

Component Performance Study

Emergency Diesel Generators

1998–2006

1 INTRODUCTION

This report presents a performance evaluation of emergency diesel generators (EDGs) 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 EDG unreliability estimates using Equipment Performance and Information Exchange (EPIX) data from 1998–2002 and maintenance unavailability (UA) performance data using MSPI Basis Document data from 2002–2004 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 2006 as reported in EPIX. The EDG failure modes considered are failure-to-start (FTS), failure-to-load-and-run (FTLR), and failure-to-run > 1 hour (FTR>1H). EDG train maintenance unavailability data for trending are from the same time period, as reported in the Reactor Oversight Program (ROP) and EPIX. In addition to the presentation of the component failure mode data and the UA data, an 8-hour unreliability is calculated and trended.

Previously, the study relied on operating experience obtained from licensee event reports, Nuclear Plant Reliability Data System (NPRDS), and EPIX.

The EPIX database (which includes as a subset the Mitigating Systems Performance Index (MSPI) designated devices) has matured to the point where component availability and reliability can be estimated with a higher degree of assurance of accuracy. In addition, the population of data is much larger than the population used in the previous study. The objective of the effort for the updated component performance studies is to obtain annual performance trends of failure rates and probabilities. An overview of the trending methods, glossary of terms, and abbreviations can be found in the [Overview and Reference](#) document on the Reactor Operational Experience Results and Databases web page.

2 SUMMARY OF FINDINGS

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

¹ Statistically significant 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).

- EPS, industry-wide EDG FTS trend. (see Figure 1)
- Frequency (events per reactor year) of start demands, EDGs. (see Figure 11)
- Frequency (events per reactor year) of FTS events, EDGs. (see Figure 14)

3 FAILURE PROBABILITIES AND FAILURE RATES

3.1 Overview

The industry-wide failure probabilities and failure rates of EDGs have been calculated from the operating experience for FTS, FTLR, and FTR>1H. The EDG data set obtained from EPIX includes EDGs in the systems listed in Table 1. Table 2 shows industry-wide failure probability and failure rate results for the EDG from Reference 1.

The EDGs are assumed to operate both when the reactor is critical and during shutdown periods. The number of EDGs 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. EDG systems.

System	Description	EDG Count
EPS	Emergency power supply	223
HPCS	High pressure core spray	8
Total		231

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

Failure Mode	5%	Median	Mean	95%	Distribution		
					Type	α	β
FTS	2.5E-04	3.0E-03	5.0E-03	1.5E-02	Beta	1.00	2.00E+02
FTLR	4.0E-04	2.5E-03	3.0E-03	8.0E-03	Beta	1.50	5.00E+02
FTR>1H	1.5E-04	7.0E-04	8.0E-04	2.0E-03	Gamma	2.00	2.50E+03

3.2 EDG Failure Probability and Failure Rate Trends

Trends in the EPS and HPCS failure probabilities and failure rates are shown in Figure 1 to Figure 6. The data for the trend plots are contained in Table 7 to Table 12.

3.2.1 EPS EDG Unreliability Trends

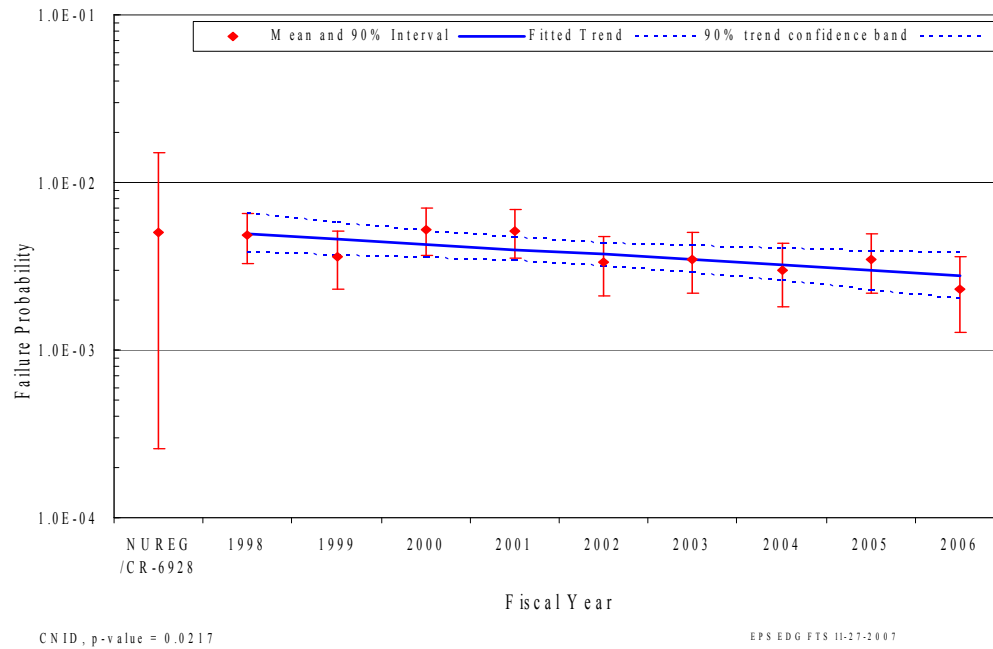


Figure 1. EPS, industry-wide EDG FTS trend.

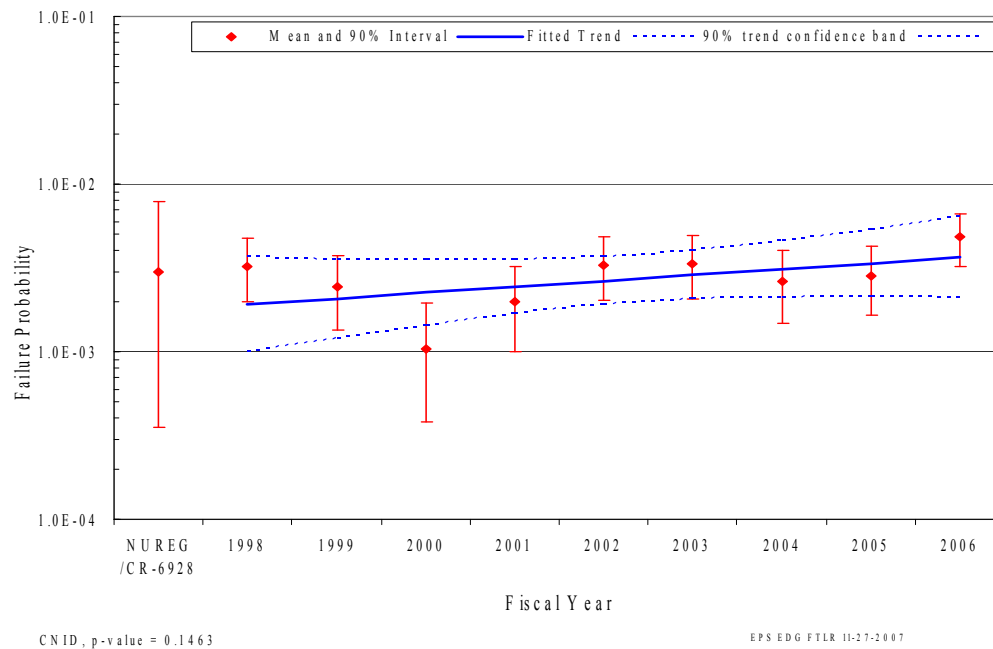


Figure 2. EPS, industry-wide EDG FTLR trend.

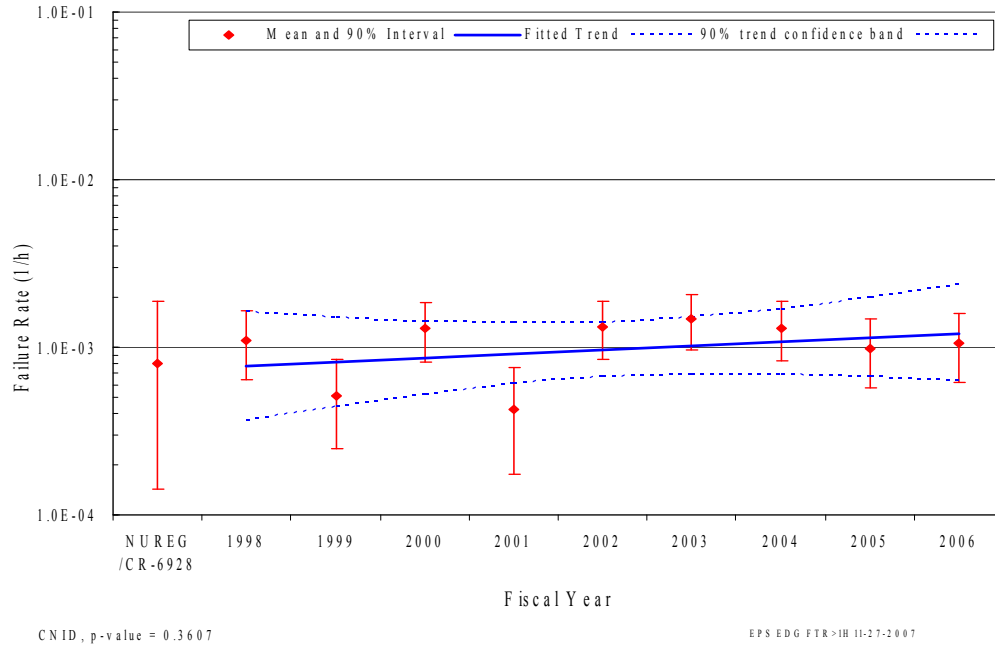


Figure 3. EPS, industry-wide EDG FTR>1H trend.

3.2.2 HPCS Unreliability Trends

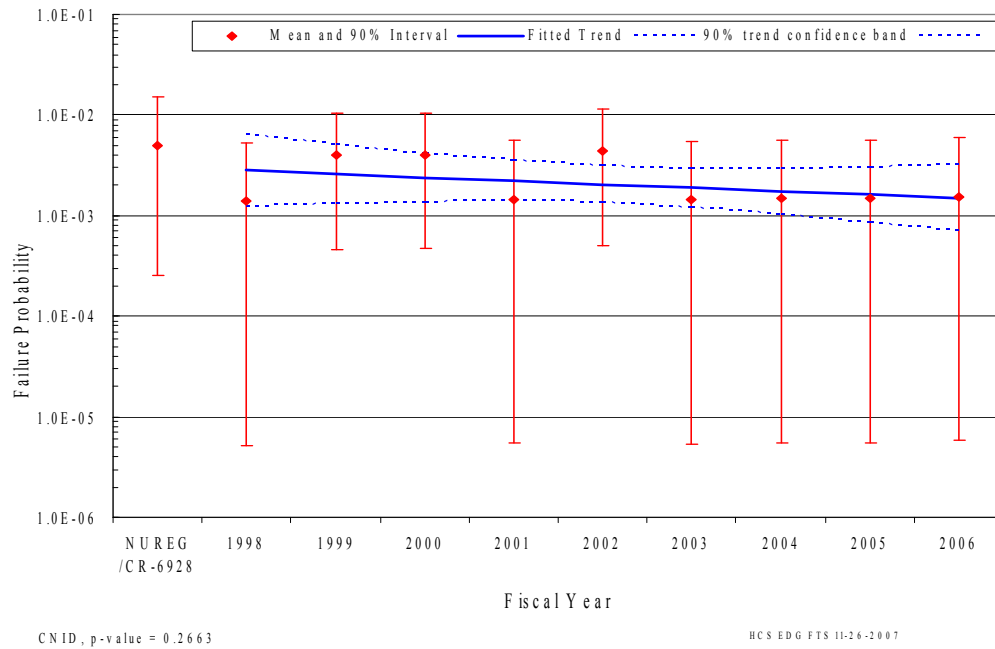


Figure 4. HPCS, industry-wide EDG FTS trend.

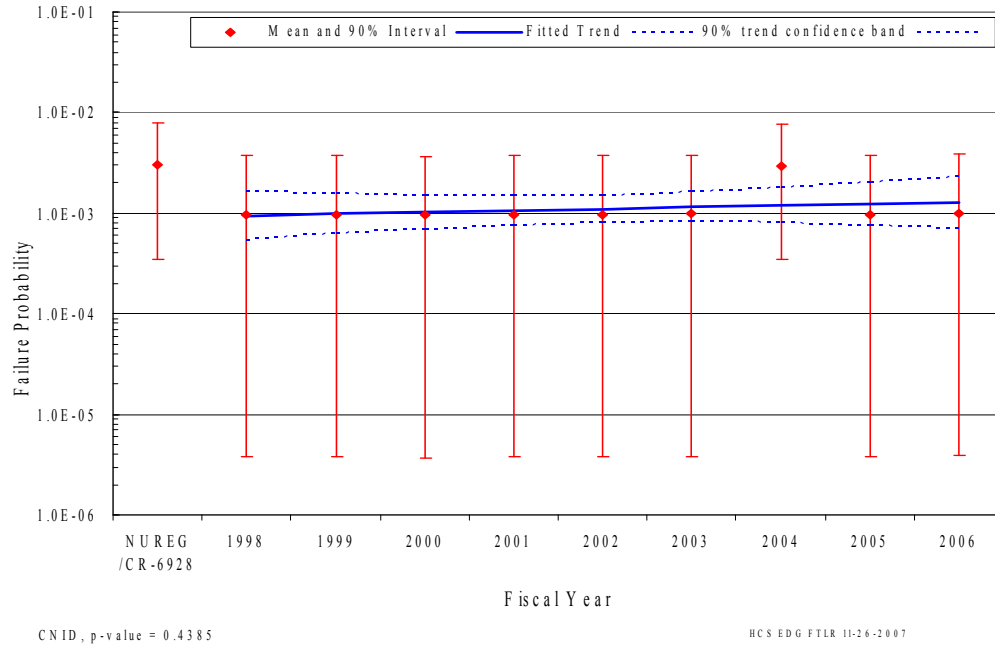


Figure 5. HPCS, industry-wide EDG FTLR trend.

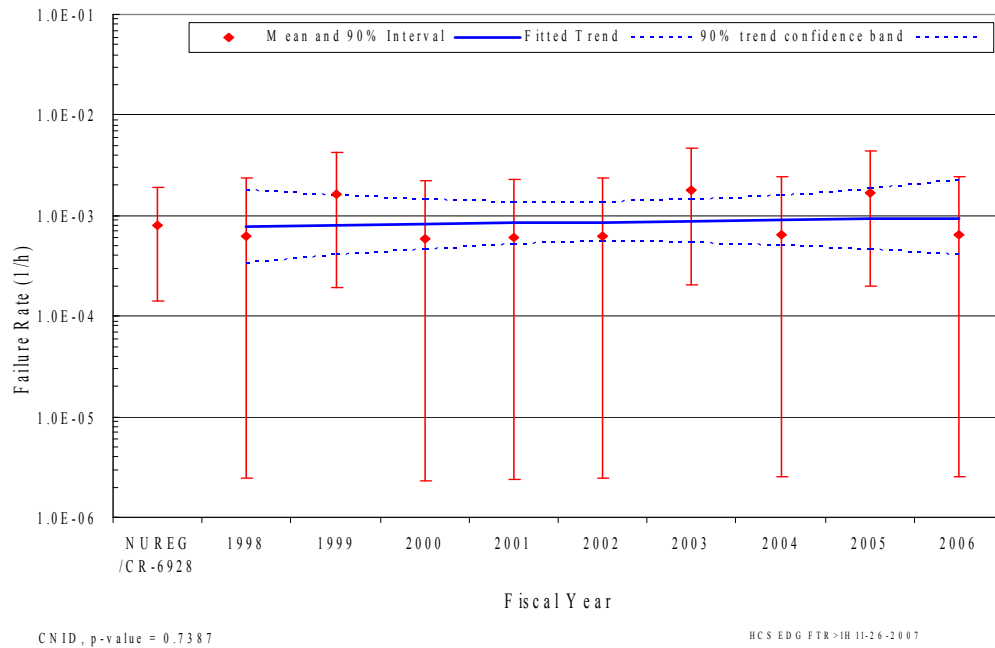


Figure 6. HPCS, industry-wide EDG FTR>1H trend.

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 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 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 UNAVAILABILITY

4.1 Overview

The industry-wide test or maintenance unavailability (UA) of EDG trains has been calculated from the operating experience. UA data are for EDG trains, which can include more than just the EDG. However, in most cases the EDG contributes the majority of the UA reported. Table 3 shows overall results for the EDG from Reference 1 based on UA data from MSPI Basis Documents, covering 2002 to 2004. In the calculations, planned and unplanned unavailable hours for a train are combined.

Table 3. Industry distributions of unavailability for EDGs.

Description	Mean	Distribution	α	β
Emergency Diesel Generator Test or Maintenance (EPS)	1.20E-02	Beta	4.00	329.33
Emergency Diesel Generator Test or Maintenance (HPCS)	1.20E-02	Beta	6.00	494.00

4.2 EDG Unavailability Trends

For the 1998-2006 period, the following are overall maintenance unavailability data. Note that these data do not supersede the data in Table 3 for use in risk assessments.

Trends in EDG train unavailability are shown in Figure 7 and Figure 8. Data tables for these figures are Table 13 and Table 14, respectively. The EDGs in systems EPS and HPCS are trended. The trend charts show the results of using data for each year based on selected system-specific component unavailability data over time. The yearly (1998–2006) unavailability and reactor critical hour data were obtained from the ROP (1998 to 2001) and EPIX (2002 to 2006) data for the EDG component. The total downtimes during operation for each plant and year were summed, and divided by the corresponding number of EDG-reactor critical hours. Unavailability data for shutdown periods are not reported.

A change in reporting requirements for UA occurred in 2002. The ROP data (1998–2001) did not include EDG overhaul outages while plants were in critical operation, while the MSPI (2002–2006) requires plants to report such outages. The annual means of these two groups are statistically significant, indicating that there is strong evidence that they differ. This change in reporting is believed to result in most of the approximately 50% increase in UA observed between the 1998–2001 data and the 2002–2006 data. Neither the 1998–2001 data nor the 2002–2006 data exhibit a statistically significant trend as shown in Figure 7.

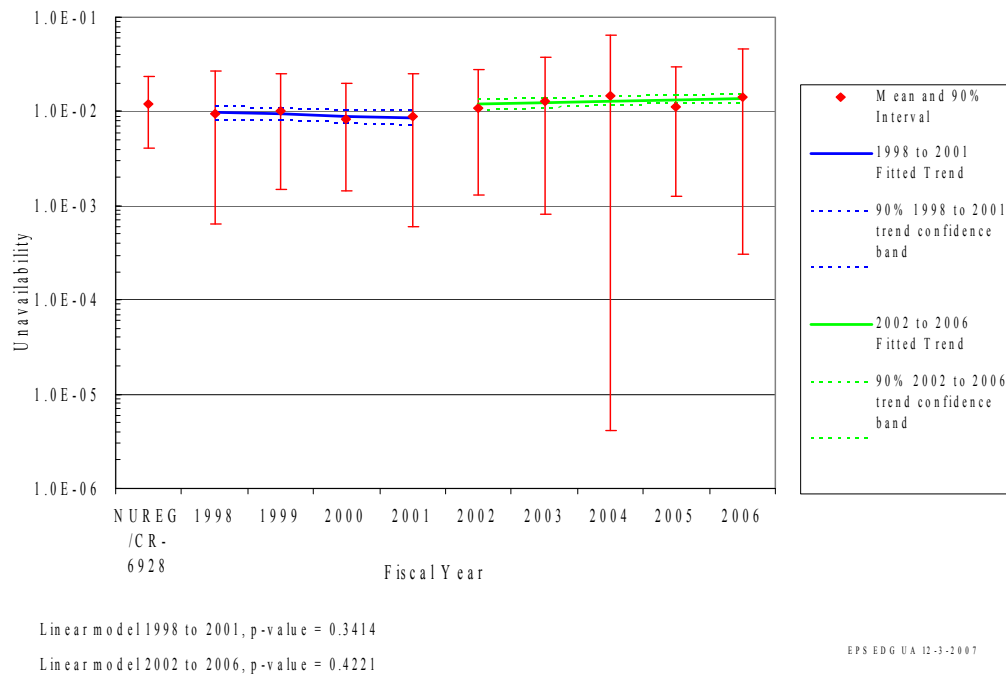


Figure 7. EPS EDG UA trend.

The mean and variance for each year is the sample mean and variance calculated from the plant-level unavailabilities for that year. The vertical bar spans the calculated 5th to 95th percentiles of the beta distribution with matching means.

Further information on the trending methods is provided in Section 3 of the [Overview and Reference](#) document. In the lower left hand corner of the trend figures, the p-value is reported.

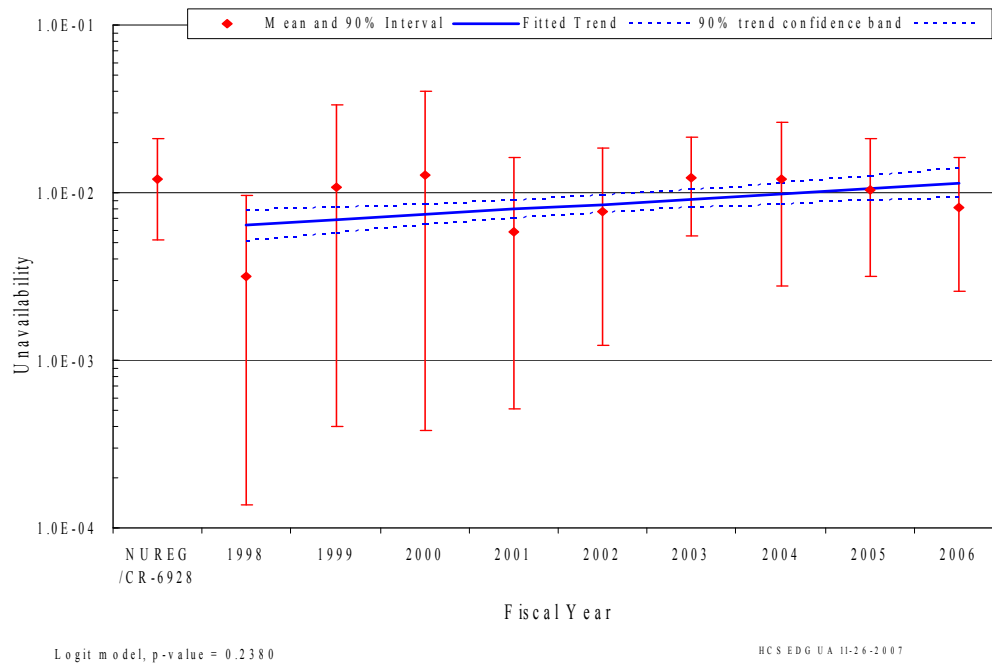


Figure 8. HPCS EDG UA trend.

5 EDG UNRELIABILITY TRENDS

Trends in total component unreliability are shown in Figure 9 and Figure 10. Plot data for these Figures are in Table 15 and Table 16, respectively. Total unreliability is defined as the result of an OR gate with the FTS, FTLR, FTR, and UA as basic event inputs. The probability of FTR is calculated for 7 hours to provide the results for an 8-hour mission. The trends are shown at the system-specific level across the industry. The trending method is described in more detail in Section 4 of the [Overview and Reference](#) document. In the lower left hand corner of the trend figures, the regression method is reported.

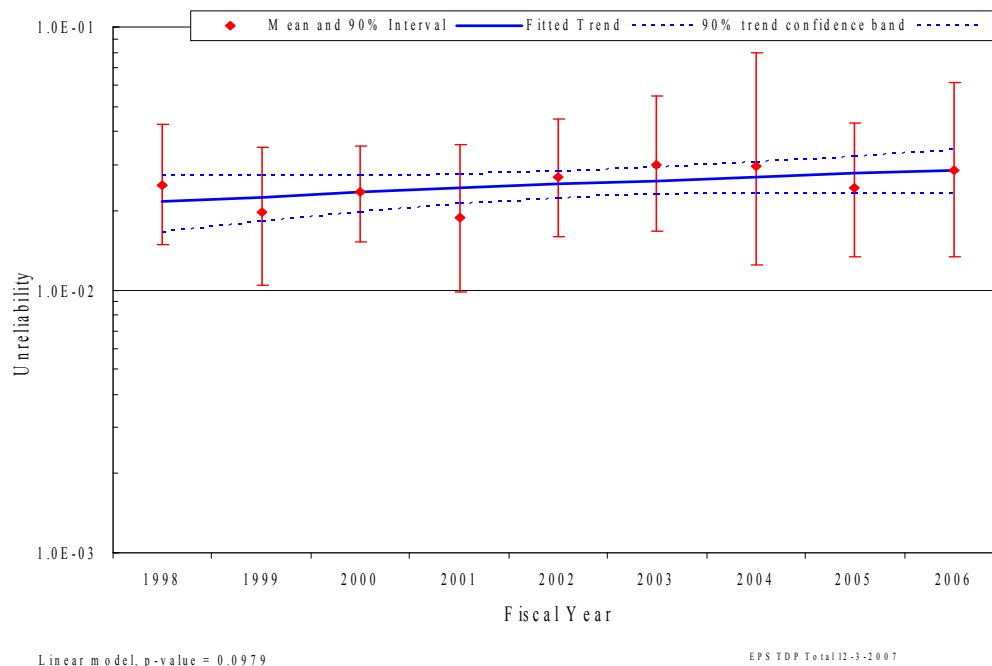


Figure 9. EPS, industry-wide EDG unreliability trend (8-hour mission).

6 ENGINEERING TRENDS

This section presents frequency trends for EDG failures and demands. The data are normalized by reactor year for plants that have the equipment being trended. Figure 11 shows the trend for EDG demands. Figure 12 shows the trend EDG load and run demands. Figure 13 shows the trend for the EDG run hours. Table 17, Table 18, and Table 19 provide the plot data, respectively.

Figure 14 shows the trend for EDG FTS events. Figure 15 shows the trend EDG FTLR events, and Figure 16 shows the trend for the EDG FTR events. Table 20, Table 21, and Table 22 provide the plot data respectively.

Table 4 summarizes the failures by system, year, for the FTS failure mode. Table 5 summarizes the failures by system, year, for the FTLR failure mode. Table 6 summarizes the failures by system, year, for the FTR>1H failure mode.

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.

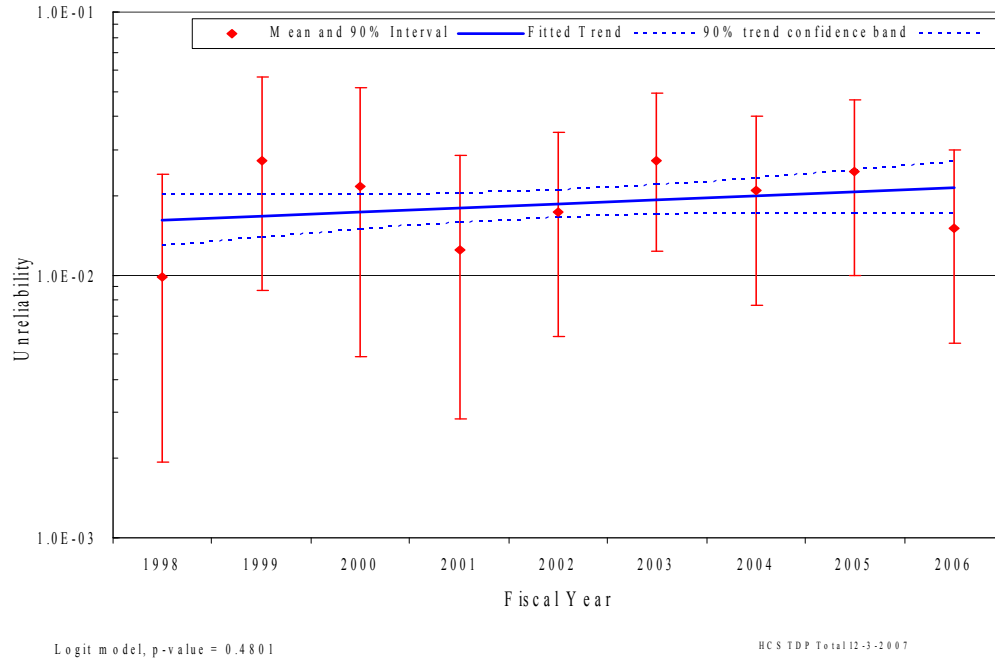


Figure 10. HPCS, industry-wide EDG unreliability trend (8-hour mission).

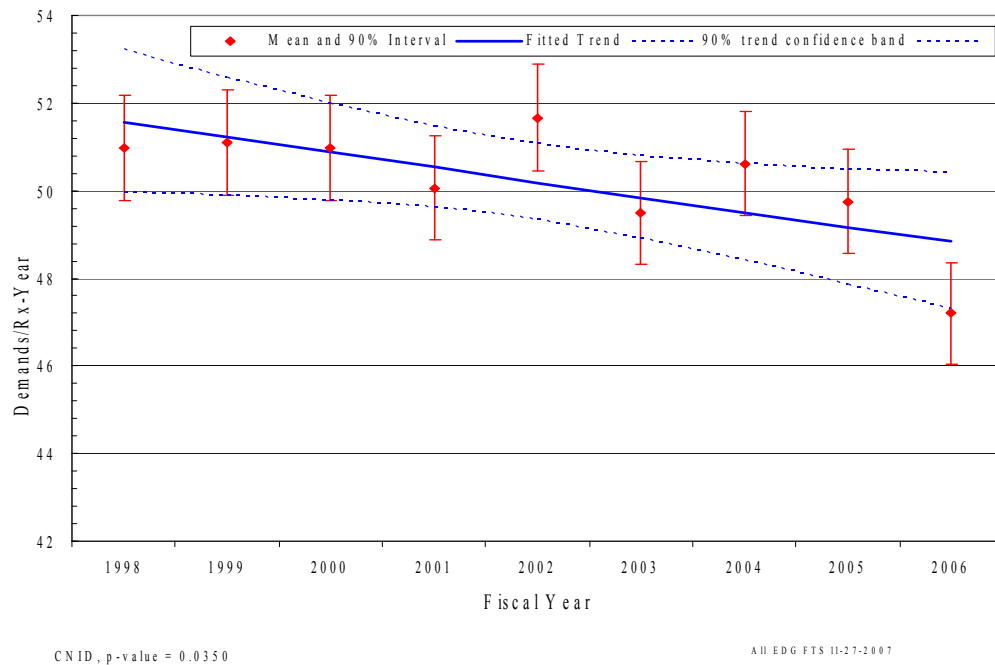


Figure 11. Frequency (events per reactor year) of start demands, EDGs.

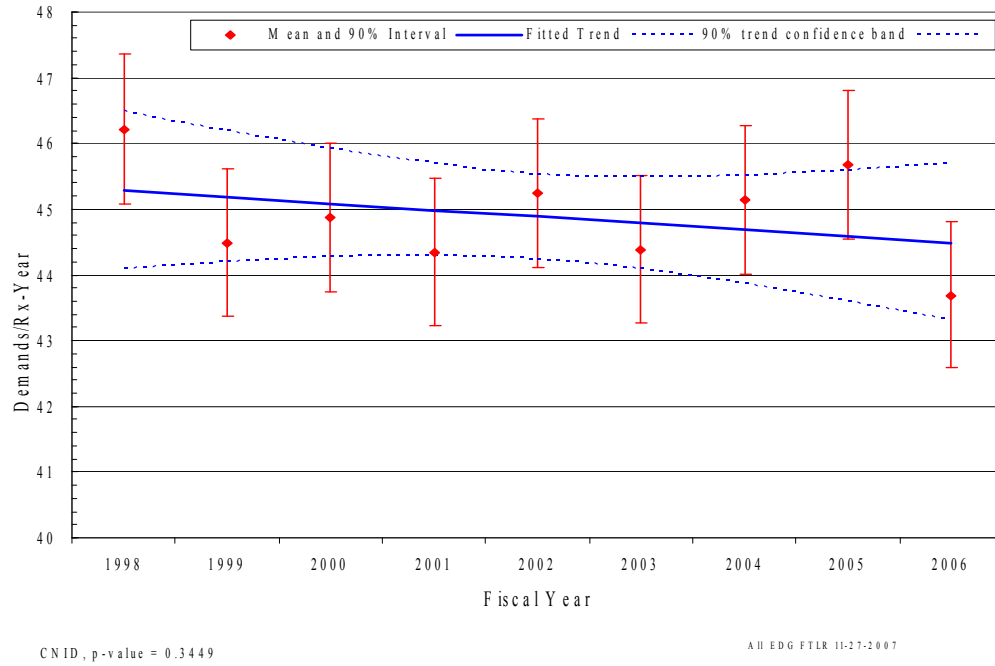


Figure 12. Frequency (events per reactor year) of load and run ≤ 1 hour demands, EDGs.

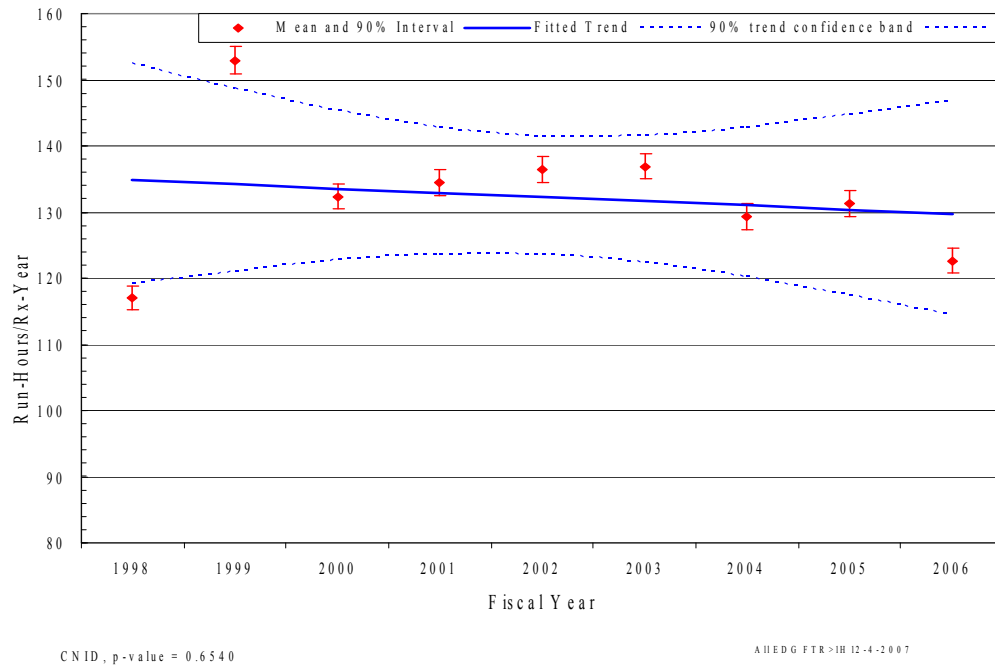


Figure 13. EDG run hours per reactor year.

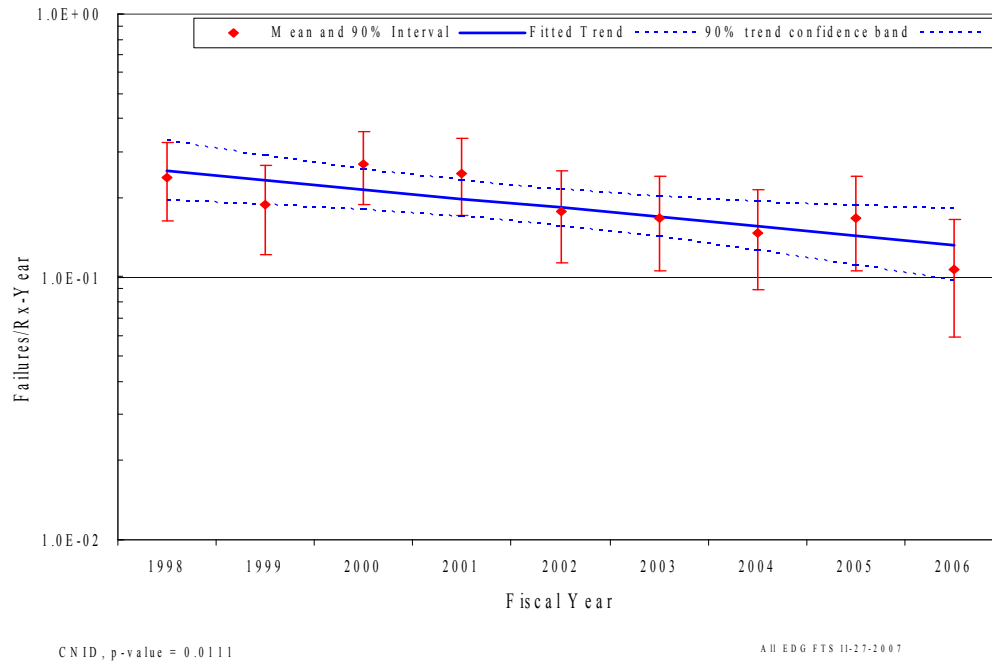


Figure 14. Frequency (events per reactor year) of FTS events, EDGs.

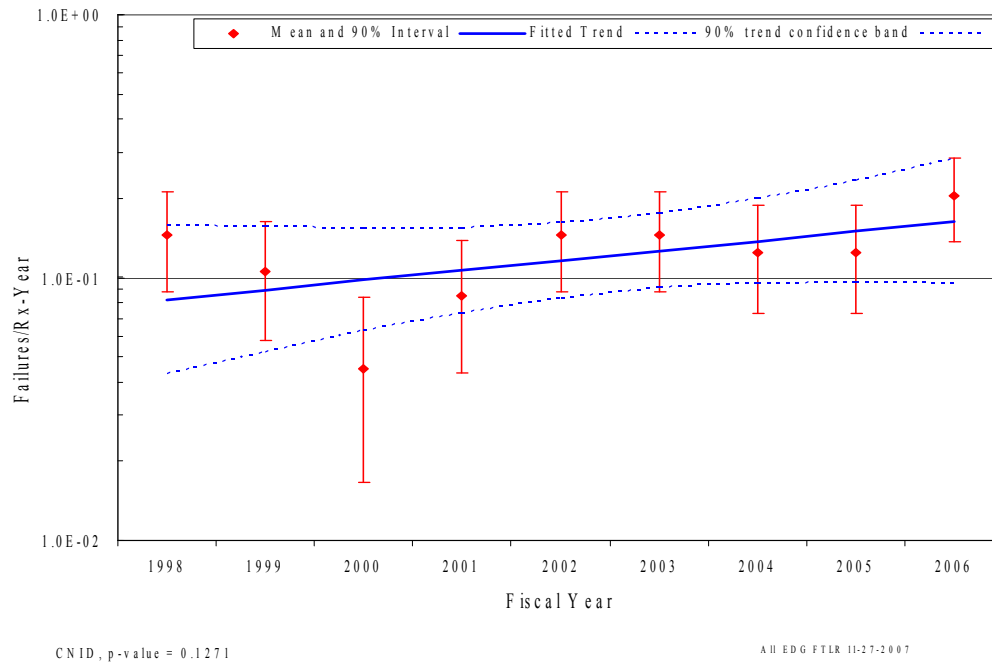


Figure 15. Frequency (events per reactor year) of FTLR events, EDGs.

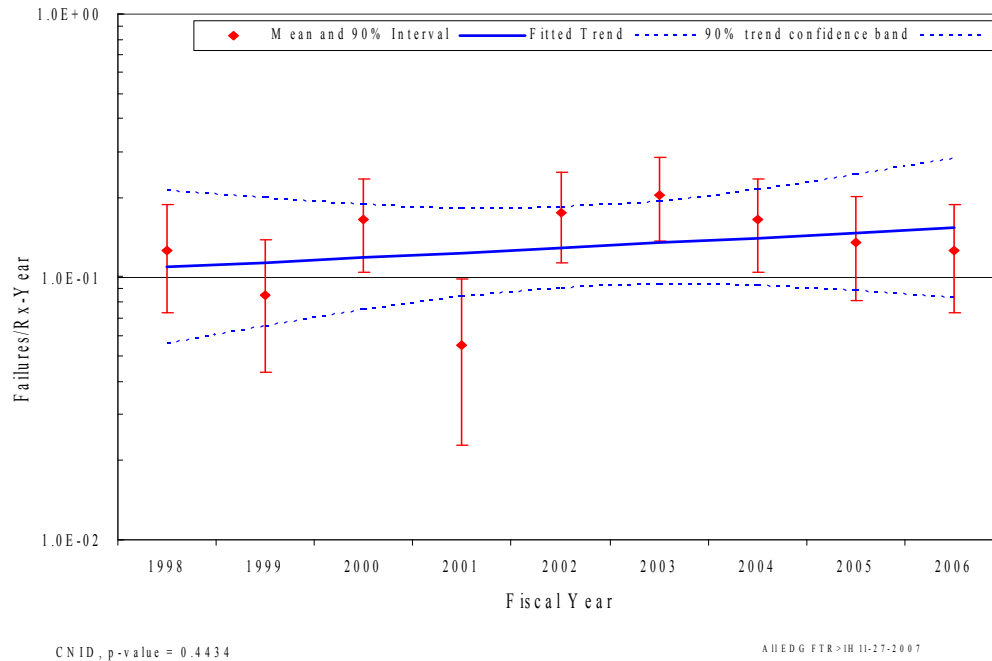


Figure 16. Frequency (events per reactor year) of FTR events, EDGs.

Table 4. Summary of EDG failure counts for the FTS failure mode over time by system.

System Code	EDG Count	EDG Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	Total	Percent of Failures
EPS	223	96.5%	23	17	25	24	16	16	14	16	10	161	98.2%
HPCS	8	3.5%	0	1	1	0	1	0	0	0	0	3	1.8%
Total	231	100.0%	23	18	26	24	17	16	14	16	10	164	100.0%

Table 5. Summary of EDG failure counts for the FTLR failure mode over time by system.

System Code	EDG Count	EDG Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	Total	Percent of Failures
EPS	223	96.5%	14	10	4	8	14	14	11	12	20	107	99.1%
HPCS	8	3.5%	0	0	0	0	0	0	1	0	0	1	0.9%
Total	231	100.0%	14	10	4	8	14	14	12	12	20	108	100.0%

Table 6. Summary of EDG failure counts for the FTR > 1H failure mode over time by system.

System Code	EDG Count	EDG Percent	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04	FY 05	FY 06	Total	Percent of Failures
EPS	223	96.5%	12	7	16	5	17	19	16	12	12	116	97.5%
HPCS	8	3.5%	0	1	0	0	0	1	0	1	0	3	2.5%
Total	231	100.0%	12	8	16	5	17	20	16	13	12	119	100.0%

7 EDG ASSEMBLY DESCRIPTION

The emergency diesel generators (EDGs) are those within the Class 1E ac electrical power system at U.S. commercial nuclear power plants and those in the high-pressure core spray (HPCS) systems. Station blackout (SBO) EDGs are not included.

The EDG includes the diesel engine with all components in the exhaust path, electrical generator, generator exciter, output breaker, combustion air, lube oil systems, fuel oil system, and starting compressed air system, and local instrumentation and control circuitry. The sequencer is excluded from the EDG component. For the service water system providing cooling to the EDGs, only the devices providing control of cooling flow to the EDG heat exchangers are included. Room heating and ventilating is not included.

8 DATA TABLES

Table 7. Plot data for EPS EDG FTS industry trend. 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						2.56E-04	1.50E-02	5.00E-03
1998	23	4729.5	4.94E-03	3.77E-03	6.46E-03	3.31E-03	6.55E-03	4.84E-03
1999	17	4725.3	4.60E-03	3.68E-03	5.74E-03	2.31E-03	5.11E-03	3.60E-03
2000	25	4732.3	4.28E-03	3.56E-03	5.14E-03	3.65E-03	7.02E-03	5.24E-03
2001	24	4656.6	3.98E-03	3.39E-03	4.68E-03	3.53E-03	6.89E-03	5.12E-03
2002	16	4813.2	3.71E-03	3.15E-03	4.36E-03	2.10E-03	4.78E-03	3.34E-03
2003	16	4599.2	3.45E-03	2.87E-03	4.15E-03	2.20E-03	4.99E-03	3.49E-03
2004	14	4728.8	3.21E-03	2.57E-03	4.01E-03	1.82E-03	4.36E-03	2.98E-03
2005	16	4633.1	2.99E-03	2.28E-03	3.91E-03	2.18E-03	4.96E-03	3.46E-03
2006	10	4403.5	2.78E-03	2.01E-03	3.84E-03	1.28E-03	3.59E-03	2.32E-03

Table 8. Plot data for EPS EDG FTLR industry trend. 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						3.52E-04	7.81E-03	3.00E-03
1998	14	4308.1	1.91E-03	9.94E-04	3.66E-03	1.97E-03	4.73E-03	3.23E-03
1999	10	4143.2	2.07E-03	1.20E-03	3.57E-03	1.34E-03	3.77E-03	2.43E-03
2000	4	4180.7	2.25E-03	1.43E-03	3.52E-03	3.81E-04	1.94E-03	1.03E-03
2001	8	4129.1	2.44E-03	1.68E-03	3.54E-03	1.01E-03	3.20E-03	1.97E-03
2002	14	4214.3	2.64E-03	1.90E-03	3.68E-03	2.01E-03	4.83E-03	3.30E-03
2003	14	4134.8	2.87E-03	2.05E-03	4.00E-03	2.05E-03	4.92E-03	3.36E-03
2004	11	4216.4	3.11E-03	2.12E-03	4.56E-03	1.49E-03	3.99E-03	2.62E-03
2005	12	4255.1	3.37E-03	2.12E-03	5.36E-03	1.65E-03	4.24E-03	2.82E-03
2006	20	4078.4	3.66E-03	2.09E-03	6.40E-03	3.20E-03	6.66E-03	4.82E-03

Table 9. Plot data for EPS EDG FTR>1H industry trend. Figure 3

FY/ Source	Failures	Run Time (h)	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						1.42E-04	1.90E-03	8.00E-04
1998	12	10894.4	7.71E-04	3.70E-04	1.61E-03	6.42E-04	1.66E-03	1.10E-03
1999	7	14237.6	8.16E-04	4.42E-04	1.51E-03	2.47E-04	8.49E-04	5.10E-04
2000	16	12354.6	8.64E-04	5.22E-04	1.43E-03	8.13E-04	1.85E-03	1.29E-03
2001	5	12553.5	9.14E-04	6.01E-04	1.39E-03	1.76E-04	7.55E-04	4.22E-04
2002	17	12756.6	9.67E-04	6.64E-04	1.41E-03	8.49E-04	1.88E-03	1.32E-03
2003	19	12764.6	1.02E-03	6.94E-04	1.51E-03	9.70E-04	2.06E-03	1.47E-03
2004	16	12138.5	1.08E-03	6.90E-04	1.70E-03	8.27E-04	1.88E-03	1.31E-03
2005	12	12192.4	1.14E-03	6.64E-04	1.97E-03	5.77E-04	1.49E-03	9.87E-04
2006	12	11454.6	1.21E-03	6.26E-04	2.34E-03	6.12E-04	1.58E-03	1.05E-03

Table 10. Plot data for HPCS EDG FTS industry trend. Figure 4

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						2.56E-04	1.50E-02	5.00E-03
1998	0	164.9	2.80E-03	1.25E-03	6.29E-03	5.20E-06	5.29E-03	1.38E-03
1999	1	180.5	2.59E-03	1.32E-03	5.09E-03	4.64E-04	1.03E-02	3.98E-03
2000	1	173.5	2.40E-03	1.37E-03	4.19E-03	4.73E-04	1.05E-02	4.05E-03
2001	0	148.1	2.22E-03	1.39E-03	3.55E-03	5.46E-06	5.55E-03	1.44E-03
2002	1	146.5	2.05E-03	1.34E-03	3.15E-03	5.10E-04	1.13E-02	4.37E-03
2003	0	151.8	1.90E-03	1.21E-03	2.98E-03	5.40E-06	5.49E-03	1.43E-03
2004	0	142.8	1.76E-03	1.04E-03	2.97E-03	5.54E-06	5.64E-03	1.47E-03
2005	0	142.8	1.63E-03	8.63E-04	3.06E-03	5.54E-06	5.64E-03	1.47E-03
2006	0	127.2	1.50E-03	7.01E-04	3.22E-03	5.81E-06	5.91E-03	1.54E-03

Table 11. Plot data for HPCS EDG FTLR industry trend. Figure 5

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						3.52E-04	7.81E-03	3.00E-03
1998	0	127.7	9.45E-04	5.39E-04	1.66E-03	3.77E-06	3.75E-03	9.77E-04
1999	0	127.5	9.82E-04	6.16E-04	1.56E-03	3.77E-06	3.76E-03	9.78E-04
2000	0	138.5	1.02E-03	6.95E-04	1.50E-03	3.69E-06	3.68E-03	9.57E-04
2001	0	127.6	1.06E-03	7.63E-04	1.47E-03	3.77E-06	3.75E-03	9.77E-04
2002	0	128.8	1.10E-03	8.07E-04	1.51E-03	3.76E-06	3.75E-03	9.75E-04
2003	0	125.8	1.15E-03	8.16E-04	1.61E-03	3.78E-06	3.77E-03	9.81E-04
2004	1	128.8	1.19E-03	7.96E-04	1.78E-03	3.43E-04	7.61E-03	2.93E-03
2005	0	128.8	1.24E-03	7.60E-04	2.02E-03	3.76E-06	3.75E-03	9.75E-04
2006	0	115.6	1.29E-03	7.17E-04	2.31E-03	3.86E-06	3.85E-03	1.00E-03

Table 12. Plot data for HPCS EDG FTR>1H industry trend. Figure 6

FY/ Source	Failures	Run Time (h)	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						1.42E-04	1.90E-03	8.00E-04
1998	0	334.1	7.81E-04	3.38E-04	1.80E-03	2.45E-06	2.39E-03	6.23E-04
1999	1	441.5	8.00E-04	3.99E-04	1.60E-03	1.93E-04	4.29E-03	1.65E-03
2000	0	387.1	8.19E-04	4.61E-04	1.45E-03	2.30E-06	2.24E-03	5.84E-04
2001	0	358.1	8.39E-04	5.15E-04	1.37E-03	2.38E-06	2.32E-03	6.05E-04
2002	0	341.1	8.59E-04	5.45E-04	1.35E-03	2.43E-06	2.37E-03	6.18E-04
2003	1	380.1	8.80E-04	5.39E-04	1.44E-03	2.07E-04	4.60E-03	1.77E-03
2004	0	307.6	9.01E-04	5.06E-04	1.61E-03	2.53E-06	2.47E-03	6.44E-04
2005	1	411.6	9.23E-04	4.59E-04	1.86E-03	2.00E-04	4.44E-03	1.70E-03
2006	0	318.2	9.45E-04	4.08E-04	2.19E-03	2.50E-06	2.44E-03	6.36E-04

Table 13. Plot data for EPS EDG UA trend. Figure 7

FY/ Source	UA Hours	Critical Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						4.10E-03	2.33E-02	1.20E-02
1998	13139.7	1412111.0	8.52E-03	6.17E-03	1.09E-02	6.47E-04	2.67E-02	9.34E-03
1999	19214.0	1869156.0	9.19E-03	7.23E-03	1.11E-02	1.49E-03	2.52E-02	1.02E-02
2000	15710.0	1887460.0	9.85E-03	8.24E-03	1.15E-02	1.42E-03	1.97E-02	8.24E-03
2001	16687.2	1889336.0	1.05E-02	9.14E-03	1.19E-02	5.97E-04	2.53E-02	8.83E-03
2002	19912.3	1828617.0	1.12E-02	9.90E-03	1.25E-02	1.30E-03	2.82E-02	1.09E-02
2003	22247.8	1736874.0	1.18E-02	1.05E-02	1.32E-02	8.19E-04	3.72E-02	1.29E-02
2004	26159.1	1775661.0	1.25E-02	1.09E-02	1.41E-02	4.05E-06	6.49E-02	1.47E-02
2005	19586.9	1731449.0	1.32E-02	1.12E-02	1.51E-02	1.26E-03	2.98E-02	1.14E-02
2006	24643.8	1764627.0	1.38E-02	1.15E-02	1.62E-02	3.01E-04	4.68E-02	1.41E-02

Table 14. Plot data for HPCS EDG UA trend. Figure 8

FY/ Source	UA Hours	Critical Hours	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
NUREG/ CR-6928						5.23E-03	2.10E-02	1.20E-02
1998	164.5	52408.0	6.38E-03	5.17E-03	7.87E-03	1.38E-04	9.59E-03	3.14E-03
1999	747.9	70080.0	6.86E-03	5.76E-03	8.17E-03	4.03E-04	3.32E-02	1.07E-02
2000	887.0	69648.0	7.37E-03	6.39E-03	8.52E-03	3.82E-04	4.03E-02	1.26E-02
2001	409.6	69781.4	7.93E-03	7.02E-03	8.96E-03	5.12E-04	1.61E-02	5.85E-03
2002	520.8	68212.8	8.53E-03	7.61E-03	9.55E-03	1.23E-03	1.86E-02	7.67E-03
2003	790.3	64476.7	9.17E-03	8.12E-03	1.04E-02	5.48E-03	2.12E-02	1.23E-02
2004	797.5	66422.6	9.86E-03	8.54E-03	1.14E-02	2.76E-03	2.64E-02	1.20E-02
2005	680.9	63863.9	1.06E-02	8.90E-03	1.26E-02	3.18E-03	2.10E-02	1.04E-02
2006	548.8	66916.8	1.14E-02	9.24E-03	1.40E-02	2.59E-03	1.61E-02	8.12E-03

Table 15. Plot data for EPS EDG unreliability trend. Figure 9

FY	Regression Curve Data Points			Plot Trend Error Bar Points		
	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	2.18E-02	1.65E-02	2.71E-02	1.49E-02	4.27E-02	2.51E-02
1999	2.26E-02	1.82E-02	2.70E-02	1.05E-02	3.50E-02	1.98E-02
2000	2.35E-02	1.98E-02	2.71E-02	1.53E-02	3.54E-02	2.35E-02
2001	2.43E-02	2.13E-02	2.74E-02	9.79E-03	3.56E-02	1.89E-02
2002	2.52E-02	2.23E-02	2.81E-02	1.59E-02	4.45E-02	2.68E-02
2003	2.61E-02	2.30E-02	2.91E-02	1.67E-02	5.46E-02	3.00E-02
2004	2.69E-02	2.33E-02	3.06E-02	1.24E-02	7.96E-02	2.95E-02
2005	2.78E-02	2.34E-02	3.22E-02	1.33E-02	4.34E-02	2.46E-02
2006	2.86E-02	2.33E-02	3.39E-02	1.34E-02	6.13E-02	2.86E-02

Table 16. Plot data for HPCS EDG unreliability trend. Figure 10

FY	Regression Curve Data Points			Plot Trend Error Bar Points		
	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	1.62E-02	1.29E-02	2.03E-02	1.94E-03	2.41E-02	9.86E-03
1999	1.68E-02	1.39E-02	2.02E-02	8.74E-03	5.64E-02	2.72E-02
2000	1.74E-02	1.49E-02	2.03E-02	4.87E-03	5.18E-02	2.17E-02
2001	1.80E-02	1.58E-02	2.05E-02	2.85E-03	2.84E-02	1.25E-02
2002	1.86E-02	1.65E-02	2.11E-02	5.86E-03	3.48E-02	1.73E-02
2003	1.93E-02	1.69E-02	2.20E-02	1.23E-02	4.90E-02	2.71E-02
2004	2.00E-02	1.71E-02	2.33E-02	7.70E-03	4.03E-02	2.09E-02
2005	2.07E-02	1.72E-02	2.50E-02	9.97E-03	4.63E-02	2.48E-02
2006	2.15E-02	1.71E-02	2.69E-02	5.49E-03	3.00E-02	1.51E-02

Table 17. Plot data for EDG start demands trend. Figure 11

FY/ Source	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	4894	96.0	5.16E+01	5.00E+01	5.32E+01	4.98E+01	5.22E+01	5.10E+01
1999	4906	96.0	5.12E+01	4.99E+01	5.26E+01	4.99E+01	5.23E+01	5.11E+01
2000	4906	96.3	5.09E+01	4.98E+01	5.20E+01	4.98E+01	5.22E+01	5.10E+01
2001	4805	96.0	5.05E+01	4.96E+01	5.15E+01	4.89E+01	5.12E+01	5.01E+01
2002	4960	96.0	5.02E+01	4.93E+01	5.11E+01	5.05E+01	5.29E+01	5.17E+01
2003	4751	96.0	4.98E+01	4.89E+01	5.08E+01	4.83E+01	5.07E+01	4.95E+01
2004	4872	96.3	4.95E+01	4.84E+01	5.06E+01	4.94E+01	5.18E+01	5.06E+01
2005	4776	96.0	4.92E+01	4.79E+01	5.05E+01	4.86E+01	5.09E+01	4.98E+01
2006	4531	96.0	4.88E+01	4.73E+01	5.04E+01	4.61E+01	4.84E+01	4.72E+01

Table 18. Plot data for EDG load and run $\leq$ 1-hour demands trend. Figure 12

FY/ Source	Demands	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	4436	96.0	4.53E+01	4.41E+01	4.65E+01	4.51E+01	4.74E+01	4.62E+01
1999	4271	96.0	4.52E+01	4.42E+01	4.62E+01	4.34E+01	4.56E+01	4.45E+01
2000	4319	96.3	4.51E+01	4.43E+01	4.59E+01	4.37E+01	4.60E+01	4.49E+01
2001	4257	96.0	4.50E+01	4.43E+01	4.57E+01	4.32E+01	4.55E+01	4.43E+01
2002	4343	96.0	4.49E+01	4.42E+01	4.55E+01	4.41E+01	4.64E+01	4.52E+01
2003	4261	96.0	4.48E+01	4.41E+01	4.55E+01	4.33E+01	4.55E+01	4.44E+01
2004	4345	96.3	4.47E+01	4.39E+01	4.55E+01	4.40E+01	4.63E+01	4.51E+01
2005	4384	96.0	4.46E+01	4.36E+01	4.56E+01	4.45E+01	4.68E+01	4.57E+01
2006	4194	96.0	4.45E+01	4.33E+01	4.57E+01	4.26E+01	4.48E+01	4.37E+01

Table 19. Plot data for EDG run hours (greater than 1H) trend. Figure 13

FY/ Source	Run Hours	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	11228	96.0	1.35E+02	1.19E+02	1.53E+02	1.15E+02	1.19E+02	1.17E+02
1999	14679	96.0	1.34E+02	1.21E+02	1.49E+02	1.51E+02	1.55E+02	1.53E+02
2000	12742	96.3	1.34E+02	1.23E+02	1.45E+02	1.30E+02	1.34E+02	1.32E+02
2001	12912	96.0	1.33E+02	1.24E+02	1.43E+02	1.33E+02	1.36E+02	1.35E+02
2002	13098	96.0	1.32E+02	1.24E+02	1.41E+02	1.34E+02	1.38E+02	1.36E+02
2003	13145	96.0	1.32E+02	1.22E+02	1.42E+02	1.35E+02	1.39E+02	1.37E+02
2004	12446	96.3	1.31E+02	1.20E+02	1.43E+02	1.27E+02	1.31E+02	1.29E+02
2005	12604	96.0	1.30E+02	1.17E+02	1.45E+02	1.29E+02	1.33E+02	1.31E+02
2006	11773	96.0	1.30E+02	1.14E+02	1.47E+02	1.21E+02	1.25E+02	1.23E+02

Table 20. Plot data for EDG FTS events trend. Figure 14

FY/ Source	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	23	96.0	2.53E-01	1.95E-01	3.29E-01	1.64E-01	3.24E-01	2.38E-01
1999	18	96.0	2.34E-01	1.88E-01	2.90E-01	1.22E-01	2.65E-01	1.88E-01
2000	26	96.3	2.15E-01	1.80E-01	2.57E-01	1.88E-01	3.59E-01	2.68E-01
2001	24	96.0	1.99E-01	1.70E-01	2.32E-01	1.72E-01	3.36E-01	2.48E-01
2002	17	96.0	1.83E-01	1.57E-01	2.14E-01	1.14E-01	2.52E-01	1.77E-01
2003	16	96.0	1.69E-01	1.41E-01	2.02E-01	1.06E-01	2.40E-01	1.67E-01
2004	14	96.3	1.56E-01	1.26E-01	1.93E-01	8.95E-02	2.15E-01	1.47E-01
2005	16	96.0	1.44E-01	1.11E-01	1.87E-01	1.06E-01	2.40E-01	1.67E-01
2006	10	96.0	1.33E-01	9.71E-02	1.81E-01	5.88E-02	1.66E-01	1.06E-01

Table 21. Plot data for EDG FTLR events trend. Figure 15

FY/ Source	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	14	96.0	8.25E-02	4.30E-02	1.58E-01	8.86E-02	2.13E-01	1.45E-01
1999	10	96.0	8.99E-02	5.21E-02	1.55E-01	5.80E-02	1.63E-01	1.05E-01
2000	4	96.3	9.79E-02	6.24E-02	1.54E-01	1.66E-02	8.44E-02	4.49E-02
2001	8	96.0	1.07E-01	7.34E-02	1.55E-01	4.34E-02	1.38E-01	8.50E-02
2002	14	96.0	1.16E-01	8.37E-02	1.61E-01	8.86E-02	2.13E-01	1.45E-01
2003	14	96.0	1.26E-01	9.12E-02	1.75E-01	8.86E-02	2.13E-01	1.45E-01
2004	12	96.3	1.38E-01	9.50E-02	1.99E-01	7.29E-02	1.88E-01	1.25E-01
2005	12	96.0	1.50E-01	9.58E-02	2.34E-01	7.31E-02	1.88E-01	1.25E-01
2006	20	96.0	1.63E-01	9.48E-02	2.81E-01	1.37E-01	2.85E-01	2.05E-01

Table 22. Plot data for EDG FTR>1H events trend. Figure 16

FY/ Source	Failures	Reactor Years	Regression Curve Data Points			Plot Trend Error Bar Points		
			Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
1998	12	96.0	1.09E-01	5.54E-02	2.13E-01	7.33E-02	1.89E-01	1.25E-01
1999	8	96.0	1.13E-01	6.46E-02	1.99E-01	4.35E-02	1.38E-01	8.53E-02
2000	16	96.3	1.18E-01	7.45E-02	1.88E-01	1.04E-01	2.37E-01	1.65E-01
2001	5	96.0	1.24E-01	8.39E-02	1.82E-01	2.30E-02	9.88E-02	5.52E-02
2002	17	96.0	1.29E-01	9.09E-02	1.83E-01	1.13E-01	2.50E-01	1.76E-01
2003	20	96.0	1.35E-01	9.38E-02	1.94E-01	1.37E-01	2.86E-01	2.06E-01
2004	16	96.3	1.41E-01	9.24E-02	2.14E-01	1.04E-01	2.37E-01	1.65E-01
2005	13	96.0	1.47E-01	8.84E-02	2.44E-01	8.11E-02	2.01E-01	1.36E-01
2006	12	96.0	1.53E-01	8.30E-02	2.83E-01	7.33E-02	1.89E-01	1.25E-01

9 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.