# Enhanced Component Performance Study

# Motor-Driven Pumps

# 1998–2011

## 1 INTRODUCTION

This report presents a performance evaluation of the centrifugal motor-driven pumps (MDPs) at U.S. commercial nuclear power plants. This report does not estimate values for use in probabilistic risk assessments (PRAs), but does evaluate component performance over time. The 2010 Component Reliability Update [Reference 1], which is an update to Reference 2 (NUREG/CR-6928) and reports MDP unreliability estimates using Equipment Performance and Information Exchange (EPIX) data from 1998–2010 and maintenance unavailability (UA) performance data using MSPI Basis Document data from 2002–2010 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 2011 as reported in EPIX. The MDP failure modes considered are for standby systems: failure-to-start (FTS), failure-to-run ≤ 1 hour (FTR≤1H), failure-to-run > 1 hour (FTR>1H), and for normally running systems: FTS and failure-to-run (FTR). MDP 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.

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. The factors analyzed for the MDP component are the differences in failures between total demands and actual unplanned (ESF) demands (Section 6.3). Statistical analyses of the differences are performed and results showing whether pooling is acceptable across these factors are shown. In addition, engineering analyses were performed with respect to time period and failure mode (Section 6.4). The factors analyzed are: sub-component, failure cause, recovery, and detection method.

# 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, the following extremely statistically significant increasing trends were identified in the MDP results.

- Frequency (demands per reactor year) of start demands, normally running MDPs. (see Figure 15)
- Normally running MDP run hours per reactor critical year. (see Figure 16)
- Standby MDP run hours per reactor critical year. (see Figure 11)

Highly statistically significant increasing trends were identified in the MDP results.

- Frequency (demands per reactor year) of start demands, standby MDPs. (see Figure 9)
- Standby MDP run hours per reactor critical year of run ≤ 1H hours. (see Figure 10)

These trends are not adverse trends; they only indicate an increase in run hours for standby pumps and demands for normally running pumps. Standby MDP run hours appear to have made a step change in the upward direction in FY 2003, which coincides with the start of the MSPI program. This gives an increasing trend over the 1998 to 2011 period. Normally running MDP start demands have increased from approximately 79 to 95 start demands per reactor year. The trend is significant, but the increase is not. Statistically significant decreasing trends were identified in the MDP results for the following:

- Failure rate estimate trend for normally running systems, industry-wide MDP FTR trend. (see Figure 5)

Highly statistically significant decreasing trends in the MDP results were identified for the following:

- Frequency (failures per reactor year) of FTS events, standby MDPs. (see Figure 12)
- Frequency (failures per reactor year) of FTS events, normally running MDPs. (see Figure 17)

Extremely statistically significant decreasing trends in the MDP results were identified for the following:

- Failure probability estimate trend for standby systems, industry-wide MDP FTS trend. (see Figure 1)
- Failure probability estimate trend for normally running systems, industry-wide MDP FTS trend. (see Figure 4)
- Pooled AFW, HPI, and HCS MDP UA trend. (see Figure 6)
- Standby systems, industry-wide MDP unreliability trend (8-hour mission). (see Figure 7)
- Normally running systems (MFW), industry-wide MDP unreliability trend (8-hour mission). (see Figure 8)

[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).

An ongoing concern in the industry is whether industry data adequately represent standby component performance during unplanned (ESF) demands. Section 6.3 shows the results of the consistency check between industry data and ESF detected failure data. The FTS, FTR<1H and FTR>1H failure mode distributions detected under ESF are superior (smaller) than the industry average distribution.

# 3 FAILURE PROBABILITIES AND FAILURE RATES

## 3.1 Overview

The industry-wide failure probabilities and failure rates of MDPs have been calculated from the operating experience for FTS, FTR≤1H, FTR>1H, and FTR. The MDP data set obtained from EPIX includes MDPs in the systems listed in Table 1. MDPs are categorized as either standby or normally running. This report follows the definition of these categories in Reference 1, which determines the status by evaluating the number of run-hours per demand. Those pumps with low run-hours per demand are standby (≤360) and those that are high are normally running (>360). Table 2 shows industry-wide failure probability and failure rate results for the MDP from Reference 1.

Table 1. MDP systems.

| System | Description | Total | Standby | Normally Running |
|---|---|---|---|---|
| | **Centrifugal Pumps** | | | |
| AFW | Auxiliary feedwater | 127 | 127 | |
| CCW | Component cooling water | 287 | | 287 |
| CDS | Condensate system | 140 | | 140 |
| CRD | Control rod drive | 47 | 8 | 39 |
| CSR | Containment spray recirculation | 151 | 151 | |
| CVC | Chemical and volume control | 62 | | 62 |
| HCS | High pressure core spray | 9 | 9 | |
| HPI | High pressure injection | 170 | 163 | 7 |
| LCS | Low pressure core spray | 75 | 70 | 5 |
| MFW | Main feedwater | 43 | | 43 |
| RHR | Residual heat removal | 307 | 307 | |
| SWN | Emergency service water (Standby) | 96 | | 96 |
| SWS | Standby service water | 392 | 392 | |
| | Total | 1906 | 1227 | 679 |
| | **Positive Displacement Pumps** | | | |
| CVC | Chemical and volume control | 65 | 2 | 63 |
| SLC | Standby liquid control | 70 | 70 | |
| | Total | 135 | 72 | 63 |
| | Grand Total | 2041 | 1299 | 742 |

The MDPs are assumed to operate both when the reactor is critical and during shutdown periods. The number of MDPs 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 2. Industry-wide distributions of $p$ (failure probability) and $\lambda$ (hourly rate) for MDPs.

| Operation | Failure Mode | 5% | Median | Mean | 95% | Distribution | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Type | $\alpha$ | $\beta$ |
| Standby | FTS | 1.63E-04 | 7.91E-04 | 9.47E-04 | 2.27E-03 | Beta | 1.95 | 2.054E+03 |
| | FTR≤1H | 1.93E-05 | 1.01E-04 | 1.23E-04 | 3.01E-04 | Beta | 1.82 | 1.479E+04 |
| | FTR>1H | 2.64E-07 | 6.44E-06 | 1.04E-05 | 3.41E-05 | Gamma | 0.78 | 7.501E+04 |
| Running/ Alternating | FTS | 4.01E-04 | 1.23E-03 | 1.36E-03 | 2.79E-03 | Beta | 3.28 | 2.406E+03 |
| | FTR | 7.36E-07 | 3.03E-06 | 3.53E-06 | 8.02E-06 | Gamma | 2.29 | 6.496E+05 |

## 3.2 MDP Failure Probability and Failure Rate Trends

The trends are shown for industry standby (Stby) and for industry normally running (NR) results.

Trends in the standby MDP failure probabilities and failure rates are shown in Figure 1 to Figure 3. The data for the trend plots are contained in Table 11 to Table 13. The standby systems from Table 1 are trended together for each failure mode. Trends in the failure probabilities and failure rates for normally operating MDPs are shown in Figure 4 and Figure 5. The data for the trend plots are contained in Table 14 and Table 15.

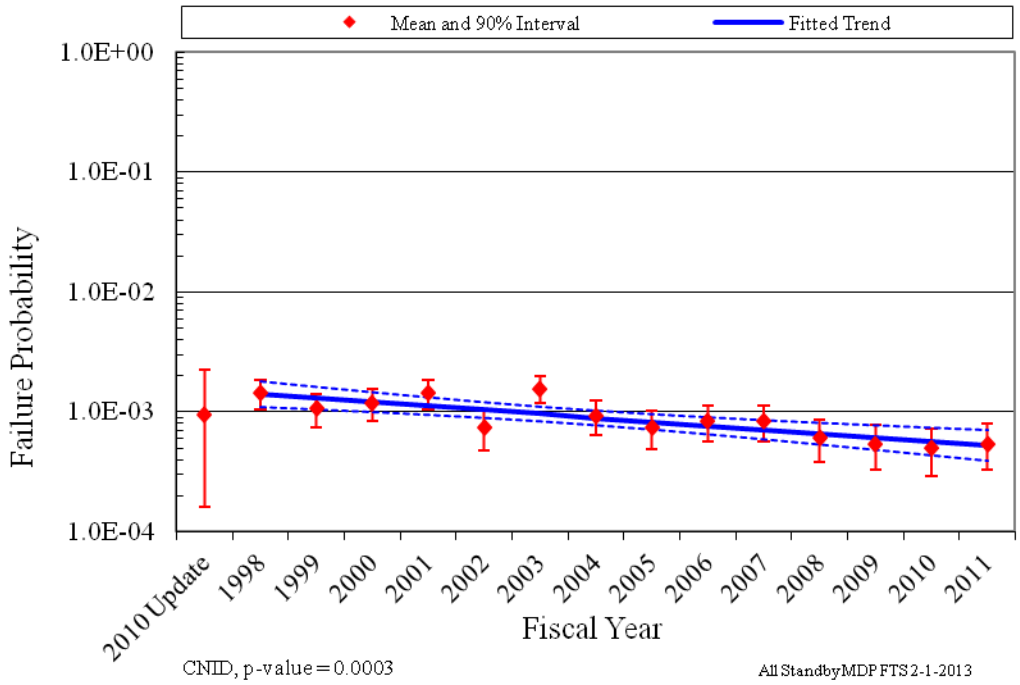


Figure 1. Failure probability estimate trend for standby systems, industry-wide MDP FTS trend.

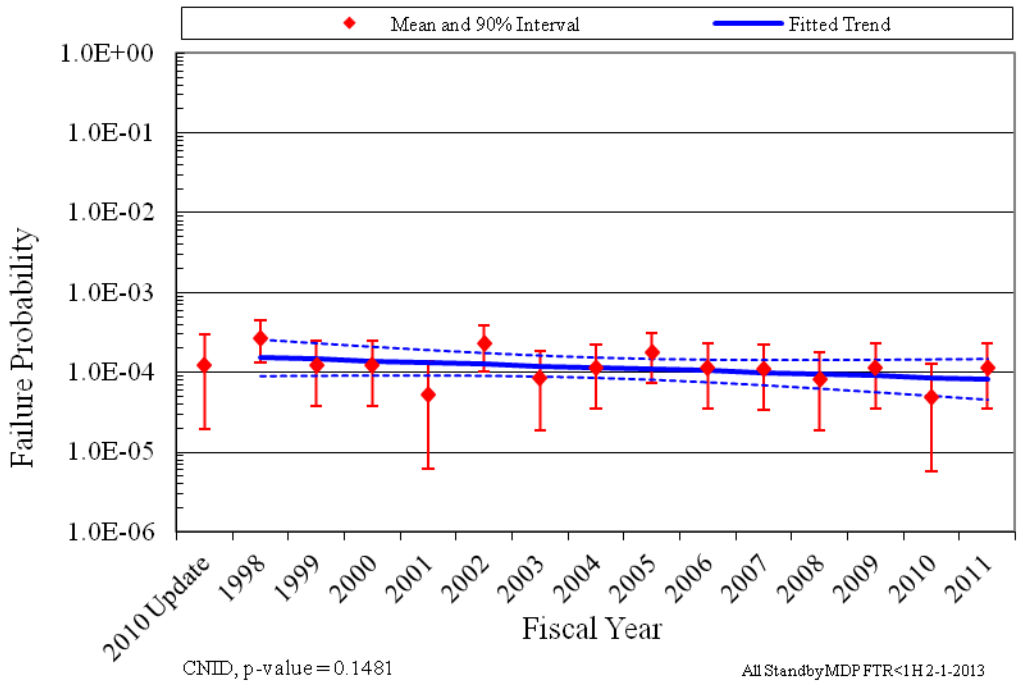


Figure 2. Failure probability estimate trend for standby systems, industry-wide MDP FTR≤1H trend.

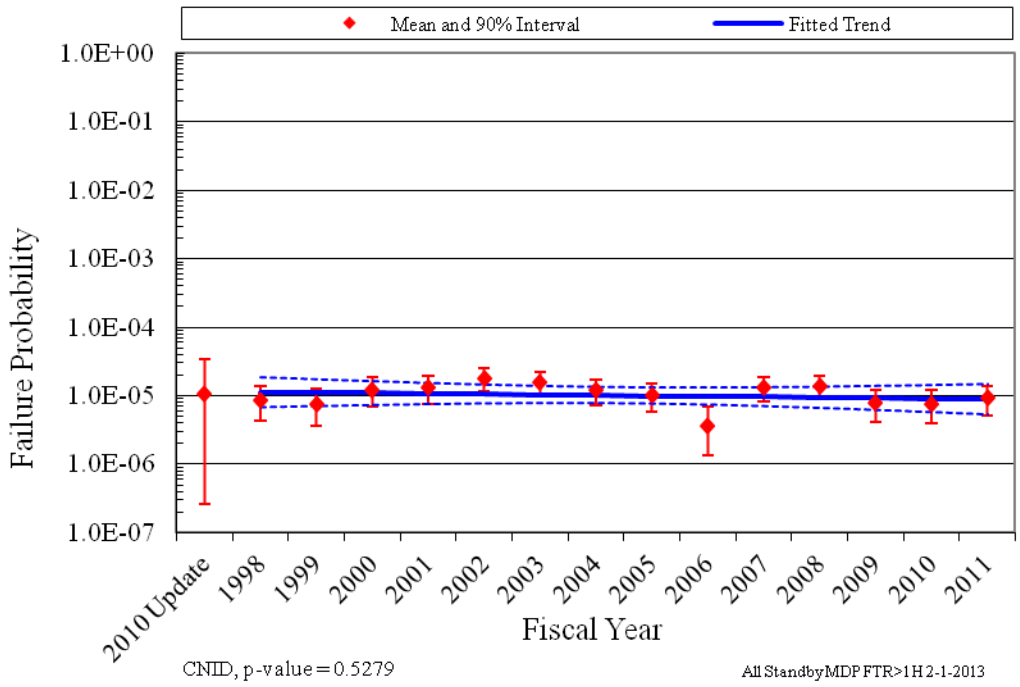


Figure 3. Failure rate estimate trend for standby systems, industry-wide MDP FTR>1H trend.

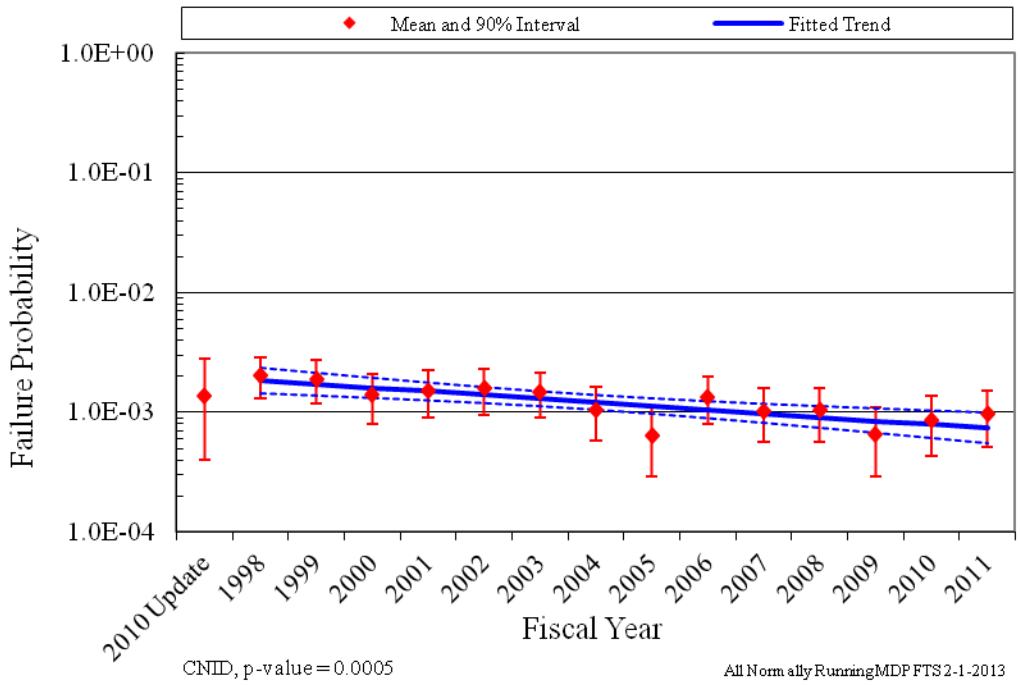


Figure 4. Failure probability estimate trend for normally running systems, industry-wide MDP FTS trend.

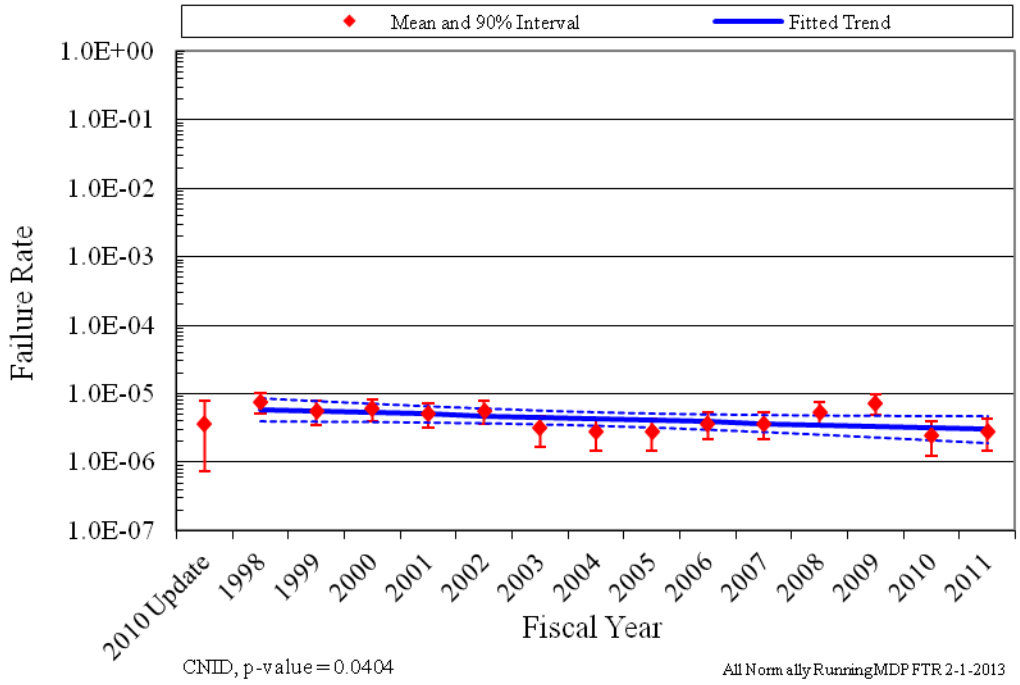


Figure 5. Failure rate estimate trend for normally running systems, industry-wide MDP FTR trend.

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 5$^{th}$ and 95$^{th}$ 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 MDP trains has been calculated from the operating experience. UA data are for MDP trains, which can include more than just the MDP. However, in most cases the MDP contributes the majority of the UA reported. Table 3 shows overall results for the MDP from Reference 1 based on UA data from MSPI Basis Documents, covering 2002 to 2010. In the calculations, planned and unplanned unavailable hours for a train are combined.

Table 3. Industry-wide distributions of unavailability for MDPs.

| Description | Mean | Distribution | α | β |
|---|---|---|---|---|
| Motor Driven Pump Test And Maintenance (AFW) | 3.63E-03 | Beta | 2.58 | 710.22 |
| Motor Driven Pump Test And Maintenance (ALL) | 7.00E-03 | Beta | 1.08 | 153.78 |
| Motor Driven Pump Test And Maintenance (CCW) | 4.79E-03 | Beta | 1.18 | 244.83 |
| Motor Driven Pump Test And Maintenance (ESW) | 1.32E-02 | Beta | 1.00 | 74.55 |
| Motor Driven Pump Test And Maintenance (HPCS) | 7.05E-03 | Beta | 6.70 | 943.80 |
| Motor Driven Pump Test And Maintenance (HPSI) | 3.45E-03 | Beta | 2.45 | 707.96 |
| Motor Driven Pump Test And Maintenance (RHR-BWR) | 5.74E-03 | Beta | 6.23 | 1078.64 |
| Motor Driven Pump Test And Maintenance (RHR-PWR) | 5.15E-03 | Beta | 2.62 | 506.37 |

## 4.2 MDP Unavailability Trends

For the 1998-2011 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.

The trend in standby MDP train unavailability is shown in Figure 6. The data for this figure is in Table 16. The MDPs in systems AFW, HPCI, and RCIC are pooled and trended (these are the systems with maintenance unavailability data currently analyzed). The trend chart shows the results of using data for each year's component unavailability data over time. The yearly (1998–2011) unavailability and reactor critical hour data were obtained from the ROP (1998 to 2001) and EPIX (2002 to 2011) data for the MDP component. The total downtimes during operation for each plant and year were summed, and divided by the corresponding number of MDP-reactor critical hours. Unavailability data for shutdown periods are not reported.

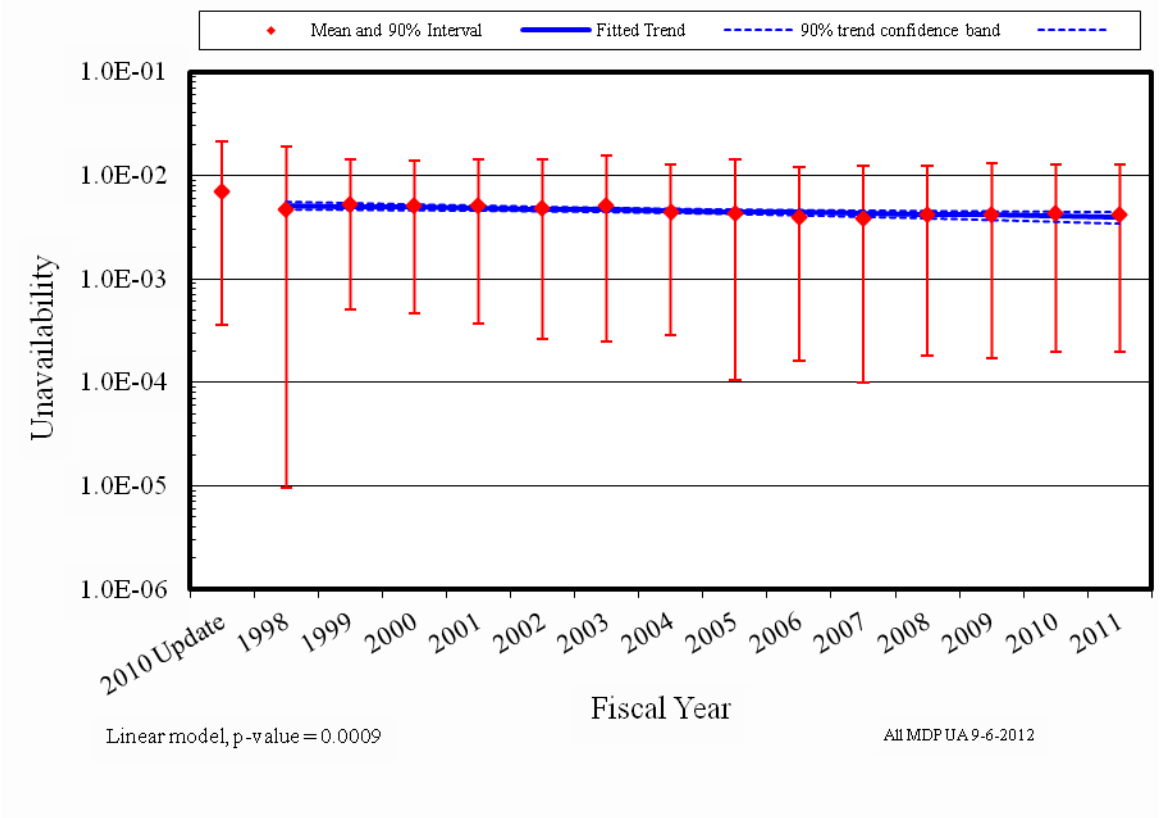


Figure 6. Pooled AFW, HPI, and HCS MDP UA trend.

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 5$^{th}$ to 95$^{th}$ percentiles of the beta distribution with matching means.

For the trend graphs, a least squares fit is sought for the linear or logit model. Section 3 in the Overview and Reference document provides further information. In the lower left hand corner of the trend figures, the p-value is reported.

# 5 MDP UNRELIABILITY TRENDS

Trends in total component unreliability are shown in Figure 7 and Figure 8. Plot data for these figures are in Table 17 and Table 18, respectively. Total unreliability is defined as the result of an OR gate with the FTS, FTR≤1H, FTR >1H (or FTR), and UA as basic event inputs. The FTR>1H is calculated for 7 hours and the FTR is calculated for 8 hours to provide the results for an 8-hour mission. Since the normally running systems MDP components do not have UA data or the FTR≤1H data, there is no UA or FTR≤1H input to the OR gate for that calculation. 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.

The standby systems from Table 2 are trended together and shown in Figure 7. The normally running systems from Table 2 are trended together and shown in Figure 8.

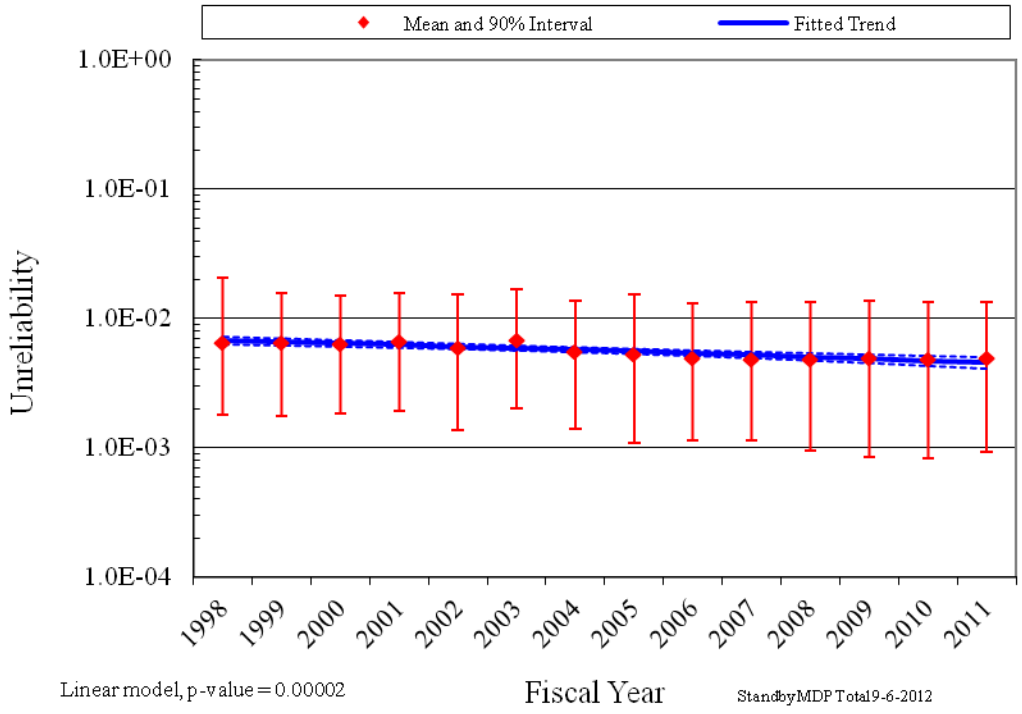


Figure 7. Standby systems, industry-wide MDP unreliability trend (8-hour mission).

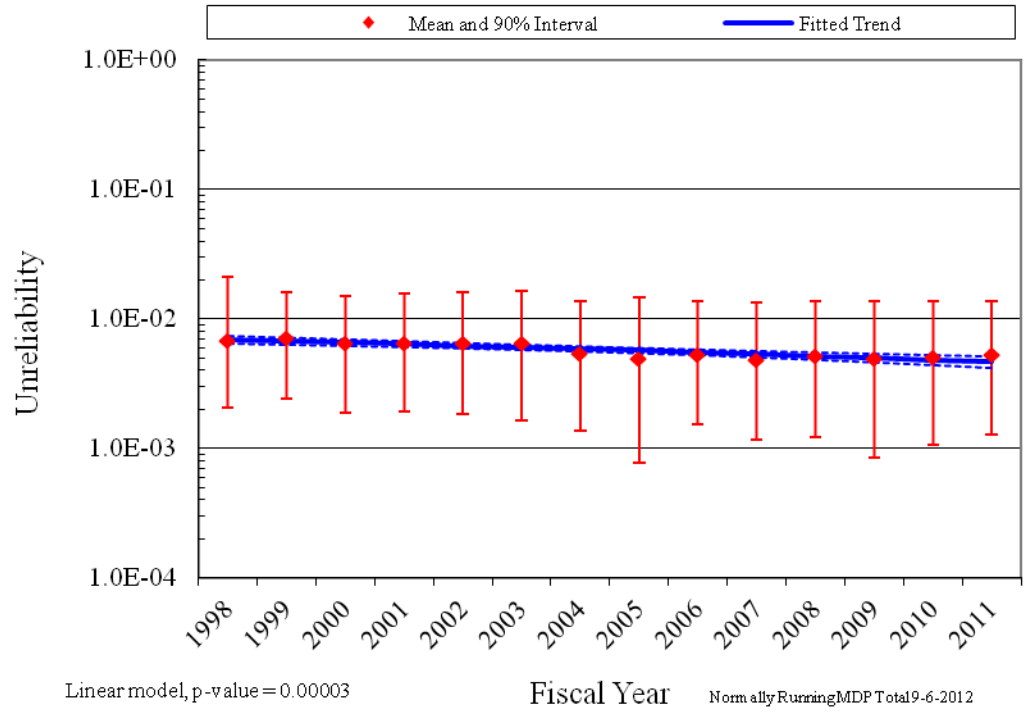


Figure 8. Normally running systems (MFW), industry-wide MDP unreliability trend (8-hour mission).

# 6 ENGINEERING TRENDS

This section presents frequency trends for MDP failures and demands. The data are normalized by reactor year for plants that have the equipment being trended. The rate methods described in Section 2 of the Overview and Reference document are used.

## 6.1 Standby MDP Engineering Trends

Figure 9 shows the trend for standby MDP start demands. Figure 10 shows the trend MDP run ≤1 hour demands. Figure 11 shows the trend for the MDP run hours. Table 19, Table 20, and Table 21 provide the plot data, respectively.

Figure 12 shows the trend for MDP FTS events. Figure 13 shows the trend MDP FTR≤1H events, and Figure 14 shows the trend for the MDP FTR events. Table 22, Table 24, and Table 25 provide the plot data, respectively. The standby systems from Table 2 are trended together for each figure.

Table 4 summarizes the failures by system and year for the FTS failure mode.

| *AFW* | *127* | *11.0%* | *4* | *5* | *3* | *3* | | *4* | | *3* | *4* | *4* | | *1* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRD | 47 | 4.1% | | 1 | | 3 | | | | | | | | |
| CSR | 151 | 13.1% | 2 | 1 | | 3 | | 9 | 4 | 2 | 1 | | 1 | |
| HCS | 9 | 0.8% | | | | | | 1 | | | 1 | | | |
| HPI | 170 | 14.7% | 4 | 2 | 3 | 5 | 4 | 2 | 7 | 2 | 2 | 3 | 4 | 3 |
| LCS | 75 | 6.5% | 2 | | | | 2 | 2 | | | | | 1 | |
| RHR | 307 | 26.6% | 9 | 7 | 9 | 7 | 2 | 9 | 5 | 6 | 3 | 5 | 3 | 2 |
| SWS | 392 | 33.9% | 13 | 10 | 14 | 14 | 10 | 14 | 9 | 7 | 11 | 11 | 7 | 8 |
| **Total** | 1278 | 100.0% | 34 | 26 | 29 | 35 | 18 | 41 | 25 | 20 | 22 | 23 | 16 | 14 |

Table 5 summarizes the failures by system and year for the FTR≤1H failure mode. Table 6 summarizes the failures by system and year for the FTR>1H failure mode. The blue highlighted values in the percent of total failures column show the five most significant contributors. Table 4,

| *AFW* | *127* | *11.0%* | *4* | *5* | *3* | *3* | | *4* | | *3* | *4* | *4* | | *1* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CRD | 47 | 4.1% | | 1 | | 3 | | | | | | | | |
| CSR | 151 | 13.1% | 2 | 1 | | 3 | | 9 | 4 | 2 | 1 | | 1 | |
| HCS | 9 | 0.8% | | | | | | 1 | | | 1 | | | |
| HPI | 170 | 14.7% | 4 | 2 | 3 | 5 | 4 | 2 | 7 | 2 | 2 | 3 | 4 | 3 |
| LCS | 75 | 6.5% | 2 | | | | 2 | 2 | | | | | 1 | |
| RHR | 307 | 26.6% | 9 | 7 | 9 | 7 | 2 | 9 | 5 | 6 | 3 | 5 | 3 | 2 |
| SWS | 392 | 33.9% | 13 | 10 | 14 | 14 | 10 | 14 | 9 | 7 | 11 | 11 | 7 | 8 |
| **Total** | 1278 | 100.0% | 34 | 26 | 29 | 35 | 18 | 41 | 25 | 20 | 22 | 23 | 16 | 14 |

Table 5, and Table 6 only include systems where failures of that failure mode have been detected.

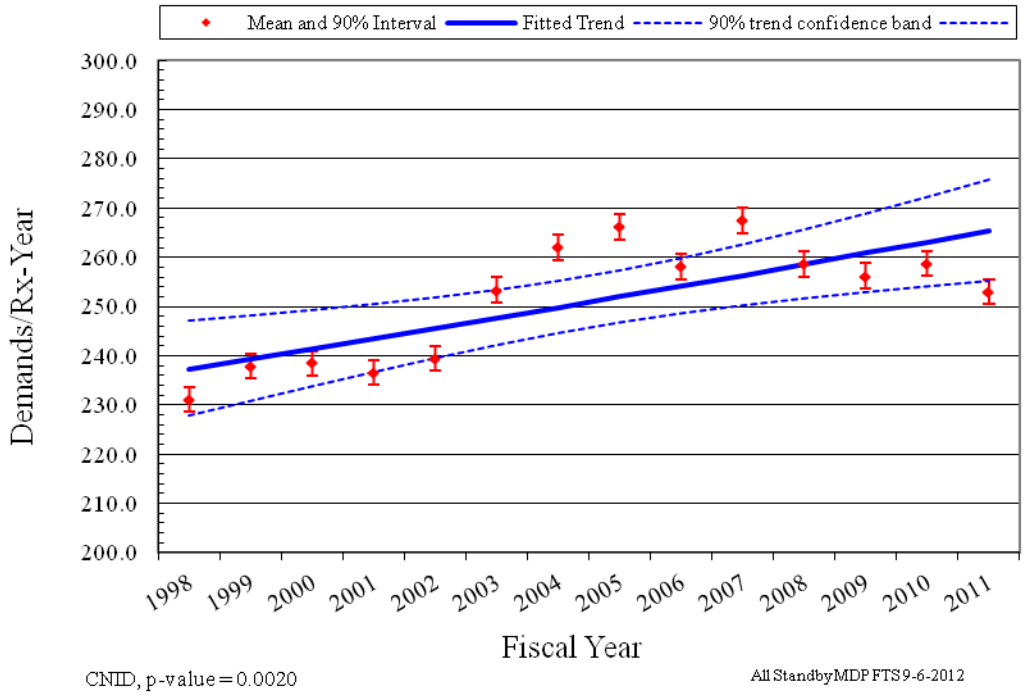


Figure 9. Frequency (demands per reactor year) of start demands, standby MDPs.

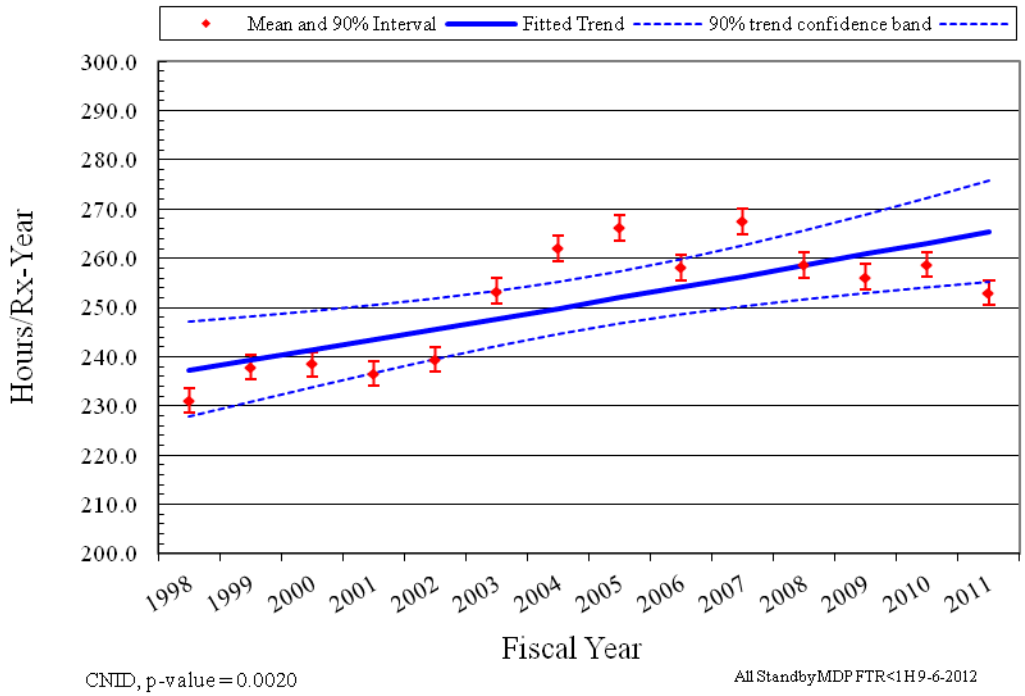


Figure 10. Standby MDP run hours per reactor critical year of run ≤ 1H hours.

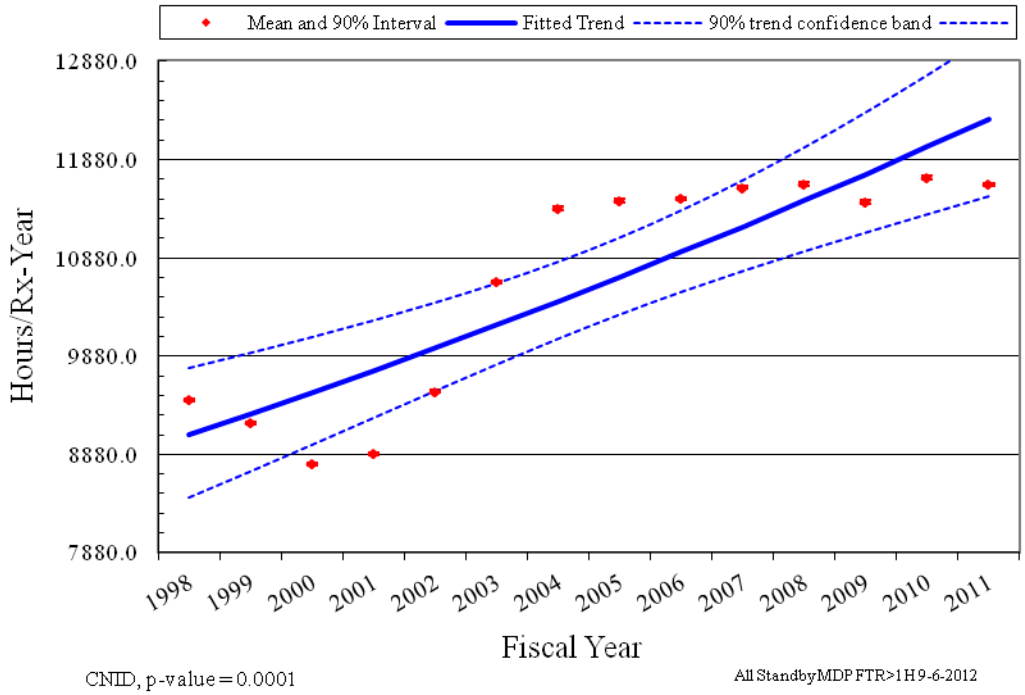


Figure 11. Standby MDP run hours per reactor critical year.

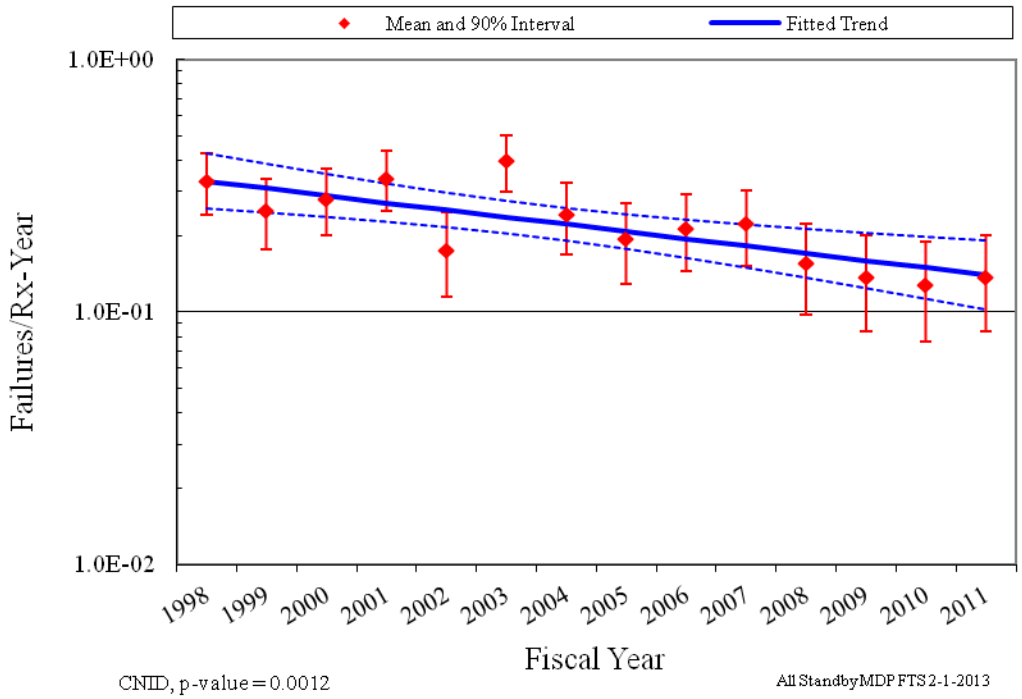


Figure 12. Frequency (failures per reactor year) of FTS events, standby MDPs.

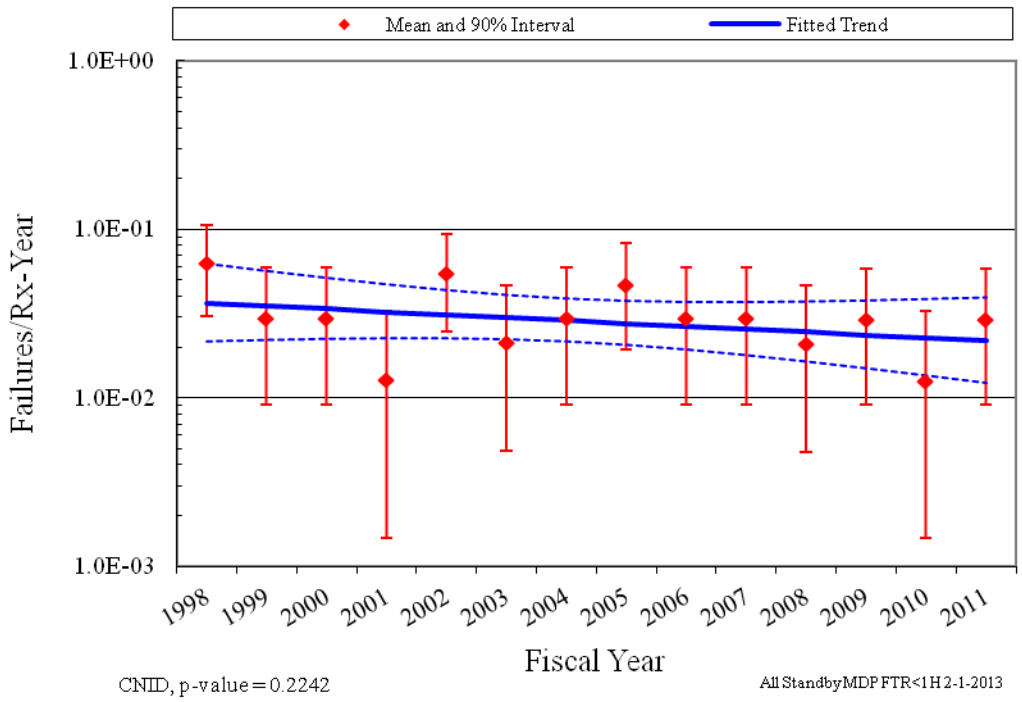


Figure 13. Frequency (failures per reactor year) of FTR≤1H events, standby MDPs.

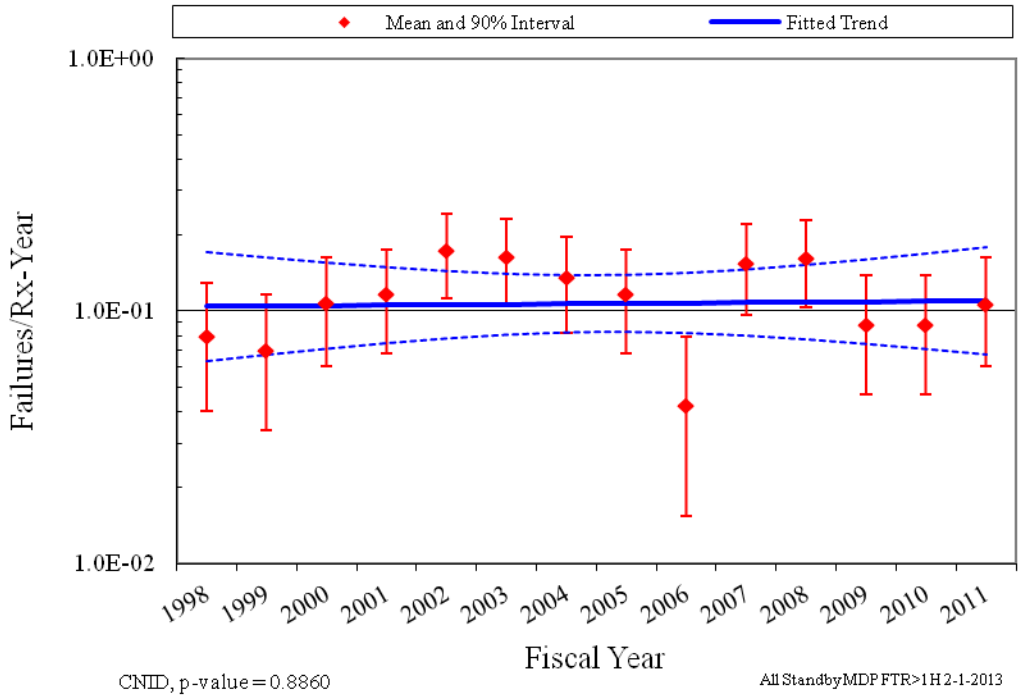


Figure 14. Frequency (failures per reactor year) of FTR>1H events, standby MDPs.

## 6.2 Normally Running MDP Engineering Trends

Figure 15 shows the trend for normally running MDP demands and Figure 16 shows the trend for the MDP run hours. Table 25 and Table 26 provide the plot data, respectively.

Figure 17 shows the trend for MDP FTS events and Figure 18 shows the trend for the MDP FTR events. Table 27 and Table 28 provide the plot data respectively. The normally running systems from Table 2 are trended for each figure.

Table 7 summarizes the failures by system and year for the FTS failure mode. Table 8 summarizes the failures by system and year for the FTR failure mode. The red highlighted values in the percent of total failures column show the five most significant contributors.

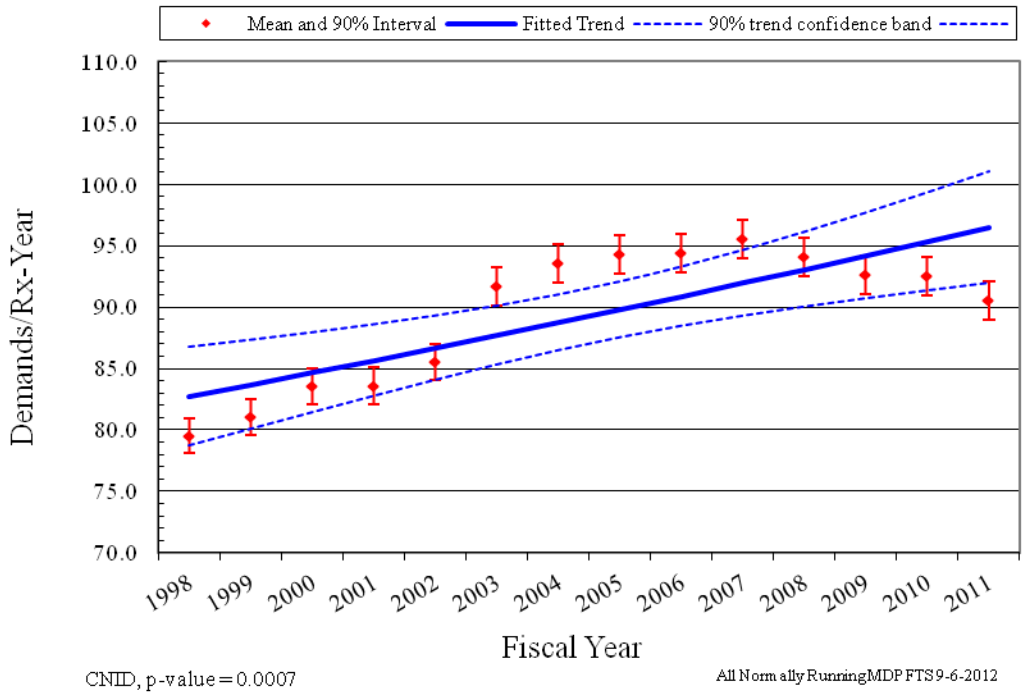


Figure 15. Frequency (demands per reactor year) of start demands, normally running MDPs.

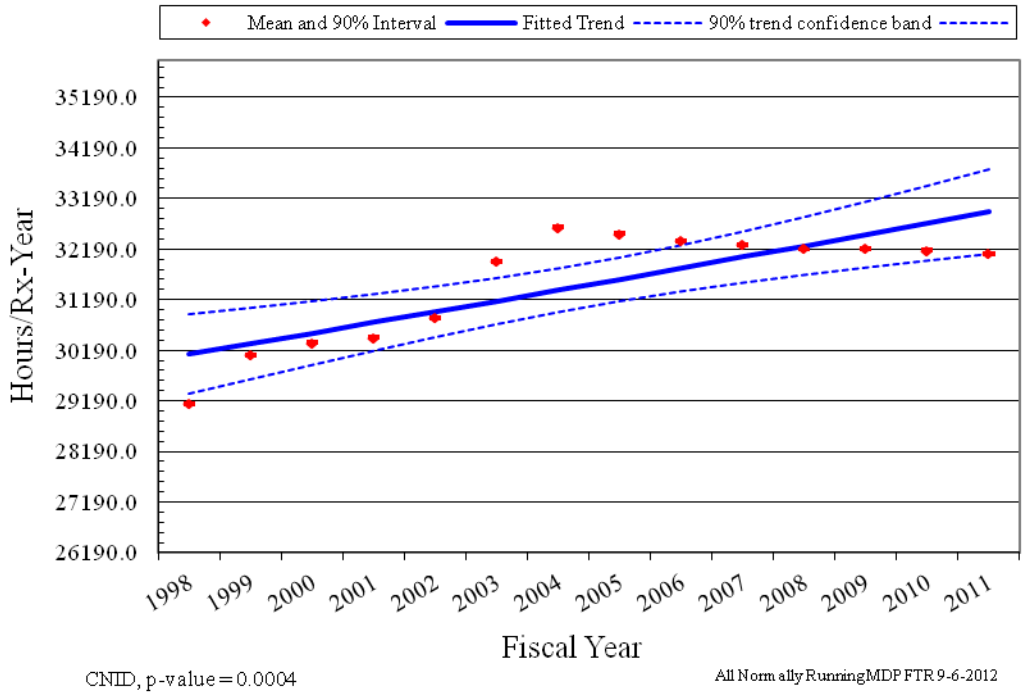


Figure 16. Normally running MDP run hours per reactor critical year.

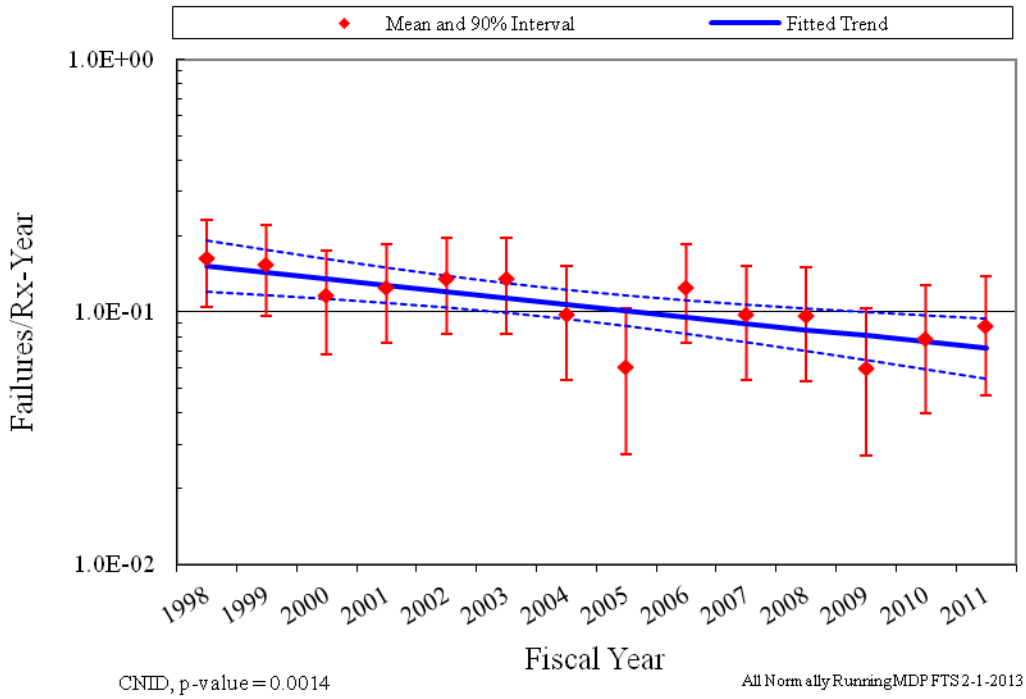


Figure 17. Frequency (failures per reactor year) of FTS events, normally running MDPs.

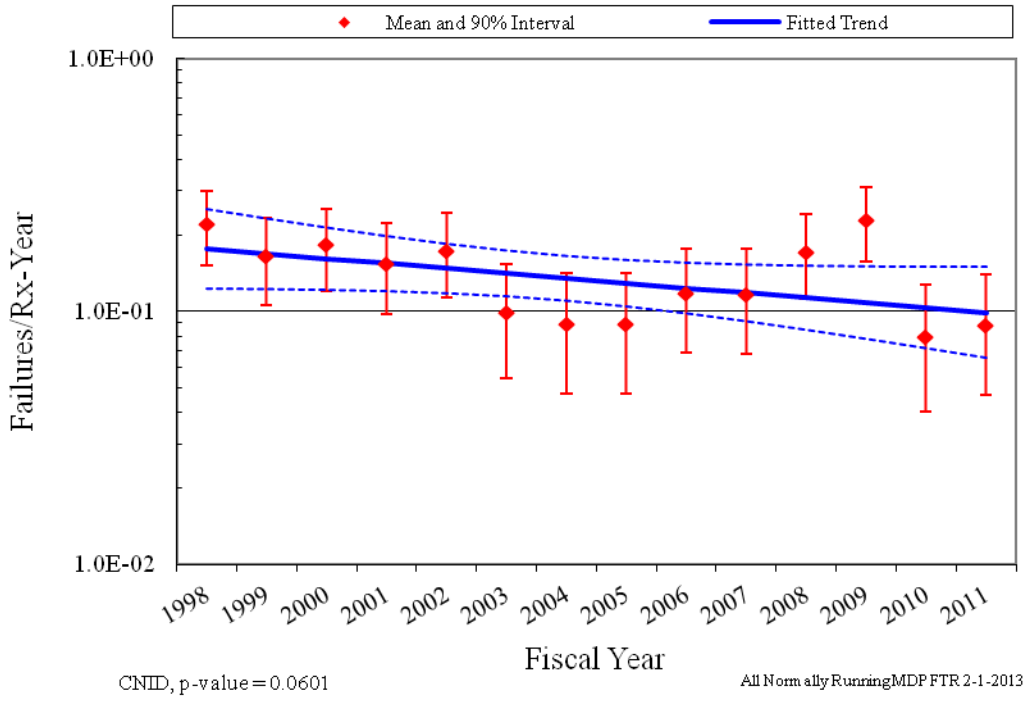


Figure 18. Frequency (failures per reactor year) of FTR events, normally running MDPs.

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

| *System Code* | *MDP Count* | *MDP 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* | *Total* | *Percent of Failures* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 127 | 11.0% | 4 | 5 | 3 | 3 | | 4 | | 3 | 4 | 4 | | 1 | 1 | 2 | 34 | **10.3%** |
| CRD | 47 | 4.1% | | 1 | | 3 | | | | | | | | | | | 4 | 1.2% |
| CSR | 151 | 13.1% | 2 | 1 | | 3 | | 9 | 4 | 2 | 1 | | 1 | | | 1 | 24 | **7.3%** |
| HCS | 9 | 0.8% | | | | | | 1 | | | 1 | | | | | | 2 | 0.6% |
| HPI | 170 | 14.7% | 4 | 2 | 3 | 5 | 4 | 2 | 7 | 2 | 2 | 3 | 4 | 3 | 1 | 5 | 47 | **14.2%** |
| LCS | 75 | 6.5% | 2 | | | | 2 | 2 | | | | | 1 | | 1 | 1 | 9 | 2.7% |
| RHR | 307 | 26.6% | 9 | 7 | 9 | 7 | 2 | 9 | 5 | 6 | 3 | 5 | 3 | 2 | 3 | 2 | 72 | **21.8%** |
| SWS | 392 | 33.9% | 13 | 10 | 14 | 14 | 10 | 14 | 9 | 7 | 11 | 11 | 7 | 8 | 7 | 3 | 138 | **41.8%** |
| **Total** | 1278 | 100.0% | 34 | 26 | 29 | 35 | 18 | 41 | 25 | 20 | 22 | 23 | 16 | 14 | 13 | 14 | 330 | 100.0% |

Table 5. Summary of standby MDP failure counts for the FTR≤1H failure mode over time by system.

| *System Code* | *MDP Count* | *MDP 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* | *Total* | *Percent of Failures* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 127 | 11.0% | 1 | 2 | 1 | | 2 | | 1 | 2 | | 1 | | | | | 10 | **22.2%** |
| CSR | 151 | 13.1% | 1 | | | | 1 | | | 2 | 1 | | | 1 | | | 6 | **13.3%** |
| HCS | 9 | 0.8% | | | | | | | | | | | | | | 1 | 1 | 2.2% |
| HPI | 170 | 14.7% | | | | 1 | | | | | | 1 | | 1 | | | 3 | **6.7%** |
| RHR | 307 | 26.6% | 1 | 1 | 1 | | 1 | | | | | | | | | | 4 | **8.9%** |
| SWS | 392 | 33.9% | 4 | | 1 | | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 21 | **46.7%** |
| **Total** | 1156 | 100.0% | 7 | 3 | 3 | 1 | 6 | 2 | 3 | 5 | 3 | 3 | 2 | 3 | 1 | 3 | 45 | 100.0% |

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

| *System Code* | *MDP Count* | *MDP 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* | *Total* | *Percent of Failures* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 127 | 11.0% | 1 | | | 5 | | 3 | | 1 | | | | | | | 10 | **6.1%** |
| CSR | 151 | 13.1% | 1 | | | 1 | 1 | 1 | 1 | | | | 1 | | 1 | 1 | 8 | **4.8%** |
| HCS | 9 | 0.8% | | | | | | | | 1 | | | | | | | 1 | 0.6% |
| HPI | 170 | 14.7% | 1 | 3 | 3 | 1 | 3 | 1 | 3 | 1 | 1 | 2 | | 1 | | 1 | 21 | **12.7%** |
| LCS | 75 | 6.5% | | | | 1 | | | | | | | | 1 | 1 | 1 | 4 | 2.4% |
| RHR | 307 | 26.6% | 1 | | 1 | | 3 | 6 | 2 | 1 | | 4 | 2 | 1 | | 2 | 23 | **13.9%** |
| SWS | 392 | 33.9% | 4 | 4 | 7 | 4 | 11 | 6 | 8 | 8 | 3 | 10 | 14 | 6 | 7 | 6 | 98 | **59.4%** |
| **Total** | 1231 | 100.0% | 8 | 7 | 11 | 12 | 18 | 17 | 14 | 12 | 4 | 16 | 17 | 9 | 9 | 11 | 165 | 100.0% |

Table 7. Summary of normally running MDP failure counts for the FTS failure mode over time by system.

| *System Code* | *MDP Count* | *MDP 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* | *Total* | *Percent of Failures* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCW | 287 | 24.8% | 7 | 9 | 1 | 7 | 4 | 8 | 5 | | 7 | 4 | 7 | 2 | 6 | 4 | 71 | **44.9%** |
| CDS | 140 | 12.1% | 2 | 3 | 4 | 1 | 2 | 1 | | | 2 | 1 | | | | 1 | 17 | **10.8%** |
| CRD | 47 | 4.1% | 2 | 1 | 3 | 1 | 2 | | | | | 1 | | | | 1 | 11 | 7.0% |
| CVC | 62 | 5.4% | 3 | 1 | | 2 | 1 | 2 | 1 | 1 | 1 | 1 | 1 | | | 1 | 15 | **9.5%** |
| MFW | 43 | 3.7% | 1 | | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | | 1 | 16 | **10.1%** |
| SWN | 96 | 8.3% | 2 | 2 | 1 | 1 | 4 | 2 | 3 | 4 | 2 | 1 | | 3 | 2 | 1 | 28 | **17.7%** |
| **Total** | 675 | 100.0% | 17 | 16 | 12 | 13 | 14 | 14 | 10 | 6 | 13 | 10 | 10 | 6 | 8 | 9 | 158 | 100.0% |

Table 8. Summary of normally running MDP failure counts for the FTR failure mode over time by system.

| *System Code* | *MDP Count* | *MDP 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* | *Total* | *Percent of Failures* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CCW | 287 | 24.8% | 3 | 3 | 7 | 3 | 4 | 4 | 2 | 3 | 1 | 4 | 4 | 6 | 3 | 2 | 49 | **24.0%** |
| CDS | 140 | 12.1% | 7 | 4 | 1 | 1 | 2 | 1 | | 1 | 2 | 2 | 1 | 6 | 1 | 2 | 31 | **15.2%** |
| CRD | 47 | 4.1% | 2 | 1 | 4 | 1 | 1 | 1 | | | | | | | 1 | 2 | 13 | 6.4% |
| CVC | 62 | 5.4% | 3 | 4 | 3 | 2 | 5 | 2 | 1 | 3 | 1 | 1 | 3 | 1 | 2 | 1 | 32 | **15.7%** |
| HPI | 170 | 14.7% | | 1 | | | 1 | 1 | | | 1 | | | | | | 4 | 2.0% |
| MFW | 43 | 3.7% | 5 | 1 | 1 | 2 | 1 | | 2 | | 1 | 2 | 1 | | | | 16 | **7.8%** |
| SWN | 96 | 8.3% | 3 | 3 | 3 | 7 | 4 | 1 | 4 | 2 | 6 | 3 | 9 | 11 | 1 | 2 | 59 | **28.9%** |
| **Total** | 845 | 100.0% | 23 | 17 | 19 | 16 | 18 | 10 | 9 | 9 | 12 | 12 | 18 | 24 | 8 | 9 | 204 | 100.0% |

## 6.3 Comparison of EPIX MDP Unplanned Demand Results with Industry Results for Standby Components

An ongoing concern in the industry is whether a combination of test, non-test demand, and actual demand data adequately represents standby component performance during unplanned demands. This comparison evaluates the same dataset for standby components that is used for the overall trends shown in this document, but limits the failure data to those that are discovered during an ESF demand and the ESF demands reported in EPIX. The data are further limited to FY 2003 to present since the ESF demand reporting in EPIX is inconsistent prior to FY 2003.

The standby MDP ESF unplanned demand data covering FY 2003 – 2011 are summarized in Table 9. Consistency between the unplanned demand data and industry-average performance from Table 2 was evaluated using the predictive distribution approach outlined in the *Handbook of Parameter Estimation for Probabilistic Risk Assessment*, NUREG/CR-6823, Sections 6.2.3.5 and 6.3.3.4 [Reference 3]. Simulation is required.

The unplanned demand data were aggregated at the plant and system level (failures and demands). Assuming each plant and system can have a different failure probability, the industry-average distribution (from Table 2) was sampled for each plant and system. The predicted number of failure events for each plant and system was evaluated using the binomial distribution with the plant-specific failure probability and its associated number of demands. Then the total number of predicted failures was obtained by summing the individual plant results. This process was repeated 1000 times (Latin hypercube sampling), each time obtaining a total number of predicted failures. The 1000 sample results were ordered from high to low. Then the actual number of unplanned demand failures observed (listed in Table 9) was compared with this ordered sample to determine the probability of observing this number of failures or greater. If the probability was greater than 0.05 and less than 0.95, then the unplanned demand performance was considered to be consistent with the industry-average distribution obtained from the EPIX data analysis.

Table 9. Standby MDP unplanned demand performance comparison with industry-average performance.

| Failure Modes | Plants | Demands or Hours | Failures | Expected Failures | Probability of ≥ Failures | Consistent with Industry-Average Performance? |
|---|---|---|---|---|---|---|
| **FTS** | 104 | 1151 | 1 | 1.1 | 0.001 | No |
| **FTR<1H** | 104 | 798 | 0 | 0.1 | 1.000 | No |
| **FTR>1H** | 104 | 18704 | 0 | 1.4 | 1.000 | No |
| **Total MDP Unreliability (8 hours)** | 104 | 1,151 and 18,703.8 h | 1 | 2.6 | 0.001 | No |

The consistency checks using unplanned demand data indicate that none of the failure observations are consistent with their industry-average distribution from Table 2. The FTS, FTR<1H, FTR>1H, and Total UR observations are superior (smaller) than the industry average distribution.

## 6.4 MDP Engineering Analysis by Failure Modes

The engineering analysis of the standby MDP failure sub-components, causes, detection methods, and recovery possibility are presented in this section. Each analysis divides the events into two periods: before July 2003 and after July 2003 (the start of the data begins in FY 1998 and the last date is FY

2011). This breakdown was chosen for two reasons: first, July 2003 represents a point in which the MSPI data collection attains a "higher level" of scrutiny; second, this date represents a point about half way through the full data period.

The second division of the events is by the failure mode determined after EPIX data review by the staff. See Section 7 for more description of failure modes.

MDP sub-component contributions to the three failure modes are presented in Figure 19. The sub-component contributions are similar to those used in the CCF database. The driver has the highest percentage contributions to failures for the fail to start failure mode. The pump subcomponent is the highest for the FTR≤1H and FTR>1H failure modes. However, the driver sub-component is still significant for the FTR≤1H and FTR>1H failure modes.

Table 10. 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. |

MDP cause group contributions to the three failure modes are presented in Figure 20. The cause groups are similar to those used in the CCF database. Table 10 shows the breakdown of the cause groups with the specific causes that were coded during the data collection. The most likely causes are internal faults, human errors, and design issues. Internal means that the cause was related to something within the MDP component such as a worn out part or the normal internal environment.

MDP detection methods to the three failure modes are presented in Figure 21. The most likely detection method for FTR<1H and FTR>1H is non-testing. The prevalent FTS detection is test demands.

MDP recovery to the three failure modes are presented in Figure 22. The overall non-recovery to recovery ratio is approximately 3.1:1.

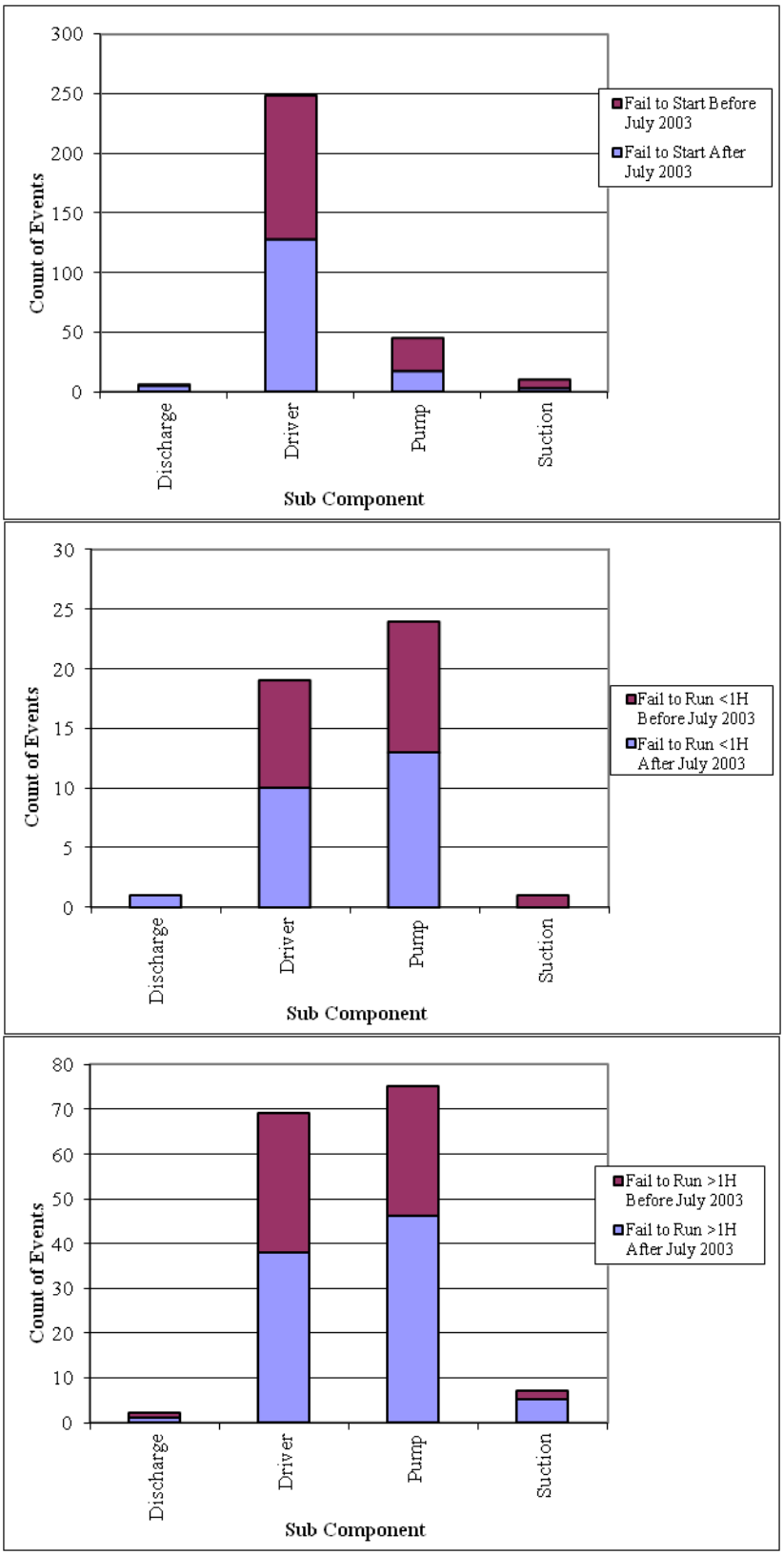


Figure 19. MDP failure breakdown by period, sub component, and failure mode.

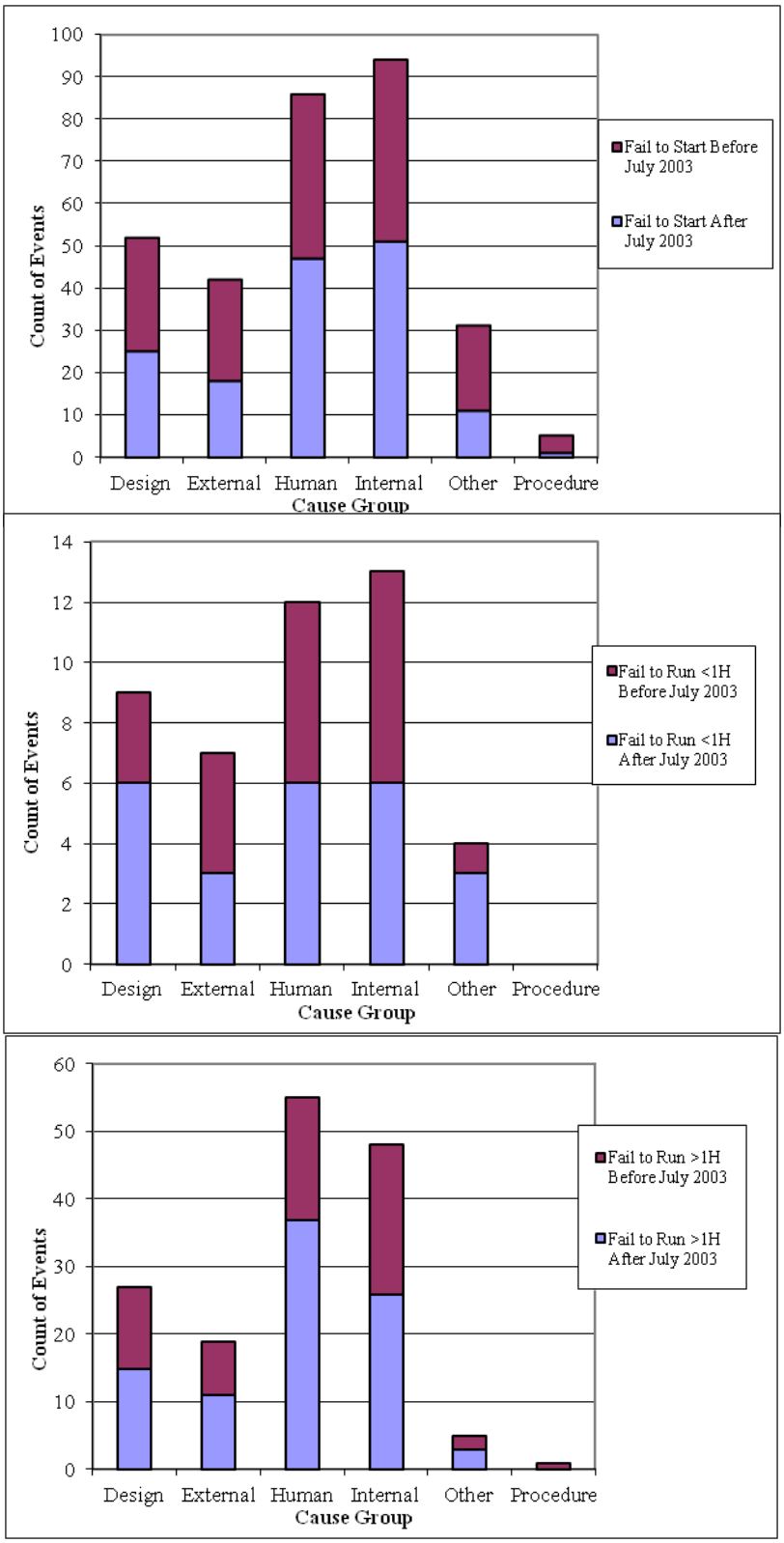


Figure 20. MDP breakdown by time period, cause group, and failure mode.

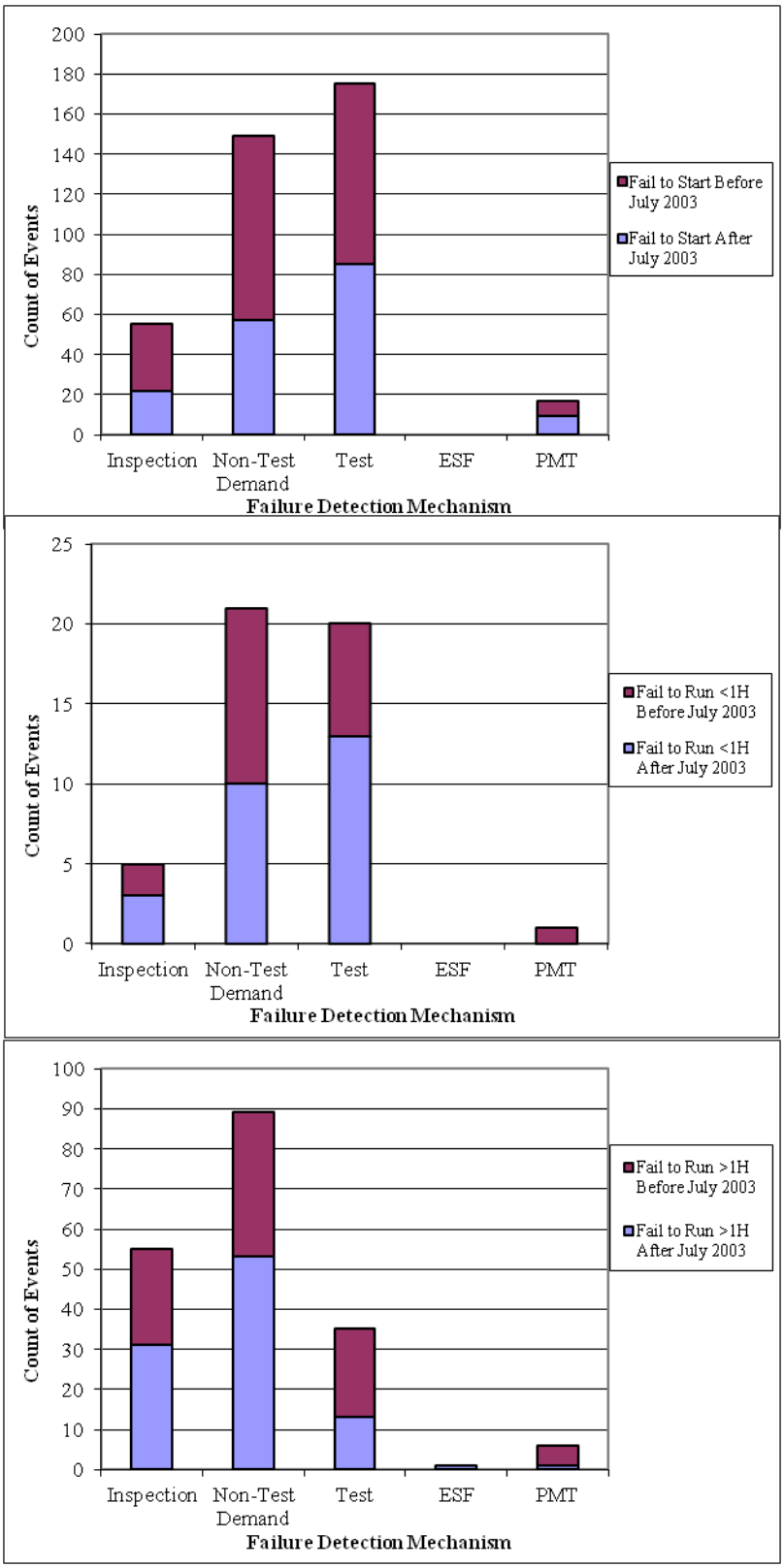


Figure 21. MDP component failure distribution by period, failure mode, and method of detection.

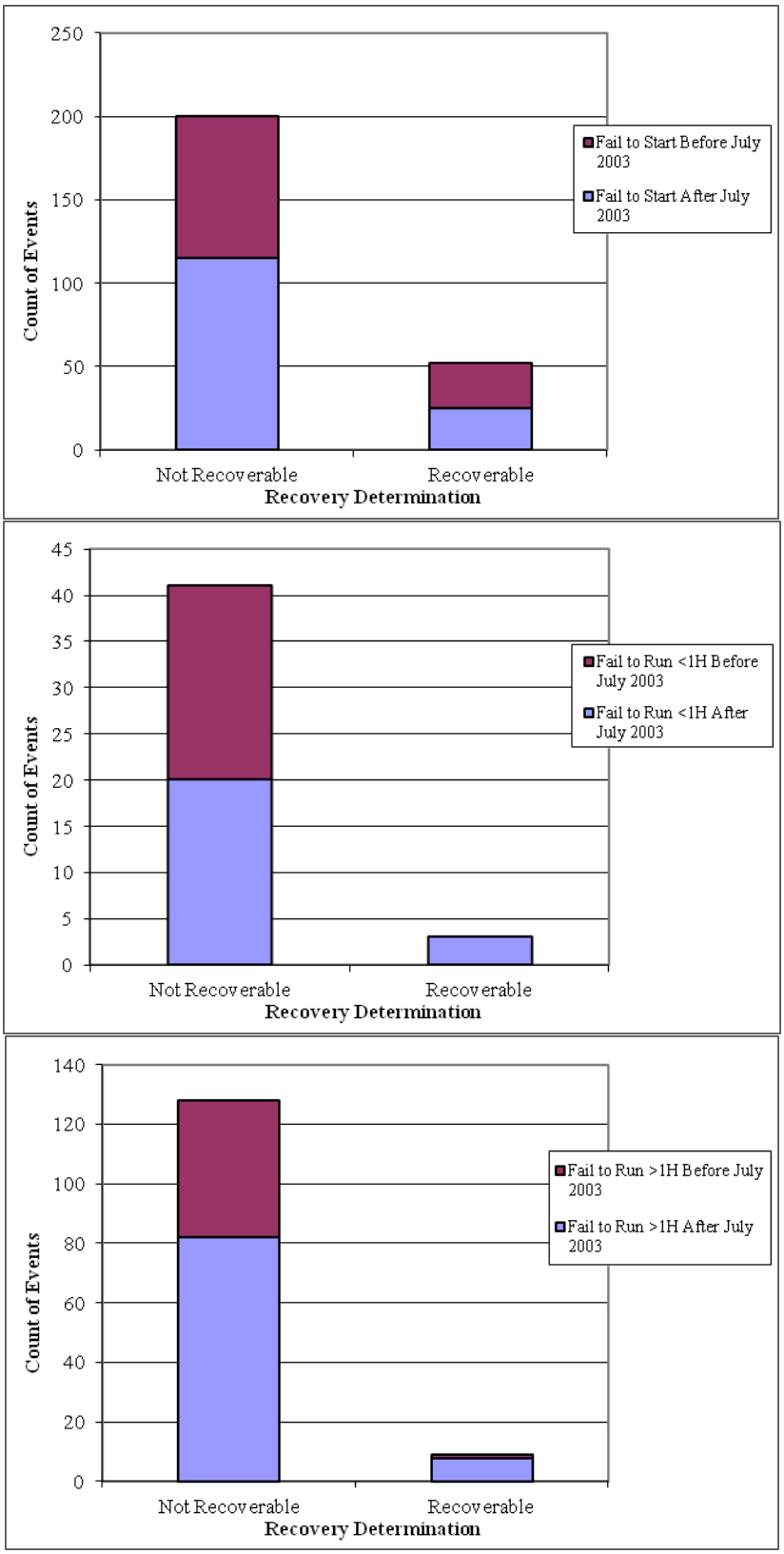


Figure 22. MDP component failure distribution by period, failure mode, and recovery.

# 7 MDP ASSEMBLY DESCRIPTION

The MDP consists of the pump, motor-driver, and circuit breaker sub-components. All of the pumps are centrifugal, but can be different configurations. The drivers are medium or large ac motors. If the MDP assembly includes a speed increaser, it is treated as a sub-component.

The MDP failure modes include fail to start (FTS), fail to run for less or equal to one hour (FTR<1H), and fail to run beyond one hour (FTR>1H). These failure modes were used in NUREG/CR-6928 and are similar to those used in the MSPI Program.

Guidelines for determining whether a component event reported in EPIX is to be included in FTS, FTR<1H, or FTR>1H are similar to those used in the MSPI Program. In general, any circumstance in which the component is not able to meet the performance requirements defined in the probabilistic risk assessment (PRA) is counted. This includes conditions revealed through testing, operational demands, unplanned demands, or discovery. Also, run failures that occur beyond the typical 24-hour mission time in PRAs are included. However, certain events are excluded: slow starting times that do not exceed the PRA success criteria, conditions that are annunciated immediately in the control room without a demand, and run events that are shown to not have caused an actual run failure within 24 hours. Also, events occurring during maintenance or post-maintenance testing that are related to the actual maintenance activities are excluded. All of the MDP events within EPIX were reviewed to ensure that they were binned to the correct failure mode – FTS, FTR<1H, FTR>1H, or no failure. However, even given detailed descriptions of failure events, this binning still required some judgment and involves some uncertainty.

Guidelines for counting demands and run hours are similar to those in the MSPI Program. Start and run demands include those resulting from tests, operational demands, and unplanned demands. Demands during maintenance and post-maintenance testing are excluded. Similarly, run hours include those from tests, operational demands, and unplanned demands.

# 8 DATA TABLES

Table 11. Plot data for standby MDP 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 |
| 2010 Update | | | | | | 1.63E-04 | 2.27E-03 | 9.47E-04 |
| 1998 | 34 | 23805.9 | 1.40E-03 | 1.10E-03 | 1.78E-03 | 1.04E-03 | 1.83E-03 | 1.42E-03 |
| 1999 | 26 | 24503.6 | 1.30E-03 | 1.05E-03 | 1.60E-03 | 7.43E-04 | 1.42E-03 | 1.06E-03 |
| 2000 | 29 | 24633.4 | 1.20E-03 | 9.99E-04 | 1.45E-03 | 8.40E-04 | 1.55E-03 | 1.17E-03 |
| 2001 | 35 | 24371.5 | 1.12E-03 | 9.46E-04 | 1.32E-03 | 1.05E-03 | 1.84E-03 | 1.42E-03 |
| 2002 | 18 | 24658.6 | 1.04E-03 | 8.92E-04 | 1.20E-03 | 4.77E-04 | 1.03E-03 | 7.34E-04 |
| 2003 | 41 | 26092.0 | 9.61E-04 | 8.34E-04 | 1.11E-03 | 1.18E-03 | 1.97E-03 | 1.56E-03 |
| 2004 | 25 | 27061.9 | 8.91E-04 | 7.74E-04 | 1.03E-03 | 6.44E-04 | 1.24E-03 | 9.24E-04 |
| 2005 | 20 | 27409.1 | 8.27E-04 | 7.11E-04 | 9.61E-04 | 4.88E-04 | 1.02E-03 | 7.33E-04 |
| 2006 | 22 | 26595.8 | 7.67E-04 | 6.49E-04 | 9.06E-04 | 5.63E-04 | 1.13E-03 | 8.29E-04 |
| 2007 | 23 | 27654.8 | 7.11E-04 | 5.89E-04 | 8.59E-04 | 5.72E-04 | 1.13E-03 | 8.33E-04 |
| 2008 | 16 | 26961.6 | 6.60E-04 | 5.32E-04 | 8.18E-04 | 3.79E-04 | 8.61E-04 | 6.00E-04 |
| 2009 | 14 | 26642.4 | 6.12E-04 | 4.80E-04 | 7.80E-04 | 3.25E-04 | 7.82E-04 | 5.33E-04 |
| 2010 | 13 | 26908.6 | 5.68E-04 | 4.32E-04 | 7.46E-04 | 2.94E-04 | 7.30E-04 | 4.92E-04 |
| 2011 | 14 | 26314.0 | 5.27E-04 | 3.89E-04 | 7.14E-04 | 3.29E-04 | 7.92E-04 | 5.40E-04 |

Table 12. Plot data for standby MDP FTR≤1H industry trend. Figure 2

| FY/ Source | Failures | Hours | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 2010 Update | | | | | | 1.93E-05 | 3.01E-04 | 1.23E-04 |
| 1998 | 7 | 23805.9 | 1.53E-04 | 9.03E-05 | 2.60E-04 | 1.31E-04 | 4.50E-04 | 2.70E-04 |
| 1999 | 3 | 24503.6 | 1.46E-04 | 9.14E-05 | 2.33E-04 | 3.80E-05 | 2.47E-04 | 1.23E-04 |
| 2000 | 3 | 24633.4 | 1.39E-04 | 9.20E-05 | 2.11E-04 | 3.79E-05 | 2.46E-04 | 1.22E-04 |
| 2001 | 1 | 24371.5 | 1.33E-04 | 9.21E-05 | 1.92E-04 | 6.20E-06 | 1.38E-04 | 5.29E-05 |
| 2002 | 6 | 24658.6 | 1.27E-04 | 9.14E-05 | 1.76E-04 | 1.03E-04 | 3.90E-04 | 2.27E-04 |
| 2003 | 2 | 26092.0 | 1.21E-04 | 8.95E-05 | 1.63E-04 | 1.90E-05 | 1.84E-04 | 8.31E-05 |
| 2004 | 3 | 27061.9 | 1.15E-04 | 8.62E-05 | 1.54E-04 | 3.49E-05 | 2.26E-04 | 1.13E-04 |
| 2005 | 5 | 27409.1 | 1.10E-04 | 8.16E-05 | 1.48E-04 | 7.28E-05 | 3.13E-04 | 1.75E-04 |
| 2006 | 3 | 26595.8 | 1.05E-04 | 7.60E-05 | 1.45E-04 | 3.54E-05 | 2.30E-04 | 1.14E-04 |
| 2007 | 3 | 27654.8 | 1.00E-04 | 6.98E-05 | 1.43E-04 | 3.42E-05 | 2.22E-04 | 1.11E-04 |
| 2008 | 2 | 26961.6 | 9.54E-05 | 6.35E-05 | 1.43E-04 | 1.85E-05 | 1.79E-04 | 8.08E-05 |
| 2009 | 3 | 26642.4 | 9.09E-05 | 5.74E-05 | 1.44E-04 | 3.54E-05 | 2.30E-04 | 1.14E-04 |
| 2010 | 1 | 26908.6 | 8.67E-05 | 5.16E-05 | 1.46E-04 | 5.69E-06 | 1.26E-04 | 4.85E-05 |
| 2011 | 3 | 26314.0 | 8.27E-05 | 4.63E-05 | 1.48E-04 | 3.58E-05 | 2.32E-04 | 1.15E-04 |

Table 13. Plot data for standby MDP 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 |
| 2010 Update | | | | | | 2.64E-07 | 3.41E-05 | 1.04E-05 |
| 1998 | 8 | 971885.8 | 1.13E-05 | 6.82E-06 | 1.89E-05 | 4.26E-06 | 1.35E-05 | 8.35E-06 |
| 1999 | 7 | 947476.5 | 1.11E-05 | 7.07E-06 | 1.76E-05 | 3.65E-06 | 1.26E-05 | 7.55E-06 |
| 2000 | 11 | 906644.2 | 1.09E-05 | 7.32E-06 | 1.64E-05 | 6.87E-06 | 1.85E-05 | 1.21E-05 |
| 2001 | 12 | 915401.8 | 1.07E-05 | 7.53E-06 | 1.53E-05 | 7.60E-06 | 1.96E-05 | 1.30E-05 |
| 2002 | 18 | 980506.0 | 1.06E-05 | 7.70E-06 | 1.45E-05 | 1.17E-05 | 2.54E-05 | 1.80E-05 |
| 2003 | 17 | 1094942.5 | 1.04E-05 | 7.80E-06 | 1.38E-05 | 9.84E-06 | 2.18E-05 | 1.53E-05 |
| 2004 | 14 | 1175841.9 | 1.02E-05 | 7.79E-06 | 1.33E-05 | 7.24E-06 | 1.74E-05 | 1.19E-05 |
| 2005 | 12 | 1180715.2 | 1.00E-05 | 7.67E-06 | 1.30E-05 | 5.95E-06 | 1.53E-05 | 1.02E-05 |
| 2006 | 4 | 1182897.6 | 9.82E-06 | 7.42E-06 | 1.30E-05 | 1.35E-06 | 6.88E-06 | 3.66E-06 |
| 2007 | 16 | 1198493.1 | 9.64E-06 | 7.08E-06 | 1.31E-05 | 8.38E-06 | 1.90E-05 | 1.33E-05 |
| 2008 | 17 | 1212729.7 | 9.47E-06 | 6.69E-06 | 1.34E-05 | 8.92E-06 | 1.98E-05 | 1.39E-05 |
| 2009 | 9 | 1190914.2 | 9.30E-06 | 6.27E-06 | 1.38E-05 | 4.09E-06 | 1.22E-05 | 7.68E-06 |
| 2010 | 9 | 1216674.4 | 9.13E-06 | 5.85E-06 | 1.42E-05 | 4.00E-06 | 1.19E-05 | 7.52E-06 |
| 2011 | 11 | 1209236.4 | 8.96E-06 | 5.44E-06 | 1.48E-05 | 5.21E-06 | 1.40E-05 | 9.16E-06 |

Table 14. Plot data for normally running MDP 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 |
| 2010 Update | | | | | | 4.01E-04 | 2.79E-03 | 1.36E-03 |
| 1998 | 17 | 8189.7 | 1.85E-03 | 1.44E-03 | 2.37E-03 | 1.30E-03 | 2.89E-03 | 2.04E-03 |
| 1999 | 16 | 8345.7 | 1.73E-03 | 1.38E-03 | 2.15E-03 | 1.19E-03 | 2.70E-03 | 1.88E-03 |
| 2000 | 12 | 8628.3 | 1.61E-03 | 1.32E-03 | 1.95E-03 | 8.08E-04 | 2.08E-03 | 1.38E-03 |
| 2001 | 13 | 8608.0 | 1.50E-03 | 1.26E-03 | 1.78E-03 | 8.95E-04 | 2.22E-03 | 1.50E-03 |
| 2002 | 14 | 8807.5 | 1.39E-03 | 1.20E-03 | 1.63E-03 | 9.60E-04 | 2.30E-03 | 1.57E-03 |
| 2003 | 14 | 9445.3 | 1.30E-03 | 1.13E-03 | 1.50E-03 | 8.98E-04 | 2.16E-03 | 1.47E-03 |
| 2004 | 10 | 9663.8 | 1.21E-03 | 1.05E-03 | 1.39E-03 | 5.75E-04 | 1.62E-03 | 1.04E-03 |
| 2005 | 6 | 9709.0 | 1.13E-03 | 9.71E-04 | 1.31E-03 | 2.91E-04 | 1.10E-03 | 6.42E-04 |
| 2006 | 13 | 9720.1 | 1.05E-03 | 8.92E-04 | 1.23E-03 | 7.96E-04 | 1.98E-03 | 1.33E-03 |
| 2007 | 10 | 9876.3 | 9.77E-04 | 8.14E-04 | 1.17E-03 | 5.63E-04 | 1.59E-03 | 1.02E-03 |
| 2008 | 10 | 9810.9 | 9.10E-04 | 7.39E-04 | 1.12E-03 | 5.67E-04 | 1.60E-03 | 1.03E-03 |
| 2009 | 6 | 9634.3 | 8.48E-04 | 6.70E-04 | 1.07E-03 | 2.93E-04 | 1.11E-03 | 6.47E-04 |
| 2010 | 8 | 9618.9 | 7.90E-04 | 6.06E-04 | 1.03E-03 | 4.32E-04 | 1.37E-03 | 8.48E-04 |
| 2011 | 9 | 9414.2 | 7.35E-04 | 5.47E-04 | 9.89E-04 | 5.15E-04 | 1.53E-03 | 9.67E-04 |

Table 15. Plot data for normally running MDP FTR industry trend. Figure 5

| 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 |
| 2010 Update | | | | | | 7.37E-07 | 8.02E-06 | 3.53E-06 |
| 1998 | 23 | 2999973.5 | 5.86E-06 | 4.03E-06 | 8.54E-06 | 5.19E-06 | 1.03E-05 | 7.55E-06 |
| 1999 | 17 | 3100252.2 | 5.57E-06 | 3.99E-06 | 7.77E-06 | 3.50E-06 | 7.75E-06 | 5.45E-06 |
| 2000 | 19 | 3132948.8 | 5.29E-06 | 3.94E-06 | 7.10E-06 | 3.96E-06 | 8.41E-06 | 6.01E-06 |
| 2001 | 16 | 3134652.3 | 5.02E-06 | 3.87E-06 | 6.52E-06 | 3.21E-06 | 7.30E-06 | 5.08E-06 |
| 2002 | 18 | 3174756.4 | 4.77E-06 | 3.78E-06 | 6.02E-06 | 3.66E-06 | 7.94E-06 | 5.63E-06 |
| 2003 | 10 | 3289506.1 | 4.53E-06 | 3.65E-06 | 5.62E-06 | 1.70E-06 | 4.80E-06 | 3.09E-06 |
| 2004 | 9 | 3369151.2 | 4.30E-06 | 3.48E-06 | 5.32E-06 | 1.45E-06 | 4.33E-06 | 2.73E-06 |
| 2005 | 9 | 3346651.7 | 4.09E-06 | 3.28E-06 | 5.09E-06 | 1.46E-06 | 4.36E-06 | 2.75E-06 |
| 2006 | 12 | 3332049.3 | 3.88E-06 | 3.05E-06 | 4.94E-06 | 2.12E-06 | 5.47E-06 | 3.63E-06 |
| 2007 | 12 | 3335557.3 | 3.69E-06 | 2.82E-06 | 4.83E-06 | 2.12E-06 | 5.46E-06 | 3.63E-06 |
| 2008 | 18 | 3357639.1 | 3.50E-06 | 2.58E-06 | 4.75E-06 | 3.47E-06 | 7.52E-06 | 5.33E-06 |
| 2009 | 24 | 3348982.4 | 3.33E-06 | 2.35E-06 | 4.70E-06 | 4.90E-06 | 9.59E-06 | 7.08E-06 |
| 2010 | 8 | 3344405.8 | 3.16E-06 | 2.14E-06 | 4.66E-06 | 1.25E-06 | 3.99E-06 | 2.46E-06 |
| 2011 | 9 | 3338126.9 | 3.00E-06 | 1.94E-06 | 4.63E-06 | 1.47E-06 | 4.37E-06 | 2.75E-06 |

Table 16. Plot data for all standby MDP unavailability trend. Figure 6

| FY | UA Hours | Critical Hours | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 2010 Update | | | | | | 3.59E-04 | 2.10E-02 | 7.00E-03 |
| 1998 | 7674.4 | 1713843.7 | 5.11E-03 | 4.69E-03 | 5.53E-03 | 9.65E-06 | 1.89E-02 | 4.72E-03 |
| 1999 | 12906.2 | 2452645.5 | 5.02E-03 | 4.65E-03 | 5.38E-03 | 5.07E-04 | 1.43E-02 | 5.28E-03 |
| 2000 | 13130.0 | 2537111.3 | 4.93E-03 | 4.61E-03 | 5.25E-03 | 4.59E-04 | 1.38E-02 | 5.06E-03 |
| 2001 | 12728.1 | 2542239.9 | 4.84E-03 | 4.56E-03 | 5.11E-03 | 3.69E-04 | 1.43E-02 | 5.04E-03 |
| 2002 | 18010.2 | 3819764.7 | 4.75E-03 | 4.51E-03 | 4.99E-03 | 2.61E-04 | 1.44E-02 | 4.86E-03 |
| 2003 | 21358.6 | 4290105.7 | 4.66E-03 | 4.43E-03 | 4.88E-03 | 2.45E-04 | 1.53E-02 | 5.08E-03 |
| 2004 | 19662.9 | 4473656.1 | 4.57E-03 | 4.35E-03 | 4.79E-03 | 2.89E-04 | 1.27E-02 | 4.42E-03 |
| 2005 | 19004.5 | 4413226.1 | 4.48E-03 | 4.24E-03 | 4.72E-03 | 1.05E-04 | 1.42E-02 | 4.33E-03 |
| 2006 | 17693.4 | 4488097.5 | 4.39E-03 | 4.12E-03 | 4.66E-03 | 1.61E-04 | 1.22E-02 | 3.95E-03 |
| 2007 | 17015.5 | 4464312.7 | 4.30E-03 | 3.98E-03 | 4.62E-03 | 1.00E-04 | 1.25E-02 | 3.84E-03 |
| 2008 | 18367.5 | 4459856.1 | 4.21E-03 | 3.85E-03 | 4.58E-03 | 1.80E-04 | 1.25E-02 | 4.10E-03 |
| 2009 | 18776.7 | 4474114.8 | 4.12E-03 | 3.70E-03 | 4.54E-03 | 1.71E-04 | 1.30E-02 | 4.21E-03 |
| 2010 | 18785.5 | 4393087.5 | 4.03E-03 | 3.56E-03 | 4.50E-03 | 1.97E-04 | 1.29E-02 | 4.25E-03 |
| 2011 | 18148.5 | 4337722.4 | 3.94E-03 | 3.41E-03 | 4.47E-03 | 1.95E-04 | 1.28E-02 | 4.21E-03 |

Table 17. Plot data for Standby MDP unreliability trend. Figure 7

| FY | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|
| | Mean | Lower (5%) | Mean | Lower (5%) | Mean | Mean |
| 1998 | 6.80E-03 | 6.30E-03 | 7.34E-03 | 1.79E-03 | 2.07E-02 | 6.52E-03 |
| 1999 | 6.60E-03 | 6.16E-03 | 7.07E-03 | 1.77E-03 | 1.56E-02 | 6.55E-03 |
| 2000 | 6.41E-03 | 6.03E-03 | 6.81E-03 | 1.84E-03 | 1.51E-02 | 6.45E-03 |
| 2001 | 6.22E-03 | 5.89E-03 | 6.56E-03 | 1.94E-03 | 1.58E-02 | 6.61E-03 |
| 2002 | 6.04E-03 | 5.76E-03 | 6.33E-03 | 1.38E-03 | 1.55E-02 | 5.99E-03 |
| 2003 | 5.86E-03 | 5.61E-03 | 6.12E-03 | 2.02E-03 | 1.70E-02 | 6.83E-03 |
| 2004 | 5.69E-03 | 5.46E-03 | 5.93E-03 | 1.41E-03 | 1.37E-02 | 5.55E-03 |
| 2005 | 5.52E-03 | 5.30E-03 | 5.75E-03 | 1.09E-03 | 1.52E-02 | 5.31E-03 |
| 2006 | 5.36E-03 | 5.13E-03 | 5.60E-03 | 1.13E-03 | 1.31E-02 | 4.91E-03 |
| 2007 | 5.20E-03 | 4.96E-03 | 5.46E-03 | 1.15E-03 | 1.35E-02 | 4.87E-03 |
| 2008 | 5.05E-03 | 4.79E-03 | 5.33E-03 | 9.53E-04 | 1.33E-02 | 4.88E-03 |
| 2009 | 4.90E-03 | 4.61E-03 | 5.21E-03 | 8.53E-04 | 1.36E-02 | 4.91E-03 |
| 2010 | 4.76E-03 | 4.44E-03 | 5.10E-03 | 8.28E-04 | 1.35E-02 | 4.88E-03 |
| 2011 | 4.62E-03 | 4.28E-03 | 4.99E-03 | 9.26E-04 | 1.34E-02 | 4.92E-03 |

Table 18. Plot data for NR MDP unreliability trend. Figure 8

| FY | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|
| | Mean | Lower (5%) | Mean | Lower (5%) | Mean | Mean |
| 1998 | 6.92E-03 | 6.47E-03 | 7.37E-03 | 2.08E-03 | 2.10E-02 | 6.80E-03 |
| 1999 | 6.75E-03 | 6.34E-03 | 7.15E-03 | 2.43E-03 | 1.62E-02 | 7.20E-03 |
| 2000 | 6.57E-03 | 6.22E-03 | 6.93E-03 | 1.86E-03 | 1.51E-02 | 6.48E-03 |
| 2001 | 6.40E-03 | 6.08E-03 | 6.72E-03 | 1.91E-03 | 1.58E-02 | 6.57E-03 |
| 2002 | 6.23E-03 | 5.95E-03 | 6.51E-03 | 1.86E-03 | 1.61E-02 | 6.47E-03 |
| 2003 | 6.06E-03 | 5.80E-03 | 6.31E-03 | 1.65E-03 | 1.66E-02 | 6.50E-03 |
| 2004 | 5.88E-03 | 5.64E-03 | 6.12E-03 | 1.35E-03 | 1.38E-02 | 5.48E-03 |
| 2005 | 5.71E-03 | 5.47E-03 | 5.95E-03 | 7.71E-04 | 1.48E-02 | 4.99E-03 |
| 2006 | 5.54E-03 | 5.28E-03 | 5.79E-03 | 1.52E-03 | 1.36E-02 | 5.30E-03 |
| 2007 | 5.36E-03 | 5.08E-03 | 5.65E-03 | 1.17E-03 | 1.35E-02 | 4.88E-03 |
| 2008 | 5.19E-03 | 4.87E-03 | 5.51E-03 | 1.23E-03 | 1.36E-02 | 5.16E-03 |
| 2009 | 5.02E-03 | 4.66E-03 | 5.38E-03 | 8.56E-04 | 1.36E-02 | 4.91E-03 |
| 2010 | 4.85E-03 | 4.44E-03 | 5.25E-03 | 1.06E-03 | 1.37E-02 | 5.12E-03 |
| 2011 | 4.67E-03 | 4.22E-03 | 5.13E-03 | 1.29E-03 | 1.38E-02 | 5.29E-03 |

Table 19. Plot data for standby MDP start demands trend. Figure 9

| FY | Demands | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 23806 | 103.0 | 2.37E+02 | 2.28E+02 | 2.47E+02 | 2.29E+02 | 2.34E+02 | 2.31E+02 |
| 1999 | 24504 | 103.0 | 2.39E+02 | 2.31E+02 | 2.48E+02 | 2.35E+02 | 2.40E+02 | 2.38E+02 |
| 2000 | 24633 | 103.3 | 2.41E+02 | 2.34E+02 | 2.49E+02 | 2.36E+02 | 2.41E+02 | 2.39E+02 |
| 2001 | 24371 | 103.0 | 2.44E+02 | 2.37E+02 | 2.51E+02 | 2.34E+02 | 2.39E+02 | 2.37E+02 |
| 2002 | 24659 | 103.0 | 2.46E+02 | 2.40E+02 | 2.52E+02 | 2.37E+02 | 2.42E+02 | 2.39E+02 |
| 2003 | 26092 | 103.0 | 2.48E+02 | 2.42E+02 | 2.53E+02 | 2.51E+02 | 2.56E+02 | 2.53E+02 |
| 2004 | 27062 | 103.3 | 2.50E+02 | 2.45E+02 | 2.55E+02 | 2.59E+02 | 2.65E+02 | 2.62E+02 |
| 2005 | 27409 | 103.0 | 2.52E+02 | 2.47E+02 | 2.57E+02 | 2.63E+02 | 2.69E+02 | 2.66E+02 |
| 2006 | 26596 | 103.0 | 2.54E+02 | 2.49E+02 | 2.60E+02 | 2.56E+02 | 2.61E+02 | 2.58E+02 |
| 2007 | 27655 | 103.4 | 2.56E+02 | 2.50E+02 | 2.63E+02 | 2.65E+02 | 2.70E+02 | 2.68E+02 |
| 2008 | 26962 | 104.3 | 2.59E+02 | 2.52E+02 | 2.66E+02 | 2.56E+02 | 2.61E+02 | 2.59E+02 |
| 2009 | 26642 | 104.0 | 2.61E+02 | 2.53E+02 | 2.69E+02 | 2.54E+02 | 2.59E+02 | 2.56E+02 |
| 2010 | 26909 | 104.0 | 2.63E+02 | 2.54E+02 | 2.72E+02 | 2.56E+02 | 2.61E+02 | 2.59E+02 |
| 2011 | 26314 | 104.0 | 2.65E+02 | 2.55E+02 | 2.76E+02 | 2.50E+02 | 2.56E+02 | 2.53E+02 |

Table 20. Plot data for standby MDP run ≤1-hour run-hours trend. Figure 10

| FY | Hours | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 23806 | 103.0 | 2.37E+02 | 2.28E+02 | 2.47E+02 | 2.29E+02 | 2.34E+02 | 2.31E+02 |
| 1999 | 24504 | 103.0 | 2.39E+02 | 2.31E+02 | 2.48E+02 | 2.35E+02 | 2.40E+02 | 2.38E+02 |
| 2000 | 24633 | 103.3 | 2.41E+02 | 2.34E+02 | 2.49E+02 | 2.36E+02 | 2.41E+02 | 2.39E+02 |
| 2001 | 24371 | 103.0 | 2.44E+02 | 2.37E+02 | 2.51E+02 | 2.34E+02 | 2.39E+02 | 2.37E+02 |
| 2002 | 24659 | 103.0 | 2.46E+02 | 2.40E+02 | 2.52E+02 | 2.37E+02 | 2.42E+02 | 2.39E+02 |
| 2003 | 26092 | 103.0 | 2.48E+02 | 2.42E+02 | 2.53E+02 | 2.51E+02 | 2.56E+02 | 2.53E+02 |
| 2004 | 27062 | 103.3 | 2.50E+02 | 2.45E+02 | 2.55E+02 | 2.59E+02 | 2.65E+02 | 2.62E+02 |
| 2005 | 27409 | 103.0 | 2.52E+02 | 2.47E+02 | 2.57E+02 | 2.63E+02 | 2.69E+02 | 2.66E+02 |
| 2006 | 26596 | 103.0 | 2.54E+02 | 2.49E+02 | 2.60E+02 | 2.56E+02 | 2.61E+02 | 2.58E+02 |
| 2007 | 27655 | 103.4 | 2.56E+02 | 2.50E+02 | 2.63E+02 | 2.65E+02 | 2.70E+02 | 2.68E+02 |
| 2008 | 26962 | 104.3 | 2.59E+02 | 2.52E+02 | 2.66E+02 | 2.56E+02 | 2.61E+02 | 2.59E+02 |
| 2009 | 26642 | 104.0 | 2.61E+02 | 2.53E+02 | 2.69E+02 | 2.54E+02 | 2.59E+02 | 2.56E+02 |
| 2010 | 26909 | 104.0 | 2.63E+02 | 2.54E+02 | 2.72E+02 | 2.56E+02 | 2.61E+02 | 2.59E+02 |
| 2011 | 26314 | 104.0 | 2.65E+02 | 2.55E+02 | 2.76E+02 | 2.50E+02 | 2.56E+02 | 2.53E+02 |

Table 21. Plot data for standby MDP run-hours trend. Figure 11

| FY | Run Hours | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 971886 | 103.0 | 9.08E+03 | 8.45E+03 | 9.76E+03 | 9.42E+03 | 9.45E+03 | 9.44E+03 |
| 1999 | 947477 | 103.0 | 9.29E+03 | 8.71E+03 | 9.91E+03 | 9.18E+03 | 9.21E+03 | 9.20E+03 |
| 2000 | 906644 | 103.3 | 9.51E+03 | 8.98E+03 | 1.01E+04 | 8.76E+03 | 8.79E+03 | 8.78E+03 |
| 2001 | 915402 | 103.0 | 9.74E+03 | 9.26E+03 | 1.02E+04 | 8.87E+03 | 8.90E+03 | 8.89E+03 |
| 2002 | 980506 | 103.0 | 9.97E+03 | 9.53E+03 | 1.04E+04 | 9.51E+03 | 9.54E+03 | 9.52E+03 |
| 2003 | 1094943 | 103.0 | 1.02E+04 | 9.80E+03 | 1.06E+04 | 1.06E+04 | 1.06E+04 | 1.06E+04 |
| 2004 | 1175842 | 103.3 | 1.04E+04 | 1.01E+04 | 1.08E+04 | 1.14E+04 | 1.14E+04 | 1.14E+04 |
| 2005 | 1180715 | 103.0 | 1.07E+04 | 1.03E+04 | 1.11E+04 | 1.14E+04 | 1.15E+04 | 1.15E+04 |
| 2006 | 1182898 | 103.0 | 1.09E+04 | 1.05E+04 | 1.14E+04 | 1.15E+04 | 1.15E+04 | 1.15E+04 |
| 2007 | 1198493 | 103.4 | 1.12E+04 | 1.07E+04 | 1.17E+04 | 1.16E+04 | 1.16E+04 | 1.16E+04 |
| 2008 | 1212730 | 104.3 | 1.15E+04 | 1.09E+04 | 1.20E+04 | 1.16E+04 | 1.16E+04 | 1.16E+04 |
| 2009 | 1190914 | 104.0 | 1.17E+04 | 1.11E+04 | 1.24E+04 | 1.14E+04 | 1.15E+04 | 1.15E+04 |
| 2010 | 1216674 | 104.0 | 1.20E+04 | 1.13E+04 | 1.27E+04 | 1.17E+04 | 1.17E+04 | 1.17E+04 |
| 2011 | 1209236 | 104.0 | 1.23E+04 | 1.15E+04 | 1.31E+04 | 1.16E+04 | 1.16E+04 | 1.16E+04 |

Table 22. Plot data for standby MDP FTS events trend. Figure 12

| FY | Failures | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 34 | 103.0 | 3.30E-01 | 2.57E-01 | 4.24E-01 | 2.42E-01 | 4.25E-01 | 3.28E-01 |
| 1999 | 26 | 103.0 | 3.09E-01 | 2.48E-01 | 3.85E-01 | 1.77E-01 | 3.37E-01 | 2.52E-01 |
| 2000 | 29 | 103.3 | 2.89E-01 | 2.38E-01 | 3.51E-01 | 2.01E-01 | 3.69E-01 | 2.80E-01 |
| 2001 | 35 | 103.0 | 2.71E-01 | 2.28E-01 | 3.22E-01 | 2.50E-01 | 4.36E-01 | 3.37E-01 |
| 2002 | 18 | 103.0 | 2.54E-01 | 2.17E-01 | 2.96E-01 | 1.14E-01 | 2.48E-01 | 1.76E-01 |
| 2003 | 41 | 103.0 | 2.37E-01 | 2.05E-01 | 2.75E-01 | 2.99E-01 | 5.00E-01 | 3.95E-01 |
| 2004 | 25 | 103.3 | 2.22E-01 | 1.92E-01 | 2.58E-01 | 1.69E-01 | 3.26E-01 | 2.42E-01 |
| 2005 | 20 | 103.0 | 2.08E-01 | 1.78E-01 | 2.43E-01 | 1.30E-01 | 2.71E-01 | 1.95E-01 |
| 2006 | 22 | 103.0 | 1.95E-01 | 1.64E-01 | 2.32E-01 | 1.46E-01 | 2.93E-01 | 2.14E-01 |
| 2007 | 23 | 103.4 | 1.83E-01 | 1.50E-01 | 2.22E-01 | 1.53E-01 | 3.03E-01 | 2.23E-01 |
| 2008 | 16 | 104.3 | 1.71E-01 | 1.37E-01 | 2.13E-01 | 9.80E-02 | 2.23E-01 | 1.55E-01 |
| 2009 | 14 | 104.0 | 1.60E-01 | 1.25E-01 | 2.06E-01 | 8.34E-02 | 2.00E-01 | 1.37E-01 |
| 2010 | 13 | 104.0 | 1.50E-01 | 1.13E-01 | 1.98E-01 | 7.61E-02 | 1.89E-01 | 1.27E-01 |
| 2011 | 14 | 104.0 | 1.40E-01 | 1.03E-01 | 1.92E-01 | 8.34E-02 | 2.00E-01 | 1.37E-01 |

Table 23. Plot data for standby MDP FTR≤1H events trend. Figure 13

| FY | Failures | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 7 | 103.0 | 3.65E-02 | 2.15E-02 | 6.20E-02 | 3.05E-02 | 1.05E-01 | 6.31E-02 |
| 1999 | 3 | 103.0 | 3.51E-02 | 2.19E-02 | 5.62E-02 | 9.11E-03 | 5.92E-02 | 2.94E-02 |
| 2000 | 3 | 103.3 | 3.37E-02 | 2.22E-02 | 5.12E-02 | 9.09E-03 | 5.90E-02 | 2.94E-02 |
| 2001 | 1 | 103.0 | 3.24E-02 | 2.24E-02 | 4.69E-02 | 1.48E-03 | 3.29E-02 | 1.26E-02 |
| 2002 | 6 | 103.0 | 3.12E-02 | 2.24E-02 | 4.33E-02 | 2.48E-02 | 9.40E-02 | 5.47E-02 |
| 2003 | 2 | 103.0 | 3.00E-02 | 2.21E-02 | 4.06E-02 | 4.82E-03 | 4.66E-02 | 2.10E-02 |
| 2004 | 3 | 103.3 | 2.88E-02 | 2.15E-02 | 3.86E-02 | 9.09E-03 | 5.90E-02 | 2.94E-02 |
| 2005 | 5 | 103.0 | 2.77E-02 | 2.05E-02 | 3.74E-02 | 1.92E-02 | 8.27E-02 | 4.63E-02 |
| 2006 | 3 | 103.0 | 2.66E-02 | 1.92E-02 | 3.69E-02 | 9.11E-03 | 5.92E-02 | 2.94E-02 |
| 2007 | 3 | 103.4 | 2.56E-02 | 1.78E-02 | 3.68E-02 | 9.09E-03 | 5.90E-02 | 2.93E-02 |
| 2008 | 2 | 104.3 | 2.46E-02 | 1.63E-02 | 3.71E-02 | 4.77E-03 | 4.61E-02 | 2.08E-02 |
| 2009 | 3 | 104.0 | 2.36E-02 | 1.49E-02 | 3.76E-02 | 9.04E-03 | 5.87E-02 | 2.92E-02 |
| 2010 | 1 | 104.0 | 2.27E-02 | 1.35E-02 | 3.84E-02 | 1.47E-03 | 3.26E-02 | 1.25E-02 |
| 2011 | 3 | 104.0 | 2.18E-02 | 1.22E-02 | 3.92E-02 | 9.04E-03 | 5.87E-02 | 2.92E-02 |

Table 24. Plot data for standby MDP FTR>1H events trend. 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 | 8 | 103.0 | 1.04E-01 | 6.37E-02 | 1.71E-01 | 4.04E-02 | 1.28E-01 | 7.92E-02 |
| 1999 | 7 | 103.0 | 1.05E-01 | 6.74E-02 | 1.62E-01 | 3.38E-02 | 1.16E-01 | 6.99E-02 |
| 2000 | 11 | 103.3 | 1.05E-01 | 7.11E-02 | 1.55E-01 | 6.08E-02 | 1.63E-01 | 1.07E-01 |
| 2001 | 12 | 103.0 | 1.05E-01 | 7.47E-02 | 1.49E-01 | 6.80E-02 | 1.75E-01 | 1.16E-01 |
| 2002 | 18 | 103.0 | 1.06E-01 | 7.80E-02 | 1.44E-01 | 1.12E-01 | 2.43E-01 | 1.72E-01 |
| 2003 | 17 | 103.0 | 1.06E-01 | 8.06E-02 | 1.40E-01 | 1.05E-01 | 2.32E-01 | 1.63E-01 |
| 2004 | 14 | 103.3 | 1.07E-01 | 8.23E-02 | 1.38E-01 | 8.22E-02 | 1.98E-01 | 1.35E-01 |
| 2005 | 12 | 103.0 | 1.07E-01 | 8.27E-02 | 1.39E-01 | 6.80E-02 | 1.75E-01 | 1.16E-01 |
| 2006 | 4 | 103.0 | 1.08E-01 | 8.18E-02 | 1.41E-01 | 1.55E-02 | 7.88E-02 | 4.19E-02 |
| 2007 | 16 | 103.4 | 1.08E-01 | 7.99E-02 | 1.46E-01 | 9.68E-02 | 2.20E-01 | 1.53E-01 |
| 2008 | 17 | 104.3 | 1.08E-01 | 7.73E-02 | 1.52E-01 | 1.03E-01 | 2.29E-01 | 1.61E-01 |
| 2009 | 9 | 104.0 | 1.09E-01 | 7.42E-02 | 1.60E-01 | 4.67E-02 | 1.39E-01 | 8.77E-02 |
| 2010 | 9 | 104.0 | 1.09E-01 | 7.09E-02 | 1.68E-01 | 4.67E-02 | 1.39E-01 | 8.77E-02 |
| 2011 | 11 | 104.0 | 1.10E-01 | 6.75E-02 | 1.78E-01 | 6.04E-02 | 1.62E-01 | 1.06E-01 |

Table 25. Plot data for normally running MDP start demands trend. Figure 15

| FY | Demands | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 8190 | 103.0 | 8.27E+01 | 7.87E+01 | 8.68E+01 | 7.81E+01 | 8.10E+01 | 7.95E+01 |
| 1999 | 8346 | 103.0 | 8.37E+01 | 8.01E+01 | 8.74E+01 | 7.96E+01 | 8.25E+01 | 8.10E+01 |
| 2000 | 8628 | 103.3 | 8.47E+01 | 8.14E+01 | 8.80E+01 | 8.21E+01 | 8.50E+01 | 8.35E+01 |
| 2001 | 8608 | 103.0 | 8.57E+01 | 8.28E+01 | 8.86E+01 | 8.21E+01 | 8.51E+01 | 8.36E+01 |
| 2002 | 8808 | 103.0 | 8.67E+01 | 8.41E+01 | 8.94E+01 | 8.40E+01 | 8.70E+01 | 8.55E+01 |
| 2003 | 9445 | 103.0 | 8.77E+01 | 8.54E+01 | 9.01E+01 | 9.02E+01 | 9.33E+01 | 9.17E+01 |
| 2004 | 9664 | 103.3 | 8.88E+01 | 8.65E+01 | 9.11E+01 | 9.20E+01 | 9.51E+01 | 9.36E+01 |
| 2005 | 9709 | 103.0 | 8.98E+01 | 8.76E+01 | 9.21E+01 | 9.27E+01 | 9.58E+01 | 9.43E+01 |
| 2006 | 9720 | 103.0 | 9.09E+01 | 8.85E+01 | 9.33E+01 | 9.28E+01 | 9.59E+01 | 9.44E+01 |
| 2007 | 9876 | 103.4 | 9.20E+01 | 8.93E+01 | 9.47E+01 | 9.40E+01 | 9.71E+01 | 9.55E+01 |
| 2008 | 9811 | 104.3 | 9.31E+01 | 9.01E+01 | 9.61E+01 | 9.25E+01 | 9.56E+01 | 9.41E+01 |
| 2009 | 9634 | 104.0 | 9.42E+01 | 9.08E+01 | 9.77E+01 | 9.11E+01 | 9.42E+01 | 9.26E+01 |
| 2010 | 9619 | 104.0 | 9.53E+01 | 9.14E+01 | 9.93E+01 | 9.09E+01 | 9.40E+01 | 9.25E+01 |
| 2011 | 9414 | 104.0 | 9.64E+01 | 9.20E+01 | 1.01E+02 | 8.90E+01 | 9.21E+01 | 9.05E+01 |

Table 26. Plot data for normally running MDP run hours trend. Figure 16

| FY | Run Hours | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 2999974 | 103.0 | 3.01E+04 | 2.93E+04 | 3.09E+04 | 2.91E+04 | 2.92E+04 | 2.91E+04 |
| 1999 | 3100252 | 103.0 | 3.03E+04 | 2.96E+04 | 3.10E+04 | 3.01E+04 | 3.01E+04 | 3.01E+04 |
| 2000 | 3132949 | 103.3 | 3.05E+04 | 2.99E+04 | 3.12E+04 | 3.03E+04 | 3.04E+04 | 3.03E+04 |
| 2001 | 3134652 | 103.0 | 3.07E+04 | 3.02E+04 | 3.13E+04 | 3.04E+04 | 3.05E+04 | 3.04E+04 |
| 2002 | 3174756 | 103.0 | 3.10E+04 | 3.05E+04 | 3.15E+04 | 3.08E+04 | 3.09E+04 | 3.08E+04 |
| 2003 | 3289506 | 103.0 | 3.12E+04 | 3.07E+04 | 3.16E+04 | 3.19E+04 | 3.20E+04 | 3.19E+04 |
| 2004 | 3369151 | 103.3 | 3.14E+04 | 3.10E+04 | 3.18E+04 | 3.26E+04 | 3.27E+04 | 3.26E+04 |
| 2005 | 3346652 | 103.0 | 3.16E+04 | 3.12E+04 | 3.20E+04 | 3.25E+04 | 3.25E+04 | 3.25E+04 |
| 2006 | 3332049 | 103.0 | 3.18E+04 | 3.14E+04 | 3.23E+04 | 3.23E+04 | 3.24E+04 | 3.23E+04 |
| 2007 | 3335557 | 103.4 | 3.20E+04 | 3.15E+04 | 3.25E+04 | 3.23E+04 | 3.23E+04 | 3.23E+04 |
| 2008 | 3357639 | 104.3 | 3.23E+04 | 3.17E+04 | 3.28E+04 | 3.22E+04 | 3.22E+04 | 3.22E+04 |
| 2009 | 3348982 | 104.0 | 3.25E+04 | 3.18E+04 | 3.31E+04 | 3.22E+04 | 3.22E+04 | 3.22E+04 |
| 2010 | 3344406 | 104.0 | 3.27E+04 | 3.20E+04 | 3.35E+04 | 3.21E+04 | 3.22E+04 | 3.22E+04 |
| 2011 | 3338127 | 104.0 | 3.29E+04 | 3.21E+04 | 3.38E+04 | 3.21E+04 | 3.21E+04 | 3.21E+04 |

Table 27. Plot data for normally running MDP FTS events trend. Figure 17

| FY | Failures | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 17 | 103.0 | 1.52E-01 | 1.21E-01 | 1.92E-01 | 1.04E-01 | 2.31E-01 | 1.63E-01 |
| 1999 | 16 | 103.0 | 1.44E-01 | 1.17E-01 | 1.76E-01 | 9.70E-02 | 2.20E-01 | 1.53E-01 |
| 2000 | 12 | 103.3 | 1.36E-01 | 1.13E-01 | 1.63E-01 | 6.77E-02 | 1.75E-01 | 1.16E-01 |
| 2001 | 13 | 103.0 | 1.28E-01 | 1.09E-01 | 1.50E-01 | 7.51E-02 | 1.86E-01 | 1.26E-01 |
| 2002 | 14 | 103.0 | 1.21E-01 | 1.05E-01 | 1.40E-01 | 8.23E-02 | 1.98E-01 | 1.35E-01 |
| 2003 | 14 | 103.0 | 1.14E-01 | 9.96E-02 | 1.30E-01 | 8.23E-02 | 1.98E-01 | 1.35E-01 |
| 2004 | 10 | 103.3 | 1.08E-01 | 9.41E-02 | 1.23E-01 | 5.37E-02 | 1.51E-01 | 9.74E-02 |
| 2005 | 6 | 103.0 | 1.02E-01 | 8.82E-02 | 1.17E-01 | 2.74E-02 | 1.04E-01 | 6.04E-02 |
| 2006 | 13 | 103.0 | 9.58E-02 | 8.21E-02 | 1.12E-01 | 7.51E-02 | 1.86E-01 | 1.26E-01 |
| 2007 | 10 | 103.4 | 9.04E-02 | 7.60E-02 | 1.08E-01 | 5.37E-02 | 1.51E-01 | 9.73E-02 |
| 2008 | 10 | 104.3 | 8.53E-02 | 7.01E-02 | 1.04E-01 | 5.32E-02 | 1.50E-01 | 9.65E-02 |
| 2009 | 6 | 104.0 | 8.05E-02 | 6.45E-02 | 1.01E-01 | 2.71E-02 | 1.03E-01 | 5.99E-02 |
| 2010 | 8 | 104.0 | 7.60E-02 | 5.92E-02 | 9.76E-02 | 3.99E-02 | 1.27E-01 | 7.83E-02 |
| 2011 | 9 | 104.0 | 7.17E-02 | 5.43E-02 | 9.48E-02 | 4.66E-02 | 1.39E-01 | 8.75E-02 |

Table 28. Plot data for normally running MDP FTR events trend. Figure 18

| FY | Failures | Reactor Years | Regression Curve Data Points | | | Plot Trend Error Bar Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 23 | 103.0 | 1.77E-01 | 1.24E-01 | 2.53E-01 | 1.51E-01 | 3.00E-01 | 2.21E-01 |
| 1999 | 17 | 103.0 | 1.69E-01 | 1.23E-01 | 2.33E-01 | 1.05E-01 | 2.34E-01 | 1.64E-01 |
| 2000 | 19 | 103.3 | 1.62E-01 | 1.22E-01 | 2.14E-01 | 1.20E-01 | 2.55E-01 | 1.83E-01 |
| 2001 | 16 | 103.0 | 1.55E-01 | 1.21E-01 | 1.99E-01 | 9.79E-02 | 2.22E-01 | 1.55E-01 |
| 2002 | 18 | 103.0 | 1.48E-01 | 1.18E-01 | 1.85E-01 | 1.13E-01 | 2.45E-01 | 1.74E-01 |
| 2003 | 10 | 103.0 | 1.42E-01 | 1.15E-01 | 1.74E-01 | 5.44E-02 | 1.53E-01 | 9.86E-02 |
| 2004 | 9 | 103.3 | 1.36E-01 | 1.11E-01 | 1.66E-01 | 4.74E-02 | 1.41E-01 | 8.89E-02 |
| 2005 | 9 | 103.0 | 1.30E-01 | 1.05E-01 | 1.60E-01 | 4.75E-02 | 1.41E-01 | 8.92E-02 |
| 2006 | 12 | 103.0 | 1.24E-01 | 9.85E-02 | 1.56E-01 | 6.86E-02 | 1.77E-01 | 1.17E-01 |
| 2007 | 12 | 103.4 | 1.19E-01 | 9.16E-02 | 1.54E-01 | 6.83E-02 | 1.76E-01 | 1.17E-01 |
| 2008 | 18 | 104.3 | 1.13E-01 | 8.47E-02 | 1.52E-01 | 1.12E-01 | 2.42E-01 | 1.72E-01 |
| 2009 | 24 | 104.0 | 1.09E-01 | 7.80E-02 | 1.51E-01 | 1.58E-01 | 3.08E-01 | 2.28E-01 |
| 2010 | 8 | 104.0 | 1.04E-01 | 7.16E-02 | 1.51E-01 | 4.03E-02 | 1.28E-01 | 7.90E-02 |
| 2011 | 9 | 104.0 | 9.93E-02 | 6.55E-02 | 1.50E-01 | 4.70E-02 | 1.40E-01 | 8.83E-02 |

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