Rates of Initiating Events at

U.S. Nuclear Power Plants

1988–2009

This report presents an analysis of initiating event frequencies at United States (U.S.) commercial nuclear power plants. The evaluation is based on the operating experience from fiscal year 1988 through 2009, as reported in Licensee Event Reports (LERs). This is the latest update to NUREG/CR-5750, updating data, frequency estimates, trends, and figures.

1 LATEST FREQUENCIES AND TRENDS

This report displays occurrence rates for the categories of initiating events that contribute to the NRC's Industry Trend monitoring program and others. Sixteen initiating event groupings are trended and displayed. BWR and PWR initiators are plotted separately for initiating events with different occurrence rates for the two plant types. Each figure is annotated with the p-value[1] for the presence of a trend since FY1988.

In accordance with the Industry Trends Program (ITP), particular starting years have been identified for each of these initiating events for baseline periods during which the initiating event frequencies are approximately constant. The baseline periods end with calendar year 2002 for all of these initiating events except for LOOP (the baseline period for LOOP comes from a more recent study—NUREG/CR-6890).

The maximum likelihood estimate (the total number of events divided by the total number of reactor critical years) is plotted for each occurrence rate in each fiscal year. For each baseline period, the maximum likelihood estimate is the ratio of the total event count (summed over the calendar years in the baseline period), divided by the corresponding sum of reactor critical years. In addition, the mean of the distribution used in the ITP (Jeffreys or empirical Bayes) is presented in Table 1.

The limits in each year are simple 5th and 95th percent confidence bounds. For the baseline period, the horizontal limits are computed from the predictive distribution (Poisson-Gamma) that describes the number of events that would be expected in a following year based on the number of events (plus 0.5), the occurrence time in the baseline period, and the exposure time in the following year. The predictive bounds for the baseline period assume that the occurrences are following a constant rate for that period and the future. Comparing future data with those bounds helps to determine whether the data are changing. Table 1 lists the initiating events, overall data, and horizontal bounds used in the plots.

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).

Table 1. Initiating events with baseline frequencies.

Initiating event functional impact category	All Data			Baseline							
	Figure	Number of events	Reactor critical years	Baseline period starting year (CY)	Baseline period ending year (CY)	Number of events	Reactor critical years	Distribution Mean	5% Lower Prediction Limit	Mean Frequency (MLE)	95% Upper Prediction Limit
Loss of offsite power	Figure 1	63	1938.731	1997	2004	24	724.4	3.59E-02[3]	0.00E+00	3.31E-02	8.51E-02
Loss of vital AC bus	Figure 2	10	1938.731	1992	2002	8	965.1	8.80E-03[1]	0.00E+00	8.29E-03	4.26E-02
Loss of vital DC bus	Figure 3	1	1938.731	1988	2002	1	1281.5	1.17E-03[2]	0.00E+00	7.80E-04	2.13E-02
Very small LOCA	Figure 4	5	1938.731	1992	2002	1	965.1	1.55E-03[3]	0.00E+00	1.04E-03	2.13E-02
Partial Loss of Component Cooling Water	Figure 5	3	1938.731	1988	2002	1	1281.5	1.17E-03[3]	0.00E+00	7.80E-04	2.13E-02
Loss of feedwater	Figure 6	204	1938.731	1993	2002	75	881.4	9.59E-02[3]	4.26E-02	9.53E-02	1.70E-01
Partial Loss of Service Water	Figure 7	4	1938.731	1988	2002	2	1281.5	1.95E-03[3]	0.00E+00	1.56E-03	2.13E-02
BWR loss of instrument air	Figure 8	12	637.2151	1991	2002	3	343.0	1.02E-02[2]	0.00E+00	8.75E-03	6.25E-02
BWR stuck open SRV	Figure 9	16	637.2151	1993	2002	6	291.5	2.23E-02[2]	0.00E+00	2.06E-02	9.38E-02
BWR loss of heat sink	Figure 10	149	637.2151	1996	2002[4]	32	208.4	1.60E-01[4]	6.25E-02	1.97E-01	3.75E-01
BWR general transients	Figure 11	843	637.2151	1997	2002[5]	151	180.1	8.40E-01[2]	5.63E-01	8.27E-01	1.16E+00

1. This distribution mean is based on a Bayesian update of the Jeffreys noninformative prior using the industry data.

2. This distribution mean is based on a constrained non-informative distribution (CNID) mean.

3. This distribution mean is based on an empirical Bayes analysis at the yearly level with the Kass-Steffey adjustment.

4 . In 2009, the loss of condenser heat sink initiating event data were reviewed to verify that the loss of condenser vacuum functional impact involved an actual loss of condenser vacuum or whether the loss of vacuum was recovered by tripping the plant. The result of this review was the reclassification of several events from Loss of Condenser Heat Sink to a general transient.

Initiating event functional impact category	All Data			Baseline							
	Figure	Number of events	Reactor critical years	Baseline period starting year (CY)	Baseline period ending year (CY)	Number of events	Reactor critical years	Distribution Mean	5% Lower Prediction Limit	Mean Frequency (MLE)	95% Upper Prediction Limit
PWR loss of instrument air	Figure 12	15	1301.516	1997	2002	3	356.7	9.81E-03[3]	0.00E+00	8.41E-03	4.84E-02
PWR steam generator tube rupture	Figure 13	3	1301.516	1991	2002	2	706.0	3.54E-03[3]	0.00E+00	2.83E-03	3.23E-02
PWR stuck open SRV	Figure 14	2	1301.516	1988	2002	2	865.9	2.88E-03[3]	0.00E+00	2.31E-03	3.23E-02
PWR loss of heat sink	Figure 15	105	1301.516	1995	2002[5]	27	474.7	5.80E-02[2]	1.61E-02	7.79E-02	1.61E-01
PWR general transients	Figure 16	1619	1301.516	1998	2002[5]	234	303.9	7.70E-01[4]	5.65E-01	7.54E-01	9.84E-01

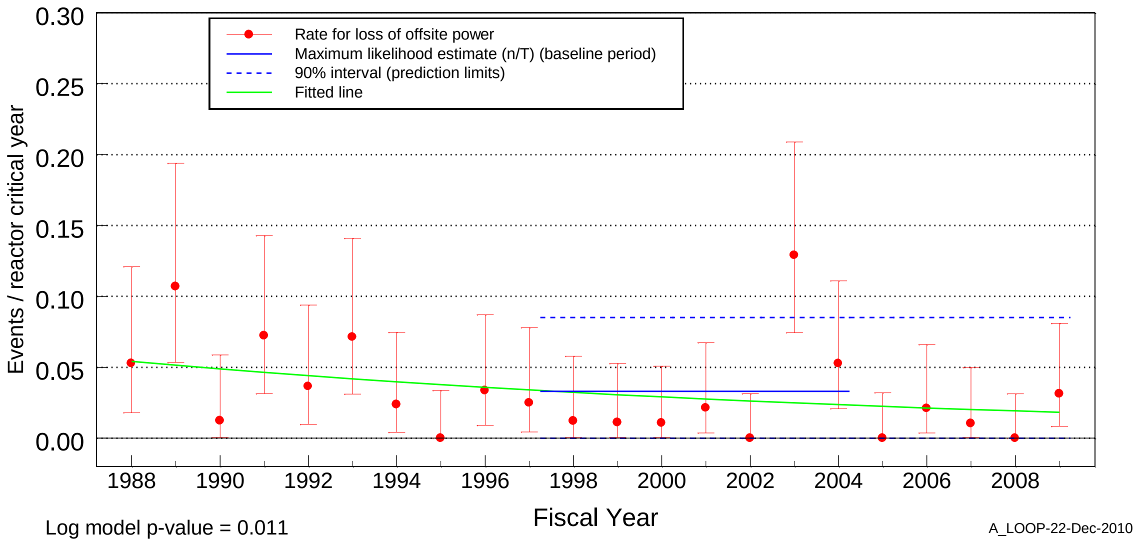

Figure 1. Frequency of initiating events with a loss of off-site power.

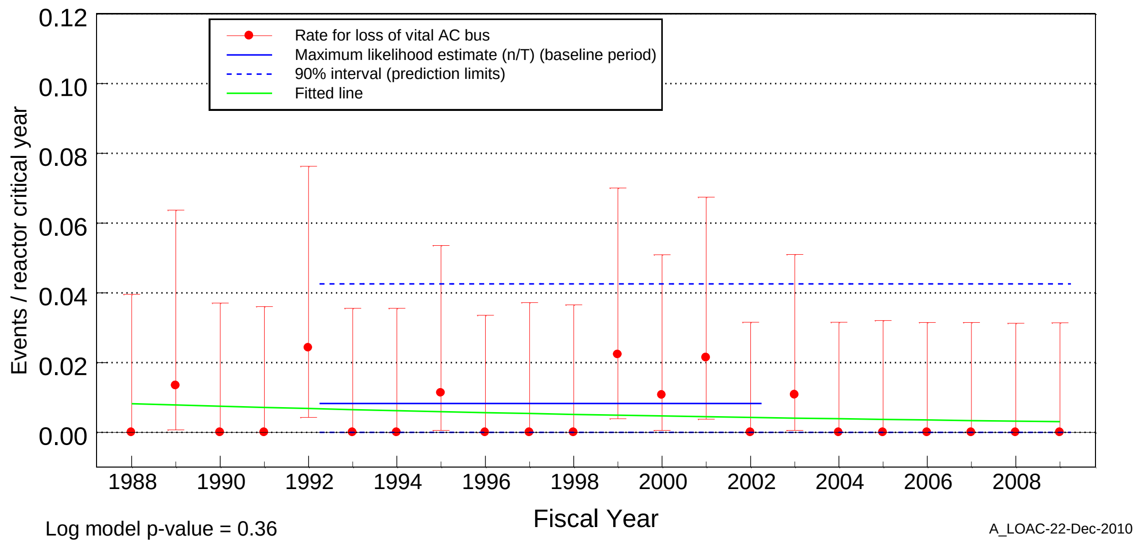

Figure 2. Frequency of initiating events with loss of vital AC bus.

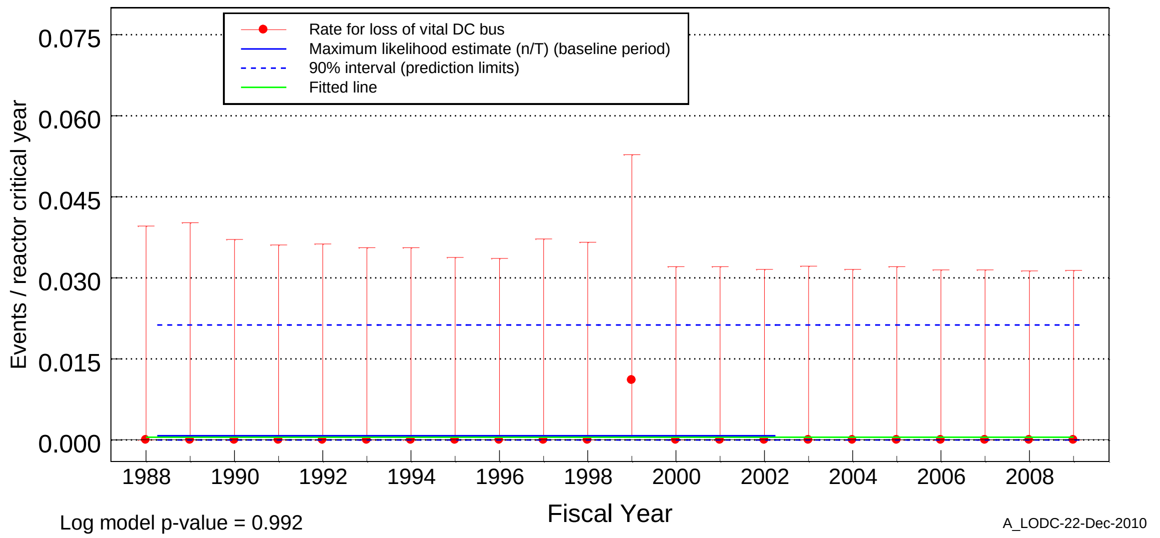

Figure 3. Frequency of initiating events with loss of vital DC bus.

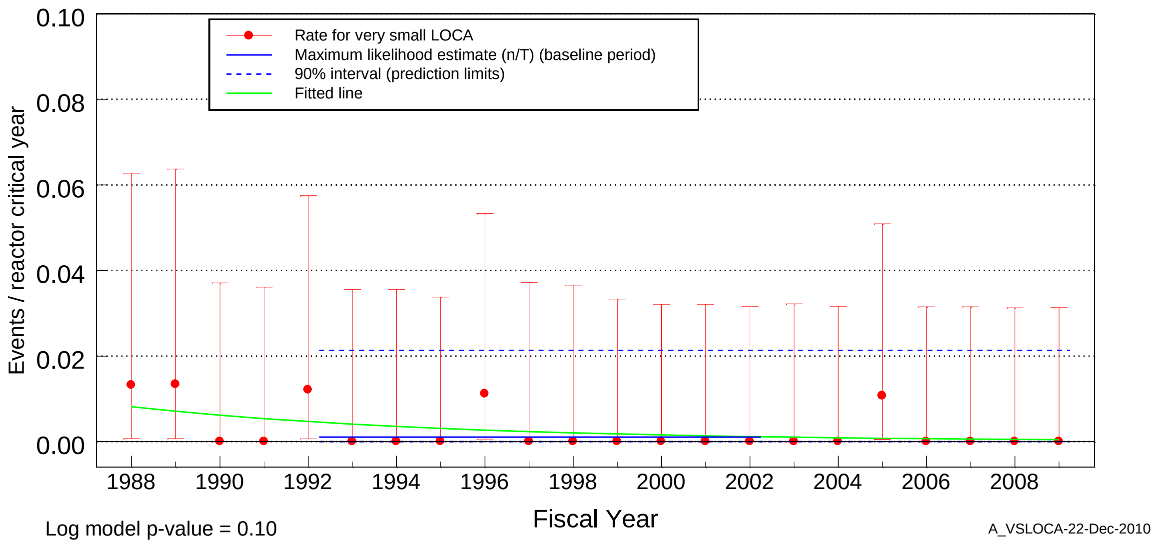

Figure 4. Frequency of initiating events with very small loss of coolant accident.

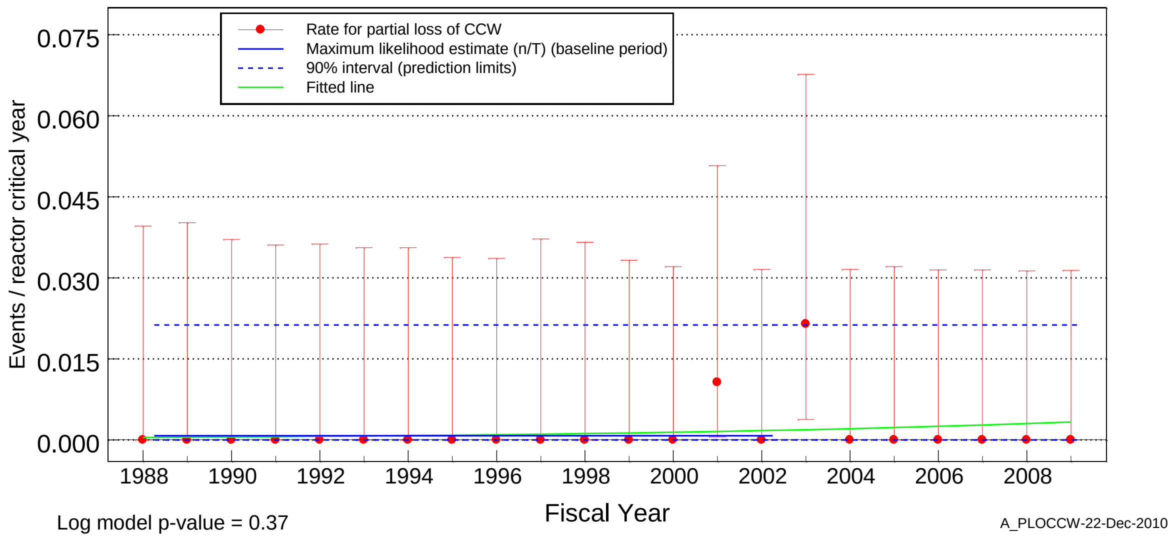

Figure 5. Frequency of initiating events with partial loss of component cooling water.

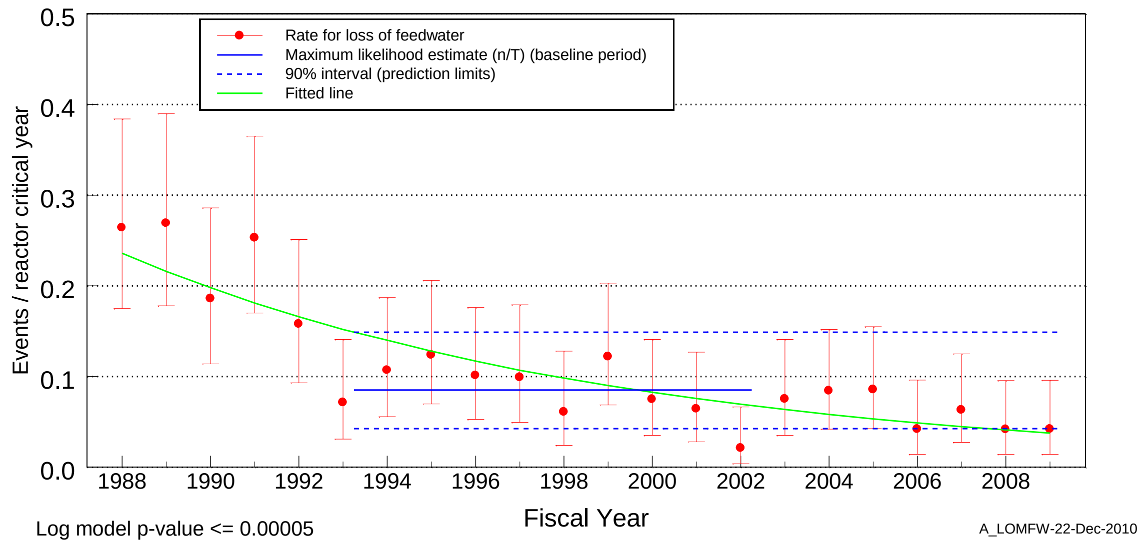

Figure 6. Frequency of initiating events with loss of feedwater.

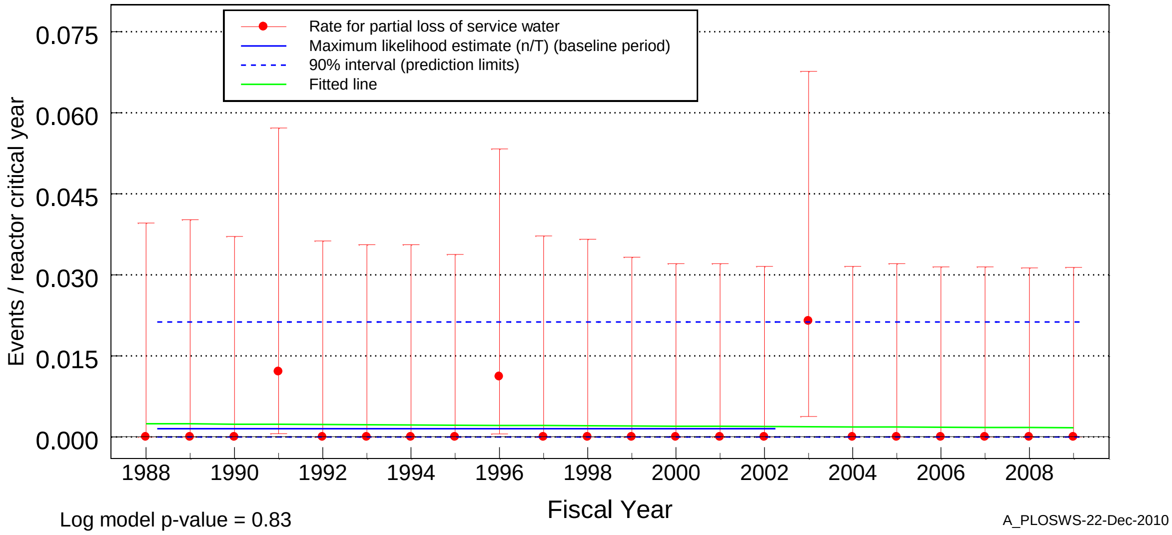

Figure 7. Frequency of initiating events with partial loss of service water.

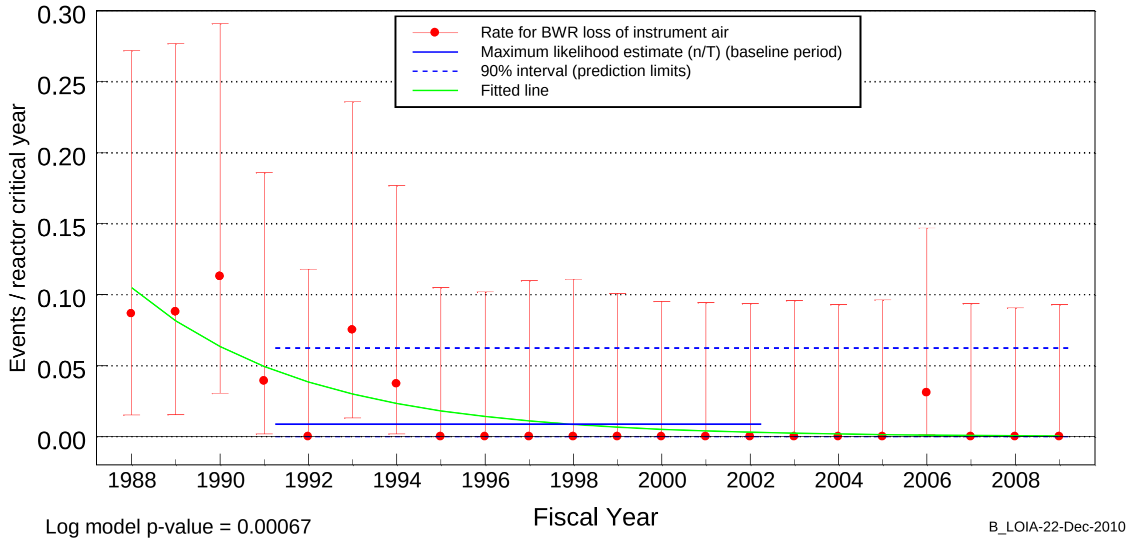

Figure 8. Frequency of BWR initiating events with loss of instrument air.

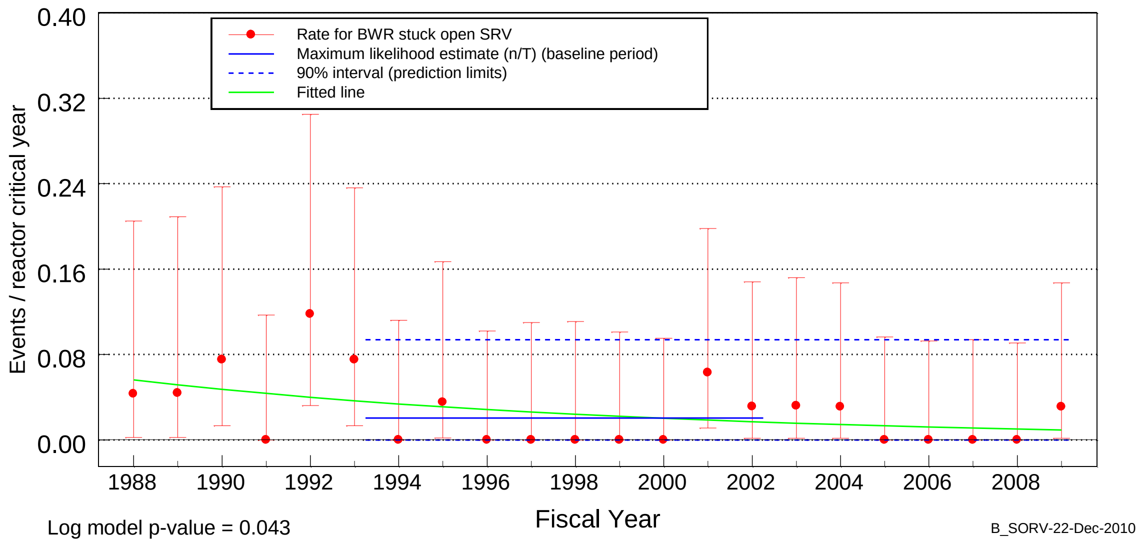

Figure 9. Frequency of BWR initiating events with stuck open safety relief valve.

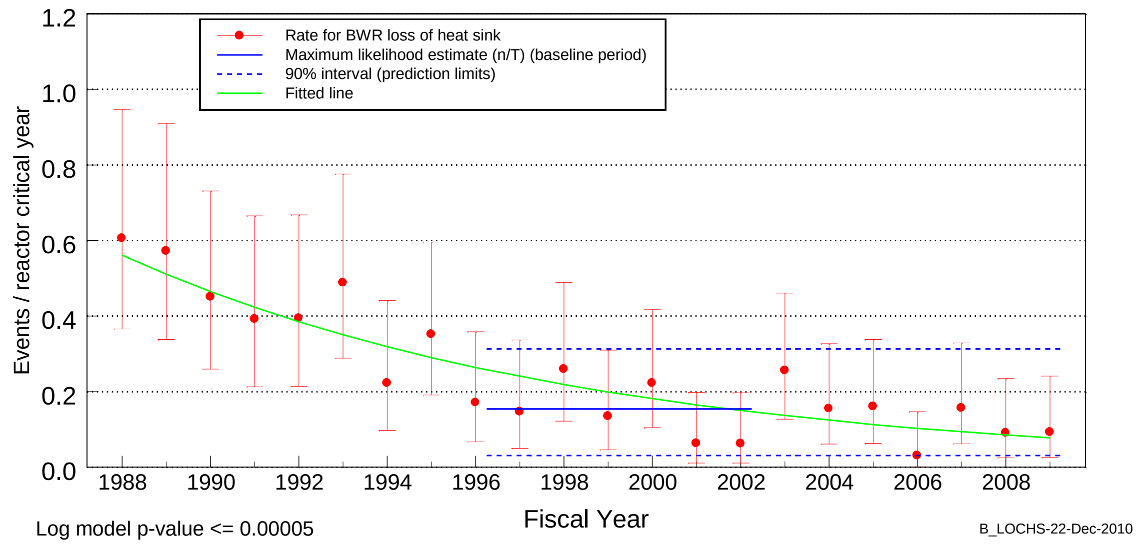

Figure 10. Frequency of BWR initiating events with loss of heat sink.

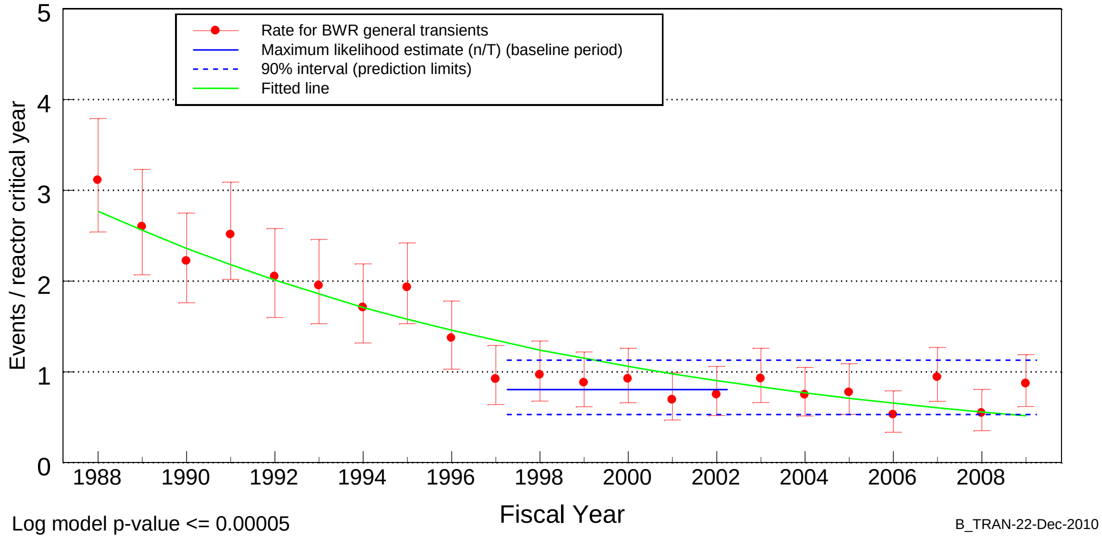

Figure 11. Frequency of BWR initiating events with general transients.

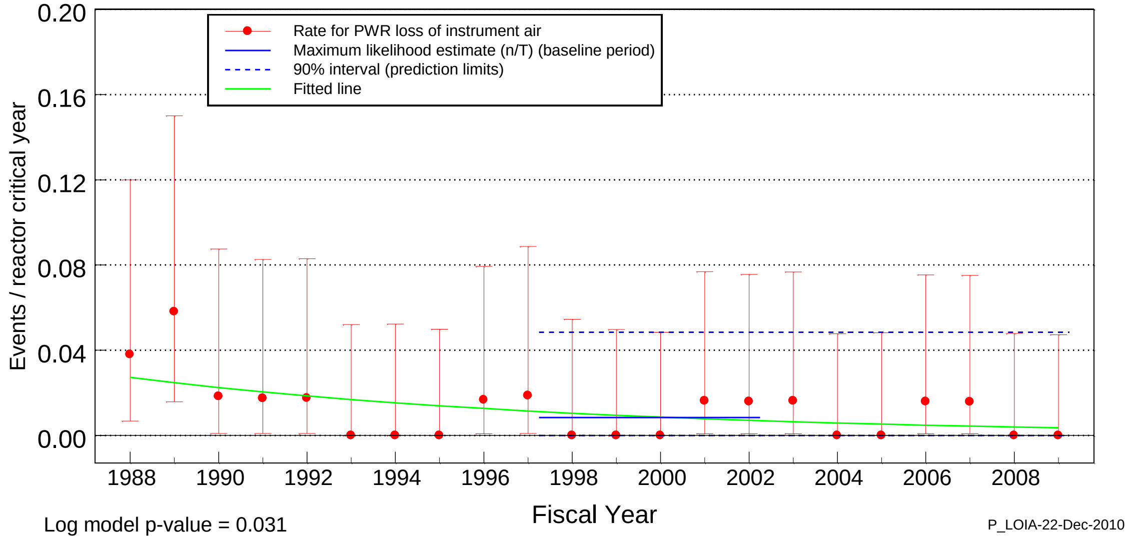

Figure 12. Frequency of PWR initiating events with loss of instrument air.

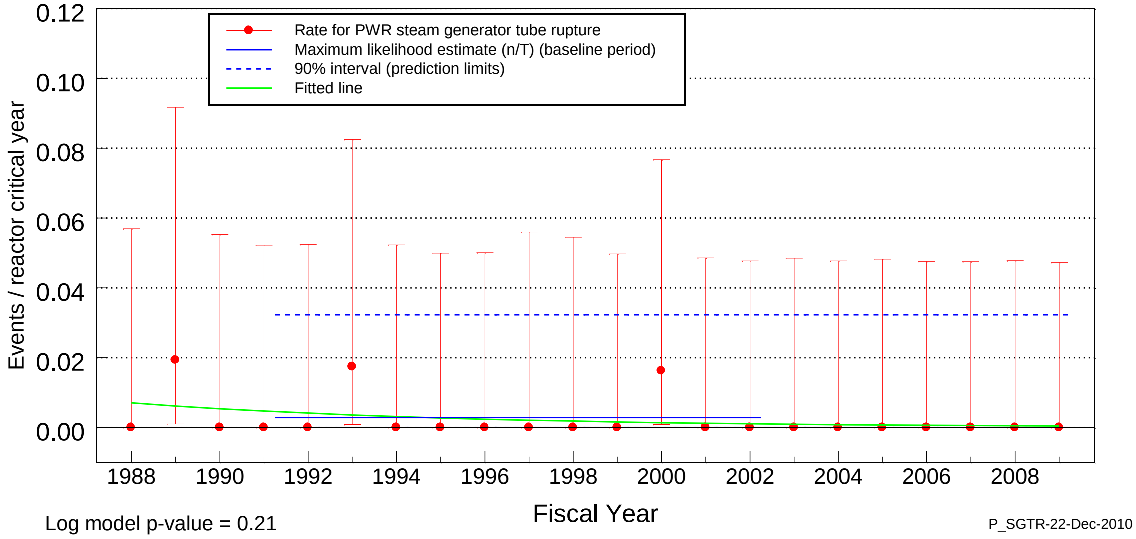

Figure 13. Frequency of PWR initiating events with steam generator tube rupture.

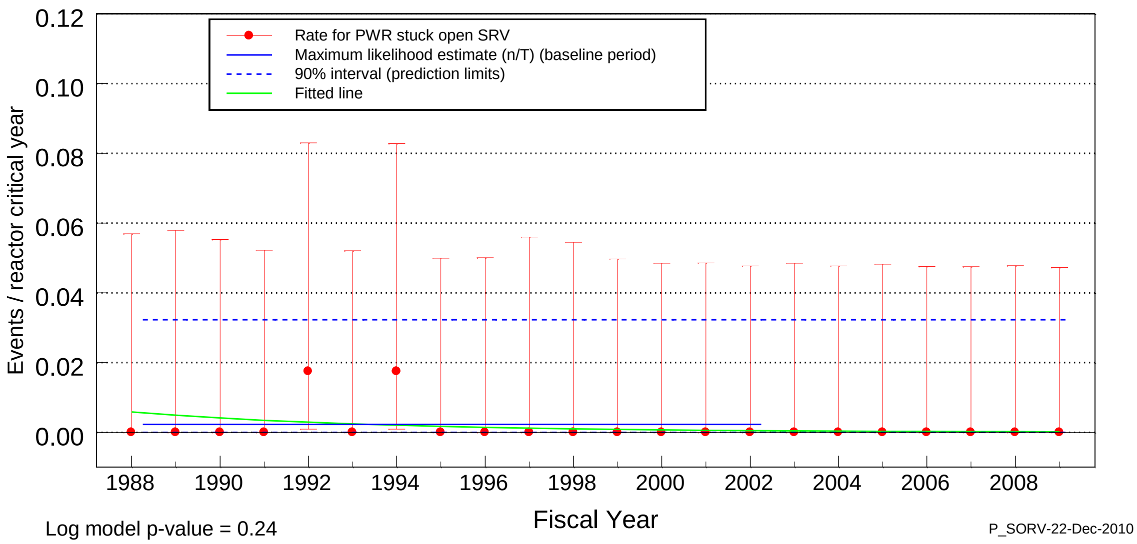

Figure 14. Frequency of PWR initiating events with stuck open safety relief valve.

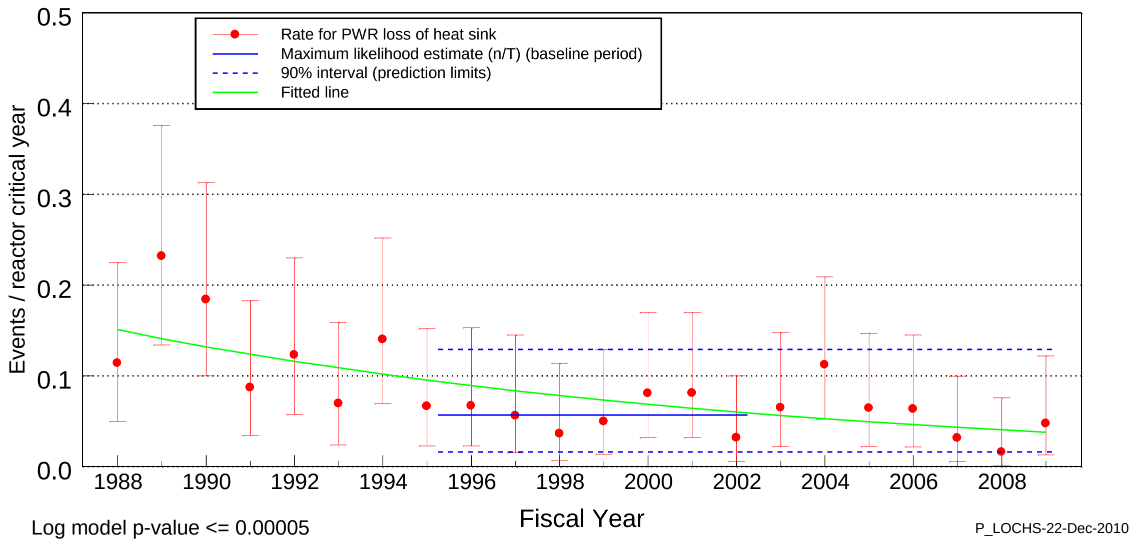

Figure 15. Frequency of PWR initiating events with loss of heat sink.

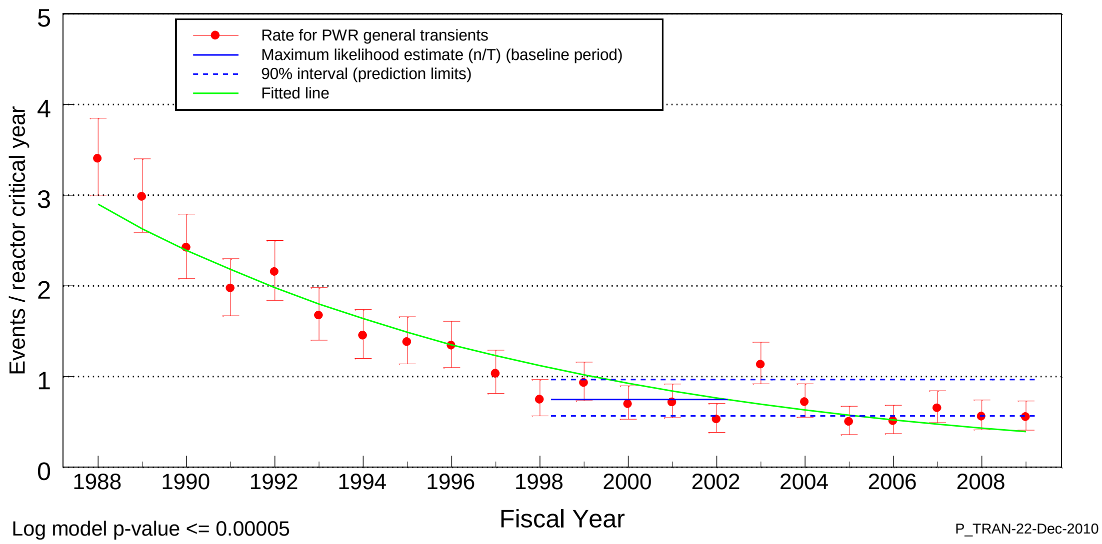

Figure 16. Frequency of PWR initiating events with general transients.