Component Performance Study

Air-Operated Valves

1998–2008

1 INTRODUCTION

This report presents a 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 (PRAs), but does evaluate component performance over time. Reference 1 (NUREG/CR-6928) reports AOV unreliability estimates using Equipment Performance and Information Exchange (EPIX) data from 1998–2002 for use in PRAs.

The trend evaluations in this study are based on the operating experience failure reports from fiscal year (FY) 1998 through FY 2008 for the component reliability as reported in EPIX. The AOV failure modes considered are failure-to-open/close (failure to operate) (FTOC) and spurious operation (SO).

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

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

2 SUMMARY OF FINDINGS

The results of this study are summarized in this section. Of particular interest is the existence of any statistically significant[1] increasing trends. In this update, no statistically significant increasing trends were identified in the AOV results. Statistically significant decreasing trends were identified in the AOV results for the following:

- All systems, industry-wide AOV FTOC trend AOVs with <= 20 demands per year. (see Figure 1)
- All systems, industry-wide AOV FTOC trend AOVs with > 20 demands per year. (see Figure 2)

[1] Statistical significance is defined in terms of the 'p-value.' A p-value is a probability indicating whether to accept or reject the null hypothesis that there is no trend in the data. P-values of less than or equal to 0.05 indicate that we are 95% confident that there is a trend in the data (reject the null hypothesis of no trend.) By convention, we use the "Michelin Guide" scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

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

Table 3 shows that 84% of the AOV FTOC failures occurred in 6 systems. Similarly, Table 4 shows that 84% of the AOV SO failures occurred in 6 systems.

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 and SO failure modes. The AOV data set obtained from EPIX was segregated to AOVs with ≤ 20 demands/year (d/yr) and AOVs with > 20 d/yr and includes AOVs in the systems listed in Table 1. NUREG/CR-6928 lists the industry failure data for AOVs with <= 20 d/yr. Table 2 shows industry-wide failure probability and failure rate results for the AOV with <= 20 d/yr from Reference 1.

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, emergency safeguard feature (ESF) demands.

Table 1. AOV systems.

		AOV Component Count		
System	Description	Total	<=20 d/yr	>20 d/yr
AFW	Auxiliary feedwater	361	280	81
CCW	Component cooling water	413	301	112
CDS	Condensate system	26	15	11
CRD	Control rod drive	118	69	49
CSR	Containment spray recirculation	32	30	2
CVC	Chemical and volume control	466	334	132
EPS	Emergency power supply	37	13	24
FWS	Firewater	1	1	
HCI	High pressure coolant injection	9	8	1
HPI	High pressure injection	95	77	18
ISO	Isolation condenser	10	6	4
LCS	Low pressure core spray	10	10	
MFW	Main feedwater	331	102	229
MSS	Main steam	105	89	16
RCI	Reactor core isolation	5	5	
RCS	Reactor coolant	94	42	52
RHR	Residual heat removal	245	228	17
SLC	Standby liquid control	1	1	
SWN	Emergency service water (Standby)	527	301	226
SWS	Standby service water	53	14	39
	Total	2939	1926	1013

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

Failure Mode	5%	Median	Mean	95%	Distribution		
					Type	α	β
FTOC	6.0E-05	8.0E-04	1.2E-03	4.0E-03	Beta	1.00	8.33E+02
SO	2.0E-11	5.0E-08	2.0E-07	9.0E-07	Gamma	0.30	1.50E+06

3.2 AOV Failure Probability and Failure Rate Trends

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

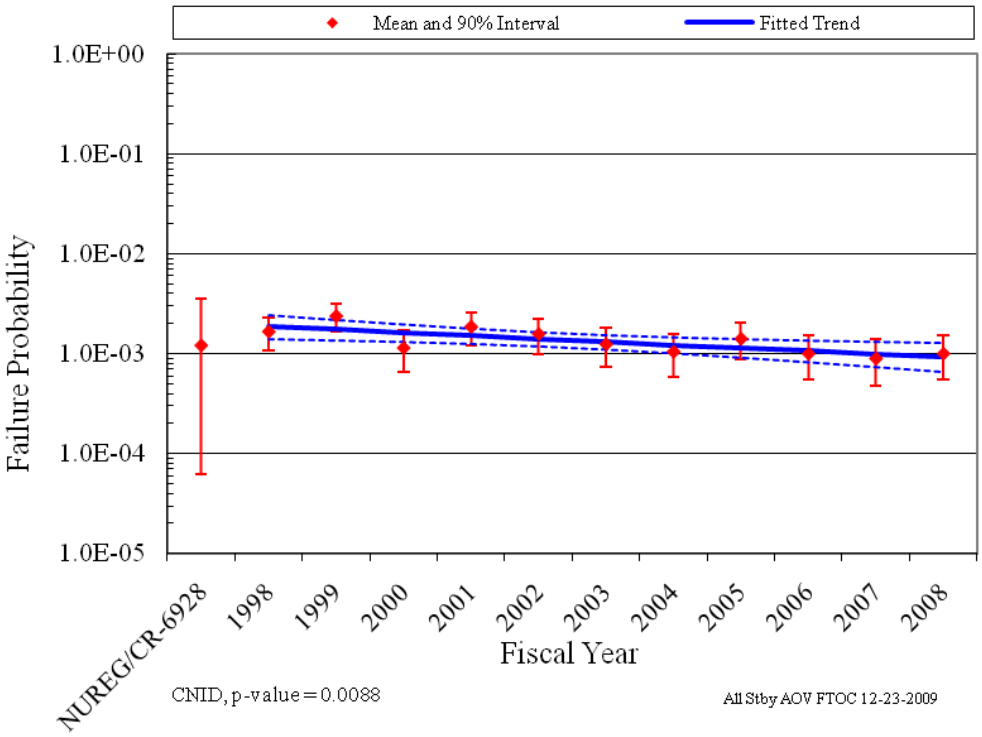

Figure 1. All systems, industry-wide AOV FTOC trend AOVs with <= 20 demands per year.

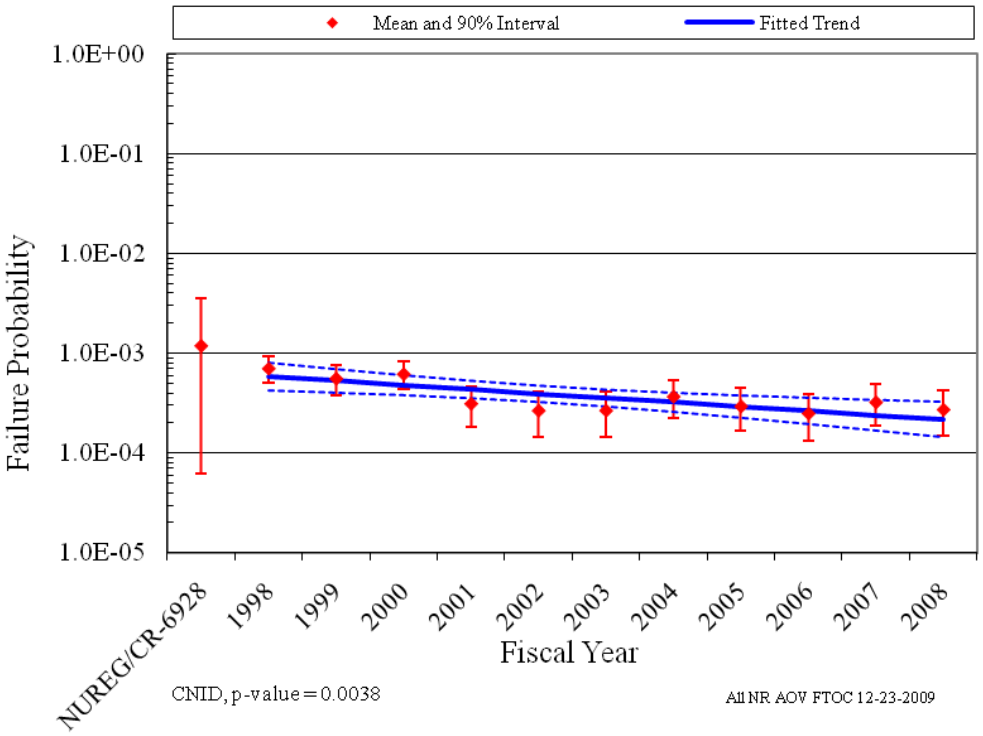

Figure 2. All systems, industry-wide AOV FTOC trend AOVs with > 20 demands per year.

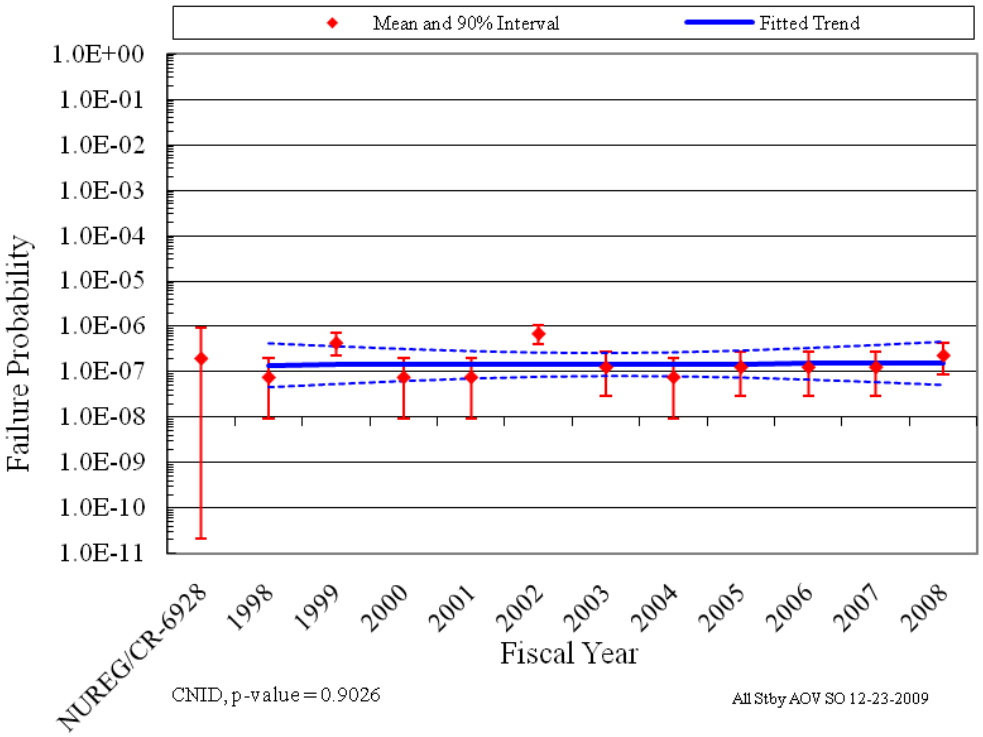

Figure 3. All systems, industry-wide AOV SO trend with <= 20 demands per year.

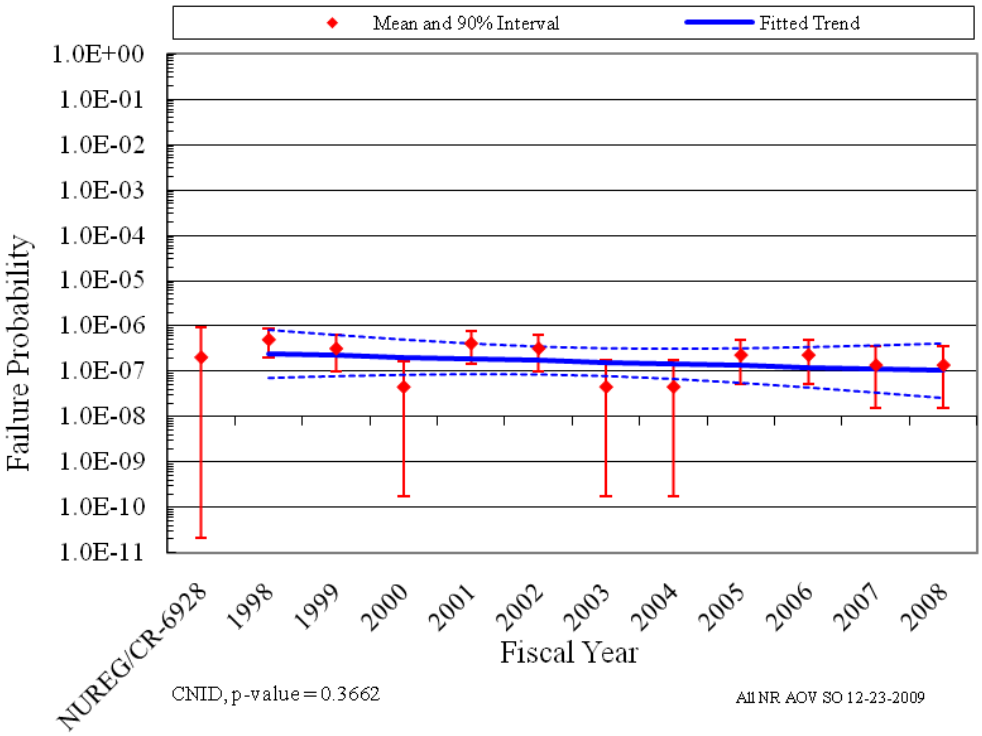

Figure 4. All systems, industry-wide AOV SO trend with > 20 demands per year.

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

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

4 ENGINEERING TRENDS

This section presents frequency trends for AOV failures and demands. The data are normalized by reactor year for plants that have the equipment being trended. Figure 5 shows the trend for AOV demands. Figure 7 shows the trend in failure events for FTOC mode, and Figure 9 shows the trend for the SO failure events. Table 3 and Table 5 summarize the failures by system, year, and the FTOC failure mode. The major contributing systems for the FTOC failure mode are AFW, CVC, ESW, and MFW. Table 4 and Table 6 summarize the failures by system, year, and the SO failure mode. The major contributing systems for the SO failure mode are AFW, CCW, CVC, and MFW. Table 11,

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

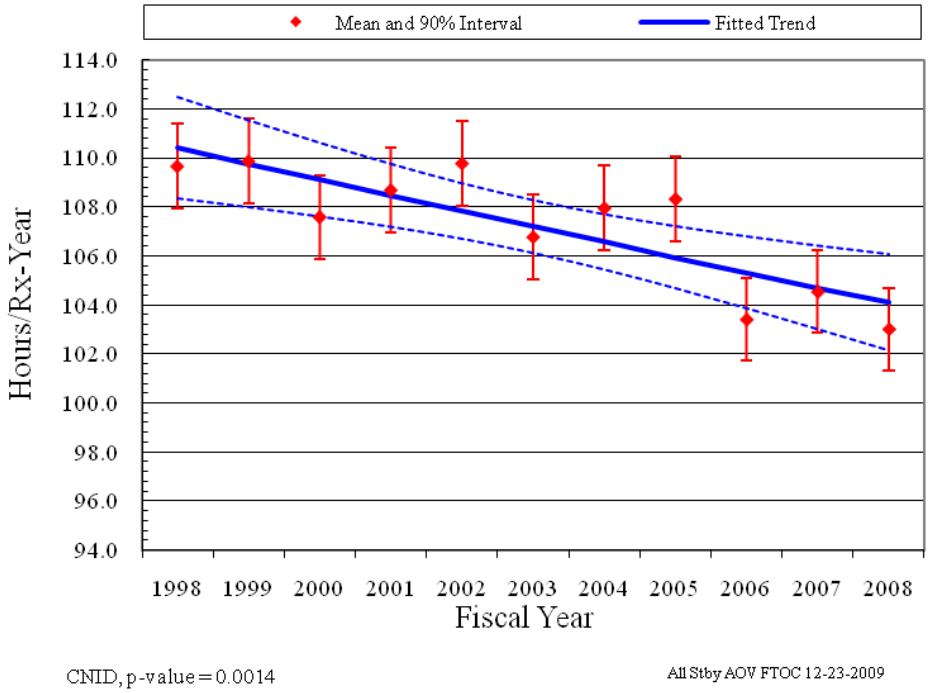

Figure 5. Frequency (demands per reactor year) of AOV operation demands, <= 20 demands per year.

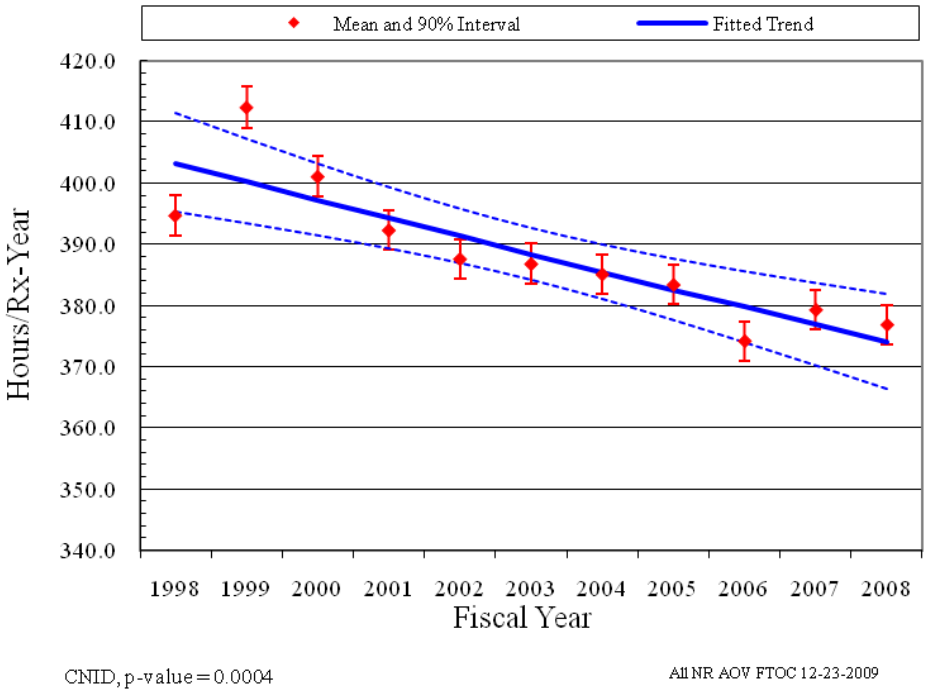

Figure 6. Frequency (demands per reactor year) of AOV operation demands, > 20 demands per year.

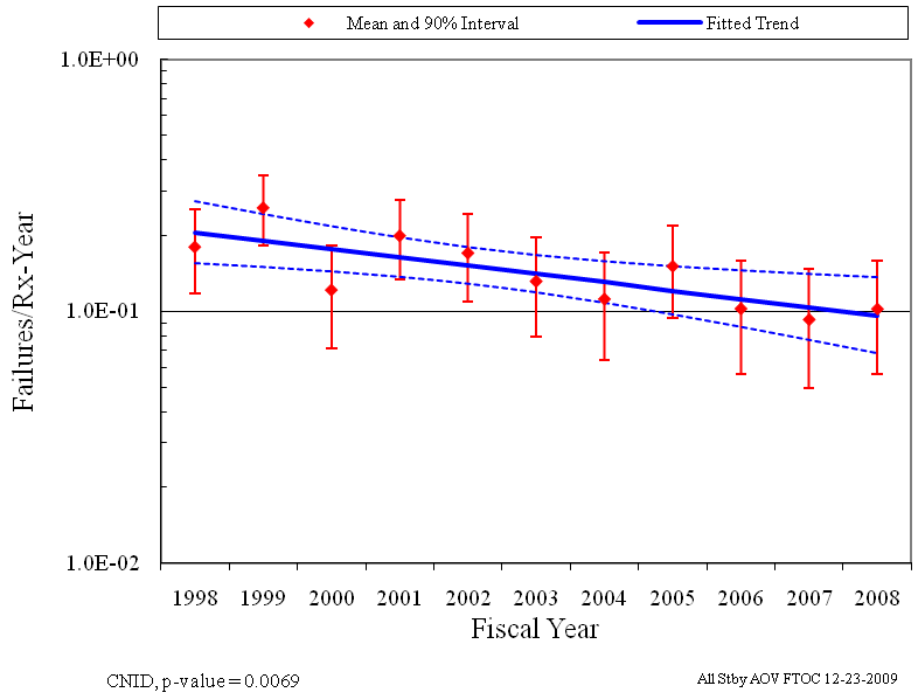

Figure 7. Frequency (failures per reactor year) of AOV FTOC events <= 20 demands per year.

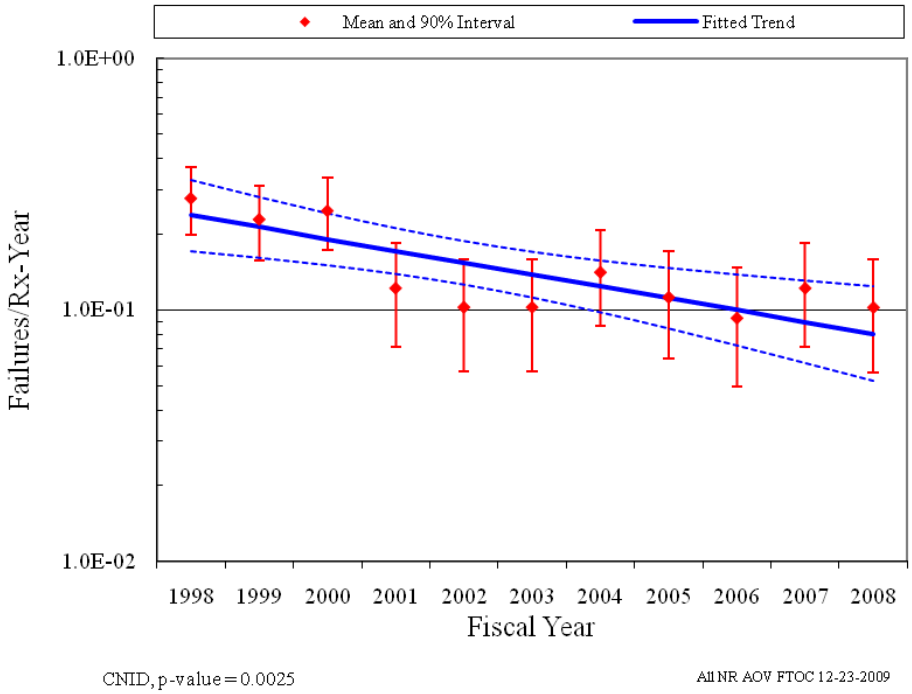

Figure 8. Frequency (failures per reactor year) of AOV FTOC events > 20 demands per year.

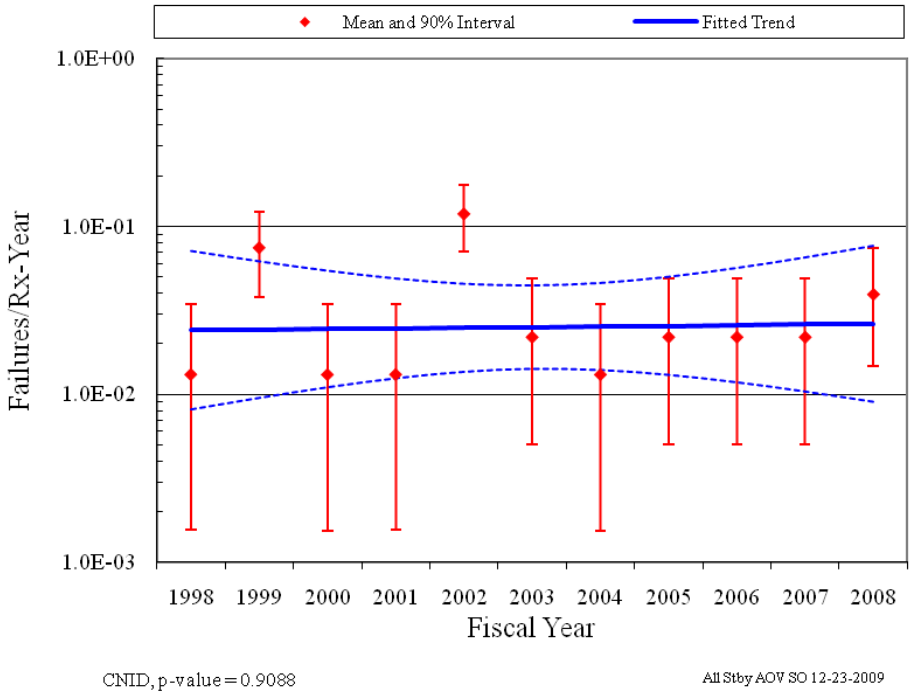

Figure 9. Frequency (failures per reactor year) of AOV SO events <= 20 demands per year.

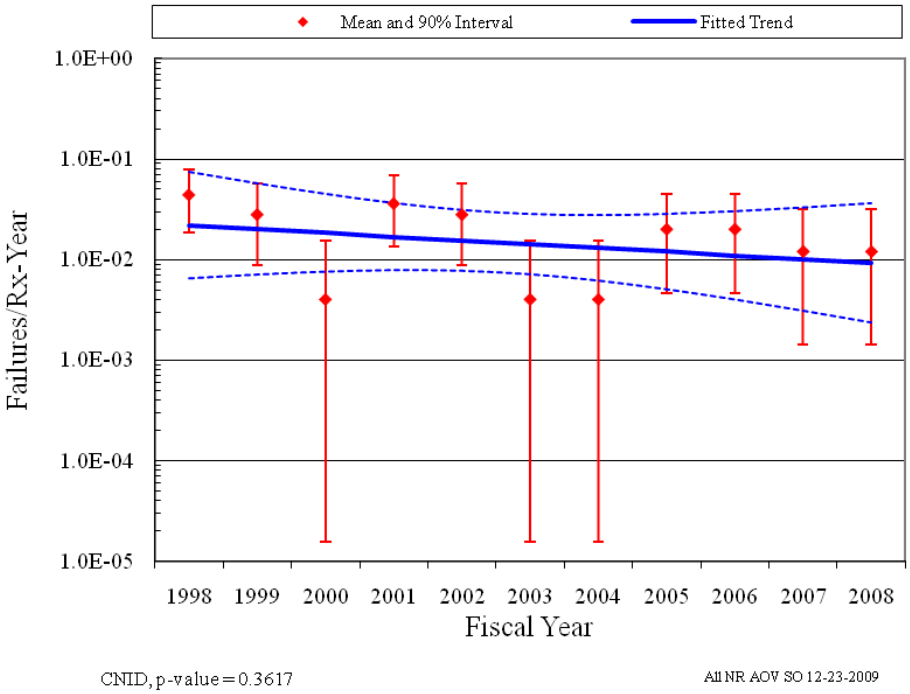

Figure 10. Frequency (failures per reactor year) of AOV SO events > 20 demands per year.

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*	*Total*	*Percent of Failures*
AFW	280	14.8%	5	1	4	5	1	1	1	8	3	1	1	31	19.4%
CCW	301	15.9%	1	1		4	4	1	1	1	2	2	2	19	11.9%
CRD	69	3.7%		1										1	0.6%
CSR	30	1.6%	1							2		1		4	2.5%
CVC	334	17.7%	2	5	1	2	4	2	1		1	2		20	12.5%
HCI	8	0.4%					1							1	0.0%
HPI	77	4.1%				1		2	1		1			5	3.1%
LCS	10	0.5%		1										1	0.6%
MFW	102	5.4%	2	6	1	3	1	2	2	2				19	11.9%
MSS	89	4.7%	1	1	4		3							9	5.6%
RCI	5	0.3%											1	1	0.6%
RCS	42	2.2%		1				1	1					3	1.9%
RHR	228	12.1%	3	4	1	1	3	2			2	2	2	20	12.5%
SWN	301	15.9%	3	4	1	4		2	4	2	1	1	4	26	16.3%
SWS	14	0.7%		1										1	0.6%
Total	1890	100.0%		1										160	100.0%

Table 4. 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*	*Total*	*Percent of Failures*
AFW	280	18.4%				1		1	1			1	1	5	13.5%
CCW	301	19.8%		1	1		7					1		10	27.0%
CRD	69	4.5%		4										4	10.8%
CVC	334	21.9%					5			1				6	16.2%
HPI	77	5.1%						1						1	2.7%
MFW	102	6.7%	1							1	2		2	6	16.2%
MSS	89	5.8%		2										2	5.4%
RCS	42	2.8%		1			1							2	5.4%
RHR	228	15.0%											1	1	2.7%
Total	1522	100.0%	1	8	1	1	13	2	1	2	2	2	4	37	100.0%

Table 5. 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*	*Total*	*Percent of Failures*
AFW	81	8.0%	2	1	3		2		3		3	2	2	18	3.2%
CCW	112	11.1%	6	6	6	3	6	2	1	3	1		1	35	6.2%
CDS	11	1.1%										1	1	2	0.4%
CRD	49	4.8%	3	5	1		1							10	1.8%
CSR	2	0.2%					1							1	0.2%
CVC	132	13.0%	10	9	6	7	8	4	2	4	1	4	7	62	10.9%
EPS	24	2.4%		1			4					1	2	8	1.4%
FWS		0.0%	1										1	2	0.4%
HCI	1	0.1%		1		1	2							4	0.7%
HPI	18	1.8%		1						2			1	4	0.7%
ISO	4	0.4%			1	4								5	0.9%
LCS		0.0%			1									1	0.2%
MFW	229	22.6%	23	26	23	13	13	13	14	10	6	13	8	162	28.5%
MSS	16	1.6%	12	23	13	11	12	7	7	6	5	2	4	102	18.0%
RCI		0.0%	5			1								6	1.1%
RCS	52	5.1%	3	2	1	4	1	2	2	1		3	1	20	3.5%
RHR	17	1.7%	3	5		1	4	1	1	2	1		1	19	3.3%
SWN	226	22.3%	7	6	17	17	7	12	6	6	5	5	6	94	16.5%
SWS	39	3.8%	4		2	1		6						13	2.3%
Total	1013	100.0%	79	86	74	63	61	47	36	34	22	31	35	568	100.0%

Table 6. 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*	*Total*	*Percent of Failures*
AFW	81	8.8%				1				1				2	2.4%
CCW	112	12.1%	1	2	5					1				9	10.7%
CVC	132	14.3%	13	1	1	1	1	1					1	19	22.6%
HPI	18	2.0%			1					1				2	2.4%
MFW	229	24.8%	4		1	4	4	1	2	2	1	2	1	22	26.2%
MSS	16	1.7%			1	1	1	5	2			3		13	15.5%
RCI		0.0%											1	1	1.2%
RCS	52	5.6%									1		1	2	2.4%
RHR	17	1.8%	2		2									4	4.8%
SWN	226	24.5%	1	3	1	2	1				1			9	10.7%
SWS	39	4.2%					1							1	1.2%
Total	922	100.0%	21	6	12	9	8	7	4	5	3	5	4	84	100.0%

5 AOV ASSEMBLY DESCRIPTION

An AOV assembly consists of a valve body and pneumatic operator sub-components (includes the circuit breaker). 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.

6 DATA TABLES

Table 7. 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
NUREG/ CR-6928						6.16E-05	3.59E-03	1.20E-03
1998	18	10855	1.87E-03	1.42E-03	2.46E-03	1.07E-03	2.32E-03	1.65E-03
1999	26	10876	1.74E-03	1.38E-03	2.21E-03	1.66E-03	3.15E-03	2.36E-03
2000	12	10680	1.62E-03	1.33E-03	1.98E-03	6.61E-04	1.70E-03	1.13E-03
2001	20	10759	1.51E-03	1.27E-03	1.80E-03	1.23E-03	2.55E-03	1.84E-03
2002	17	10867	1.41E-03	1.20E-03	1.66E-03	9.99E-04	2.21E-03	1.56E-03
2003	13	10570	1.31E-03	1.11E-03	1.55E-03	7.38E-04	1.83E-03	1.23E-03
2004	11	10716	1.22E-03	1.02E-03	1.47E-03	5.90E-04	1.59E-03	1.04E-03
2005	15	10723	1.14E-03	9.20E-04	1.41E-03	8.69E-04	2.03E-03	1.40E-03
2006	10	10237	1.06E-03	8.26E-04	1.37E-03	5.46E-04	1.54E-03	9.91E-04
2007	9	10349	9.90E-04	7.38E-04	1.33E-03	4.72E-04	1.41E-03	8.87E-04
2008	10	10226	9.22E-04	6.57E-04	1.29E-03	5.47E-04	1.54E-03	9.92E-04

Table 8. 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
NUREG/ CR-6928						6.16E-05	3.59E-03	1.20E-03
1998	28	39077	5.86E-04	4.23E-04	8.10E-04	5.03E-04	9.36E-04	7.06E-04
1999	23	40826	5.30E-04	4.02E-04	6.99E-04	3.83E-04	7.59E-04	5.58E-04
2000	25	39815	4.80E-04	3.79E-04	6.08E-04	4.33E-04	8.35E-04	6.20E-04
2001	12	38838	4.35E-04	3.54E-04	5.35E-04	1.82E-04	4.69E-04	3.12E-04
2002	10	38373	3.94E-04	3.24E-04	4.79E-04	1.46E-04	4.12E-04	2.65E-04
2003	10	38294	3.57E-04	2.91E-04	4.37E-04	1.46E-04	4.13E-04	2.65E-04
2004	14	38230	3.23E-04	2.57E-04	4.06E-04	2.24E-04	5.38E-04	3.67E-04
2005	11	37956	2.93E-04	2.24E-04	3.82E-04	1.67E-04	4.48E-04	2.93E-04
2006	9	37047	2.65E-04	1.94E-04	3.62E-04	1.32E-04	3.93E-04	2.48E-04
2007	12	37551	2.40E-04	1.67E-04	3.45E-04	1.88E-04	4.85E-04	3.22E-04
2008	10	37412	2.17E-04	1.43E-04	3.30E-04	1.50E-04	4.22E-04	2.71E-04

Table 9. Plot data for industry-wide AOV SO trend with <= 20 demands per year. Figure 3

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						2.14E-11	9.15E-07	2.00E-07
1998	1	16976880	1.41E-07	4.74E-08	4.17E-07	9.04E-09	2.01E-07	7.71E-08
1999	8	16968120	1.42E-07	5.55E-08	3.62E-07	2.23E-07	7.09E-07	4.37E-07
2000	1	16968120	1.43E-07	6.42E-08	3.19E-07	9.05E-09	2.01E-07	7.71E-08
2001	1	16871760	1.45E-07	7.26E-08	2.87E-07	9.09E-09	2.02E-07	7.75E-08
2002	13	16871760	1.46E-07	7.94E-08	2.68E-07	4.17E-07	1.04E-06	6.98E-07
2003	2	16871760	1.47E-07	8.27E-08	2.62E-07	2.96E-08	2.86E-07	1.29E-07
2004	1	16871760	1.49E-07	8.14E-08	2.71E-07	9.09E-09	2.02E-07	7.75E-08
2005	2	16871760	1.50E-07	7.63E-08	2.95E-07	2.96E-08	2.86E-07	1.29E-07
2006	2	16871760	1.51E-07	6.89E-08	3.33E-07	2.96E-08	2.86E-07	1.29E-07
2007	2	16871760	1.53E-07	6.08E-08	3.84E-07	2.96E-08	2.86E-07	1.29E-07
2008	4	16871760	1.54E-07	5.30E-08	4.50E-07	8.59E-08	4.37E-07	2.33E-07

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

FY/ Source	Failures	Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						2.14E-11	9.15E-07	2.00E-07
1998	5	8961480	2.42E-07	7.18E-08	8.17E-07	2.04E-07	8.75E-07	4.89E-07
1999	3	8952720	2.22E-07	7.83E-08	6.32E-07	9.65E-08	6.26E-07	3.12E-07
2000	0	8952720	2.04E-07	8.38E-08	4.99E-07	1.75E-10	1.71E-07	4.45E-08
2001	4	8873880	1.88E-07	8.68E-08	4.07E-07	1.49E-07	7.59E-07	4.04E-07
2002	3	8873880	1.73E-07	8.55E-08	3.48E-07	9.72E-08	6.31E-07	3.14E-07
2003	0	8873880	1.59E-07	7.91E-08	3.18E-07	1.76E-10	1.72E-07	4.48E-08
2004	0	8873880	1.46E-07	6.85E-08	3.10E-07	1.76E-10	1.72E-07	4.48E-08
2005	2	8873880	1.34E-07	5.63E-08	3.19E-07	5.14E-08	4.96E-07	2.24E-07
2006	2	8873880	1.23E-07	4.46E-08	3.39E-07	5.14E-08	4.96E-07	2.24E-07
2007	1	8873880	1.13E-07	3.46E-08	3.69E-07	1.58E-08	3.50E-07	1.35E-07
2008	1	8873880	1.04E-07	2.65E-08	4.07E-07	1.58E-08	3.50E-07	1.35E-07

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

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	10855	99.0	1.10E+02	1.08E+02	1.12E+02	1.08E+02	1.11E+02	1.10E+02
1999	10876	99.0	1.10E+02	1.08E+02	1.12E+02	1.08E+02	1.12E+02	1.10E+02
2000	10680	99.3	1.09E+02	1.08E+02	1.11E+02	1.06E+02	1.09E+02	1.08E+02
2001	10759	99.0	1.08E+02	1.07E+02	1.10E+02	1.07E+02	1.10E+02	1.09E+02
2002	10867	99.0	1.08E+02	1.07E+02	1.09E+02	1.08E+02	1.12E+02	1.10E+02
2003	10570	99.0	1.07E+02	1.06E+02	1.08E+02	1.05E+02	1.08E+02	1.07E+02
2004	10716	99.3	1.07E+02	1.05E+02	1.08E+02	1.06E+02	1.10E+02	1.08E+02
2005	10723	99.0	1.06E+02	1.05E+02	1.07E+02	1.07E+02	1.10E+02	1.08E+02
2006	10237	99.0	1.05E+02	1.04E+02	1.07E+02	1.02E+02	1.05E+02	1.03E+02
2007	10349	99.0	1.05E+02	1.03E+02	1.06E+02	1.03E+02	1.06E+02	1.05E+02
2008	10226	99.3	1.04E+02	1.02E+02	1.06E+02	1.01E+02	1.05E+02	1.03E+02

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

FY	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	39077	99.0	4.03E+02	3.95E+02	4.11E+02	3.91E+02	3.98E+02	3.95E+02
1999	40826	99.0	4.00E+02	3.93E+02	4.07E+02	4.09E+02	4.16E+02	4.12E+02
2000	39815	99.3	3.97E+02	3.91E+02	4.03E+02	3.98E+02	4.04E+02	4.01E+02
2001	38838	99.0	3.94E+02	3.89E+02	3.99E+02	3.89E+02	3.96E+02	3.92E+02
2002	38373	99.0	3.91E+02	3.87E+02	3.96E+02	3.84E+02	3.91E+02	3.88E+02
2003	38294	99.0	3.88E+02	3.84E+02	3.93E+02	3.84E+02	3.90E+02	3.87E+02
2004	38230	99.3	3.85E+02	3.81E+02	3.90E+02	3.82E+02	3.88E+02	3.85E+02
2005	37956	99.0	3.83E+02	3.78E+02	3.88E+02	3.80E+02	3.87E+02	3.83E+02
2006	37047	99.0	3.80E+02	3.74E+02	3.85E+02	3.71E+02	3.77E+02	3.74E+02
2007	37551	99.0	3.77E+02	3.70E+02	3.84E+02	3.76E+02	3.83E+02	3.79E+02
2008	37412	99.3	3.74E+02	3.66E+02	3.82E+02	3.74E+02	3.80E+02	3.77E+02

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

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	18	99.0	2.06E-01	1.55E-01	2.73E-01	1.18E-01	2.55E-01	1.81E-01
1999	26	99.0	1.91E-01	1.49E-01	2.43E-01	1.82E-01	3.47E-01	2.59E-01
2000	12	99.3	1.77E-01	1.44E-01	2.17E-01	7.12E-02	1.83E-01	1.22E-01
2001	20	99.0	1.64E-01	1.37E-01	1.96E-01	1.33E-01	2.78E-01	2.00E-01
2002	17	99.0	1.52E-01	1.28E-01	1.79E-01	1.10E-01	2.43E-01	1.71E-01
2003	13	99.0	1.41E-01	1.19E-01	1.67E-01	7.89E-02	1.96E-01	1.32E-01
2004	11	99.3	1.30E-01	1.08E-01	1.58E-01	6.38E-02	1.71E-01	1.12E-01
2005	15	99.0	1.21E-01	9.69E-02	1.51E-01	9.42E-02	2.20E-01	1.51E-01
2006	10	99.0	1.12E-01	8.64E-02	1.45E-01	5.66E-02	1.60E-01	1.03E-01
2007	9	99.0	1.04E-01	7.68E-02	1.40E-01	4.94E-02	1.47E-01	9.28E-02
2008	10	99.3	9.62E-02	6.80E-02	1.36E-01	5.65E-02	1.59E-01	1.02E-01

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

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	28	99.0	2.38E-01	1.72E-01	3.29E-01	1.99E-01	3.70E-01	2.79E-01
1999	23	99.0	2.13E-01	1.62E-01	2.81E-01	1.58E-01	3.13E-01	2.30E-01
2000	25	99.3	1.91E-01	1.51E-01	2.42E-01	1.74E-01	3.35E-01	2.49E-01
2001	12	99.0	1.72E-01	1.39E-01	2.11E-01	7.14E-02	1.84E-01	1.22E-01
2002	10	99.0	1.54E-01	1.26E-01	1.88E-01	5.66E-02	1.60E-01	1.03E-01
2003	10	99.0	1.38E-01	1.12E-01	1.70E-01	5.66E-02	1.60E-01	1.03E-01
2004	14	99.3	1.24E-01	9.80E-02	1.57E-01	8.63E-02	2.07E-01	1.41E-01
2005	11	99.0	1.11E-01	8.45E-02	1.46E-01	6.40E-02	1.72E-01	1.12E-01
2006	9	99.0	9.98E-02	7.22E-02	1.38E-01	4.94E-02	1.47E-01	9.29E-02
2007	12	99.0	8.95E-02	6.15E-02	1.30E-01	7.14E-02	1.84E-01	1.22E-01
2008	10	99.3	8.03E-02	5.21E-02	1.24E-01	5.65E-02	1.59E-01	1.02E-01

Table 15. Plot data for frequency (events per reactor year) of AOV SO events <= 20 demands per year. Figure 9

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	1	99.0	2.40E-02	8.10E-03	7.14E-02	1.55E-03	3.44E-02	1.32E-02
1999	8	99.0	2.42E-02	9.49E-03	6.20E-02	3.82E-02	1.21E-01	7.49E-02
2000	1	99.3	2.45E-02	1.10E-02	5.46E-02	1.55E-03	3.43E-02	1.32E-02
2001	1	99.0	2.47E-02	1.24E-02	4.91E-02	1.55E-03	3.44E-02	1.32E-02
2002	13	99.0	2.49E-02	1.36E-02	4.57E-02	7.11E-02	1.77E-01	1.19E-01
2003	2	99.0	2.51E-02	1.41E-02	4.47E-02	5.04E-03	4.88E-02	2.20E-02
2004	1	99.3	2.53E-02	1.39E-02	4.62E-02	1.55E-03	3.43E-02	1.32E-02
2005	2	99.0	2.56E-02	1.30E-02	5.03E-02	5.04E-03	4.88E-02	2.20E-02
2006	2	99.0	2.58E-02	1.17E-02	5.67E-02	5.04E-03	4.88E-02	2.20E-02
2007	2	99.0	2.60E-02	1.03E-02	6.54E-02	5.04E-03	4.88E-02	2.20E-02
2008	4	99.3	2.62E-02	9.00E-03	7.65E-02	1.46E-02	7.43E-02	3.95E-02

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

FY	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	5	99.0	2.18E-02	6.47E-03	7.38E-02	1.84E-02	7.91E-02	4.42E-02
1999	3	99.0	2.00E-02	7.05E-03	5.70E-02	8.71E-03	5.66E-02	2.81E-02
2000	0	99.3	1.84E-02	7.54E-03	4.49E-02	1.58E-05	1.54E-02	4.01E-03
2001	4	99.0	1.69E-02	7.80E-03	3.66E-02	1.34E-02	6.80E-02	3.62E-02
2002	3	99.0	1.55E-02	7.68E-03	3.13E-02	8.71E-03	5.66E-02	2.81E-02
2003	0	99.0	1.42E-02	7.10E-03	2.86E-02	1.58E-05	1.54E-02	4.02E-03
2004	0	99.3	1.31E-02	6.14E-03	2.78E-02	1.58E-05	1.54E-02	4.01E-03
2005	2	99.0	1.20E-02	5.04E-03	2.86E-02	4.61E-03	4.45E-02	2.01E-02
2006	2	99.0	1.10E-02	3.99E-03	3.04E-02	4.61E-03	4.45E-02	2.01E-02
2007	1	99.0	1.01E-02	3.10E-03	3.30E-02	1.41E-03	3.14E-02	1.21E-02
2008	1	99.3	9.28E-03	2.37E-03	3.64E-02	1.41E-03	3.14E-02	1.20E-02

7 REFERENCE

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