Enhanced Component Performance Study: Air-Operated Valves 1998–2012

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Idaho National Laboratory

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ABSTRACT

This report presents an enhanced performance evaluation of air-operated valves (AOVs) 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 2012 for the component reliability as reported in the Equipment Performance and Information Exchange (EPIX). Results (beta distributions for failure probabilities upon demand and gamma distributions for rates) are used as inputs to the U.S. Nuclear Regulatory Commission standardized plant analysis risk models of U.S. commercial nuclear power plants. The AOV failure modes considered are failure-to-open/close, failure to operate or control, and spurious operation. 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. No statistically significant increasing trends were identified in the AOV results. Statistically significant decreasing trends were identified in two areas: AOV operation demands less than or equal to 20 demands per year and greater than 20 demands.

CONTENTS

FIGURES

TABLES

ACRONYMS

AOV   air-operated valve

EPIX   Equipment Performance and Information Exchange

FTOC   failure-to-open/close
FTOP   failure to operate or control
FY   fiscal year

MSPI   Mitigating Systems Performance Index

NPRDS   Nuclear Plant Reliability Data System

SO   spurious operation

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1. INTRODUCTION

This report presents an enhanced performance evaluation of air-operated valves (AOVs) at U.S. commercial nuclear power plants. This report does not estimate values for use in probabilistic risk assessments, but does evaluate component performance over time. The 2010 Component Reliability Update (Reference 1), which is an update to Reference 2 (NUREG/CR-6928), reports the current AOV unreliability estimates using Equipment Performance and Information Exchange (EPIX) data from 1998 through 2010 for use in probabilistic risk assessments.

The data used in this study are based on the operating experience failure reports from fiscal year (FY)-98 through FY-12 for the component reliability as reported in EPIX. The AOV 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.

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.

The objective of the enhanced component performance study is to present an analysis of factors that could influence the system and component trends in addition to annual performance trends of failure rates and probabilities. Engineering analyses were performed with respect to time period and failure mode (Section 4.2). The factors analyzed are: sub-component, failure cause, detection method, recovery.

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, no statistically significant increasing trends were identified in the AOV results.

Statistically significant decreasing trends were identified in the AOV results for the following:

- Frequency (demands per reactor year) of AOV operation demands, ≤ 20 demands per year. (see Figure 7)

- Frequency (demands per reactor year) of AOV operation demands, > 20 demands per year. (see Figure 8)

Considering the low-demand AOVs; Table 3 shows that 94% of the AOV FTOC failures occurred in seven systems. Table 4 shows that 100% of the AOV FTOP failures occurred in seven systems. Similarly, Table 5 shows that 91% of the AOV SO failures occurred in four systems.

Considering the high-demand AOVs; Table 6 shows that 94% of the AOV FTOC failures occurred in five systems. Table 7 shows that 93% of the AOV FTOP failures occurred in three systems. Similarly, Table 8 shows that 100% of the AOV SO failures occurred in five systems.

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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 AOVs have been calculated from the operating experience for the FTOC, FTOP, and SO failure modes. The AOV data set obtained from EPIX was segregated to AOVs with ≤ 20 demands/yr and AOVs with > 20 demands/yr and includes AOVs in the systems listed in Table 1. Reference 1 lists the industry failure data for AOVs with ≤ 20 demands/yr.

Table 2 shows industry-wide failure probability and failure rate results for the AOV with ≤ 20 demands/yr from Reference 1. No results are shown for > 20 demands/yr AOVs because Reference 1 does not present results for > 20 demands/yr.

The AOVs 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. AOV systems.

System	Description	AOV Component Count		
		Total	≤20 demands/yr	>20 demands/yr
AFW	Auxiliary feedwater	360	193	167
CCW	Component cooling water	436	295	141
CRD	Control rod drive	117	66	51
CSR	Containment spray recirculation	30	28	2
HCI	High pressure coolant injection	14	7	7
HPI	High pressure injection	94	70	24
ISO	Isolation condenser	10	6	4
LCS	Low pressure core spray	12	10	2
RCI	Reactor core isolation	8	6	2
RCS	Reactor coolant	109	52	57
RHR	Residual heat removal	259	126	133
SWN	Normally running service water	511	296	215
	Total	**1960**	**1155**	**805**

Table 2. Industry-wide distributions of p (failure probability) and λ (hourly rate) for AOVs (≤ 20 demands/yr).

Failure Mode	5%	Median	Mean	95%	Distribution		
					Type	α	β
FTOC	6.27E−05	6.86E−04	9.51E−04	2.74E−03	Beta	1.11	1.168E+03
FTOP	2.66E−08	1.93E−07	2.49E−07	6.59E−07	Gamma	1.42	5.719E+06
SO	2.04E−09	7.46E−08	1.31E−07	4.49E−07	Gamma	0.68	5.211E+06

3.2 AOV 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.
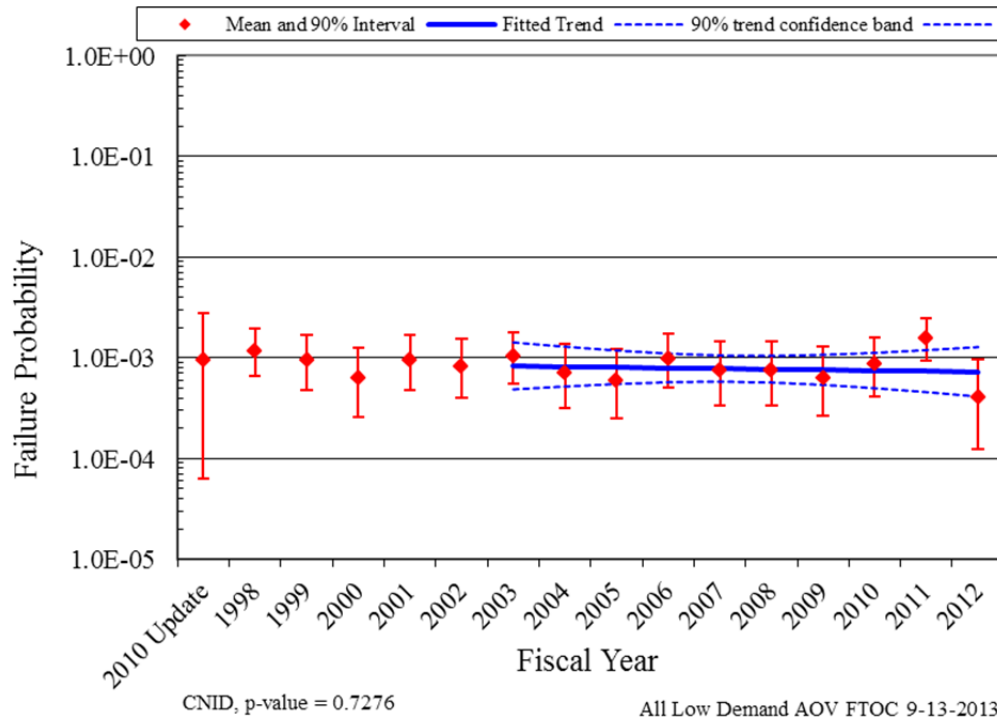
Figure 1. Failure probability estimate trend for AOV FTOC, all systems, industry-wide trend of AOVs with ≤ 20 demands per year.
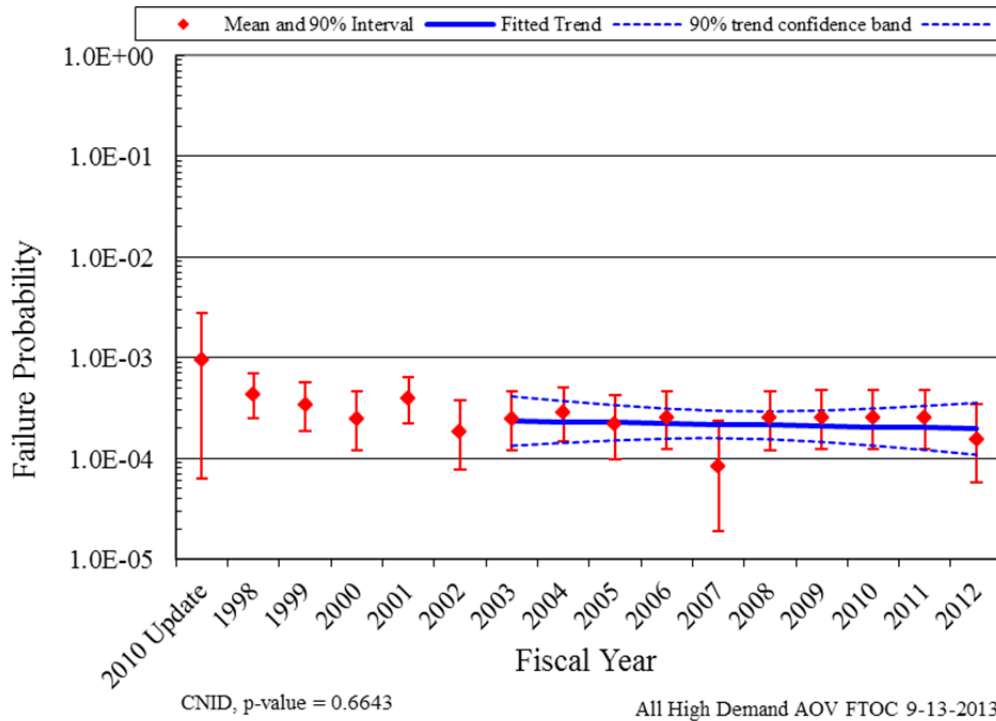
Figure 2. Failure probability estimate trend for AOV FTOC, all systems, industry-wide trend of AOVs with > 20 demands per year.
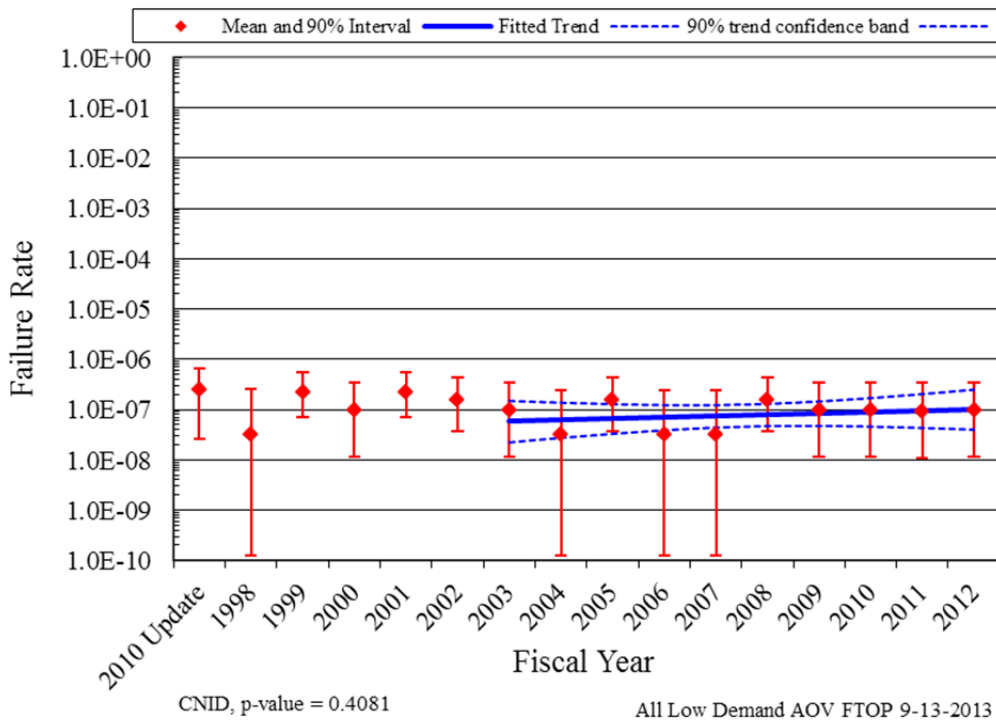
Figure 3. Failure rate estimate trend for AOV FTOP, all systems, industry-wide trend of AOVs with ≤ 20 demands per year.
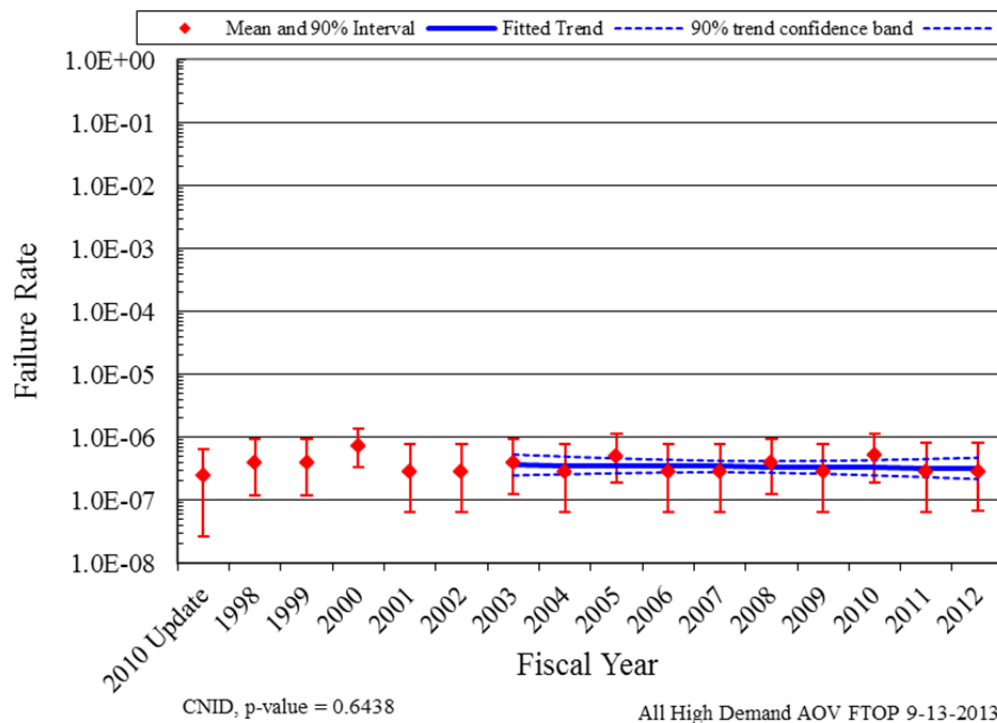
Figure 4. Failure rate estimate trend for AOV FTOP, all systems, industry-wide trend of AOVs with > 20 demands per year.
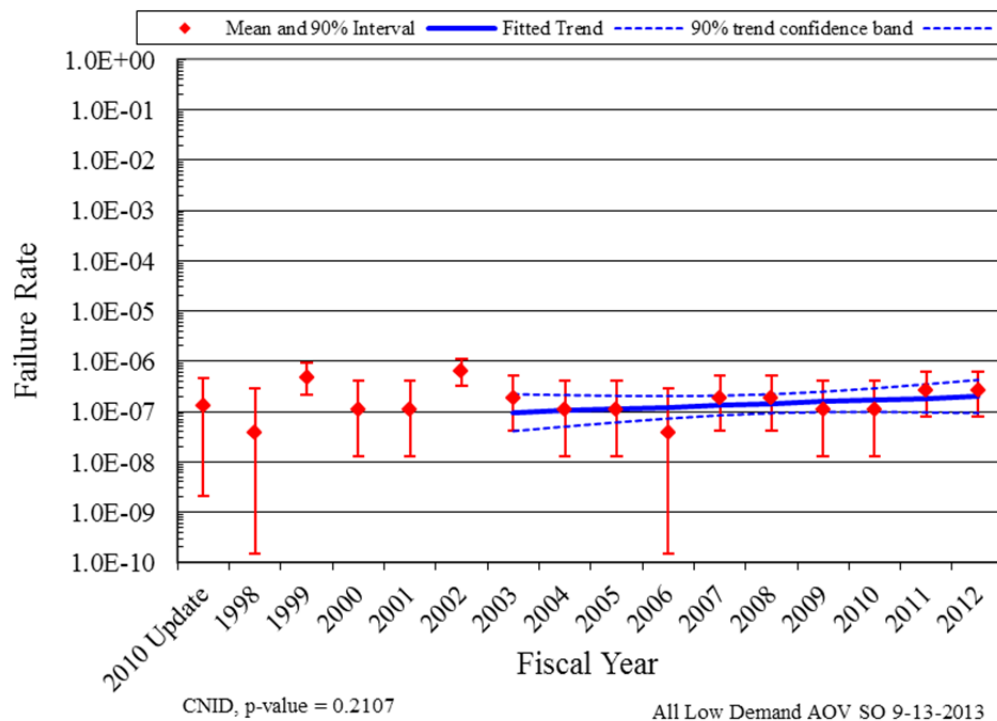
Figure 5. Failure rate estimate trend for AOV SO, all systems, industry-wide trend of AOVs with ≤ 20 demands per year.
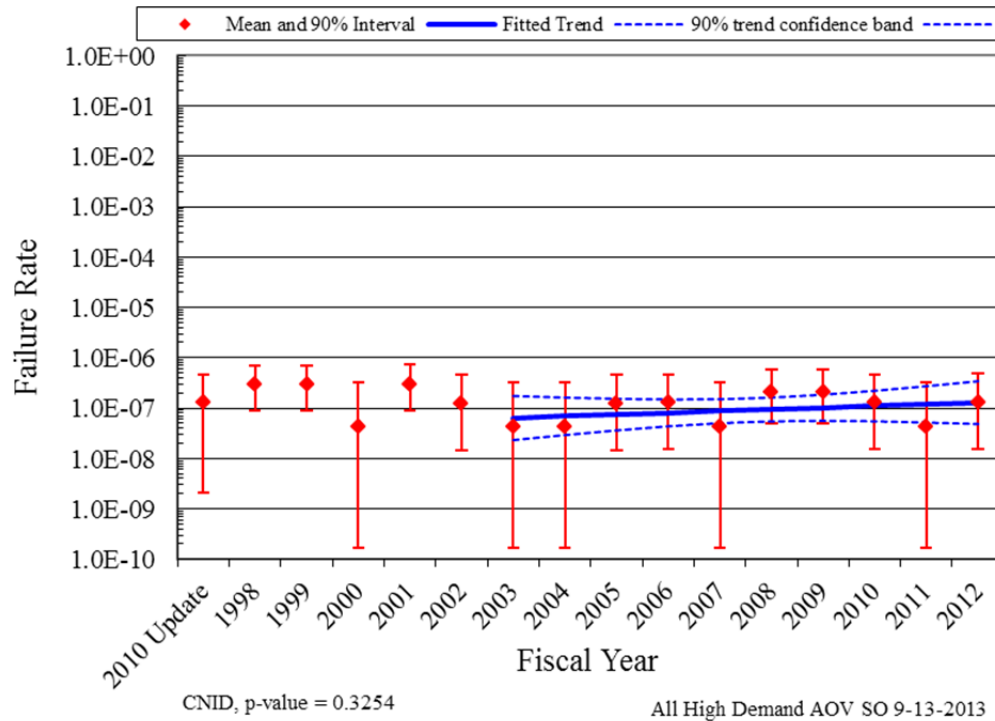
Figure 6. Failure rate estimate trend for AOV SO, all systems, industry-wide trend of AOVs with > 20 demands per year.

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 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

4.1 Overview

This section presents frequency trends for AOV 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 AOV demands of ≤ 20 demands per reactor-year AOVs. Figure 9 shows the trend in failure events for FTOC mode for AOV ≤ 20 demands, and Figure 13 shows the trend for the SO failure events for AOV ≤ 20 demands.

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

Table 3 summarizes the failures by system, year, and the FTOC failure mode for AOV ≤ 20 demands. The systems contributing 50% or more (in bold) to the FTOC failure mode are AFW, CCW, HPI, RHR, SWN, and SWS. Table 4 summarizes the failures by system, year, and the FTOP failure mode for AOV ≤ 20 demands. The systems contributing 50% or more (in bold) to the FTOP failure mode are AFW, CCW, SWN, and SWS. Table 5 summarizes the failures by system, year, and the SO failure mode for AOV ≤ 20 demands. The systems together contributing 50% or more (in bold) to the SO failure mode are AFW, CCW, and CRD.

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

Tables 16–23 provide the plot data for frequency (per reactor year) of AOV 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.
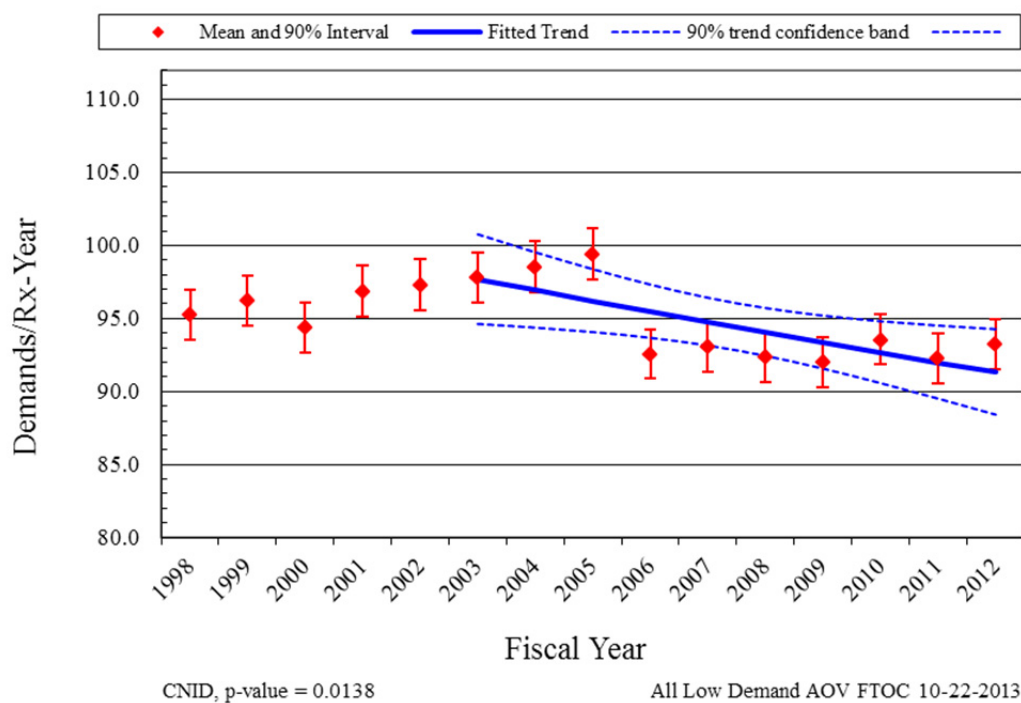
Figure 7. Frequency (demands per reactor year) of AOV operation demands, ≤ 20 demands per year.
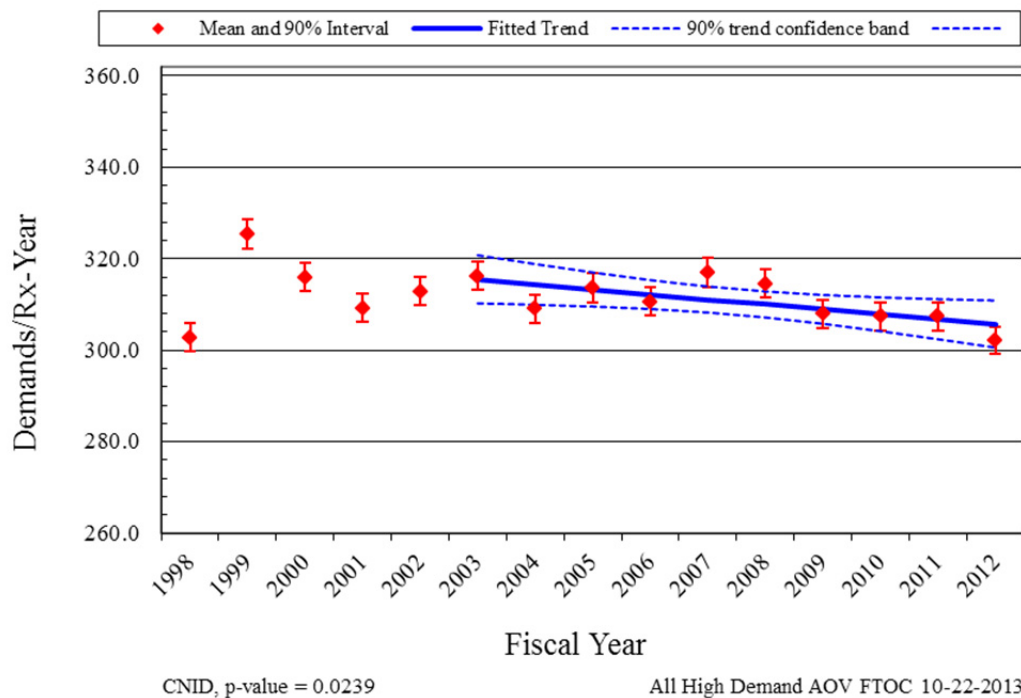
Figure 8. Frequency (demands per reactor year) of AOV operation demands, > 20 demands per year.
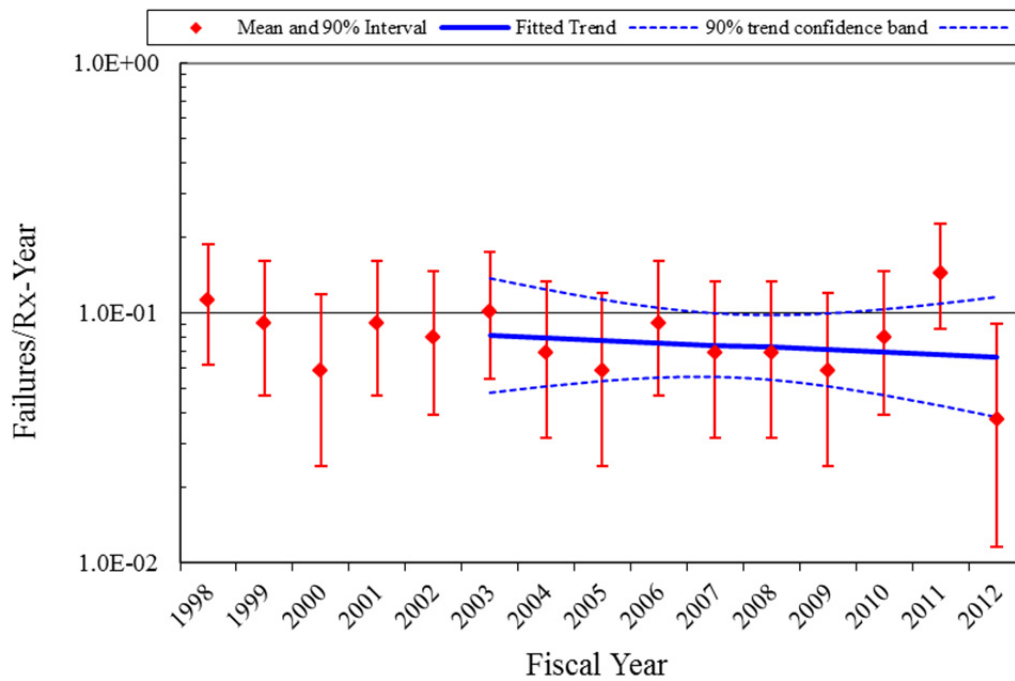
CNID, p-value = 0.6020   All Low Demand AOV FTOC 9-11-2013

Figure 9. Frequency (failures per reactor year) of AOV FTOC events ≤ 20 demands per year.
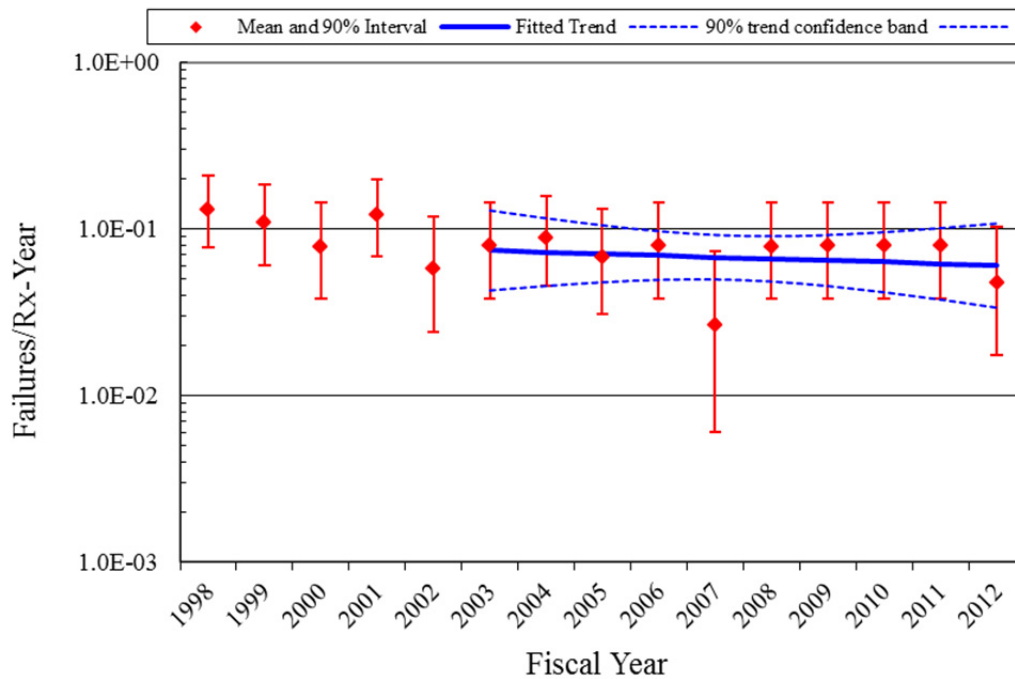
CNID, p-value = 0.6016   All High Demand AOV FTOC 9-11-2013

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

Figure 11. Frequency (failures per reactor year) of AOV FTOP events ≤ 20 demands per year.
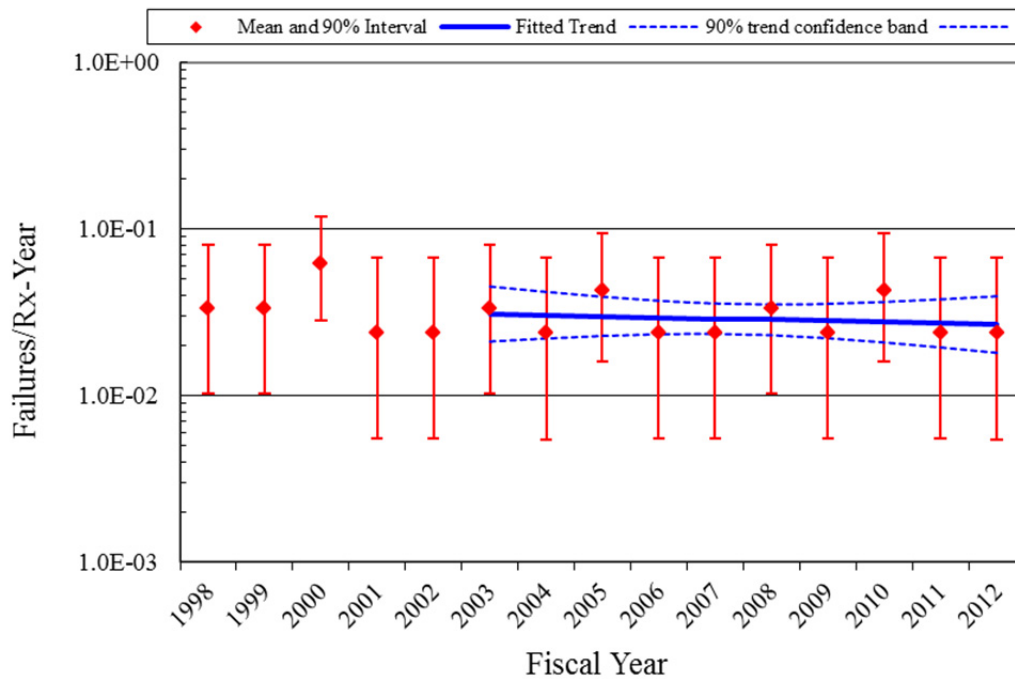
Figure 12. Frequency (failures per reactor year) of AOV FTOP events > 20 demands per year.
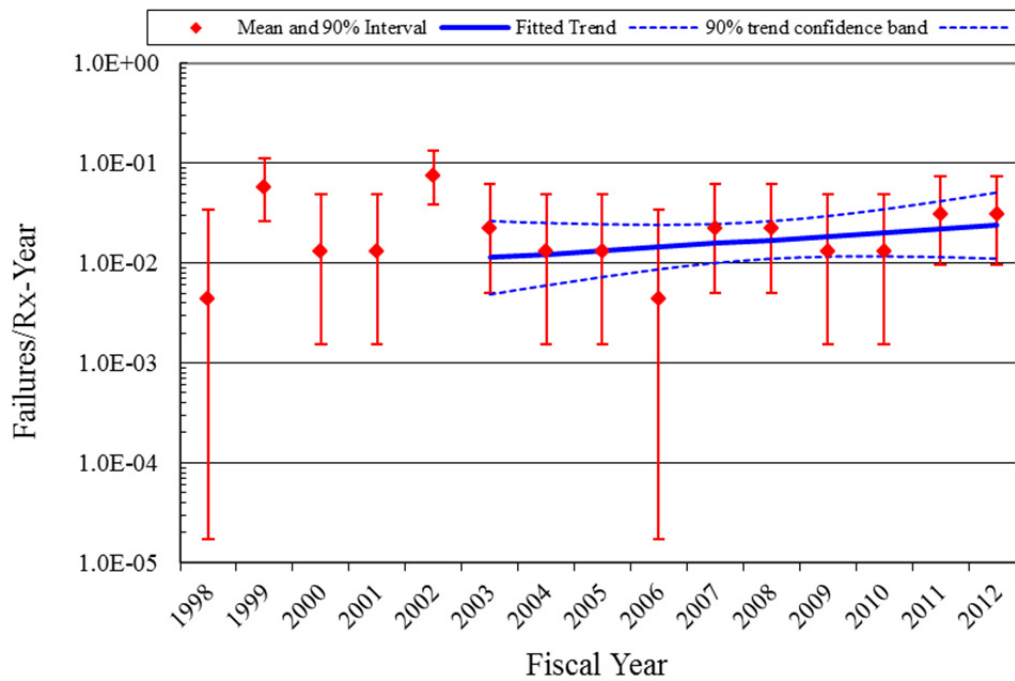
Figure 13. Frequency (failures per reactor year) of AOV SO events ≤ 20 demands per year.
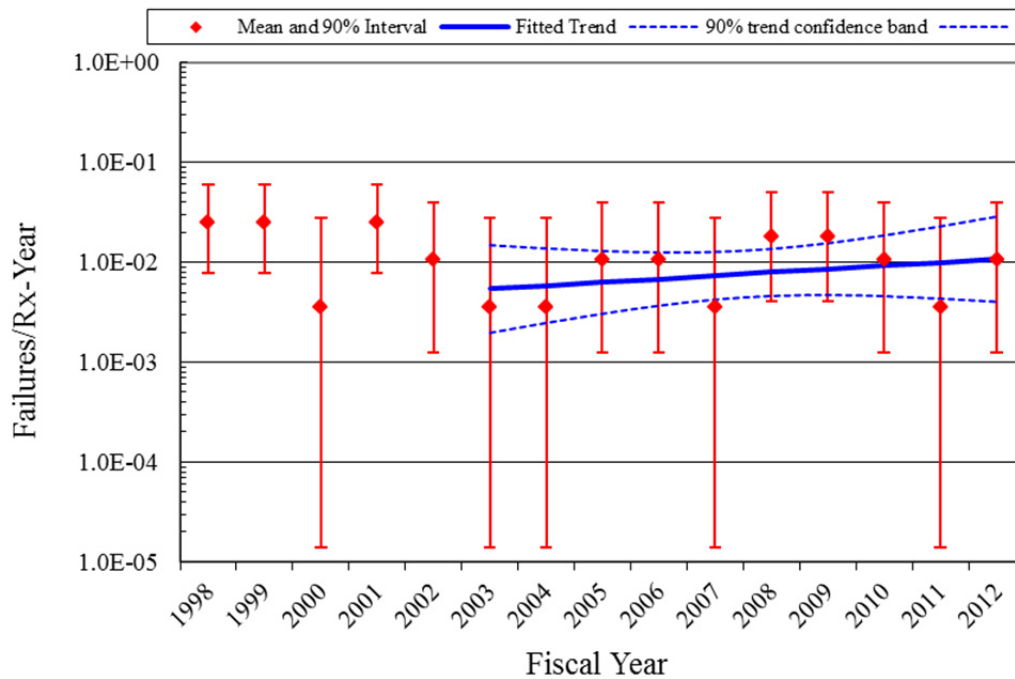
Figure 14. Frequency (failures per reactor year) of AOV SO events > 20 demands per year.

Table 3. Summary of AOV 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	194	16.7%	5	1	3	3	3			2	2	1	1	1	3			25	**23.6%**
CCW	295	25.4%				2	3		1	1	2	2	1		1	3		16	**15.1%**
CRD	66	5.7%		1												1		2	1.9%
CSR	28	2.4%								1		1						2	1.9%
HPI	70	6.0%						2			1		1			3		7	**6.6%**
LCS	10	0.9%		1														1	0.9%
RCI	6	0.5%											1					1	0.9%
RCS	52	4.5%		1				1	1					1	1	1		6	5.7%
RHR	126	10.8%	1	1			1		1			2	1		1	1		9	**8.5%**
SWN	296	25.5%	4	3	2	3		2	3	1	3		1	3	1	2	2	30	**28.3%**
SWS	20	1.7%						4								2	1	7	**6.6%**
Total	1163	100%	10	8	5	8	7	9	6	5	8	6	6	5	7	13	3	106	100%

Table 4. Summary of AOV failure counts for the FTOP 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	194	21.9%			1										1			2	**11.1%**
CCW	295	33.3%		1		1	1			1			1	1				6	**33.3%**
HPI	70	7.9%				1												1	5.6%
ISO	6	0.7%					1											1	5.6%
RCI	6	0.7%														1		1	5.6%
SWN	296	33.4%		1		1		1		1			1					5	**27.8%**
SWS	20	2.3%		1													1	2	**11.1%**
Total	887	100%		3	1	3	2	1		2			2	1	1	1	1	18	100%

Table 5. Summary of AOV 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	194	23.6%				1		1	1	1		1	1	1		1		8	**25.0%**
CCW	295	35.8%	1	1			7					1			1	1	3	15	**46.9%**
CRD	66	8.0%	4															4	**12.5%**
HPI	70	8.5%						1										1	3.1%
RCS	52	6.3%	1				1											2	6.3%
RHR	126	15.3%										1						1	3.1%
SWS	20	2.4%														1		1	3.1%
Total	823		6	1		1	8	2	1	1		2	2	1	1	3	3	32	100%

Table 6. Summary of AOV 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	166	20.8%		1	1	3	1	2	5	3	3		2		1	2	3	27	**25.2%**
CCW	141	17.7%	2		3			1			1				1		1	9	8.4%
CRD	51	6.4%	2															2	1.9%
RCS	57	7.1%				4		2	2	1		1			1			11	10.3%
RHR	133	16.7%	1	7	1		1	1			1	1	1	2	2	2		20	**18.7%**
SWN	215	26.9%	3	2	2	4	3	1	1	2	2		4	5	2	3		34	**31.8%**
SWS	35	4.4%	4															4	3.7%
Total	798	100%	12	10	7	11	5	7	8	6	7	2	7	7	7	7	4	107	100%

Table 7. Summary of AOV failure counts for the FTOP 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	166	23.3%	1		1						2	1				1		6	**14.3%**
CCW	141	19.8%	1										1					2	4.8%
RCS	57	8.0%													1			1	2.4%
RHR	133	18.7%	1	1				1					1				1	5	11.9%
SWN	215	30.2%		2	5	2	1	3	2	4		1	1	2	3	1	1	28	**66.7%**
Total	712	100%	3	3	6	2	2	3	2	4	2	2	3	2	4	2	2	42	100%

Table 8. Summary of AOV 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	FY-10	FY-11	FY-12	Total	Percent of Failures
AFW	**166**	**25.3%**				1			1						1			**3**	**16.7%**
CCW	141	21.5%		1												1		2	11.1%
RCI	**2**	**0.3%**										1						**1**	**5.6%**
RHR	133	20.2%	2									1						3	**16.7%**
SWN	**215**	**32.7%**	1	2		2	1				1			2				**9**	**50.0%**
Total	657	100%	3	3		3	1		1	1		2	2	1		1		18	100%

4.2 AOV Engineering Analysis by Failure Modes

The engineering analysis of AOV failure sub-components, causes, detection methods, and recovery are presented in this section. Each analysis first divides the events into two categories: AOVs with ≤ 20 demands/yr [Low-Demands] and AOVs with > 20 demands/yr [High-Demands].

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

AOV 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.

AOV 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 and FTOP failure modes is grouped as Internal. Internal means that the cause was related to something within the AOV component such as a worn out part or the normal internal environment. The second most likely cause for the FTOC and FTOP failure mode is grouped as Human, which includes human action, procedures and maintenance. The most likely cause for the SO failure mode is grouped as Human or Design. Of particular interest is the Human cause group.

AOV detection methods to the three failure modes are presented in Figure 17. Note that there are differences between the Low-Demand and High-Demand detection methods.

Low-Demand—the most likely detection method for FTOC is a testing demand. The most likely detection method for FTOP and SO is an actual demand.

High-Demand—the most likely detection method for FTOC is a non-test demand followed by testing. The most likely detection method for FTOP and SO is an actual demand.

AOV recovery to the three failure modes are presented in Figure 18. The overall non-recoverable to recoverable 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	Design error or inadequacy	Used when a design error is made.
Design	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.
External	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	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.
Human	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	Internal environment	The internal environment led to the failure. Debris/Foreign material as well as an operating medium chemistry issue.
Internal	Setpoint drift	Used when the cause of a failure is the result of setpoint drift or adjustment.
Internal	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	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.
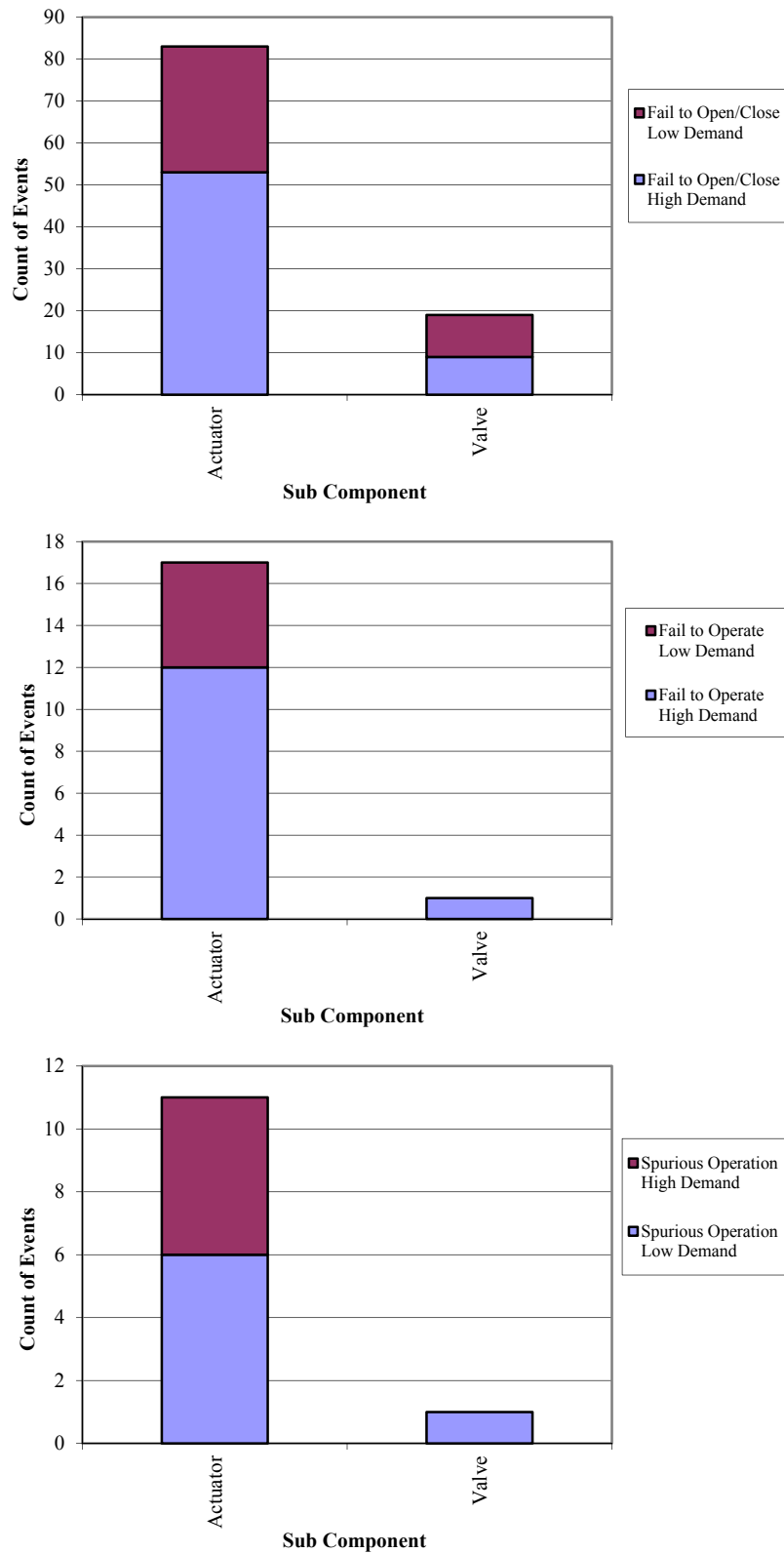
Figure 15. AOV failure breakdown by period, sub component, and failure mode.
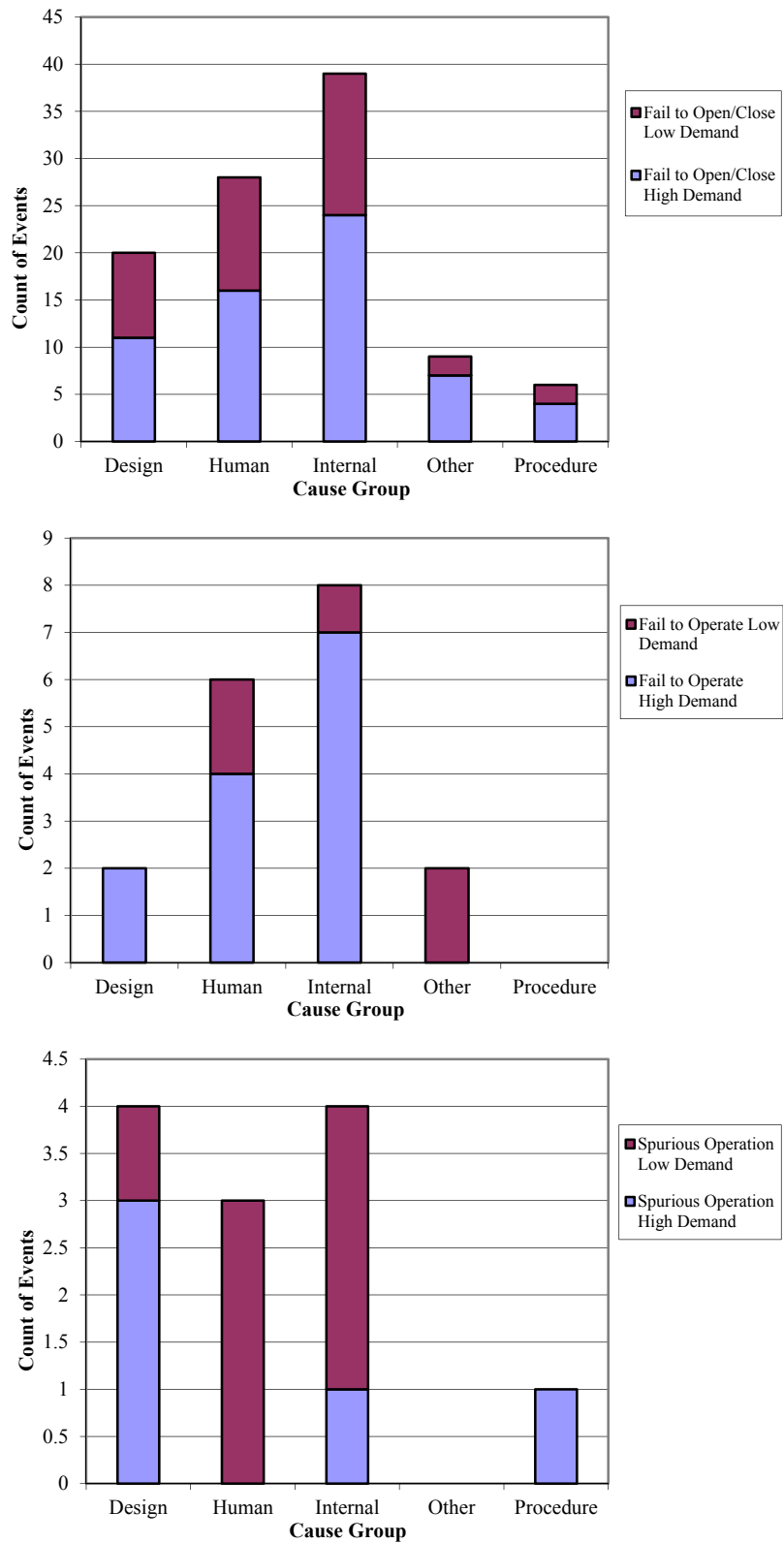
Figure 16. AOV breakdown by time period, cause group, and failure mode.
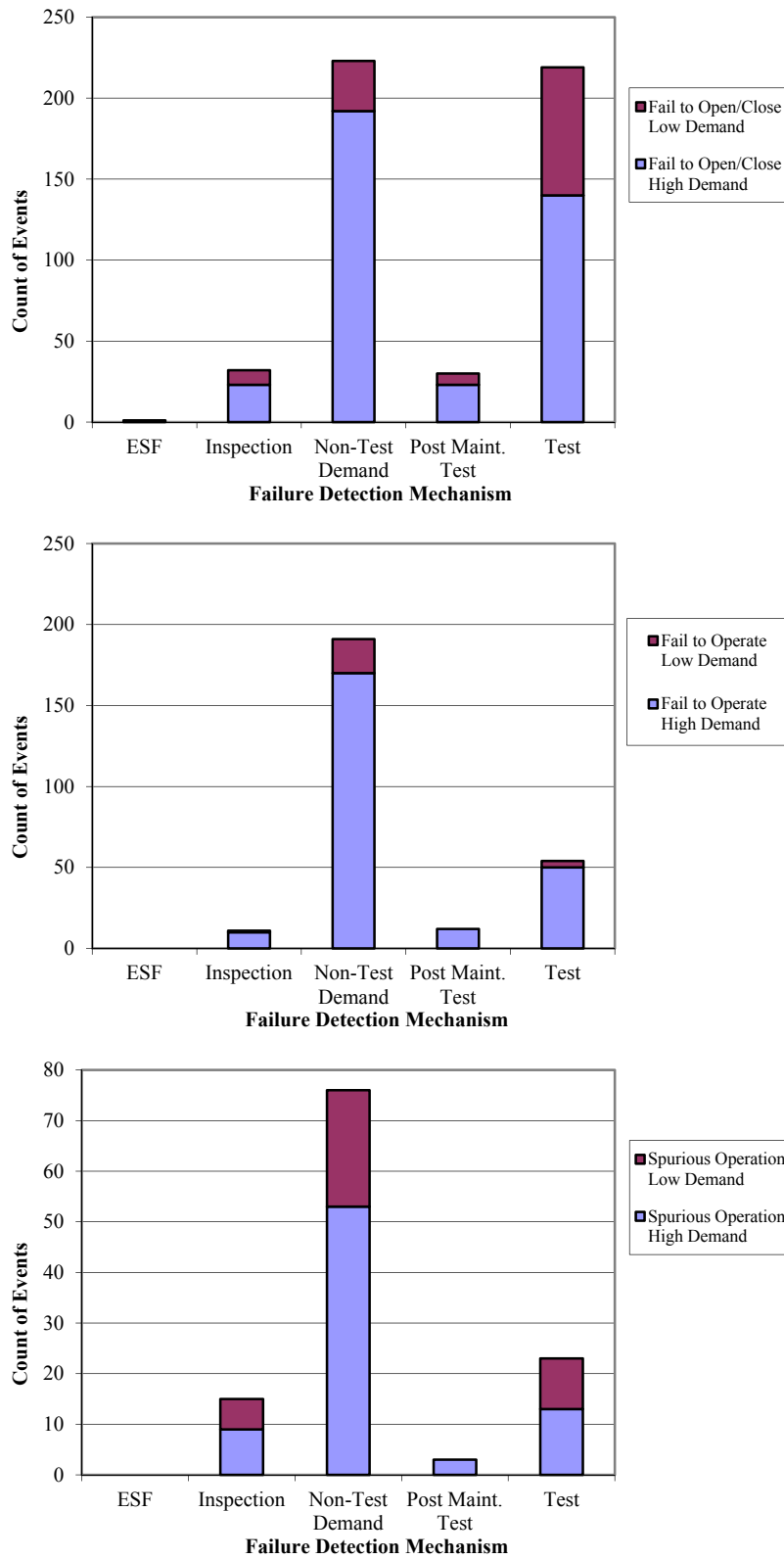
Figure 17. AOV component failure distribution by period, failure mode, and method of detection.
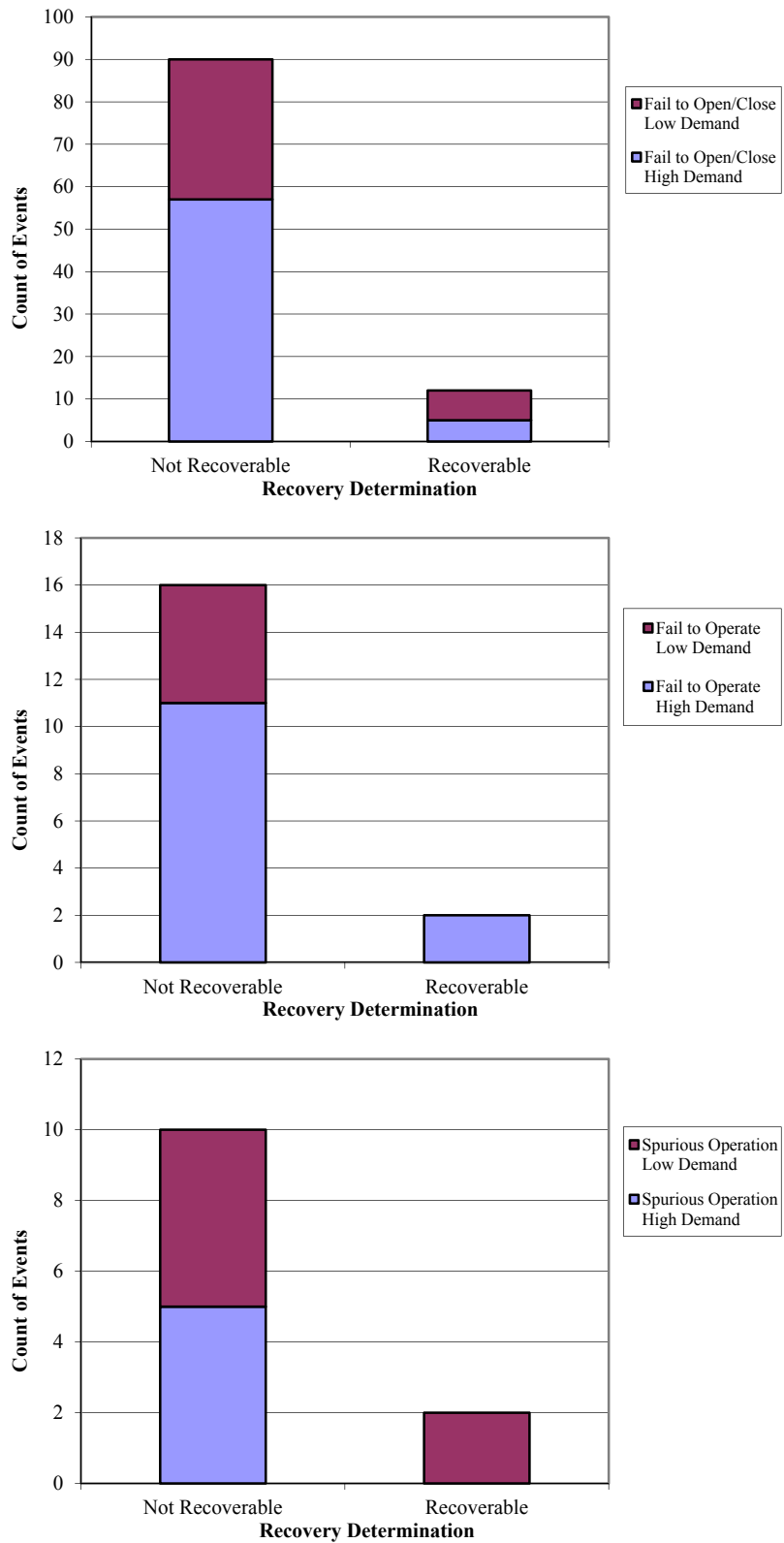
Figure 18. AOV component failure distribution by period, failure mode, and recovery.

5. AOV ASSEMBLY DESCRIPTION

An AOV assembly consists of a valve body and pneumatic operator sub-components. The valve body is generally a globe or butterfly type. The pneumatic operator is generally a piston or diaphragm type actuator. Main steam isolation valves and power operated relief valves are excluded from the AOV study even though pneumatically operated, as these are valves with different design and operating features.

The piece-parts of the valve body are the stem, packing, and internals. The pneumatic operator piece-parts may include piston internals/seals or diaphragm, positioner, mechanical linkage, volume booster, pilot valve, bolting, air regulator, airline, and wiring/contacts. Failures associated with instrument air systems that are not integral to the AOV assembly (e.g., contamination from the instrument air system that failed the AOV) are excluded in the AOV analysis.

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

6. DATA TABLES

Table 10. Plot data for industry-wide AOV 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
Update 2010						6.27E−05	2.74E−03	9.51E−04
1998	10	8,284.2				6.52E−04	1.98E−03	1.18E−03
1999	8	8,371.0				4.83E−04	1.68E−03	9.47E−04
2000	5	8,231.5				2.59E−04	1.27E−03	6.23E−04
2001	8	8,425.5				4.80E−04	1.67E−03	9.42E−04
2002	7	8,464.3				4.01E−04	1.52E−03	8.27E−04
2003	9	8,506.7	8.32E−04	4.86E−04	1.42E−03	5.56E−04	1.79E−03	1.04E−03
2004	6	8,592.2	8.20E−04	5.20E−04	1.29E−03	3.20E−04	1.36E−03	7.07E−04
2005	5	8,649.1	8.08E−04	5.51E−04	1.18E−03	2.47E−04	1.21E−03	5.95E−04
2006	8	8,052.8	7.96E−04	5.73E−04	1.10E−03	5.01E−04	1.74E−03	9.82E−04
2007	6	8,095.6	7.84E−04	5.81E−04	1.06E−03	3.39E−04	1.44E−03	7.47E−04
2008	6	8,056.5	7.72E−04	5.69E−04	1.05E−03	3.40E−04	1.44E−03	7.51E−04
2009	5	8,003.9	7.61E−04	5.40E−04	1.07E−03	2.66E−04	1.30E−03	6.39E−04
2010	7	8,137.0	7.50E−04	5.00E−04	1.12E−03	4.16E−04	1.58E−03	8.58E−04
2011	13	8,024.7	7.39E−04	4.57E−04	1.19E−03	9.37E−04	2.47E−03	1.57E−03
2012	3	8,131.5	7.28E−04	4.14E−04	1.28E−03	1.24E−04	9.68E−04	4.01E−04
Total	106	124,026.5						

Table 11. Plot data for industry-wide AOV 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
Update 2010						6.27E−05	2.74E−03	9.51E−04
1998	12	26,651.6				2.53E−04	6.95E−04	4.33E−04
1999	10	28,626.8				1.88E−04	5.71E−04	3.41E−04
2000	7	27,878.7				1.21E−04	4.59E−04	2.49E−04
2001	11	27,216.8				2.23E−04	6.40E−04	3.91E−04
2002	5	27,533.2				7.70E−05	3.76E−04	1.85E−04
2003	7	27,825.5	2.35E−04	1.34E−04	4.14E−04	1.21E−04	4.60E−04	2.50E−04
2004	8	27,270.1	2.31E−04	1.43E−04	3.72E−04	1.47E−04	5.12E−04	2.89E−04
2005	6	27,599.5	2.26E−04	1.51E−04	3.38E−04	9.89E−05	4.20E−04	2.18E−04
2006	7	27,332.6	2.22E−04	1.57E−04	3.13E−04	1.23E−04	4.67E−04	2.54E−04
2007	2	27,892.2	2.18E−04	1.59E−04	2.98E−04	1.90E−05	2.34E−04	8.31E−05
2008	7	27,759.2	2.13E−04	1.55E−04	2.93E−04	1.21E−04	4.61E−04	2.50E−04
2009	7	27,106.6	2.09E−04	1.46E−04	3.00E−04	1.24E−04	4.71E−04	2.56E−04
2010	7	27,052.1	2.05E−04	1.34E−04	3.13E−04	1.24E−04	4.72E−04	2.56E−04
2011	7	27,048.6	2.01E−04	1.22E−04	3.33E−04	1.24E−04	4.72E−04	2.57E−04
2012	4	26,661.9	1.97E−04	1.09E−04	3.57E−04	5.76E−05	3.41E−04	1.56E−04
Total	107	411,455.5						

Table 12. Plot data for industry-wide AOV FTOP 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
Update 2010						2.66E−08	6.59E−07	2.49E−07
1998	0	10,231,680.0				1.25E−10	2.49E−07	3.19E−08
1999	3	10,205,400.0				6.93E−08	5.41E−07	2.24E−07
2000	1	10,249,200.0				1.12E−08	3.53E−07	9.56E−08
2001	3	10,301,760.0				6.88E−08	5.37E−07	2.22E−07
2002	2	10,301,760.0				3.64E−08	4.47E−07	1.59E−07
2003	1	10,310,520.0	5.76E−08	2.23E−08	1.49E−07	1.12E−08	3.51E−07	9.52E−08
2004	0	10,319,280.0	6.12E−08	2.73E−08	1.37E−07	1.25E−10	2.48E−07	3.17E−08
2005	2	10,319,280.0	6.50E−08	3.30E−08	1.28E−07	3.63E−08	4.46E−07	1.59E−07
2006	0	10,380,600.0	6.91E−08	3.89E−08	1.23E−07	1.24E−10	2.47E−07	3.16E−08
2007	0	10,310,520.0	7.35E−08	4.40E−08	1.23E−07	1.25E−10	2.48E−07	3.17E−08
2008	2	10,319,280.0	7.81E−08	4.71E−08	1.30E−07	3.63E−08	4.46E−07	1.59E−07
2009	1	10,301,760.0	8.30E−08	4.75E−08	1.45E−07	1.12E−08	3.52E−07	9.53E−08
2010	1	10,301,760.0	8.82E−08	4.60E−08	1.69E−07	1.12E−08	3.52E−07	9.53E−08
2011	1	10,459,440.0	9.38E−08	4.32E−08	2.04E−07	1.11E−08	3.48E−07	9.43E−08
2012	1	10,363,080.0	9.97E−08	3.99E−08	2.49E−07	1.11E−08	3.50E−07	9.49E−08
Total	18	154,675,320.0						

Table 13. Plot data for industry-wide AOV FTOP trend with > 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
Update 2010						2.66E−08	6.59E−07	2.49E−07
1998	3	7,507,320.0				1.22E−07	9.50E−07	3.93E−07
1999	3	7,533,600.0				1.21E−07	9.47E−07	3.92E−07
2000	6	7,551,120.0				3.29E−07	1.40E−06	7.26E−07
2001	2	7,454,760.0				6.47E−08	7.94E−07	2.82E−07
2002	2	7,507,320.0				6.43E−08	7.90E−07	2.81E−07
2003	3	7,472,280.0	3.63E−07	2.48E−07	5.31E−07	1.22E−07	9.53E−07	3.94E−07
2004	2	7,472,280.0	3.58E−07	2.59E−07	4.94E−07	6.46E−08	7.93E−07	2.82E−07
2005	4	7,481,040.0	3.53E−07	2.69E−07	4.63E−07	1.87E−07	1.11E−06	5.07E−07
2006	2	7,446,000.0	3.48E−07	2.76E−07	4.39E−07	6.47E−08	7.95E−07	2.83E−07
2007	2	7,446,000.0	3.43E−07	2.78E−07	4.24E−07	6.47E−08	7.95E−07	2.83E−07
2008	3	7,463,520.0	3.39E−07	2.74E−07	4.19E−07	1.22E−07	9.54E−07	3.95E−07
2009	2	7,446,000.0	3.34E−07	2.63E−07	4.23E−07	6.47E−08	7.95E−07	2.83E−07
2010	4	7,349,640.0	3.29E−07	2.49E−07	4.36E−07	1.90E−07	1.12E−06	5.14E−07
2011	2	7,367,160.0	3.25E−07	2.33E−07	4.53E−07	6.53E−08	8.02E−07	2.85E−07
2012	2	7,253,280.0	3.20E−07	2.16E−07	4.74E−07	6.62E−08	8.13E−07	2.89E−07
Total	42	111,751,320.0						

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

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
Update 2010						2.04E−09	4.49E−07	1.31E−07
1998	0	10,231,680.0				1.47E−10	2.92E−07	3.74E−08
1999	6	10,205,400.0				2.21E−07	9.37E−07	4.87E−07
2000	1	10,249,200.0				1.31E−08	4.14E−07	1.12E−07
2001	1	10,301,760.0				1.31E−08	4.12E−07	1.12E−07
2002	8	10,301,760.0				3.23E−07	1.12E−06	6.33E−07
2003	2	10,310,520.0	9.53E−08	4.09E−08	2.22E−07	4.26E−08	5.23E−07	1.86E−07
2004	1	10,319,280.0	1.03E−07	5.03E−08	2.13E−07	1.31E−08	4.11E−07	1.12E−07
2005	1	10,319,280.0	1.12E−07	6.12E−08	2.06E−07	1.31E−08	4.11E−07	1.12E−07
2006	0	10,380,600.0	1.22E−07	7.30E−08	2.04E−07	1.45E−10	2.89E−07	3.70E−08
2007	2	10,310,520.0	1.32E−07	8.44E−08	2.08E−07	4.26E−08	5.23E−07	1.86E−07
2008	2	10,319,280.0	1.44E−07	9.32E−08	2.22E−07	4.26E−08	5.23E−07	1.86E−07
2009	1	10,301,760.0	1.56E−07	9.78E−08	2.49E−07	1.31E−08	4.12E−07	1.12E−07
2010	1	10,301,760.0	1.69E−07	9.85E−08	2.91E−07	1.31E−08	4.12E−07	1.12E−07
2011	3	10,459,440.0	1.84E−07	9.65E−08	3.50E−07	7.97E−08	6.22E−07	2.57E−07
2012	3	10,363,080.0	2.00E−07	9.31E−08	4.28E−07	8.03E−08	6.27E−07	2.59E−07
Total	32	154,675,320.0						

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

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
Update 2010						2.04E−09	4.49E−07	1.31E−07
1998	3	7,507,320.0				9.13E−08	7.13E−07	2.95E−07
1999	3	7,533,600.0				9.11E−08	7.11E−07	2.94E−07
2000	0	7,551,120.0				1.65E−10	3.28E−07	4.20E−08
2001	3	7,454,760.0				9.17E−08	7.16E−07	2.96E−07
2002	1	7,507,320.0				1.48E−08	4.66E−07	1.26E−07
2003	0	7,472,280.0	6.38E−08	2.32E−08	1.75E−07	1.66E−10	3.30E−07	4.22E−08
2004	0	7,472,280.0	6.89E−08	2.93E−08	1.62E−07	1.66E−10	3.30E−07	4.22E−08
2005	1	7,481,040.0	7.45E−08	3.62E−08	1.53E−07	1.49E−08	4.67E−07	1.27E−07
2006	1	7,446,000.0	8.06E−08	4.37E−08	1.49E−07	1.49E−08	4.69E−07	1.27E−07
2007	0	7,446,000.0	8.71E−08	5.04E−08	1.51E−07	1.66E−10	3.31E−07	4.23E−08
2008	2	7,463,520.0	9.42E−08	5.48E−08	1.62E−07	4.84E−08	5.95E−07	2.11E−07
2009	2	7,446,000.0	1.02E−07	5.61E−08	1.85E−07	4.85E−08	5.96E−07	2.12E−07
2010	1	7,349,640.0	1.10E−07	5.47E−08	2.22E−07	1.50E−08	4.73E−07	1.28E−07
2011	0	7,367,160.0	1.19E−07	5.19E−08	2.73E−07	1.68E−10	3.33E−07	4.26E−08
2012	1	7,253,280.0	1.29E−07	4.83E−08	3.43E−07	1.51E−08	4.76E−07	1.29E−07
Total	18	111,751,320.0						

Table 16. Plot data for frequency (events per reactor year) of AOV operation demands with ≤ 20 demands per year. Figure 7

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	8,284	87.0				9.35E+01	9.70E+01	9.52E+01
1999	8,371	87.0				9.45E+01	9.80E+01	9.62E+01
2000	8,232	87.2				9.27E+01	9.61E+01	9.44E+01
2001	8,426	87.0				9.51E+01	9.86E+01	9.68E+01
2002	8,464	87.0				9.56E+01	9.90E+01	9.73E+01
2003	8,507	87.0	9.77E+01	9.46E+01	1.01E+02	9.60E+01	9.95E+01	9.78E+01
2004	8,592	87.2	9.69E+01	9.44E+01	9.95E+01	9.68E+01	1.00E+02	9.85E+01
2005	8,649	87.0	9.62E+01	9.41E+01	9.84E+01	9.77E+01	1.01E+02	9.94E+01
2006	8,053	87.0	9.55E+01	9.37E+01	9.73E+01	9.09E+01	9.43E+01	9.26E+01
2007	8,096	87.0	9.48E+01	9.32E+01	9.64E+01	9.14E+01	9.48E+01	9.31E+01
2008	8,056	87.2	9.41E+01	9.25E+01	9.57E+01	9.07E+01	9.41E+01	9.24E+01
2009	8,004	87.0	9.34E+01	9.16E+01	9.52E+01	9.03E+01	9.37E+01	9.20E+01
2010	8,137	87.0	9.27E+01	9.06E+01	9.48E+01	9.18E+01	9.53E+01	9.35E+01
2011	8,025	87.0	9.20E+01	8.95E+01	9.45E+01	9.06E+01	9.39E+01	9.22E+01
2012	8,132	87.2	9.13E+01	8.84E+01	9.43E+01	9.15E+01	9.49E+01	9.32E+01
Total	124,027	1,306.0						

Table 17. Plot data for frequency (events per reactor year) of AOV operation demands with > 20 demands per year. Figure 8

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	26,652	88.0				3.00E+02	3.06E+02	3.03E+02
1999	28,627	88.0				3.22E+02	3.28E+02	3.25E+02
2000	27,879	88.2				3.13E+02	3.19E+02	3.16E+02
2001	27,217	88.0				3.06E+02	3.12E+02	3.09E+02
2002	27,533	88.0				3.10E+02	3.16E+02	3.13E+02
2003	27,826	88.0	3.15E+02	3.10E+02	3.21E+02	3.13E+02	3.19E+02	3.16E+02
2004	27,270	88.2	3.14E+02	3.10E+02	3.19E+02	3.06E+02	3.12E+02	3.09E+02
2005	27,600	88.0	3.13E+02	3.10E+02	3.17E+02	3.11E+02	3.17E+02	3.14E+02
2006	27,333	88.0	3.12E+02	3.09E+02	3.15E+02	3.08E+02	3.14E+02	3.11E+02
2007	27,892	88.0	3.11E+02	3.08E+02	3.14E+02	3.14E+02	3.20E+02	3.17E+02
2008	27,759	88.2	3.10E+02	3.07E+02	3.13E+02	3.11E+02	3.18E+02	3.15E+02
2009	27,107	88.0	3.09E+02	3.06E+02	3.12E+02	3.05E+02	3.11E+02	3.08E+02
2010	27,052	88.0	3.08E+02	3.04E+02	3.12E+02	3.04E+02	3.11E+02	3.07E+02
2011	27,049	88.0	3.07E+02	3.02E+02	3.11E+02	3.04E+02	3.10E+02	3.07E+02
2012	26,662	88.2	3.06E+02	3.01E+02	3.11E+02	2.99E+02	3.05E+02	3.02E+02
Total	411,456	1,321.0						

Table 18. Plot data for frequency (events per reactor year) of AOV FTOC events with ≤ 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	10	87.0				6.21E−02	1.88E−01	1.12E−01
1999	8	87.0				4.64E−02	1.61E−01	9.10E−02
2000	5	87.2				2.44E−02	1.19E−01	5.88E−02
2001	8	87.0				4.64E−02	1.61E−01	9.10E−02
2002	7	87.0				3.89E−02	1.48E−01	8.03E−02
2003	9	87.0	8.13E−02	4.80E−02	1.38E−01	5.42E−02	1.75E−01	1.02E−01
2004	6	87.2	7.95E−02	5.09E−02	1.24E−01	3.15E−02	1.34E−01	6.94E−02
2005	5	87.0	7.78E−02	5.35E−02	1.13E−01	2.45E−02	1.20E−01	5.89E−02
2006	8	87.0	7.61E−02	5.52E−02	1.05E−01	4.64E−02	1.61E−01	9.10E−02
2007	6	87.0	7.44E−02	5.56E−02	9.98E−02	3.16E−02	1.34E−01	6.96E−02
2008	6	87.2	7.28E−02	5.41E−02	9.81E−02	3.15E−02	1.34E−01	6.94E−02
2009	5	87.0	7.12E−02	5.09E−02	9.96E−02	2.45E−02	1.20E−01	5.89E−02
2010	7	87.0	6.97E−02	4.69E−02	1.04E−01	3.89E−02	1.48E−01	8.03E−02
2011	13	87.0	6.82E−02	4.26E−02	1.09E−01	8.65E−02	2.28E−01	1.45E−01
2012	3	87.2	6.67E−02	3.83E−02	1.16E−01	1.16E−02	9.04E−02	3.74E−02
Total	106	1,306.0						

Table 19. Plot data for frequency (events per reactor year) of AOV FTOC events with > 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	12	88.0				7.69E−02	2.11E−01	1.32E−01
1999	10	88.0				6.10E−02	1.85E−01	1.10E−01
2000	7	88.2				3.81E−02	1.45E−01	7.87E−02
2001	11	88.0				6.89E−02	1.98E−01	1.21E−01
2002	5	88.0				2.41E−02	1.18E−01	5.79E−02
2003	7	88.0	7.44E−02	4.28E−02	1.29E−01	3.82E−02	1.45E−01	7.89E−02
2004	8	88.2	7.27E−02	4.55E−02	1.16E−01	4.55E−02	1.58E−01	8.92E−02
2005	6	88.0	7.10E−02	4.79E−02	1.05E−01	3.10E−02	1.31E−01	6.84E−02
2006	7	88.0	6.94E−02	4.95E−02	9.71E−02	3.82E−02	1.45E−01	7.89E−02
2007	2	88.0	6.78E−02	4.99E−02	9.22E−02	6.03E−03	7.40E−02	2.63E−02
2008	7	88.2	6.62E−02	4.84E−02	9.06E−02	3.81E−02	1.45E−01	7.87E−02
2009	7	88.0	6.47E−02	4.55E−02	9.21E−02	3.82E−02	1.45E−01	7.89E−02
2010	7	88.0	6.32E−02	4.17E−02	9.59E−02	3.82E−02	1.45E−01	7.89E−02
2011	7	88.0	6.18E−02	3.77E−02	1.01E−01	3.82E−02	1.45E−01	7.89E−02
2012	4	88.2	6.04E−02	3.38E−02	1.08E−01	1.74E−02	1.03E−01	4.72E−02
Total	107	1,321.0						

Table 20. Plot data for frequency (events per reactor year) of AOV FTOP events with ≤ 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	0	87.0				1.48E−05	2.94E−02	3.76E−03
1999	3	87.0				8.16E−03	6.37E−02	2.64E−02
2000	1	87.2				1.32E−03	4.16E−02	1.13E−02
2001	3	87.0				8.16E−03	6.37E−02	2.64E−02
2002	2	87.0				4.31E−03	5.30E−02	1.88E−02
2003	1	87.0	6.82E−03	2.65E−03	1.76E−02	1.32E−03	4.17E−02	1.13E−02
2004	0	87.2	7.26E−03	3.24E−03	1.62E−02	1.48E−05	2.94E−02	3.76E−03
2005	2	87.0	7.71E−03	3.92E−03	1.52E−02	4.31E−03	5.30E−02	1.88E−02
2006	0	87.0	8.20E−03	4.62E−03	1.46E−02	1.48E−05	2.94E−02	3.76E−03
2007	0	87.0	8.72E−03	5.22E−03	1.46E−02	1.48E−05	2.94E−02	3.76E−03
2008	2	87.2	9.28E−03	5.59E−03	1.54E−02	4.30E−03	5.29E−02	1.88E−02
2009	1	87.0	9.86E−03	5.65E−03	1.72E−02	1.32E−03	4.17E−02	1.13E−02
2010	1	87.0	1.05E−02	5.47E−03	2.01E−02	1.32E−03	4.17E−02	1.13E−02
2011	1	87.0	1.12E−02	5.14E−03	2.42E−02	1.32E−03	4.17E−02	1.13E−02
2012	1	87.2	1.19E−02	4.75E−03	2.96E−02	1.32E−03	4.16E−02	1.13E−02
Total	18	1,306.0						

Table 21. Plot data for frequency (events per reactor year) of AOV FTOP events with > 20 demands per year.
Figure 10

| | | | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
FY	Failures	Reactor Years	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	3	88.0				1.04E−02	8.09E−02	3.35E−02
1999	3	88.0				1.04E−02	8.09E−02	3.35E−02
2000	6	88.2				2.81E−02	1.19E−01	6.20E−02
2001	2	88.0				5.47E−03	6.72E−02	2.39E−02
2002	2	88.0				5.47E−03	6.72E−02	2.39E−02
2003	3	88.0	3.09E−02	2.11E−02	4.52E−02	1.04E−02	8.09E−02	3.35E−02
2004	2	88.2	3.04E−02	2.20E−02	4.20E−02	5.46E−03	6.71E−02	2.38E−02
2005	4	88.0	2.99E−02	2.28E−02	3.92E−02	1.59E−02	9.40E−02	4.30E−02
2006	2	88.0	2.94E−02	2.34E−02	3.71E−02	5.47E−03	6.72E−02	2.39E−02
2007	2	88.0	2.90E−02	2.35E−02	3.57E−02	5.47E−03	6.72E−02	2.39E−02
2008	3	88.2	2.85E−02	2.31E−02	3.52E−02	1.03E−02	8.07E−02	3.34E−02
2009	2	88.0	2.80E−02	2.21E−02	3.55E−02	5.47E−03	6.72E−02	2.39E−02
2010	4	88.0	2.76E−02	2.09E−02	3.65E−02	1.59E−02	9.40E−02	4.30E−02
2011	2	88.0	2.71E−02	1.95E−02	3.78E−02	5.47E−03	6.72E−02	2.39E−02
2012	2	88.2	2.67E−02	1.81E−02	3.95E−02	5.46E−03	6.71E−02	2.38E−02
Total	42	1,321.0						

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

| | | | 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	87.0				1.73E−05	3.45E−02	4.41E−03
1999	6	87.0				2.60E−02	1.10E−01	5.73E−02
2000	1	87.2				1.55E−03	4.87E−02	1.32E−02
2001	1	87.0				1.55E−03	4.88E−02	1.32E−02
2002	8	87.0				3.82E−02	1.33E−01	7.50E−02
2003	2	87.0	1.13E−02	4.86E−03	2.63E−02	5.05E−03	6.20E−02	2.20E−02
2004	1	87.2	1.23E−02	5.98E−03	2.52E−02	1.55E−03	4.87E−02	1.32E−02
2005	1	87.0	1.33E−02	7.27E−03	2.44E−02	1.55E−03	4.88E−02	1.32E−02
2006	0	87.0	1.45E−02	8.67E−03	2.41E−02	1.73E−05	3.45E−02	4.41E−03
2007	2	87.0	1.57E−02	1.00E−02	2.46E−02	5.05E−03	6.20E−02	2.20E−02
2008	2	87.2	1.71E−02	1.11E−02	2.63E−02	5.04E−03	6.19E−02	2.20E−02
2009	1	87.0	1.85E−02	1.16E−02	2.95E−02	1.55E−03	4.88E−02	1.32E−02
2010	1	87.0	2.01E−02	1.17E−02	3.46E−02	1.55E−03	4.88E−02	1.32E−02
2011	3	87.0	2.18E−02	1.15E−02	4.16E−02	9.56E−03	7.46E−02	3.09E−02
2012	3	87.2	2.37E−02	1.11E−02	5.08E−02	9.54E−03	7.45E−02	3.08E−02
Total	32	1,306.0						

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

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	3	88.0				7.75E−03	6.05E−02	2.50E−02
1999	3	88.0				7.75E−03	6.05E−02	2.50E−02
2000	0	88.2				1.40E−05	2.79E−02	3.57E−03
2001	3	88.0				7.75E−03	6.05E−02	2.50E−02
2002	1	88.0				1.26E−03	3.96E−02	1.07E−02
2003	0	88.0	5.41E−03	1.97E−03	1.49E−02	1.41E−05	2.79E−02	3.58E−03
2004	0	88.2	5.84E−03	2.48E−03	1.38E−02	1.40E−05	2.79E−02	3.57E−03
2005	1	88.0	6.31E−03	3.06E−03	1.30E−02	1.26E−03	3.96E−02	1.07E−02
2006	1	88.0	6.81E−03	3.68E−03	1.26E−02	1.26E−03	3.96E−02	1.07E−02
2007	0	88.0	7.35E−03	4.25E−03	1.27E−02	1.41E−05	2.79E−02	3.58E−03
2008	2	88.2	7.93E−03	4.61E−03	1.36E−02	4.09E−03	5.02E−02	1.79E−02
2009	2	88.0	8.56E−03	4.71E−03	1.56E−02	4.10E−03	5.03E−02	1.79E−02
2010	1	88.0	9.24E−03	4.59E−03	1.86E−02	1.26E−03	3.96E−02	1.07E−02
2011	0	88.0	9.97E−03	4.34E−03	2.29E−02	1.41E−05	2.79E−02	3.58E−03
2012	1	88.2	1.08E−02	4.03E−03	2.87E−02	1.26E−03	3.95E−02	1.07E−02
Total	18	1,321.0						

7. REFERENCES

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