SO, all systems, industry-wide trend of MOVs with > 20 demands per year.

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 7 shows the trend for total MOV FTOC demands of ≤ 20 demands per reactor-year. Figure 9 shows the trend in failure events for FTOC mode for MOV ≤ 20 demands, Figure 11 shows the trend in failure events for FTOP mode for MOV ≤ 20 demands, and Figure 13 shows the trend for the SO failure events for MOV ≤ 20 demands.

Figure 8 shows the trend for total MOV demands of > 20 demands per reactor-year. Figure 10 shows the trend in failure events for FTOC mode for MOV > 20 demands, Figure 12 shows the trend in failure events for FTOP mode for MOV > 20 demands, and Figure 14 shows the trend for the SO failure events for MOV > 20 demands.

Table 3 summarizes the failures by system, year, and the FTOC failure mode of MOV ≤ 20 demands. The systems contributing 50% or more (in bold) to the FTOC failure mode in Table 3 are AFW, CCW, HCI, HPI, LCS, RCI, RHR, and SWN. Table 4 summarizes the failures by system, year, and the FTOP failure mode of MOV ≤ 20 demands. The systems contributing 50% or more (in bold) to the FTOP failure mode in Table 4 are AFW, CCW, HPI, RHR, and SWN.

Table 5 summarizes the failures by system, year, and the SO failure mode of MOV ≤ 20 demands. The systems contributing 50% or more (in bold) to the SO failure mode in Table
are CCW, LCS, RCI, and RHR.

Table 6 summarizes the failures by system, year, and the FTOC failure mode of MOV > 20 demands. The systems contributing 50% or more (in bold) to the FTOC failure mode in Table 6 are AFW, CCW, RCI, RHR, SWN, and SWS. Table 7 summarizes the failures by system, year, and the FTOP failure mode of MOV > 20 demands. The systems contributing 50% or more (in bold) to the FTOP failure mode in Table 7 are AFW, CCW, LCS, RHR, SWN, and SWS. Table 8 summarizes the failures by system, year, and the SO failure mode of MOV > 20 demands. The contributing systems in Table 8 for the SO failure mode are RCI, RHR, and SWN.

Tables 16–23 provide the frequency (per reactor year) of MOV demands, FTOC events, FTOP 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 [7].

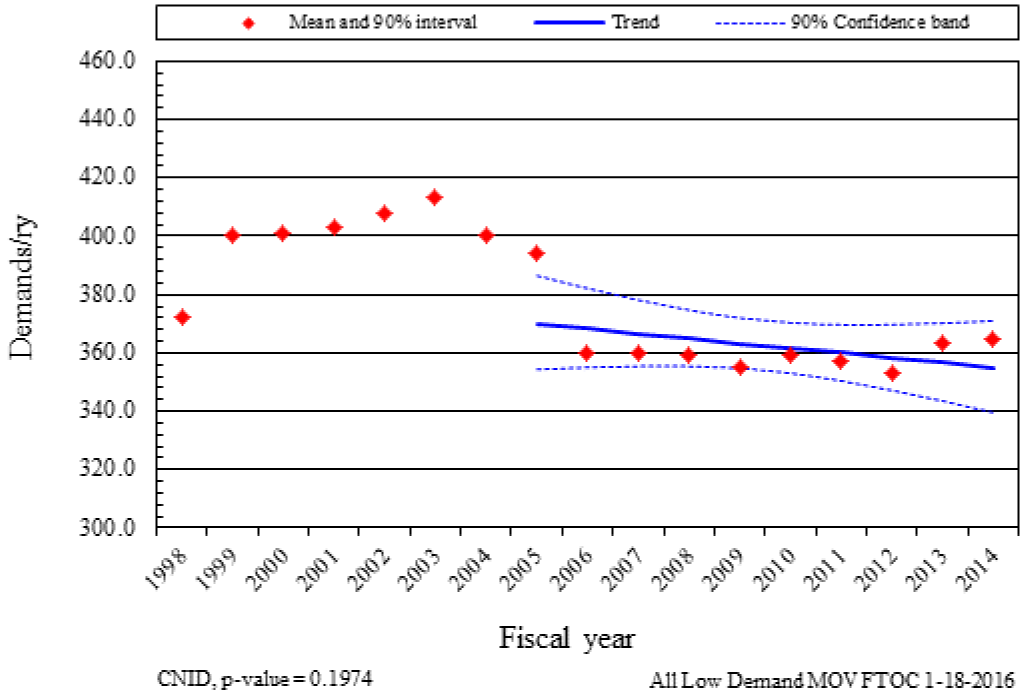

Figure 7. Frequency (demands per reactor year) of MOV FTOC demands, ≤ 20 demands per year.

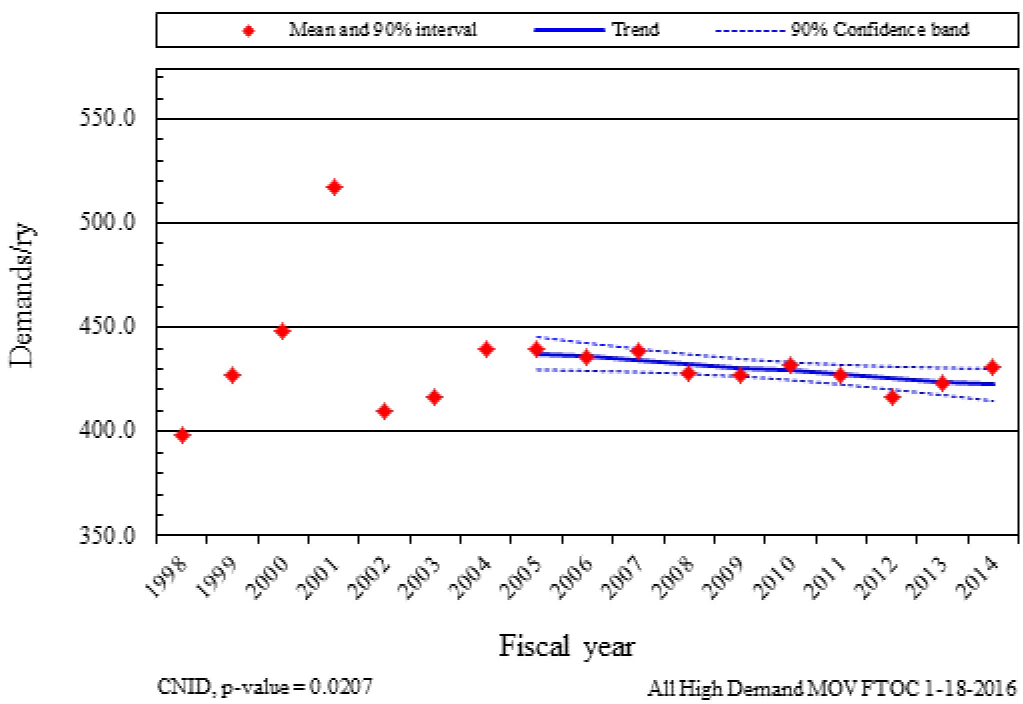

Figure 8. Frequency (demands per reactor year) of MOV FTOC demands, > 20 demands per year.

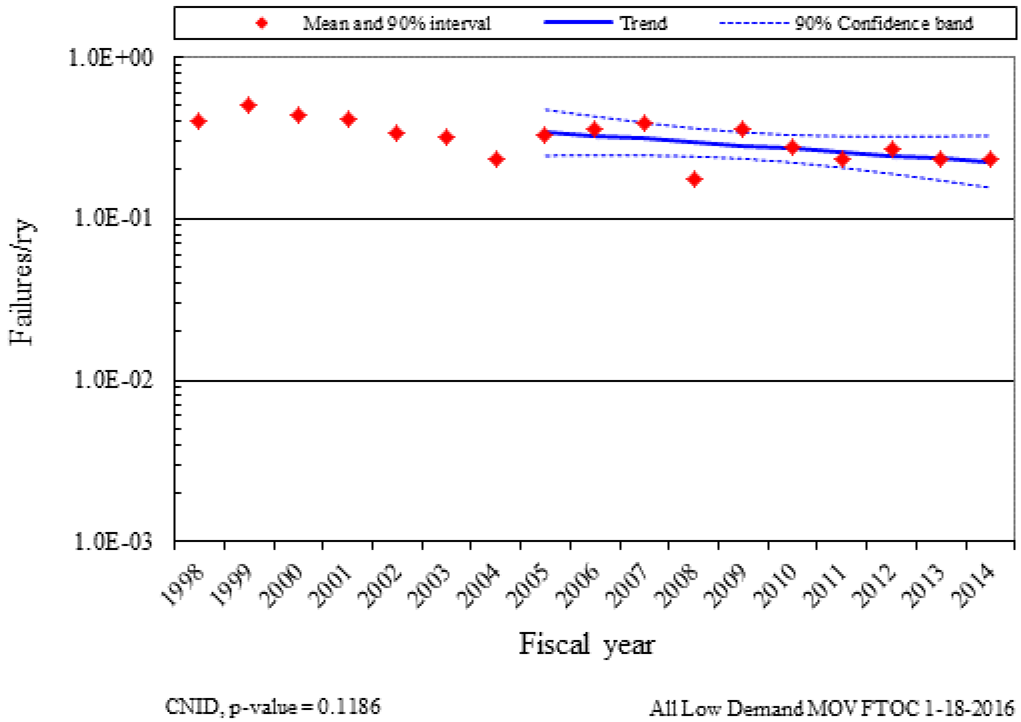

Figure 9. Frequency (failures per reactor year) of MOV FTOC events ≤ 20 demands per year.

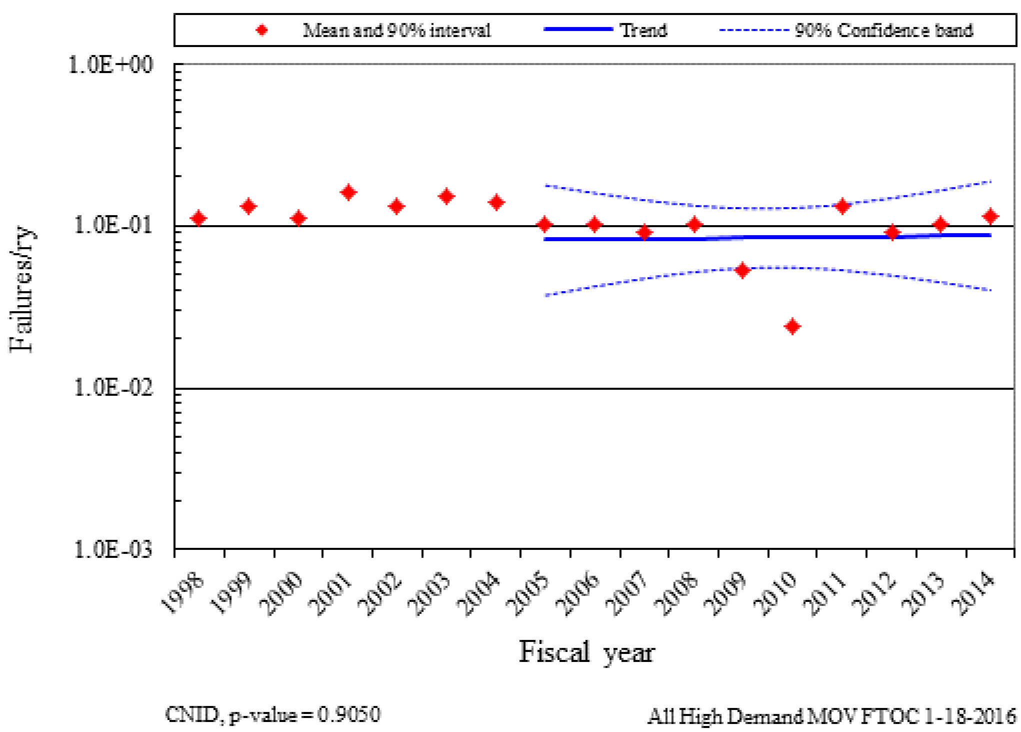

Figure 10. Frequency (failures per reactor year) of MOV FTOC events > 20 demands per year.

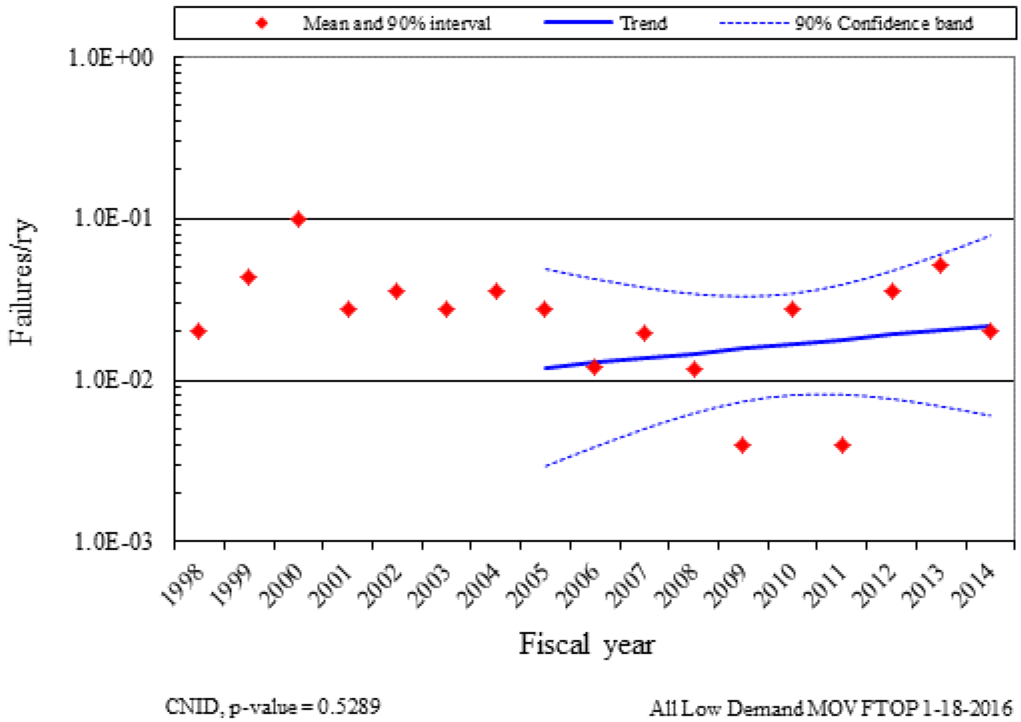

Figure 11. Frequency (failures per reactor year) of MOV FTOP events ≤ 20 demands per year.

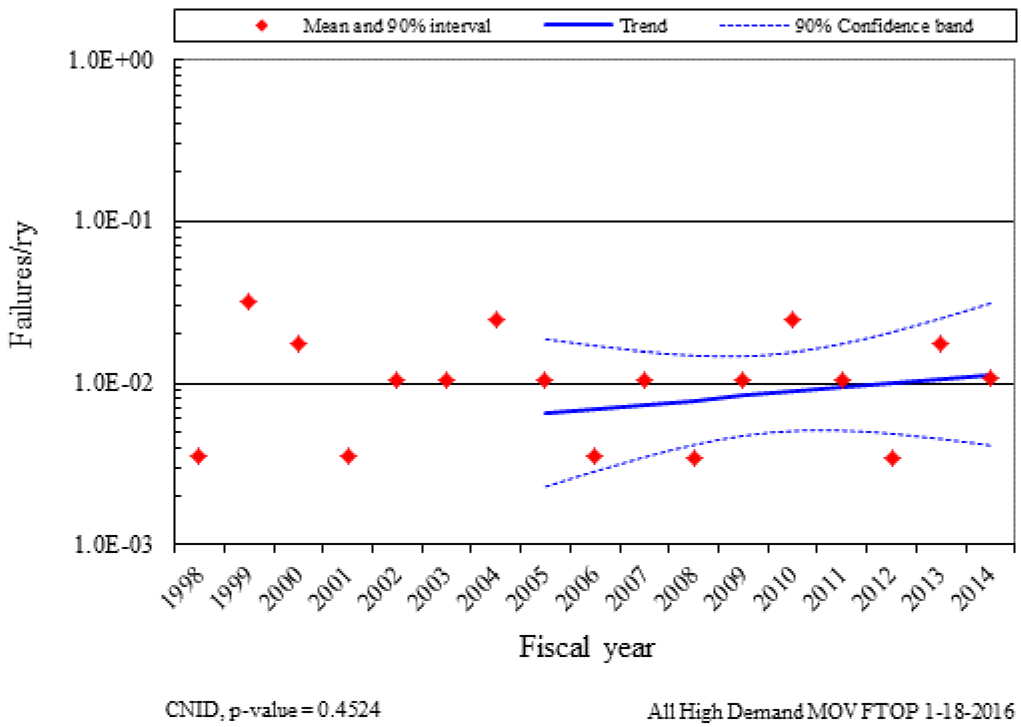

Figure 12. Frequency (failures per reactor year) of MOV FTOP events > 20 demands per year.

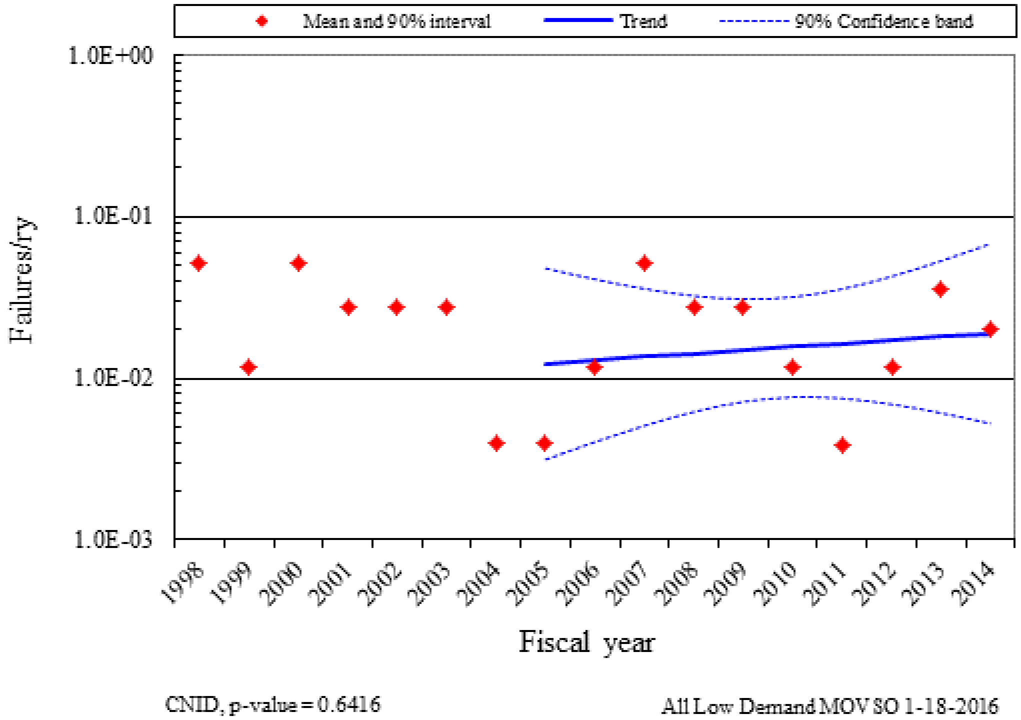

Figure 13. Frequency (failures per reactor year) of MOV SO events ≤ 20 demands per year.

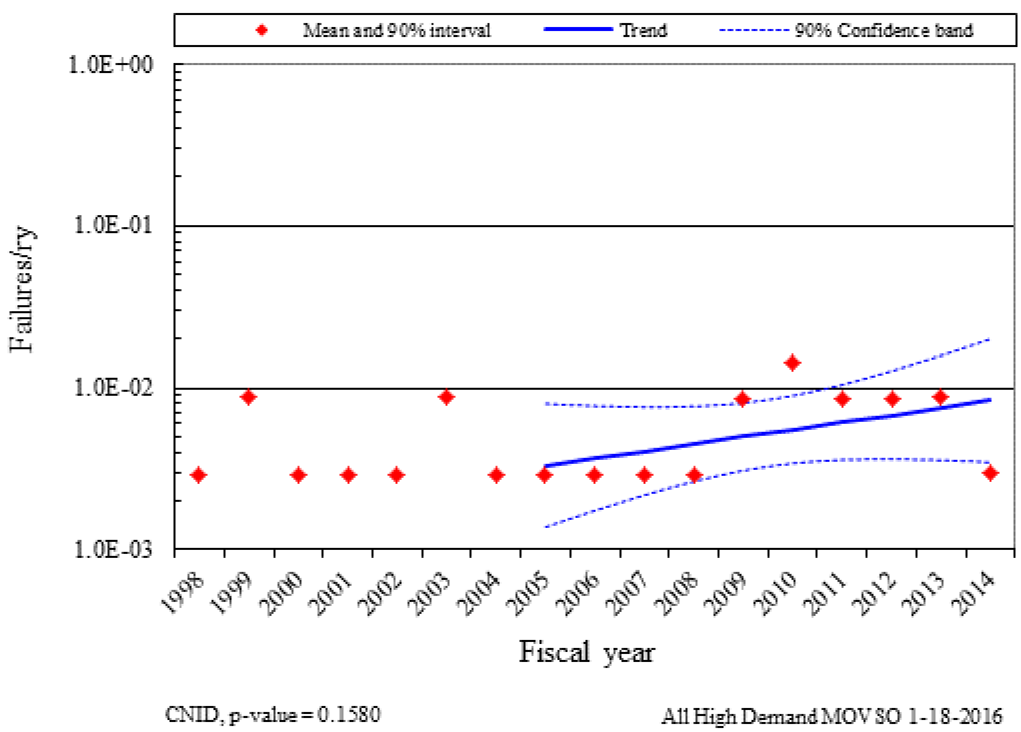

Figure 14. Frequency (failures per reactor year) of MOV SO events > 20 demands per year.

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	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
AFW	448	7.4%	3	1	5	2	5	5	3	2		4	30	**10.2%**
CCW	675	11.2%	2	2	1		3	3	2	1	2		16	**5.4%**
CRD	10	0.2%											0	0.0%
CSR	326	5.4%		1		1	1		2	2		1	8	2.7%
CVC	13	0.2%											0	0.0%
HCI	247	4.1%	2	3	8		8	1		3	1	1	27	**9.2%**
HCS	28	0.5%											0	0.0%
HPI	963	16.0%	5	3	3	1	3	3	3	1	4	4	30	**10.2%**
ISO	14	0.2%	2						1				3	1.0%
LCS	205	3.4%		1	1				1	4	1	1	9	**3.1%**
RCI	303	5.0%	4	3	3	2	2	1	2	5	1	2	25	**8.5%**
RCS	102	1.7%		1			1			1	2		5	1.7%
RHR	1807	30.0%	14	16	17	8	9	14	5	7	6	7	103	**34.9%**
SWN	682	11.3%	1	6	1	4	4	2	3	2	6	3	32	**10.8%**
SWS	193	3.2%			1		1		2				4	1.4%
VSS	14	0.2%	1		1						1		3	1.0%
Total	6030	100%	34	37	41	18	37	29	24	28	24	23	295	100%

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

System Code	Valve Count	Valve Percent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
AFW	448	7.8%				1		1		1	1		4	**18.2%**
CCW	675	11.7%	1										1	4.5%
CSR	326	5.7%											0	0.0%
HCI	247	4.3%			1						1		2	**9.1%**
HPI	963	16.7%						1		2			3	**13.6%**
RCI	303	5.3%											0	0.0%
RCS	102	1.8%	1										1	4.5%
RHR	1807	31.4%		1	1			1		1	2		6	**27.3%**
SWN	682	11.8%	1								2	1	4	**18.2%**
SWS	193	3.4%											0	0.0%
VSS	14	0.2%										1	1	4.5%
Total	5760	100%	3	1	2	1	0	3	0	4	6	2	22	100%

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

System Code	Valve Count	Valve Percent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
AFW	448	9.2%											0	0.0%
CCW	675	13.8%				2	2						4	**19.0%**
CSR	326	6.7%											0	0.0%
HCI	247	5.1%			1			1				1	3	**14.3%**
LCS	205	4.2%		1	4								5	**23.8%**
RCI	303	6.2%				1	1			1	3	1	7	**33.3%**
RHR	1807	37.0%			1						1		2	9.5%
SWN	682	14.0%											0	0.0%
SWS	193	4.0%											0	0.0%
Total	4886	100%	0	1	6	3	3	1	0	1	4	2	21	100%

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

System Code	Valve Count	Valve Percent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
AFW	133	11.1%	2	2	1		1	1	1	3	2	2	15	**16.9%**
CCW	161	13.4%				1			1	1		1	4	4.5%
CSR	21	1.7%										1	1	1.1%
HCI	23	1.9%	1	1		1			2			1	6	**6.7%**
HCS	19	1.6%				1							1	1.1%
HPI	116	9.7%							1		1		2	2.2%
LCS	29	2.4%				1			1	1			3	3.4%
RCI	32	2.7%	2						1	1	1		5	**5.6%**
RCS	7	0.6%											0	0.0%
RHR	299	24.9%	4	3	6	3	3	1	5	2	3	3	33	**37.1%**
SWN	270	22.5%	1	3	1	2	1			1	2	1	12	**13.5%**
SWS	91	7.6%		1	1	1			1		1	2	7	**7.9%**
Total	1201	100%	10	10	9	10	5	2	13	9	10	11	89	100%

Table 7. Summary of MOV failure counts for the FTOP failure mode over time by system > 20 demands per year.

System Code	Valve Count	Valve Percent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
AFW	133	13.5%			1				1				2	**20.0%**
CCW	161	16.4%	1					1				1	3	**30.0%**
LCS	29	3.0%											0	0.0%
RHR	299	30.4%					1	1			1		3	**30.0%**
SWN	270	27.5%									1		1	10.0%
SWS	91	9.3%						1					1	10.0%
Total	983	100%	1	0	1	0	1	3	1	0	2	1	10	100%

Table 8. Summary of MOV failure counts for the SO failure mode over time by system > 20 demands per year.

System Code	Valve Count	Valve Percent	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	Total	Percent of Failures
RCI	32	5.3%						2			1		3	**50.0%**
RHR	299	49.8%					1		1	1			3	**50.0%**
SWN	270	44.9%											0	0.0%
Total	601	100%	0	0	0	0	1	2	1	1	1	0	6	100%

4.1 MOV Engineering Analysis by Failure Modes

The engineering analysis of MOV failure sub-components, causes, detection methods, and recovery are presented in this section. Each analysis first divides the events into two categories: MOVs with ≤ 20 demands per year (low-demands) and MOVs with > 20 demands per year (high-demands).

The second division of the events is by the failure mode determined after ICES data review by the staff. See Section 5 for more description of failure modes.

MOV sub-component contributions to the three failure modes are presented in Figure 15. The sub-component contributions are similar to those used in the CCF database. For all three failure modes, the actuator is the largest contributor to the failure rates/probabilities.

MOV cause group contributions to the three failure modes are presented in Figure 16. The cause groups are similar to those used in the CCF database. Table 9 shows the breakdown of the cause groups with the specific causes that were coded during the data collection. The most likely cause for the FTOC, FTOP, and SO failure modes is grouped as Internal. Internal means that the cause was related to something within the MOV component such as a worn out part or the normal internal environment. Of particular interest is the Human cause group. The human cause group is primarily influenced by maintenance and operating procedures and practices. In addition, the External Cause group is increasing in importance for the SO failure mode.

MOV detection methods to the three failure modes are presented in Figure 17. The most likely detection method for the FTOC failure mode is a testing demand. The FTOP and SO detection modes are heavily influenced by testing and non-test demands.

MOV recovery to the three failure modes are presented in Figure 18. The overall non-recovery to recovery ratio is approximately 7:1.

Table 9. Component failure cause groups.

Group	Specific Cause	Description
Design	Construction/installation error or inadequacy	Used when a construction or installation error is made during the original or modification installation. This includes specification of incorrect component or material.
	Design error or inadequacy	Used when a design error is made.
	Manufacturing error or inadequacy	Used when a manufacturing error is made during component manufacture.
External	State of other component	Used when the cause of a failure is the result of a component state that is not associated with the component that failed. An example would be the diesel failed due to no fuel in the fuel storage tanks.
	Ambient environmental stress	Used when the cause of a failure is the result of an environmental condition from the location of the component.
Human	Accidental action (unintentional or undesired human errors)	Used when a human error (during the performance of an activity) results in an unintentional or undesired action.
	Human action procedure	Used when the procedure is not followed or the procedure is incorrect. For example: when a missed step or incorrect step in a surveillance procedure results in a component failure.
	Inadequate maintenance	Used when a human error (during the performance of maintenance) results in an unintentional or undesired action.
Internal	Internal to component, piece-part	Used when the cause of a failure is a non-specific result of a failure internal to the component that failed other than aging or wear.
	Internal environment	The internal environment led to the failure. Debris/Foreign material as well as an operating medium chemistry issue.
	Set point drift	Used when the cause of a failure is the result of set point drift or adjustment.
	Age/Wear	Used when the cause of the failure is a non-specific aging or wear issue.
Other	Unknown	Used when the cause of the failure is not known.
	Other (stated cause does not fit other categories)	Used when the cause of a failure is provided but it does not meet any one of the descriptions.
Procedure	Inadequate procedure	Used when the cause of a failure is the result of an inadequate procedure operating or maintenance.

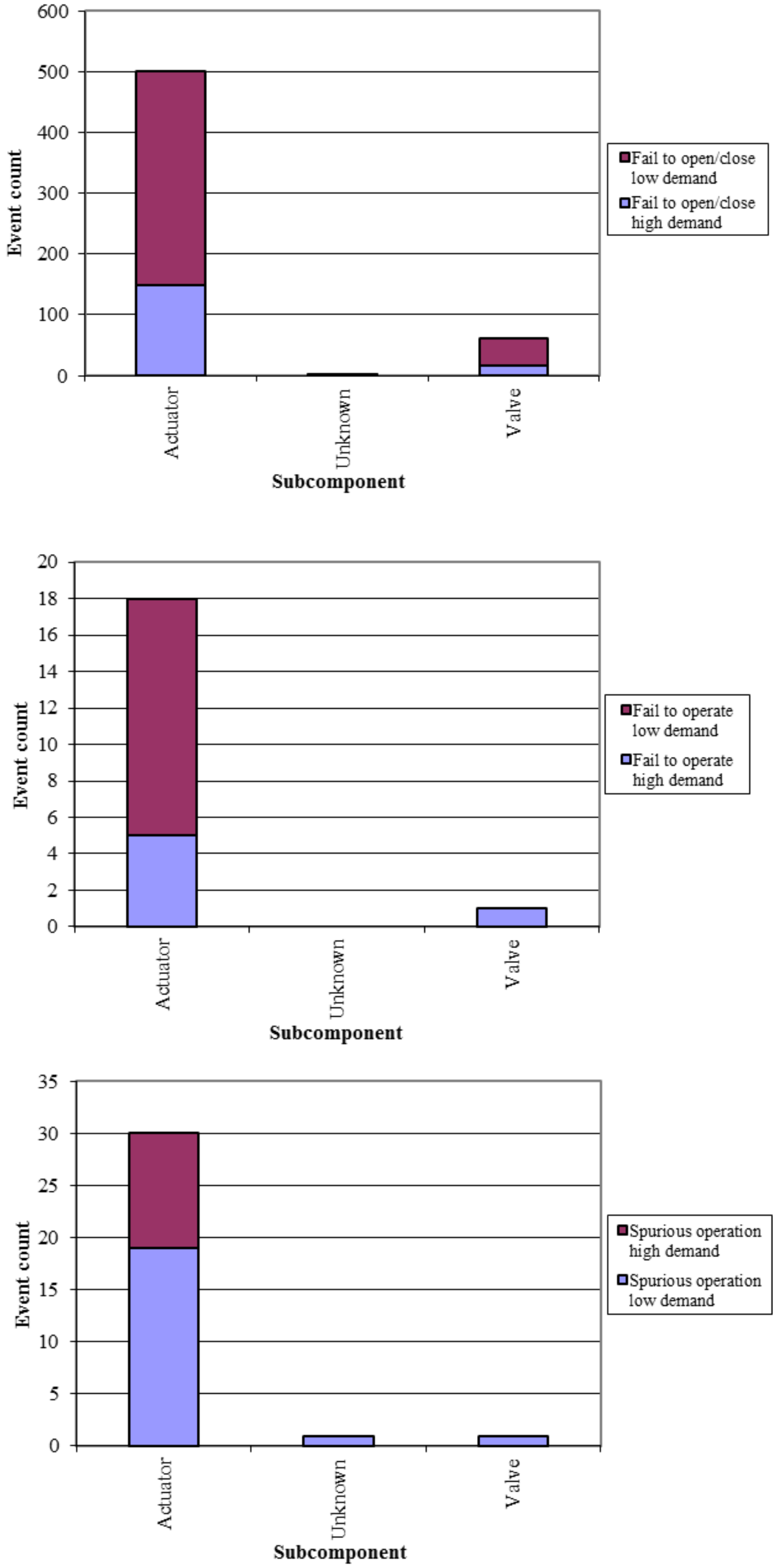

Figure 15. MOV failure event breakdown by subcomponent, failure mode, and demand rate.

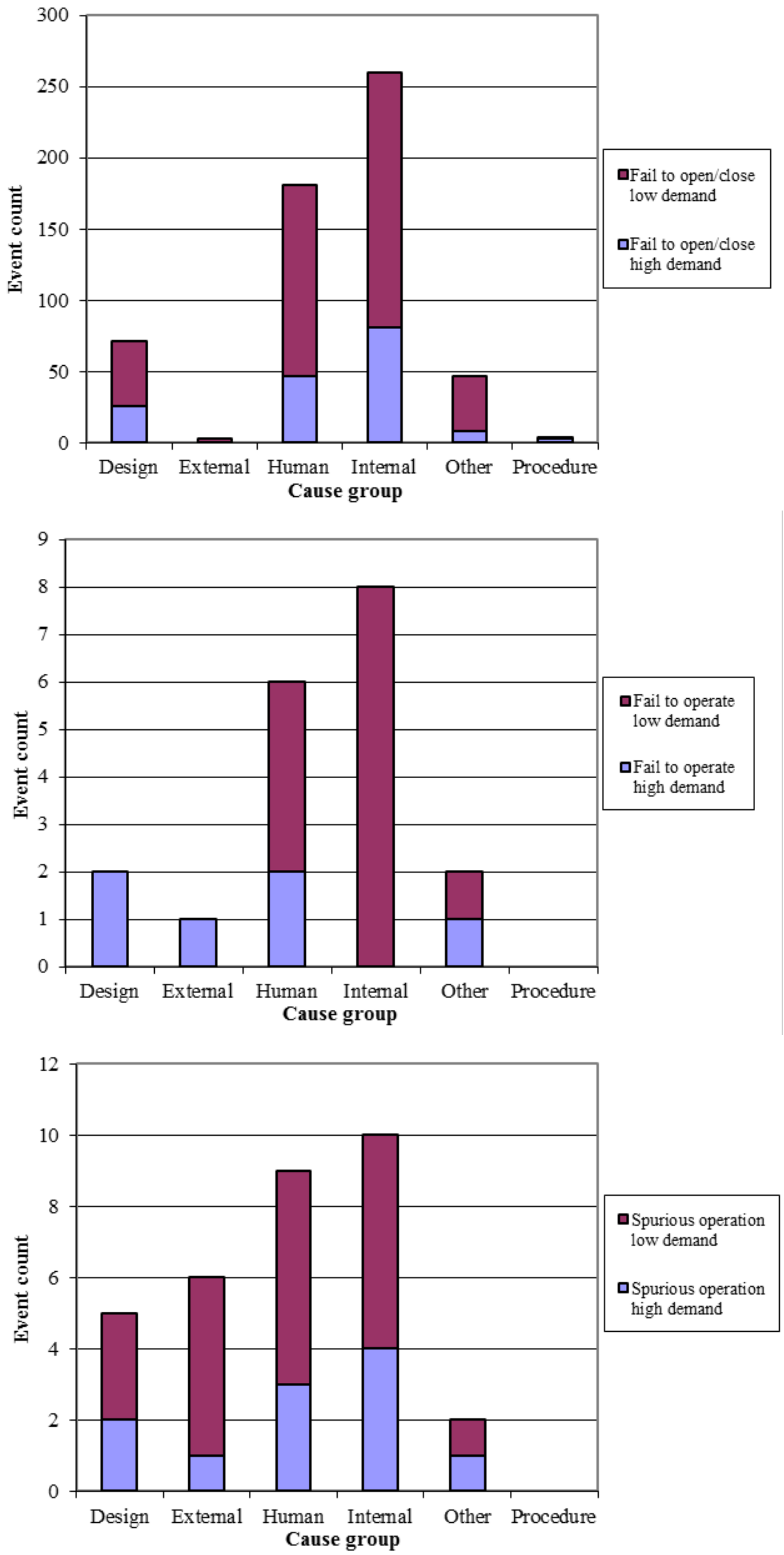

Figure 16. MOV failure event breakdown by cause group, failure mode, and demand rate.

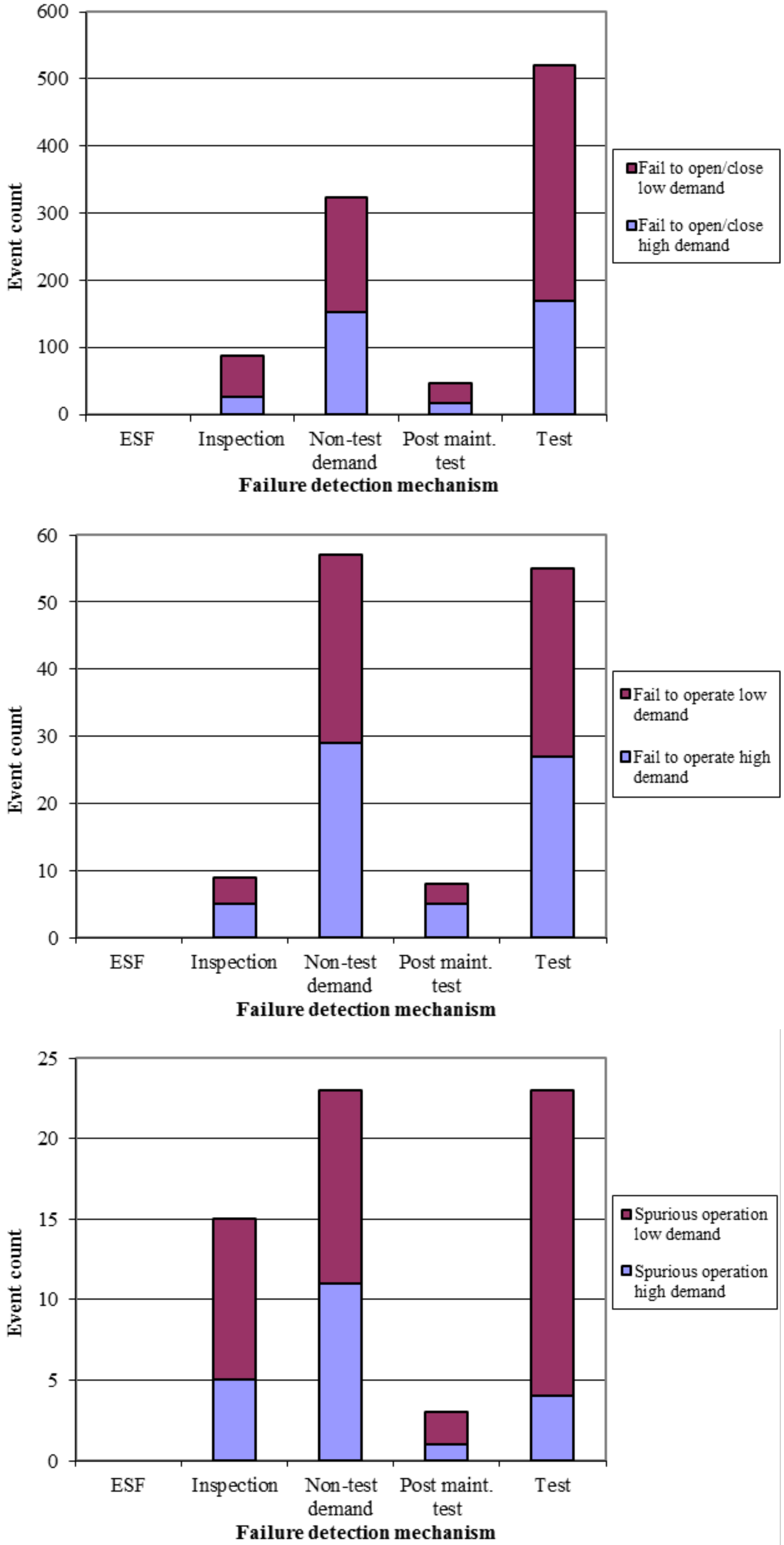

Figure 17. MOV failure event breakdown by method of detection, failure mode, and demand rate.

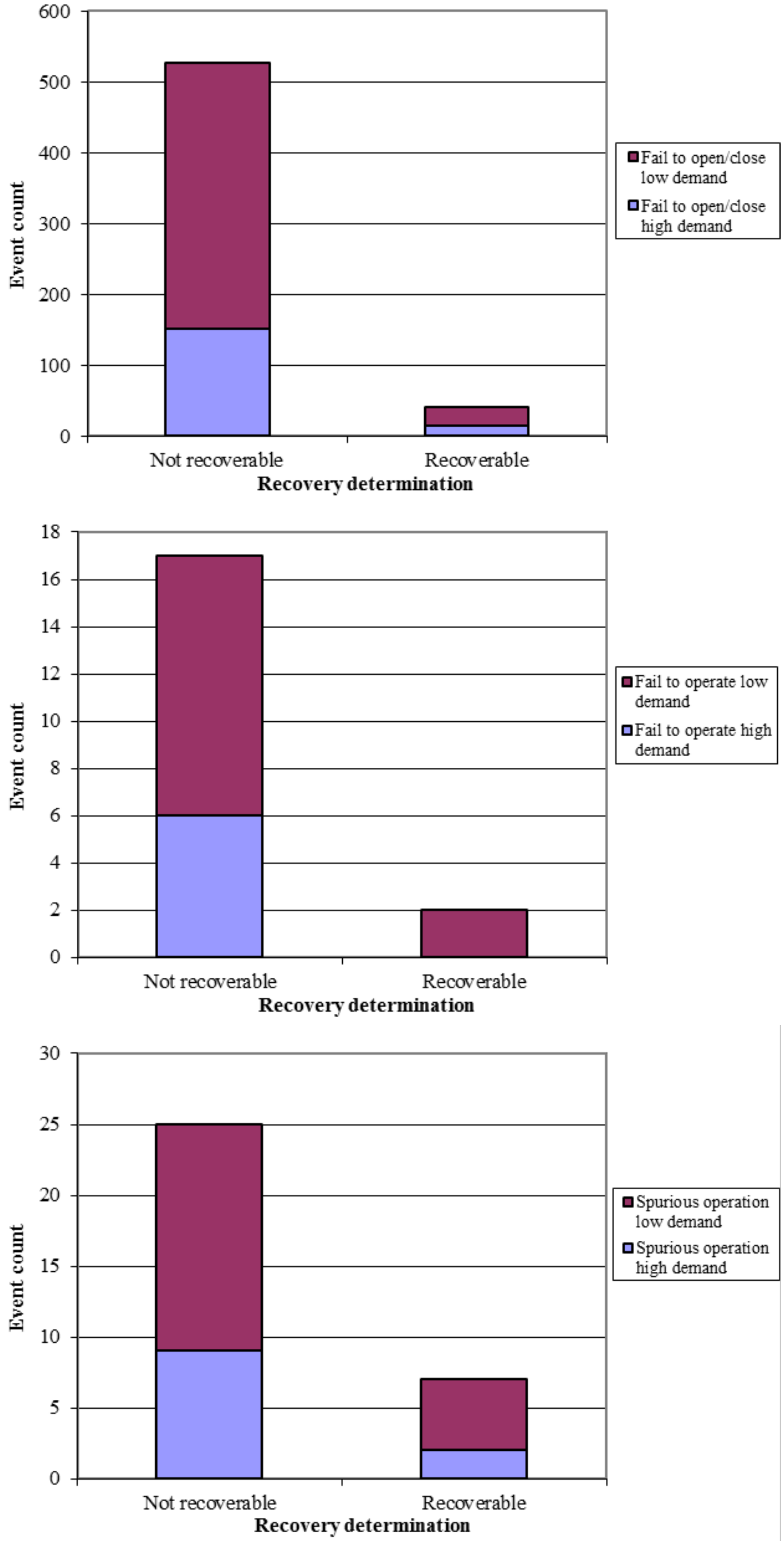

Figure 18. MOV failure event breakdown by recoverability, failure mode, and demand rate.

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 or ac/dc actuator is generally manufactured by Limitorque or Rotork.

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.

Failure modes for the MOV include fail to open/close, which combines the FTOC failure modes into a single category; FTOP, which is a rate-based failure mode that includes FTC for a flow/temperature control device and any other rate-based failure modes not including SO, which includes spurious opening and spurious closing.

6. DATA TABLES

Table 10. Plot data for Figure 1, industry-wide MOV FTOC trend with ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY/ Source	**Failures**	**Demands**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
2010 Update						1.76E-04	2.27E-03	9.63E-04
1998	41	38,320.0				8.09E-04	1.38E-03	1.07E-03
1999	52	41,217.0				9.84E-04	1.58E-03	1.25E-03
2000	45	41,399.0				8.33E-04	1.39E-03	1.08E-03
2001	43	41,518.3				7.89E-04	1.33E-03	1.03E-03
2002	35	41,983.9				6.17E-04	1.10E-03	8.33E-04
2003	33	42,575.4				5.69E-04	1.03E-03	7.75E-04
2004	24	41,327.7				4.04E-04	8.18E-04	5.84E-04
2005	34	40,614.7	9.16E-04	6.58E-04	1.28E-03	6.17E-04	1.11E-03	8.36E-04
2006	37	37,104.1	8.80E-04	6.65E-04	1.16E-03	7.43E-04	1.30E-03	9.94E-04
2007	41	37,213.8	8.45E-04	6.68E-04	1.07E-03	8.32E-04	1.42E-03	1.10E-03
2008	18	37,464.6	8.12E-04	6.63E-04	9.95E-04	3.16E-04	7.16E-04	4.86E-04
2009	37	36,929.4	7.80E-04	6.46E-04	9.43E-04	7.46E-04	1.31E-03	9.98E-04
2010	29	37,360.4	7.49E-04	6.15E-04	9.13E-04	5.57E-04	1.06E-03	7.76E-04
2011	24	37,169.9	7.20E-04	5.74E-04	9.02E-04	4.49E-04	9.08E-04	6.48E-04
2012	28	36,813.2	6.91E-04	5.29E-04	9.04E-04	5.43E-04	1.04E-03	7.61E-04
2013	24	37,248.8	6.64E-04	4.84E-04	9.12E-04	4.48E-04	9.06E-04	6.47E-04
2014	23	36,500.5	6.38E-04	4.40E-04	9.26E-04	4.35E-04	8.93E-04	6.33E-04
Total	568	662,760.7						

Table 11. Plot data for Figure 2, industry-wide MOV FTOC trend with > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY/ Source	Failures	Demands	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
2010 Update						1.76E-04	2.27E-03	9.63E-04
1998	11	38,684.9				1.60E-04	4.59E-04	2.80E-04
1999	13	41,394.8				1.85E-04	4.87E-04	3.09E-04
2000	11	43,584.7				1.43E-04	4.10E-04	2.50E-04
2001	16	50,203.8				1.99E-04	4.74E-04	3.14E-04
2002	13	39,803.7				1.92E-04	5.05E-04	3.20E-04
2003	15	40,408.1				2.26E-04	5.54E-04	3.63E-04
2004	14	42,769.0				1.96E-04	4.99E-04	3.21E-04
2005	10	42,687.5	1.87E-04	8.52E-05	4.08E-04	1.29E-04	3.91E-04	2.33E-04
2006	10	42,268.1	1.88E-04	9.70E-05	3.66E-04	1.30E-04	3.94E-04	2.35E-04
2007	9	42,701.2	1.90E-04	1.09E-04	3.33E-04	1.12E-04	3.63E-04	2.11E-04
2008	10	42,061.4	1.92E-04	1.20E-04	3.09E-04	1.31E-04	3.96E-04	2.36E-04
2009	5	41,874.9	1.95E-04	1.27E-04	2.98E-04	5.17E-05	2.53E-04	1.24E-04
2010	2	42,363.9	1.97E-04	1.29E-04	3.01E-04	1.28E-05	1.57E-04	5.59E-05
2011	13	41,873.2	1.99E-04	1.24E-04	3.18E-04	1.83E-04	4.81E-04	3.05E-04
2012	9	40,981.2	2.01E-04	1.15E-04	3.49E-04	1.17E-04	3.77E-04	2.19E-04
2013	10	40,860.0	2.03E-04	1.05E-04	3.92E-04	1.34E-04	4.07E-04	2.43E-04
2014	11	40,538.8	2.05E-04	9.42E-05	4.46E-04	1.53E-04	4.39E-04	2.68E-04
Total	182	715,059.1						

Table 12. Plot data for Figure 3, industry-wide MOV FTOP trend with ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY/ Source	**Failures**	**Demands**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
2010 Update						7.40E-09	1.74E-07	6.62E-08
1998	2	52,568,760.0				8.91E-09	1.09E-07	3.89E-08
1999	5	52,726,440.0				3.55E-08	1.73E-07	8.53E-08
2000	12	52,761,480.0				1.13E-07	3.11E-07	1.94E-07
2001	3	52,735,200.0				1.68E-08	1.31E-07	5.43E-08
2002	4	52,691,400.0				2.58E-08	1.53E-07	6.98E-08
2003	3	52,735,200.0				1.68E-08	1.31E-07	5.43E-08
2004	4	52,682,640.0				2.58E-08	1.53E-07	6.98E-08
2005	3	52,717,680.0	2.37E-08	5.82E-09	9.62E-08	1.68E-08	1.31E-07	5.43E-08
2006	1	52,761,480.0	2.52E-08	7.65E-09	8.32E-08	2.73E-09	8.58E-08	2.33E-08
2007	2	52,743,960.0	2.69E-08	9.85E-09	7.35E-08	8.88E-09	1.09E-07	3.88E-08
2008	1	52,787,760.0	2.87E-08	1.23E-08	6.71E-08	2.73E-09	8.58E-08	2.32E-08
2009	0	52,849,080.0	3.06E-08	1.45E-08	6.46E-08	3.04E-11	6.05E-08	7.74E-09
2010	3	52,822,800.0	3.26E-08	1.58E-08	6.72E-08	1.68E-08	1.31E-07	5.42E-08
2011	0	53,427,240.0	3.48E-08	1.59E-08	7.61E-08	3.02E-11	6.00E-08	7.67E-09
2012	4	52,989,240.0	3.71E-08	1.49E-08	9.22E-08	2.57E-08	1.52E-07	6.95E-08
2013	6	52,717,680.0	3.96E-08	1.34E-08	1.17E-07	4.57E-08	1.94E-07	1.01E-07
2014	2	52,621,320.0	4.22E-08	1.17E-08	1.52E-07	8.90E-09	1.09E-07	3.88E-08
Total	55	897,339,360.0						

Table 13. Plot data for Figure 4, industry-wide MOV FTOP trend with > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY/ Source	Failures	Demands	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
2010 Update						7.40E-09	1.74E-07	6.62E-08
1998	0	10,398,120.0				1.27E-10	2.52E-07	3.23E-08
1999	4	10,564,560.0				1.06E-07	6.28E-07	2.87E-07
2000	2	10,582,080.0				3.65E-08	4.49E-07	1.60E-07
2001	0	10,573,320.0				1.26E-10	2.49E-07	3.19E-08
2002	1	10,582,080.0				1.12E-08	3.53E-07	9.57E-08
2003	1	10,590,840.0				1.12E-08	3.53E-07	9.56E-08
2004	3	10,625,880.0				6.89E-08	5.38E-07	2.23E-07
2005	1	10,634,640.0	5.99E-08	2.10E-08	1.71E-07	1.12E-08	3.52E-07	9.54E-08
2006	0	10,625,880.0	6.36E-08	2.61E-08	1.55E-07	1.25E-10	2.49E-07	3.18E-08
2007	1	10,643,400.0	6.75E-08	3.19E-08	1.43E-07	1.12E-08	3.52E-07	9.53E-08
2008	0	10,739,760.0	7.16E-08	3.79E-08	1.35E-07	1.24E-10	2.47E-07	3.16E-08
2009	1	10,687,200.0	7.60E-08	4.31E-08	1.34E-07	1.11E-08	3.51E-07	9.51E-08
2010	3	10,731,000.0	8.06E-08	4.62E-08	1.41E-07	6.85E-08	5.35E-07	2.21E-07
2011	1	10,827,360.0	8.56E-08	4.64E-08	1.58E-07	1.11E-08	3.48E-07	9.42E-08
2012	0	10,757,280.0	9.08E-08	4.43E-08	1.86E-07	1.24E-10	2.47E-07	3.15E-08
2013	2	10,669,680.0	9.64E-08	4.11E-08	2.26E-07	3.63E-08	4.46E-07	1.59E-07
2014	1	10,608,360.0	1.02E-07	3.74E-08	2.80E-07	1.12E-08	3.53E-07	9.55E-08
Total	21	180,841,440.0						

Table 14. Plot data for Figure 5, industry-wide MOV SO trend with ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY/ Source	Failures	Hours	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
2010 Update						2.54E-10	1.24E-07	3.39E-08
1998	6	52,568,760.0				4.54E-08	1.93E-07	1.00E-07
1999	1	52,726,440.0				2.71E-09	8.51E-08	2.31E-08
2000	6	52,761,480.0				4.53E-08	1.92E-07	9.99E-08
2001	3	52,735,200.0				1.67E-08	1.30E-07	5.38E-08
2002	3	52,691,400.0				1.67E-08	1.30E-07	5.39E-08
2003	3	52,735,200.0				1.67E-08	1.30E-07	5.38E-08
2004	0	52,682,640.0				3.03E-11	6.01E-08	7.70E-09
2005	0	52,717,680.0	2.41E-08	6.16E-09	9.43E-08	3.02E-11	6.01E-08	7.69E-09
2006	1	52,761,480.0	2.53E-08	7.92E-09	8.06E-08	2.70E-09	8.51E-08	2.31E-08
2007	6	52,743,960.0	2.65E-08	9.97E-09	7.02E-08	4.53E-08	1.92E-07	9.99E-08
2008	3	52,787,760.0	2.77E-08	1.21E-08	6.34E-08	1.67E-08	1.30E-07	5.38E-08
2009	3	52,849,080.0	2.91E-08	1.40E-08	6.04E-08	1.66E-08	1.30E-07	5.37E-08
2010	1	52,822,800.0	3.05E-08	1.49E-08	6.22E-08	2.70E-09	8.50E-08	2.30E-08
2011	0	53,427,240.0	3.19E-08	1.46E-08	6.96E-08	2.99E-11	5.95E-08	7.61E-09
2012	1	52,989,240.0	3.34E-08	1.34E-08	8.32E-08	2.69E-09	8.48E-08	2.30E-08
2013	4	52,717,680.0	3.50E-08	1.19E-08	1.04E-07	2.56E-08	1.51E-07	6.92E-08
2014	2	52,621,320.0	3.67E-08	1.02E-08	1.32E-07	8.82E-09	1.08E-07	3.85E-08
Total	43	897,339,360.0						

Table 15. Plot data for Figure 6, industry-wide MOV SO trend, > 20 demands per year.

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
2010 Update						2.54E-10	1.24E-07	3.39E-08
1998	0	10,398,120.0				1.06E-10	2.10E-07	2.68E-08
1999	1	10,564,560.0				9.36E-09	2.95E-07	7.98E-08
2000	0	10,582,080.0				1.05E-10	2.08E-07	2.66E-08
2001	0	10,573,320.0				1.05E-10	2.08E-07	2.66E-08
2002	0	10,582,080.0				1.05E-10	2.08E-07	2.66E-08
2003	1	10,590,840.0				9.35E-09	2.94E-07	7.97E-08
2004	0	10,625,880.0				1.04E-10	2.07E-07	2.65E-08
2005	0	10,634,640.0	3.04E-08	1.26E-08	7.36E-08	1.04E-10	2.07E-07	2.65E-08
2006	0	10,625,880.0	3.36E-08	1.59E-08	7.12E-08	1.04E-10	2.07E-07	2.65E-08
2007	0	10,643,400.0	3.72E-08	1.98E-08	7.00E-08	1.04E-10	2.07E-07	2.65E-08
2008	0	10,739,760.0	4.12E-08	2.40E-08	7.05E-08	1.04E-10	2.06E-07	2.64E-08
2009	1	10,687,200.0	4.55E-08	2.80E-08	7.39E-08	9.30E-09	2.93E-07	7.93E-08
2010	2	10,731,000.0	5.03E-08	3.10E-08	8.17E-08	3.02E-08	3.71E-07	1.32E-07
2011	1	10,827,360.0	5.57E-08	3.26E-08	9.52E-08	9.23E-09	2.91E-07	7.87E-08
2012	1	10,757,280.0	6.16E-08	3.28E-08	1.16E-07	9.27E-09	2.92E-07	7.90E-08
2013	1	10,669,680.0	6.81E-08	3.23E-08	1.44E-07	9.31E-09	2.93E-07	7.94E-08
2014	0	10,608,360.0	7.53E-08	3.12E-08	1.82E-07	1.04E-10	2.07E-07	2.65E-08
Total	8	180,841,440.0						

Table 16. Plot data for Figure 7, frequency (demands per reactor year) of MOV FTOC demands, ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Demands**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	38,320	103.0				3.69E+02	3.75E+02	3.72E+02
1999	41,217	103.0				3.97E+02	4.03E+02	4.00E+02
2000	41,399	103.3				3.98E+02	4.04E+02	4.01E+02
2001	41,518	103.0				4.00E+02	4.06E+02	4.03E+02
2002	41,984	103.0				4.04E+02	4.11E+02	4.08E+02
2003	42,575	103.0				4.10E+02	4.17E+02	4.13E+02
2004	41,328	103.3				3.97E+02	4.03E+02	4.00E+02
2005	40,615	103.0	3.70E+02	3.54E+02	3.87E+02	3.91E+02	3.98E+02	3.94E+02
2006	37,104	103.0	3.68E+02	3.55E+02	3.82E+02	3.57E+02	3.63E+02	3.60E+02
2007	37,214	103.4	3.67E+02	3.56E+02	3.78E+02	3.57E+02	3.63E+02	3.60E+02
2008	37,465	104.3	3.65E+02	3.55E+02	3.75E+02	3.56E+02	3.62E+02	3.59E+02
2009	36,929	104.0	3.63E+02	3.55E+02	3.72E+02	3.52E+02	3.58E+02	3.55E+02
2010	37,360	104.0	3.62E+02	3.53E+02	3.70E+02	3.56E+02	3.62E+02	3.59E+02
2011	37,170	104.0	3.60E+02	3.50E+02	3.70E+02	3.54E+02	3.60E+02	3.57E+02
2012	36,813	104.3	3.58E+02	3.47E+02	3.70E+02	3.50E+02	3.56E+02	3.53E+02
2013	37,249	102.6	3.57E+02	3.44E+02	3.70E+02	3.60E+02	3.66E+02	3.63E+02
2014	36,501	100.0	3.55E+02	3.40E+02	3.71E+02	3.62E+02	3.68E+02	3.65E+02
Total	662,761	1,754.1						

Table 17. Plot data for Figure 8, frequency (demands per reactor year) of MOV FTOC demands, > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Demands**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	38,685	97.0				3.95E+02	4.02E+02	3.99E+02
1999	41,395	97.0				4.23E+02	4.30E+02	4.27E+02
2000	43,585	97.3				4.45E+02	4.52E+02	4.48E+02
2001	50,204	97.0				5.14E+02	5.21E+02	5.18E+02
2002	39,804	97.0				4.07E+02	4.14E+02	4.10E+02
2003	40,408	97.0				4.13E+02	4.20E+02	4.17E+02
2004	42,769	97.3				4.36E+02	4.43E+02	4.40E+02
2005	42,688	97.0	4.38E+02	4.30E+02	4.46E+02	4.37E+02	4.44E+02	4.40E+02
2006	42,268	97.0	4.36E+02	4.29E+02	4.43E+02	4.32E+02	4.39E+02	4.36E+02
2007	42,701	97.4	4.34E+02	4.29E+02	4.40E+02	4.35E+02	4.42E+02	4.39E+02
2008	42,061	98.3	4.32E+02	4.28E+02	4.37E+02	4.25E+02	4.31E+02	4.28E+02
2009	41,875	98.0	4.31E+02	4.27E+02	4.35E+02	4.24E+02	4.31E+02	4.27E+02
2010	42,364	98.0	4.29E+02	4.25E+02	4.33E+02	4.29E+02	4.36E+02	4.32E+02
2011	41,873	98.0	4.27E+02	4.23E+02	4.32E+02	4.24E+02	4.31E+02	4.27E+02
2012	40,981	98.3	4.26E+02	4.20E+02	4.31E+02	4.14E+02	4.20E+02	4.17E+02
2013	40,860	96.6	4.24E+02	4.18E+02	4.31E+02	4.20E+02	4.27E+02	4.23E+02
2014	40,539	94.0	4.22E+02	4.15E+02	4.30E+02	4.28E+02	4.35E+02	4.31E+02
Total	715,059	1,652.0						

Table 18. Plot data for Figure 9, frequency (events per reactor year) of MOV FTOC events with ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	41	103.0				3.01E-01	5.13E-01	3.96E-01
1999	52	103.0				3.93E-01	6.31E-01	5.01E-01
2000	45	103.3				3.33E-01	5.55E-01	4.33E-01
2001	43	103.0				3.17E-01	5.35E-01	4.15E-01
2002	35	103.0				2.51E-01	4.48E-01	3.39E-01
2003	33	103.0				2.35E-01	4.27E-01	3.20E-01
2004	24	103.3				1.62E-01	3.27E-01	2.33E-01
2005	34	103.0	3.41E-01	2.46E-01	4.74E-01	2.43E-01	4.38E-01	3.29E-01
2006	37	103.0	3.26E-01	2.47E-01	4.30E-01	2.68E-01	4.70E-01	3.58E-01
2007	41	103.4	3.11E-01	2.47E-01	3.93E-01	3.00E-01	5.11E-01	3.95E-01
2008	18	104.3	2.97E-01	2.43E-01	3.63E-01	1.14E-01	2.57E-01	1.74E-01
2009	37	104.0	2.84E-01	2.35E-01	3.42E-01	2.65E-01	4.66E-01	3.55E-01
2010	29	104.0	2.71E-01	2.23E-01	3.30E-01	2.00E-01	3.79E-01	2.79E-01
2011	24	104.0	2.59E-01	2.07E-01	3.24E-01	1.60E-01	3.25E-01	2.32E-01
2012	28	104.3	2.47E-01	1.90E-01	3.22E-01	1.92E-01	3.67E-01	2.69E-01
2013	24	102.6	2.36E-01	1.72E-01	3.24E-01	1.63E-01	3.29E-01	2.35E-01
2014	23	100.0	2.26E-01	1.56E-01	3.27E-01	1.59E-01	3.26E-01	2.31E-01
Total	568	1,754.1						

Table 19. Plot data for Figure 10, frequency (events per reactor year) of MOV FTOC events with > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	11	97.0				6.39E-02	1.84E-01	1.12E-01
1999	13	97.0				7.88E-02	2.08E-01	1.32E-01
2000	11	97.3				6.37E-02	1.83E-01	1.12E-01
2001	16	97.0				1.02E-01	2.43E-01	1.61E-01
2002	13	97.0				7.88E-02	2.08E-01	1.32E-01
2003	15	97.0				9.41E-02	2.31E-01	1.51E-01
2004	14	97.3				8.62E-02	2.19E-01	1.41E-01
2005	10	97.0	8.14E-02	3.72E-02	1.78E-01	5.66E-02	1.72E-01	1.03E-01
2006	10	97.0	8.20E-02	4.22E-02	1.59E-01	5.66E-02	1.72E-01	1.03E-01
2007	9	97.4	8.26E-02	4.72E-02	1.44E-01	4.92E-02	1.59E-01	9.24E-02
2008	10	98.3	8.32E-02	5.18E-02	1.34E-01	5.59E-02	1.70E-01	1.01E-01
2009	5	98.0	8.38E-02	5.48E-02	1.28E-01	2.21E-02	1.08E-01	5.32E-02
2010	2	98.0	8.44E-02	5.53E-02	1.29E-01	5.54E-03	6.80E-02	2.42E-02
2011	13	98.0	8.50E-02	5.32E-02	1.36E-01	7.81E-02	2.06E-01	1.31E-01
2012	9	98.3	8.56E-02	4.93E-02	1.49E-01	4.88E-02	1.58E-01	9.16E-02
2013	10	96.6	8.62E-02	4.48E-02	1.66E-01	5.68E-02	1.72E-01	1.03E-01
2014	11	94.0	8.69E-02	4.01E-02	1.88E-01	6.58E-02	1.89E-01	1.16E-01
Total	182	1,652.0						

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

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	2	103.0				4.55E-03	5.58E-02	1.99E-02
1999	5	103.0				1.82E-02	8.88E-02	4.37E-02
2000	12	103.3				5.79E-02	1.59E-01	9.90E-02
2001	3	103.0				8.60E-03	6.72E-02	2.78E-02
2002	4	103.0				1.32E-02	7.81E-02	3.57E-02
2003	3	103.0				8.60E-03	6.72E-02	2.78E-02
2004	4	103.3				1.32E-02	7.79E-02	3.57E-02
2005	3	103.0	1.20E-02	2.94E-03	4.89E-02	8.60E-03	6.72E-02	2.78E-02
2006	1	103.0	1.28E-02	3.88E-03	4.24E-02	1.40E-03	4.40E-02	1.19E-02
2007	2	103.4	1.37E-02	5.01E-03	3.75E-02	4.53E-03	5.57E-02	1.98E-02
2008	1	104.3	1.46E-02	6.26E-03	3.42E-02	1.38E-03	4.35E-02	1.18E-02
2009	0	104.0	1.56E-02	7.41E-03	3.30E-02	1.55E-05	3.08E-02	3.94E-03
2010	3	104.0	1.67E-02	8.11E-03	3.45E-02	8.54E-03	6.66E-02	2.76E-02
2011	0	104.0	1.79E-02	8.16E-03	3.91E-02	1.55E-05	3.08E-02	3.94E-03
2012	4	104.3	1.91E-02	7.67E-03	4.75E-02	1.31E-02	7.73E-02	3.54E-02
2013	6	102.6	2.04E-02	6.90E-03	6.03E-02	2.35E-02	9.96E-02	5.18E-02
2014	2	100.0	2.18E-02	6.04E-03	7.87E-02	4.66E-03	5.72E-02	2.03E-02
Total	55	1,754.1						

Table 21. Plot data for Figure 12, frequency (events per reactor year) of MOV FTOP events with > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	0	97.0				1.37E-05	2.73E-02	3.49E-03
1999	4	97.0				1.16E-02	6.86E-02	3.14E-02
2000	2	97.3				3.99E-03	4.90E-02	1.74E-02
2001	0	97.0				1.37E-05	2.73E-02	3.49E-03
2002	1	97.0				1.23E-03	3.86E-02	1.05E-02
2003	1	97.0				1.23E-03	3.86E-02	1.05E-02
2004	3	97.3				7.55E-03	5.89E-02	2.44E-02
2005	1	97.0	6.54E-03	2.29E-03	1.87E-02	1.23E-03	3.86E-02	1.05E-02
2006	0	97.0	6.95E-03	2.85E-03	1.69E-02	1.37E-05	2.73E-02	3.49E-03
2007	1	97.4	7.39E-03	3.49E-03	1.56E-02	1.22E-03	3.85E-02	1.04E-02
2008	0	98.3	7.85E-03	4.16E-03	1.48E-02	1.36E-05	2.70E-02	3.46E-03
2009	1	98.0	8.35E-03	4.74E-03	1.47E-02	1.22E-03	3.84E-02	1.04E-02
2010	3	98.0	8.87E-03	5.07E-03	1.55E-02	7.51E-03	5.86E-02	2.43E-02
2011	1	98.0	9.43E-03	5.10E-03	1.74E-02	1.22E-03	3.84E-02	1.04E-02
2012	0	98.3	1.00E-02	4.88E-03	2.06E-02	1.36E-05	2.70E-02	3.46E-03
2013	2	96.6	1.07E-02	4.53E-03	2.50E-02	4.01E-03	4.92E-02	1.75E-02
2014	1	94.0	1.13E-02	4.13E-03	3.11E-02	1.25E-03	3.95E-02	1.07E-02
Total	21	1,652.0						

Table 22. Plot data for Figure 13, frequency (events per reactor year) of MOV SO events ≤ 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	6	103.0				2.32E-02	9.84E-02	5.12E-02
1999	1	103.0				1.39E-03	4.36E-02	1.18E-02
2000	6	103.3				2.31E-02	9.82E-02	5.11E-02
2001	3	103.0				8.53E-03	6.66E-02	2.76E-02
2002	3	103.0				8.53E-03	6.66E-02	2.76E-02
2003	3	103.0				8.53E-03	6.66E-02	2.76E-02
2004	0	103.3				1.54E-05	3.07E-02	3.93E-03
2005	0	103.0	1.23E-02	3.14E-03	4.80E-02	1.55E-05	3.08E-02	3.94E-03
2006	1	103.0	1.29E-02	4.04E-03	4.10E-02	1.39E-03	4.36E-02	1.18E-02
2007	6	103.4	1.35E-02	5.10E-03	3.58E-02	2.31E-02	9.81E-02	5.10E-02
2008	3	104.3	1.42E-02	6.21E-03	3.24E-02	8.45E-03	6.59E-02	2.73E-02
2009	3	104.0	1.49E-02	7.16E-03	3.09E-02	8.47E-03	6.61E-02	2.73E-02
2010	1	104.0	1.56E-02	7.64E-03	3.19E-02	1.37E-03	4.32E-02	1.17E-02
2011	0	104.0	1.64E-02	7.51E-03	3.57E-02	1.54E-05	3.05E-02	3.91E-03
2012	1	104.3	1.72E-02	6.91E-03	4.27E-02	1.37E-03	4.31E-02	1.17E-02
2013	4	102.6	1.80E-02	6.10E-03	5.33E-02	1.31E-02	7.77E-02	3.55E-02
2014	2	100.0	1.89E-02	5.25E-03	6.81E-02	4.62E-03	5.67E-02	2.02E-02
Total	43	1,754.1						

Table 23. Plot data for Figure 14, frequency (events per reactor year) of MOV SO events > 20 demands per year.

			Regression Curve Data Points			Plot Trend Error Bar Points		
FY	**Failures**	**Reactor Years**	**Mean**	**Lower (5%)**	**Upper (95%)**	**Lower (5%)**	**Upper (95%)**	**Mean**
1998	0	97.0				1.14E-05	2.27E-02	2.91E-03
1999	1	97.0				1.02E-03	3.22E-02	8.73E-03
2000	0	97.3				1.14E-05	2.27E-02	2.91E-03
2001	0	97.0				1.14E-05	2.27E-02	2.91E-03
2002	0	97.0				1.14E-05	2.27E-02	2.91E-03
2003	1	97.0				1.02E-03	3.22E-02	8.73E-03
2004	0	97.3				1.14E-05	2.27E-02	2.91E-03
2005	0	97.0	3.32E-03	1.38E-03	7.99E-03	1.14E-05	2.27E-02	2.91E-03
2006	0	97.0	3.68E-03	1.75E-03	7.76E-03	1.14E-05	2.27E-02	2.91E-03
2007	0	97.4	4.08E-03	2.18E-03	7.64E-03	1.14E-05	2.27E-02	2.90E-03
2008	0	98.3	4.52E-03	2.65E-03	7.71E-03	1.14E-05	2.26E-02	2.89E-03
2009	1	98.0	5.00E-03	3.09E-03	8.10E-03	1.02E-03	3.20E-02	8.68E-03
2010	2	98.0	5.54E-03	3.43E-03	8.97E-03	3.31E-03	4.07E-02	1.45E-02
2011	1	98.0	6.14E-03	3.60E-03	1.05E-02	1.02E-03	3.20E-02	8.68E-03
2012	1	98.3	6.80E-03	3.64E-03	1.27E-02	1.02E-03	3.20E-02	8.67E-03
2013	1	96.6	7.53E-03	3.58E-03	1.58E-02	1.03E-03	3.23E-02	8.75E-03
2014	0	94.0	8.34E-03	3.48E-03	2.00E-02	1.16E-05	2.31E-02	2.96E-03
Total	8	1,652.0						

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