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# Enhanced Component Performance Study: Turbine-Driven Pumps 1998–2022

July 2023

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# ABSTRACT

This report presents an enhanced performance evaluation of turbine-driven pumps (TDPs) at U.S. commercial nuclear power plants. The data used in this study are based on the operating experience failure reports from calendar year 1998 through 2022 as reported in the Institute of Nuclear Power Operations (INPO) Industry Reporting and Information System (IRIS). The TDP failure modes considered for standby systems are fail to start (FTS), fail to run (FTR) for one hour of operation (FTR≤1H), FTR after one hour of operation (FTR>1H), and for normally running systems FTS and FTR. An eight-hour unreliability estimate is also calculated and trended. The component reliability estimates and the reliability data are trended for the most recent 10-year period while yearly estimates for reliability are provided for the entire study period.

No increasing trends were identified for TDPs for the most recent 10-year period:

The following decreasing trends were identified for TDPs for the most recent 10-year period:

- Standby TDP FTR>1H failure rate
- Normally running TDP FTR failure rate
- Standby TDP unavailability
- Standby MDP total unreliability (8-hour mission)
- Standby TDP frequency of start demands (demands per reactor year)
- Standby TDP frequency of FTR≤1H hours (hours per reactor year)
- Standby TDP frequency of FTR>1H events (failures per reactor year)
- Normally running TDP frequency of start demands
- Normally running TDP frequency of run hours
- Normally running TDP frequency of FTR events.

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# ACRONYMS

| | |
|---|---|
| AFW | auxiliary feed water |
| AOV | air-operated valve |
| CCF | common-cause failure |
| CNID | constrained noninformative prior distribution |
| EDG | emergency diesel generator |
| EPIX | Equipment Performance and Information Exchange |
| EPS | emergency power supply |
| ESF | engineered safety feature |
| FTR≤1H | fail to run for one hour of operation |
| FTR>1H | fail to run after one hour of operation |
| FTR | fail to run |
| FTS | fail to start |
| HPCI | high-pressure coolant injection |
| HPCS | high-pressure core spray |
| ICES | INPO Consolidated Events Database |
| INL | Idaho National Laboratory |
| INPO | Institute of Nuclear Power Operations |
| IRIS | Industry Reporting and Information System |
| MDP | motor-driven pump |
| MFW | main feed water |
| MOV | motor-operated valve |
| MSPI | Mitigating Systems Performance Index |
| NPRDS | Nuclear Plant Reliability Data System |
| NRC | Nuclear Regulatory Commission |
| OLS | ordinary least squares |
| PMT | post maintenance testing |
| PRA | probabilistic risk assessment |
| RCIC | reactor core isolation cooling |
| SPAR | standardized plant analysis risk |
| TDP | turbine-driven pump |
| UA | unavailability |

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# Enhanced Component Performance Study: Turbine-Driven Pumps 1998–2022

## 1. INTRODUCTION

This report presents an enhanced performance evaluation of turbine-driven pumps (TDPs) at U.S. commercial nuclear power plants from 1998 through 2022. The objective of each updated component performance study is to obtain annual performance trends of failure rates and probabilities and to present an analysis of factors that could influence the component trends. This year's update continues with the two changes implemented in the 2016 update that are different from earlier updates: (1) the update results are based on calendar year instead of the federal fiscal year, and (2) the failure events included in the update are "hard" failures (i.e., the p-values indicating the likelihood the component would have failed during a 24-hour mission are 1.0). Previous updates (2015 and before) include lesser p-values indicating a degraded condition that probably would have caused failure during a 24-hour mission but were not quite hard failures at their outset.

The enhanced component performance studies are conducted for the following component types: air-operated valves (AOVs), emergency diesel generators (EDGs), motor-driven pumps (MDPs), motor-operated valves (MOVs), and TDPs. The TDP performance analysis was originally published as NUREG-1715, Volume 1, in April 2000 [1], and then updated annually in a series of reports, with the last one being documented in INL/RPT-22-66598, *Enhanced Component Performance Study: Turbine-Driven Pumps 1998-2020* [2]. The Nuclear Regulatory Commission (NRC) Reactor Operational Experience Results and Databases webpage provides the link to the historical and current results of component performance studies (http://nrcoe.inl.gov/CompPerf). An overview of the trending methods, glossary of terms, and abbreviations is documented in the paper *Overview and Reference* [3] that can also be found from https://nrcoe.inl.gov/.

The data used in this study are based on the operating experience failure reports from Institute of Nuclear Power Operations (INPO) *Industry Reporting and Information System (IRIS)* [4], formerly the Equipment Performance and Information Exchange Database (EPIX) and INPO Consolidated Events Database (ICES) [5]. Maintenance unavailability (UA) performance data came from the Reactor Oversight Process program's Mitigating Systems Performance Index (MSPI) program [6] and IRIS. Previously, the study relied on operating experience obtained from licensee event reports, Nuclear Plant Reliability Data System (NPRDS), and EPIX. The IRIS database (which includes the MSPI designated devices as a subset) has matured to the point where both component availability and reliability can be estimated with a high degree of accuracy.

TDPs are categorized as either standby or normally running. The TDP failure modes considered for standby systems are fail to start (FTS), fail to run (FTR) for one hour of operation (FTR≤1H), and FTR after one hour of operation (FTR>1H). The TDP failure modes considered for normally running systems are FTS and FTR. Annual failure probabilities (failures per demand) are provided for FTS and FTR≤1H events. Annual failure rates (failures per run hour) are provided for FTR > 1H and FTR events. TDP train maintenance unavailability probabilities are also considered. In addition to the presentation of the component failure mode data and the UA data, an 8-hour total unreliability is calculated and trended. Each of the estimates is trended for the most recent 10-year period while yearly estimates are provided for the entire study period.

While this report provides an overview of operational data and evaluates component performance over time, it makes no attempt to estimate values for use in probabilistic risk assessments (PRAs) or Standardized Plant Analysis Risk (SPAR) models. The *2020 Parameter Update* documented in INL/EXT-21-65055 [7] is the most recent update to NUREG/CR-6928, *Industry-Average Performance for Components and Initiating Events at U.S Commercial Nuclear Power Plants* [8], using data through 2020 and provides component unreliability estimates for SPAR models. Estimates from that report are included herein for comparison. Those estimates are labelled "SPAR 2020" in the associated tables and figures.

Section 2 of this report presents the summary of findings from the study, with particular emphasis on the existence of any statistically significant increasing or decreasing trends in component performances. Section 3 provides the annual estimates of failure probabilities and rates related to TDPs as well as the trending of the estimates. Section 4 provides TDP train UA estimates and their trends. Section 5 estimates the annual total unreliability and the trends for TDPs. Section 6 presents various engineering analyses performed for TDPs such as the trend for demands/run hours per plant reactor year, the trend for failures per plant reactor year, and the breakdown of TDP failures by subcomponents, failure causes, detection methods, and recovery possibility. A comparison of IRIS TDP unplanned demand results with the *2020 Parameter Update* for standby TDPs is also conducted in Section 6 in order to determine whether the current data are consistent with the estimated values used in PRA. Section 7 provides the TDP assembly information. Section 8 presents the plot data for various figures in previous sections.

# 2. SUMMARY OF FINDINGS

The results of this study are summarized in this section. Of particular interest is the existence of any statistically significant[a] increasing trends.

## 2.1 Increasing Trends

### 2.1.1 Extremely Statistically Significant

- None.

### 2.1.2 Highly Statistically Significant

- None.

### 2.1.3 Statistically Significant

- None.

## 2.2 Decreasing Trends

### 2.2.1 Extremely Statistically Significant

- An extremely statistically significant **decreasing trend** was identified in the **standby TDP unavailability** estimates with a p-value of 0.0002 (see Figure 6). The same trend was observed in the *2020 TDP Update* study [2].
- An extremely statistically significant **decreasing trend** was identified in the **standby TDP unreliability (8-hour mission)** estimates with a p-value of 0.0007 (see Figure 7). The same trend was observed in the *2020 TDP Update* study as highly statistically significant.
- An extremely statistically significant **decreasing trend** was identified in the **standby TDP frequency of FTR>1H events** estimates with a p-value of 0.0003 (see Figure 14). The same trend was observed in the *2020 TDP Update* study as highly statistically significant.
- An extremely statistically significant **decreasing trend** was identified in the **normally running TDP frequency of run hours** estimates with a p-value of 0.0009 (see Figure 16). The same trend was observed in the *2020 TDP Update* study.

### 2.2.2 Highly Statistically Significant

- A highly statistically significant **decreasing trend** was identified in the **standby TDP FTR>1H failure rate** estimates with a p-value of 0.001 (see Figure 3). The same trend was observed in the *2020 TDP Update* study as statistically significant.
- A highly statistically significant **decreasing trend** was identified in **normally running TDP FTR failure rate** estimates with a p-value of 0.0027 (see Figure 5). This is a new trend that was not observed in the *2020 TDP Update* study.
- A highly statistically significant **decreasing trend** was identified in **normally running TDP frequency of start demands** estimates with a p-value of 0.001 (see Figure 15). The same trend was observed in the *2020 TDP Update* study.

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a. 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 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).

- A highly statistically significant **decreasing trend** was identified in the **normally running TDP frequency of FTR events** estimates with a p-value of 0.0024 (see Figure 18). This is a new trend that was not observed in the *2020 TDP Update* study.

### 2.2.3 Statistically Significant

- A statistically significant **decreasing trend** was identified in the **standby TDP frequency of start demands** estimates with a p-value of 0.0109 (see Figure 9). This is a new trend that was not observed in the *2020 TDP Update* study.
- A statistically significant **decreasing trend** was identified in the **standby TDP frequency of FTR≤1H hours** estimates with a p-value of 0.0109 (see Figure 10). This is a new trend that was not observed in the *2020 TDP Update* study.

## 2.3 Consistency Check Results

An ongoing concern in the industry is whether industry-average failure estimates adequately predict standby component performance during unplanned (ESF) demands. Section 6.3 provides the results of a consistency check that compare failure predictions obtained via simulation tests on industry-average parameters from the *2020 Parameter Update* against operational failure counts obtained from actual TDP performance with ESF demands. These consistency checks show that the FTS and FTR>1H failure observations in the non-test, operational ESF demand data lie within the corresponding industry-average failure estimate distributions, provided in the *2020 Parameter Update* (Table 2), that were based on both test and non-test operational ESF demands. However, the FTR≤1H failure observations are not consistent with the industry-average failure estimate distributions, which means that the TDP performs worse on an actual non-test, operational ESF demand than on a test demand.

# 3. FAILURE PROBABILITIES AND FAILURE RATES

## 3.1 Overview

TDPs are categorized as either standby or normally running. The industry-wide failure probabilities and failure rates have been calculated from the operating experience for standby pump FTS, FTR≤1H, and FTR>1H, and for normally running pumps FTS and FTR. The TDP data set obtained from IRIS includes TDPs in the systems listed in Table 1. This report follows the definition of these categories in previous studies, which determines the status by evaluating the number of run-hours per demand. The pumps with low run-hours per demand (≤360) are considered standby while those with higher run-hours per demand (>360) are considered normally running.

Table 2 shows industry-wide failure probability and failure rate results for the TDP from *2020 Parameter Update* [7]. The *2020 Parameter Update* results are provided for comparison purposes and are important because they are intended for use in PRA. The results in this section demonstrate the extent to which the *2020 Parameter Update* results remain suitable estimates for use in PRA.

The TDPs are assumed to operate both when the reactor is critical and during shutdown periods with sufficient steam pressure. The number of TDPs in operation is the number that have been in operation at any time during the study period. New devices put in service during the period are included, as are devices that were in service at one time but have since been removed from service. All demand types are considered—testing, non-testing, and, as applicable, ESF demands. Non-test demands are those actual plant demands that are not ESF demands.

Table 1. TDP systems.

| System | Description | Total | Normally Running | Standby |
|---|---|---|---|---|
| AFW | Auxiliary feed water | 75 | | 75 |
| HPCI | High-pressure coolant injection | 28 | | 28 |
| MFW | Main feed water | 43 | 43 | |
| RCIC | Reactor core isolation cooling | 31 | | 31 |
| | Total | 177 | 43 | 134 |

Table 2. Industry-wide distributions of p (failure probability) and λ (hourly rate) in the *2020 Parameter Update* for TDPs [7].

| Operation | Failure Mode | 5% | Median | Mean | 95% | Distribution | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Type | $\alpha$ | $\beta$ |
| Standby | FTS | 4.59E-4 | 4.02E-3 | 5.32E-3 | 1.47E-2 | Beta | 1.26 | 2.35E+02 |
| | FTR≤1H | 5.17E-6 | 1.04E-3 | 2.56E-3 | 1.03E-2 | Gamma | 0.44 | 1.73E+02 |
| | FTR>1H | 1.23E-5 | 2.56E-3 | 6.35E-3 | 2.55E-2 | Gamma | 0.44 | 6.95E+01 |
| Running/ Alternating | FTS | 5.45E-5 | 2.52E-3 | 4.60E-3 | 1.62E-2 | Beta | 0.63 | 1.37E+02 |
| | FTR | 2.53E-7 | 5.37E-6 | 8.45E-6 | 2.71E-5 | Gamma | 0.82 | 9.76E+04 |

## 3.2 TDP Failure Probability and Failure Rate Trends

This section estimates industry-wide annual failure probabilities and failure rates for standby and normally running TDPs in the entire study period which covers 1998 through 2022. The estimates are trended for the most recent 10-year period.

The failure probability and failure rate estimates in this section were obtained from a Bayesian update process. The means from the posterior distributions were plotted for each year. The 5th and 95th percentiles from the posterior distributions are also provided and give an indication of the relative uncertainty in the estimated parameters from year to year. When there are no failures, the interval is larger than the interval for years when there are one or more failures because of the form of the posterior variance. Each update utilizes a relatively "flat" constrained noninformative prior distribution (CNID), which has wide bounds [3, 9]. CNID is a compromise between an informative prior and the Jeffreys noninformative prior. The mean of the CNID uses prior belief and is based on a pooling of the component or event type data for the years going into the plot (i.e., the most recent 10-year period), but the dispersion is defined to correspond to little information (i.e., relatively flat by set) so that the prior distributions do not create large changes in the data.

For **failure rates** or Poisson data, the CNID is a gamma distribution, with the mean ($\mu$) given by prior belief and calculated as:

$$\mu = \frac{\sum f_i + 0.5}{\sum T_i} \tag{1}$$

where $f_i$ and $T_i$ are the failures and operating/standby time for the i$^{th}$ year, respectively. The CNID shape parameter ($\alpha$) is a constant number of 0.5. The posterior distribution mean for the i$^{th}$ year ($\mu_i$) can be calculated as:

$$\mu_i = \frac{f_i + 0.5}{\frac{0.5}{\mu} + T_i} \tag{2}$$

For **failure probabilities** or binomial data, the CNID is a beta distribution, with the mean given by prior belief and calculated as:

$$\mu = \frac{\sum f_i + 0.5}{\sum D_i + 1} \tag{3}$$

where $f_i$ and $D_i$ are the failures and demands for the i$^{th}$ year, respectively. The CNID shape parameter ($\alpha$) is a number between 0.3 and 0.5 based on the mean μ (see Table C.8 of [9]). The posterior distribution mean for the i$^{th}$ year ($\mu_i$) can be calculated as:

$$\mu_i = \frac{f_i + \alpha}{\frac{\alpha}{\mu} + D_i} \tag{4}$$

The horizontal curves plotted around the regression lines in the graphs form 90% simultaneous confidence bands for the fitted lines. The bounds are larger than ordinary confidence bands for the individual coefficients because they form a confidence band for 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 to assess evidence against the slope of the regression line being zero. Low p-values indicate strong evidence that the slopes are not zero and, therefore, suggest a trend does exist. P-values of less than or equal to 0.05 indicate strong evidence that there is a trend in the data (reject the null hypothesis of no trend). By convention, this study uses the Michelin Guide scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

The regression methods are all based on ordinary least squares (OLS), which minimizes the residuals, or the square of the vertical distance between the annual data points and the fitted regression line. The p-values assume normal distributions for the residuals, with the same variability in the residuals across the years. In the case where the data involve failure counts, the iterative reweighted least squares method is

used to account for the fact that count data are not expected to have a constant variance (for example, the variance for Poisson-distributed counts is equal to the expected number of counts, which is expected to vary proportionally to the expected number of counts). Further information on the trending methods is provided in Section 2 of *Overview and Reference* [3].

A final feature of the trend graphs is that the baseline industry values from the *2020 Parameter Update* (Table 2) are shown as "SPAR 2020" in the graphs for comparison.

Figure 1 to Figure 5 provide the plots for industry-wide failure probabilities/rates of standby and normally running TDPs. The data for these plots are provided in Section 8:

- Figure 1 shows the failure probability estimate trends for standby TDP FTS
- Figure 2 shows the failure probability estimate trends for standby TDP FTR≤1H
- Figure 3 shows the failure rate estimate trends for standby TDP FTR>1H
- Figure 4 shows the failure probability estimate trends for normally running TDP FTS
- Figure 5 shows the failure rate estimate trends for normally running TDP FTR.

The following trend was identified for TDP failure probabilities/rates for FTS, FTR≤1H, and FTR>1H events in the most recent 10-year period:

- **Decreasing trend** in the **standby TDP FTR>1H failure rate** estimates, which is highly statistically significant with a p-value of 0.001 (see Figure 3). The same trend was observed in the *2020 TDP Update* study as statistically significant [2]
- **Decreasing trend** in the **normally running TDP FTR failure rate** estimates, which is highly statistically significant with a p-value of 0.0027 (see Figure 5). This is a new trend that was not observed in the *2020 TDP Update* study.

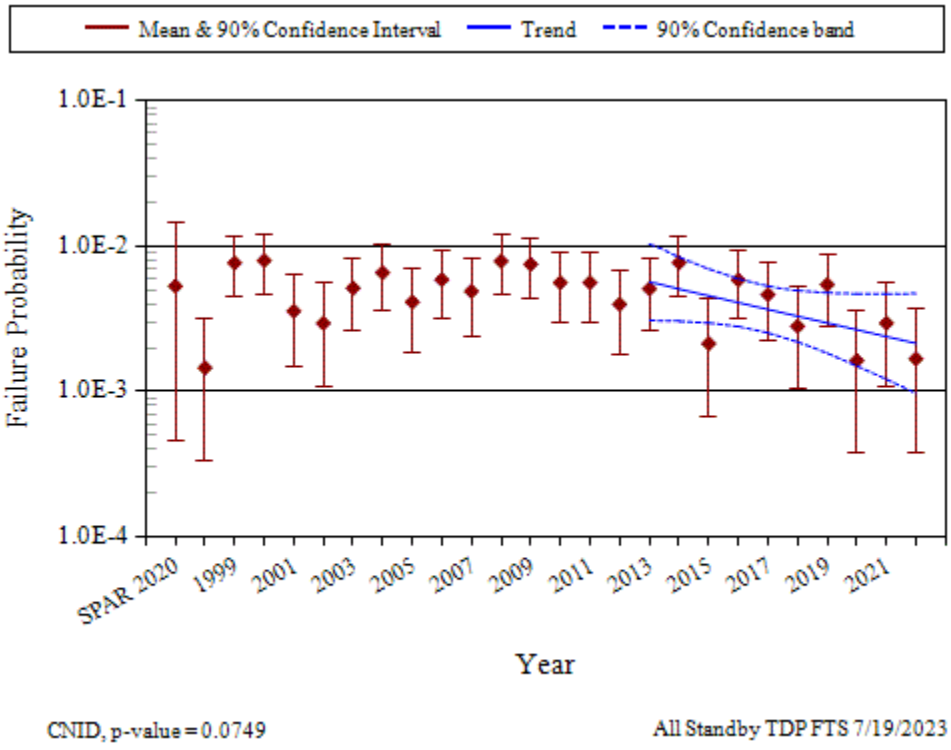


Figure 1. Failure probability estimate trend for standby TDP FTS.

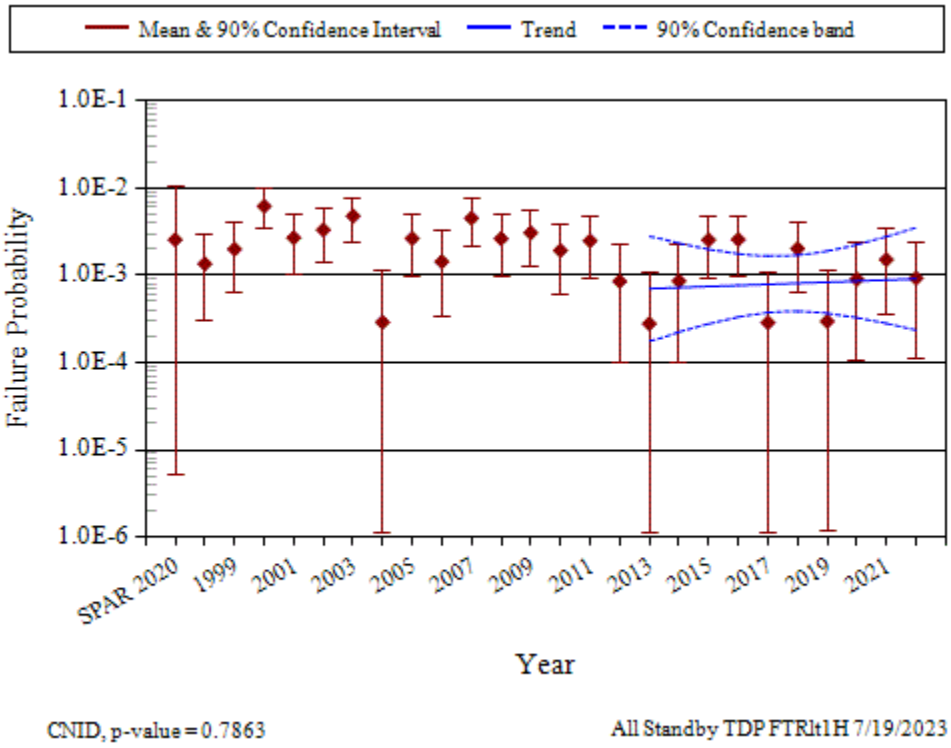


Figure 2. Failure probability estimate trend for standby TDP FTR≤1H.

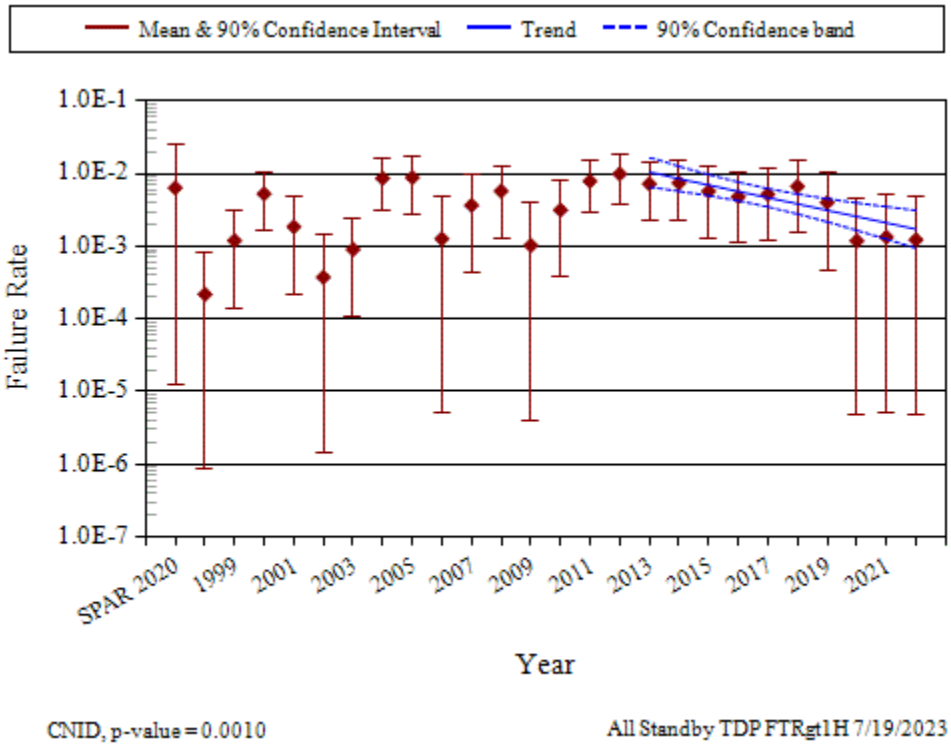


Figure 3. Failure rate estimate trend for standby TDP FTR>1H.

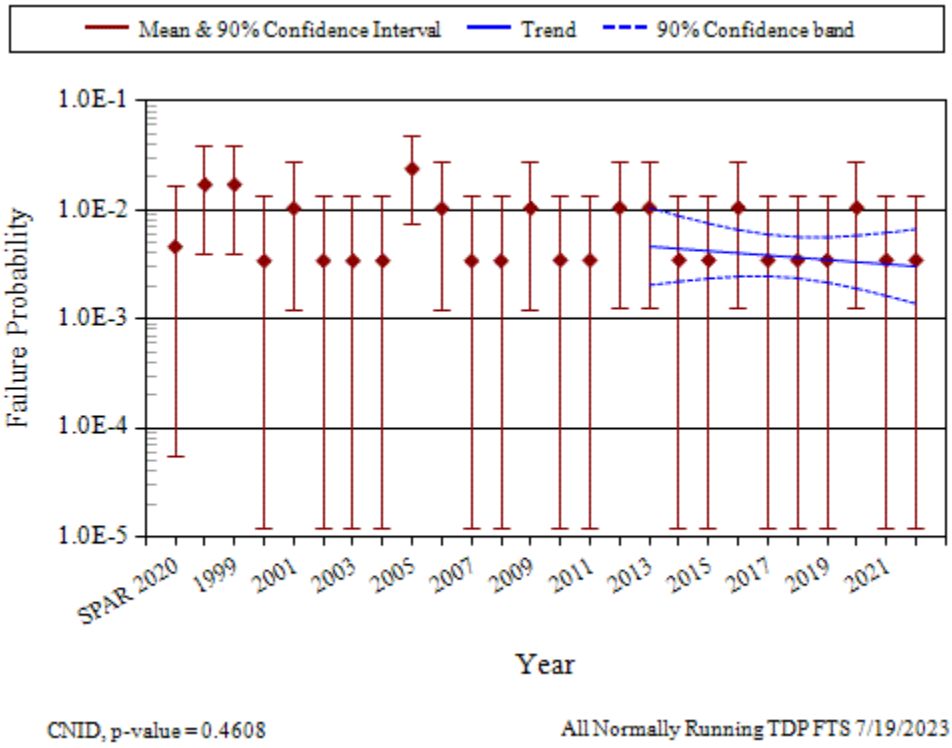


Figure 4. Failure probability estimate trend for normally running TDP FTS.

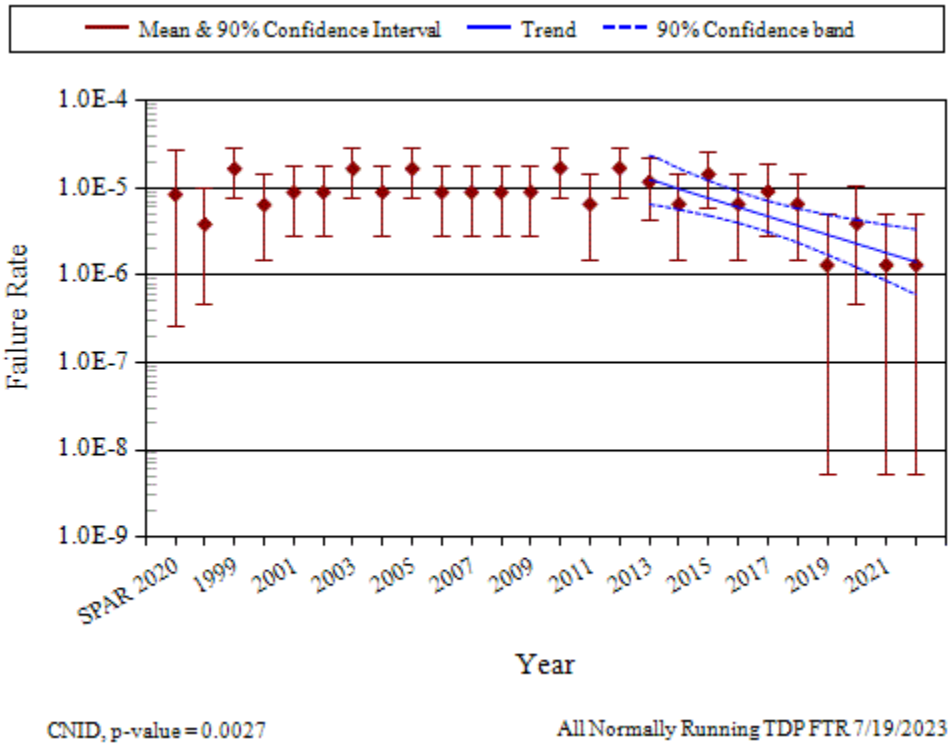


Figure 5. Failure rate estimate trend for normally running TDP FTR.

# 4. UNAVAILABILITY

## 4.1 Overview

The industry-wide test or maintenance UA of TDP trains has been calculated from operating experience. UA data are for TDP trains, which can include more than just the TDP. However, in most cases the TDP contributes the majority of the UA reported. Table 3 shows overall results for the TDP from the *2020 Parameter Update* [7] which is based on UA data from the IRIS database (which includes the MSPI designated devices as a subset). In the calculations, planned and unplanned unavailable hours for a train are combined.

Table 3. Industry-average distributions of unavailability in the *2020 Parameter Update* [7] for TDPs.

| Description | Distribution | Mean | α | β |
|---|---|---|---|---|
| TDP Test or Maintenance (AFW) | Normal | 4.64E-3 | 0.0046 | 0.0030 |
| TDP Test or Maintenance (HPCI) | Normal | 1.11E-2 | 0.0111 | 0.0028 |
| TDP Test or Maintenance (RCIC) | Normal | 1.01E-2 | 0.0101 | 0.0043 |
| TDP Test or Maintenance (All) | Normal | 7.30E-3 | 0.0073 | 0.0044 |

## 4.2 TDP Unavailability Trends

This section presents overall maintenance UA data for the 1998–2022 period. Note that these data do not supersede the data in Table 3 for use in risk assessments.

The trend in standby TDP train unavailability is shown in Figure 6. The data for this figure is in Section 8. The TDPs in the systems with maintenance UA data currently analyzed (e.g., AFW, HPCI, and RCIC) are pooled and trended. The trend chart shows the results of using data for each year's component UA data over time. The yearly unavailability and reactor critical hour data were obtained from the Reactor Oversight Process program (1998 to 2001) and IRIS (2002 to 2022) data for the TDP component. The total downtimes during operation for each plant and year were summed and divided by the corresponding number of TDP-reactor critical hours. UA data for shutdown periods are not reported.

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

For the trend graphs, a least squares fit is sought for the linear or logit model depending upon which is more appropriate. Section 3 in *Overview and Reference* provides further information [3]. In the lower left-hand corner of the trend figures, the regression method and the p-value are reported. A review of the p-value identified the following trend for the most recent 10-year period:

- **Decreasing trend** in the **standby TDP unavailability** estimates, which is extremely statistically significant with a p-value of 0.0002 (see Figure 6). The same trend was observed in the *2020 TDP Update* study [2]
- **Decreasing trend** in the **standby TDP unreliability (8-hour mission)** estimates, which is extremely statistically significant with a p-value of 0.0007 (see Figure 7). The same trend was observed in the *2020 TDP Update* study as highly statistically significant.

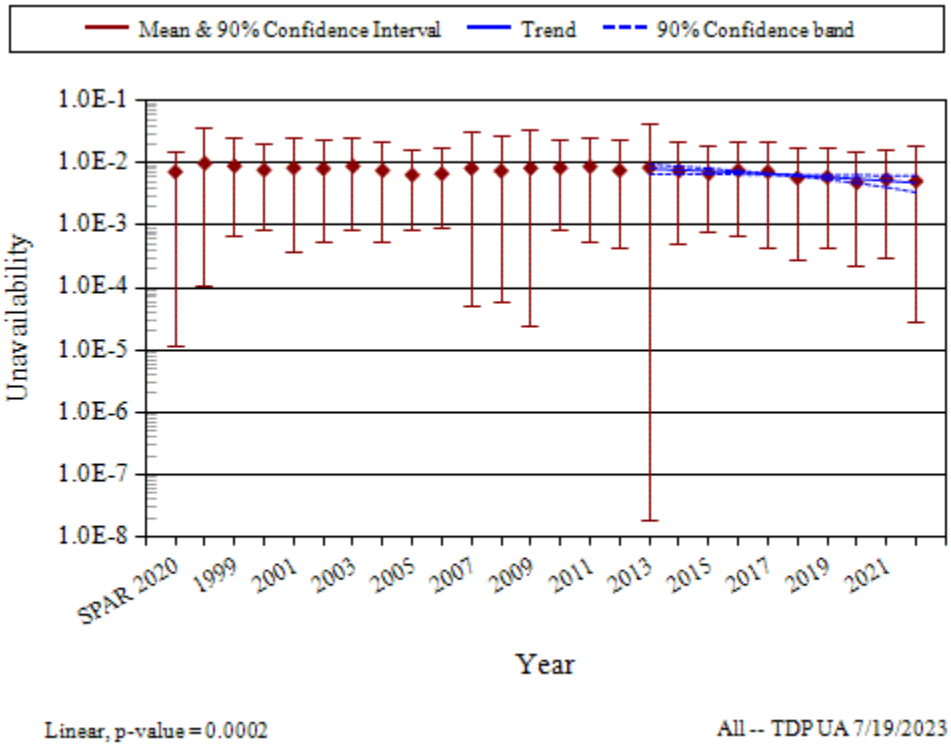


Figure 6. Pooled standby TDP UA trend.

# 5. TDP UNRELIABILITY TRENDS

Trends in total component unreliability are shown in Figure 7 and Figure 8. Plot data for these figures are in Section 8. Total unreliability is defined as the result of the union of the UA, FTS, FTR≤1H, and FTR>1H (or FTR) failure probabilities. 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 TDP components do not have UA data or the FTR≤1H data, there is no UA or FTR≤1H for that calculation. The trending method is described in more detail in Section 4 of *Overview and Reference* [3]. In the lower left-hand corner of the trend figures, the regression method and the p-value are reported. A review of the p-value identified the following trend for the most recent 10-year period:

- **Decreasing trend** in the **standby TDP unreliability (8-hour mission)** estimates, which is extremely statistically significant with a p-value of 0.0007 (see Figure 7). The same trend was observed in the *2020 TDP Update* study as highly statistically significant [2].

Because there is no total unreliability estimates in the *2020 Parameter Update*, there is no *2020 Parameter Update* baseline industry values shown in Figure 7 and Figure 8 for comparison purpose.

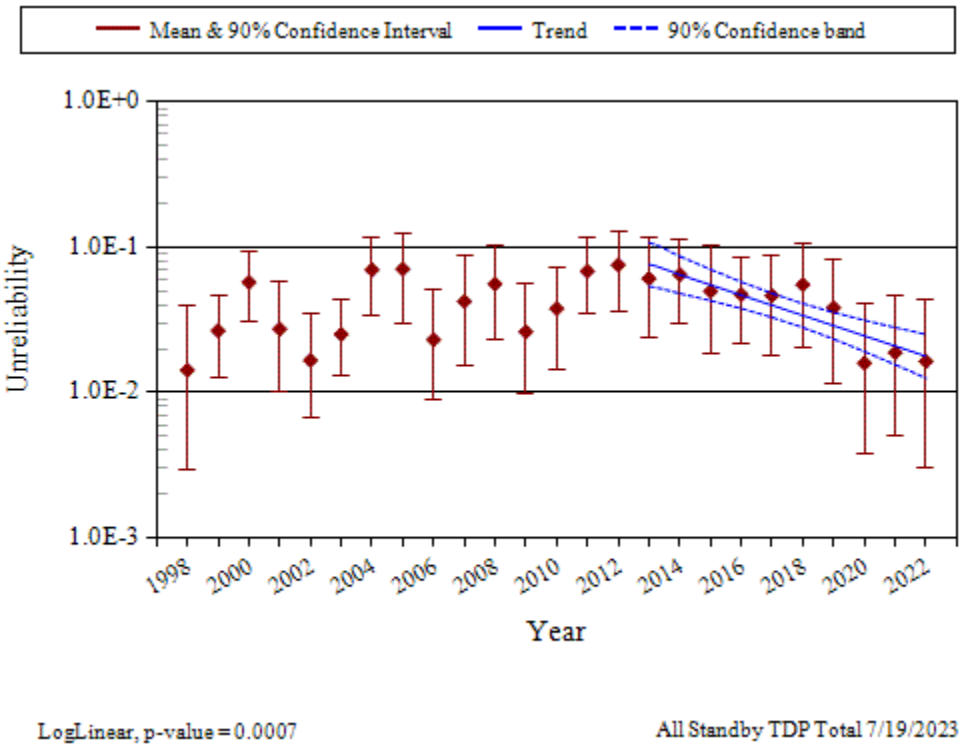


Figure 7. Standby TDP unreliability trend (8-hour mission).

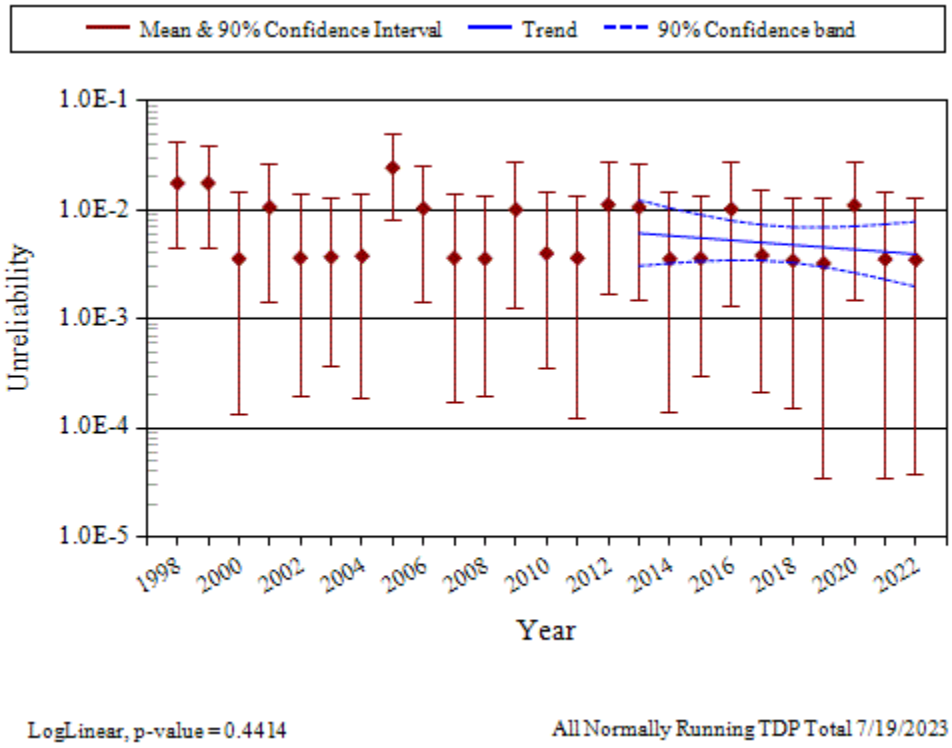


Figure 8. Normally running TDP unreliability trend (8-hour mission).

# 6. ENGINEERING ANALYSIS

This section presents various engineering analyses performed for TDP. Frequency trends of component failures and demands are presented in Sections 6.1 and 6.2 for standby and normally running TDPs, respectively. The data are normalized by reactor year for plants that have the equipment being trended. A comparison of IRIS TDP unplanned demand results with the industry-average results for standby TDPs is presented in Section 6.3 to determine whether the current data are consistent with the *2020 Parameter Update* values used in PRA. An engineering analysis of TDP failure breakdown by failure mode and other factors is presented in Section 6.4. The factors analyzed include subcomponents, failure causes, detection methods, and recovery possibility.

## 6.1 Standby TDP Engineering Trends

This section presents frequency trends for standby TDP failures and demands. The data are normalized by reactor year for plants that have the equipment being trended. The trends provide an overview of the demand counts and failure counts associated with each failure mode across the years.

Figure 9 to Figure 14 provide the plot for frequency (per reactor year) of standby TDP start demands, run < 1H hours, run > 1H hours, FTS events, FTR≤1H events, and FTR>1H events:

- Figure 9 shows the trend for standby TDP frequency of start demands
- Figure 10 shows the trend for standby TDP run hours per reactor year of run ≤ 1H hours
- Figure 11 shows the trend for standby TDP run > 1H hours per reactor year
- Figure 12 shows the trend for standby TDP frequency of FTS events
- Figure 13 shows the trend for standby TDP FTR≤1H events per reactor year
- Figure 14 shows the trend for standby TDP FTR>1H events per reactor year.

The data for the figures listed above are provided in Section 8. The standby systems from Table 1 are trended together for each figure.

In the lower left-hand corner of the trend figures, the regression p-values are reported along with the prior distribution used in the Bayesian update. A review of these p-values identified the following trend for standby TDP for the most recent 10-year period:

- **Decreasing trend** in the **standby TDP frequency of start demand** estimates, which is statistically significant with a p-value of 0.0109 (see Figure 9). This is a new trend that was not observed in the *2020 TDP Update* study [2]
- **Decreasing trend** in the **standby TDP frequency of FTR≤1H hours** estimates, which is statistically significant with a p-value of 0.0109 (see Figure 10). This is a new trend that was not observed in the *2020 TDP Update* study
- **Decreasing trend** in the **standby TDP frequency of FTR>1H events** estimates, which is extremely statistically significant with a p-value of 0.0003 (see Figure 14). The same trend was observed in the *2020 TDP Update* study as highly statistically significant.

Table 4 to Table 6 provide a summary of TDP (both standby and normally running) FTS, FTR≤1H, FTR>1H, and FTR failure counts by system and year during the most recent 10-year period (FTR≤1H and FTR>1H are failure modes for standby TDPs in AFW, HPCI, and RCIC systems, while FTR is the failure mode for normally running TDPs in MFW system):

- Table 4 presents the TDP FTS failure counts by system and year
- Table 5 presents the TDP FTR≤1H failure counts by system and year

- Table 6 presents the TDP FTR>1H failure counts by system and year.

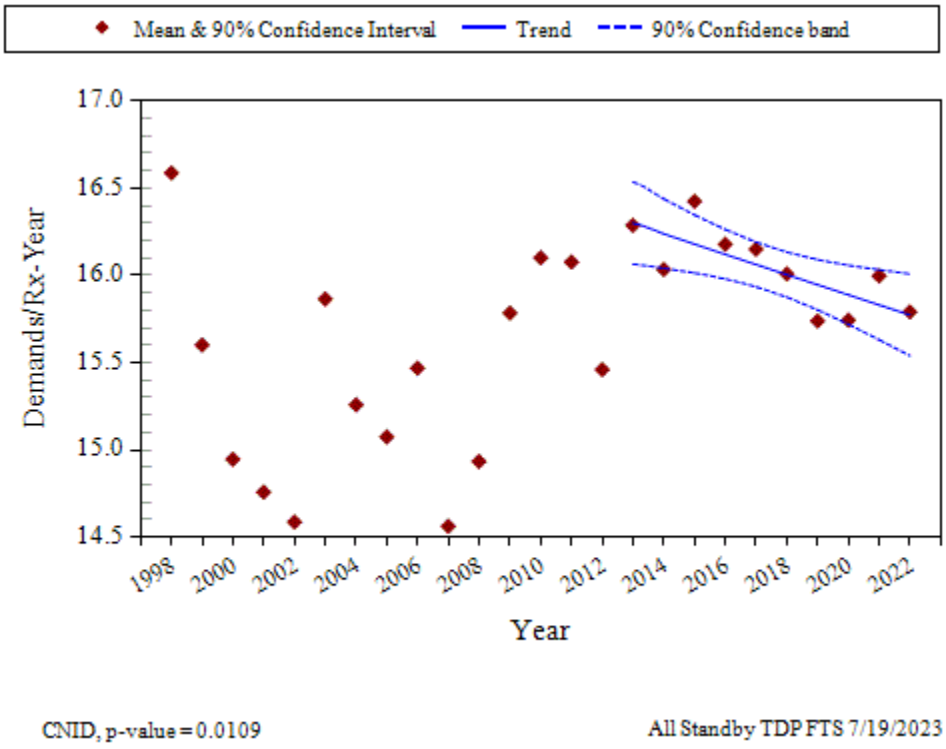


Figure 9. Frequency of start demands (demands per reactor year) for standby TDPs.

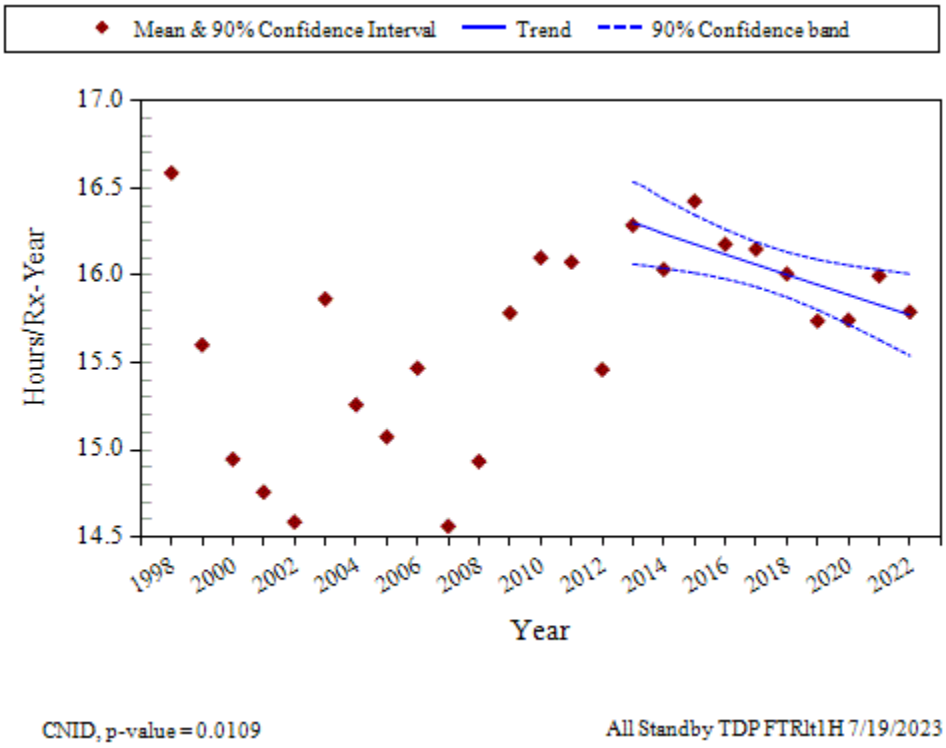


Figure 10. Frequency of run ≤ 1H hours (hours per reactor year) trend for standby TDPs.

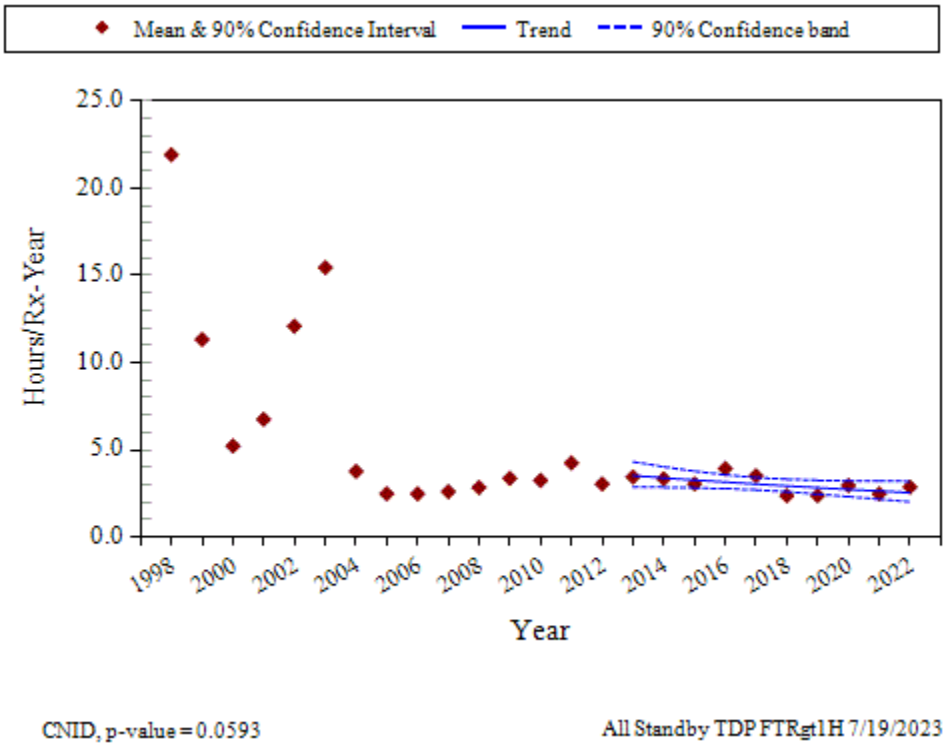


Figure 11. Frequency of run > 1H hours (hours per reactor year) trend for standby TDPs.

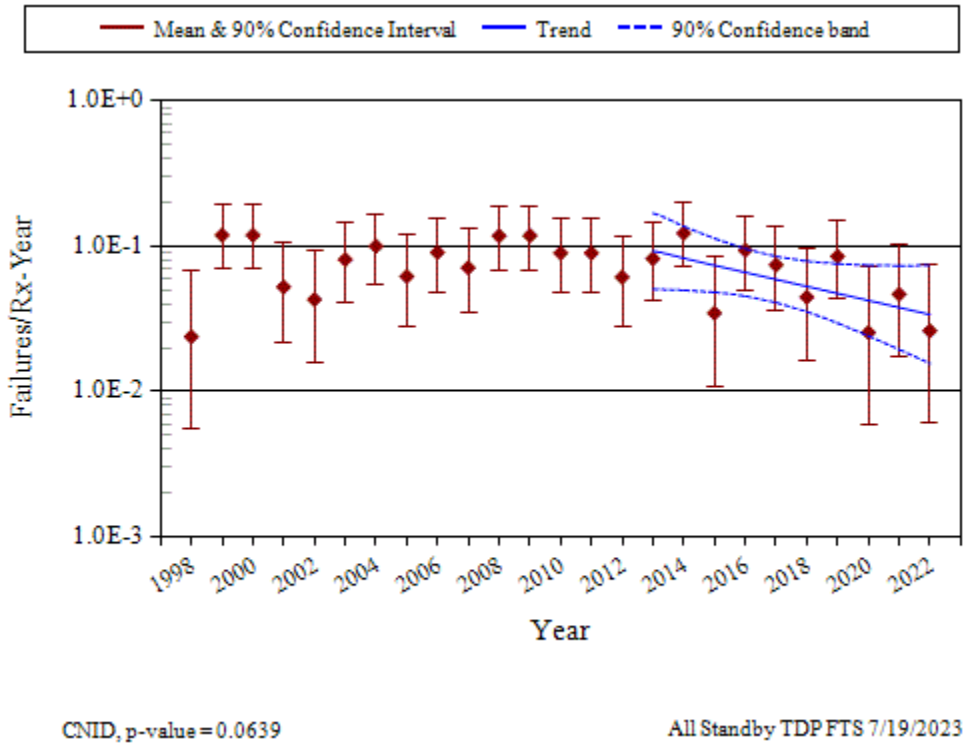


Figure 12. Frequency of FTS events (events per reactor year) trend for standby TDPs.

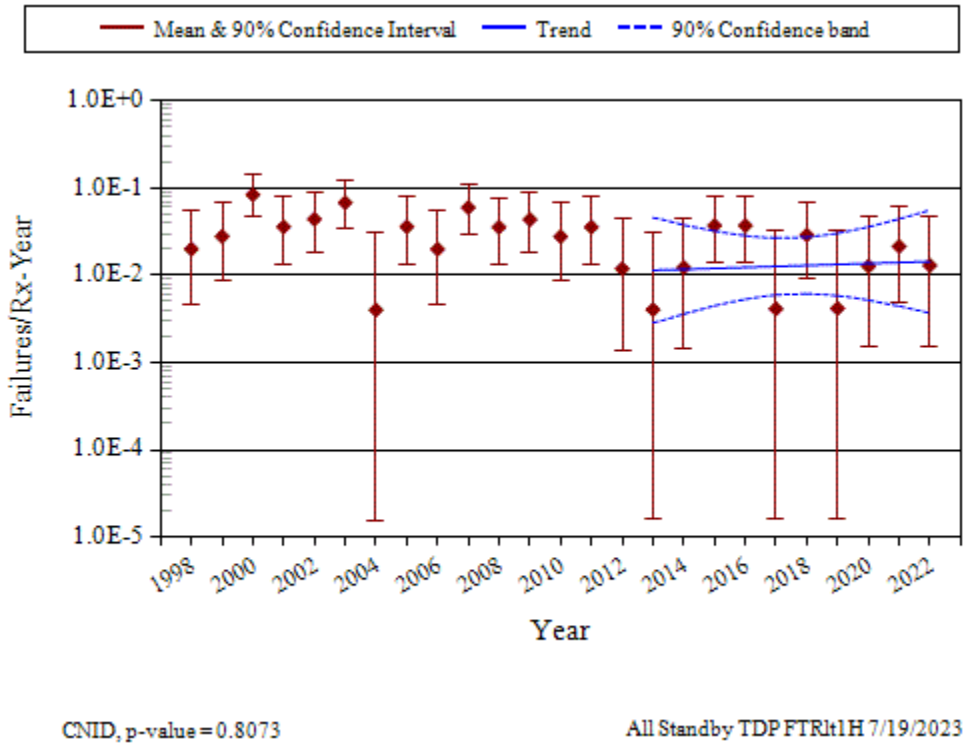


Figure 13. Frequency of FTR≤1H events (events per reactor year) trend for standby TDPs.

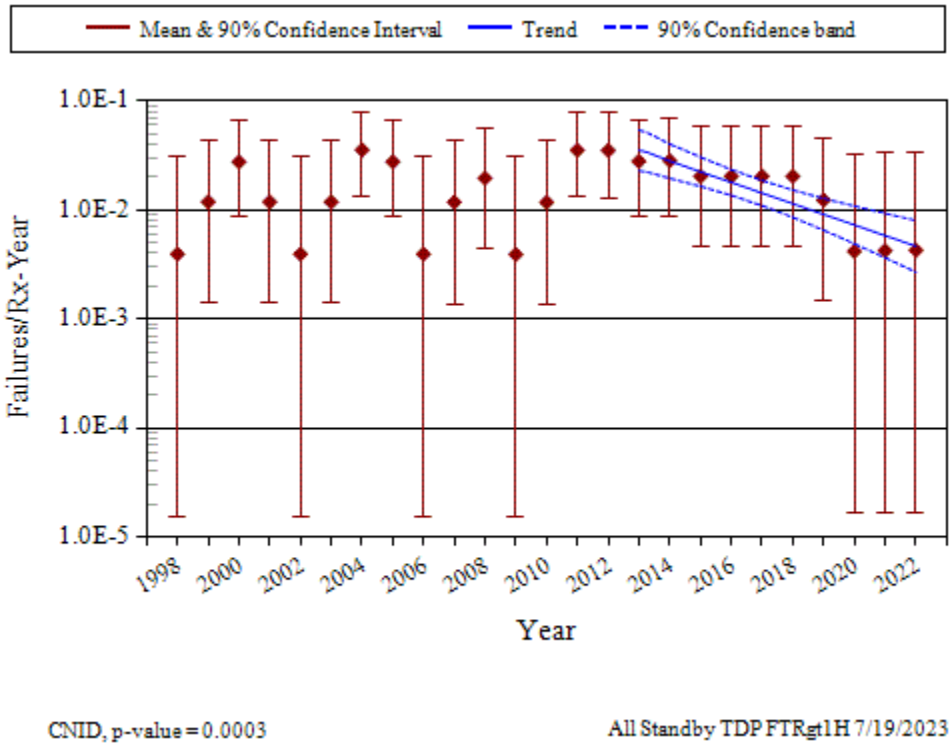


Figure 14. Frequency of FTR>1H events (events per reactor year) trend for standby TDPs.

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

| System Code | TDP Count | TDP Percent | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total | Percent of Failures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 75 | 42.4% | 4 | 11 | 2 | 2 | 4 | 3 | 4 | | 2 | | 32 | 51.6% |
| HPCI | 28 | 15.8% | 3 | | | 4 | 1 | 1 | 4 | 1 | 1 | 1 | 16 | 25.8% |
| MFW | 43 | 24.3% | 1 | | | 1 | | | | 1 | | | 3 | 4.8% |
| RCIC | 31 | 17.5% | 1 | 1 | 1 | 3 | 2 | | | 1 | 1 | 1 | 11 | 17.7% |
| Total | 177 | 100.0% | 9 | 12 | 3 | 10 | 7 | 4 | 8 | 3 | 4 | 2 | 62 | 100.0% |

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

| System Code | TDP Count | TDP Percent | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total | Percent of Failures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 75 | 56.0% | | 1 | 3 | 1 | | 1 | | | | | 6 | 37.5% |
| HPCI | 28 | 20.9% | | | 1 | 2 | | | | | 1 | 1 | 5 | 31.3% |
| RCIC | 31 | 23.1% | | | | 1 | | 2 | | 1 | 1 | | 5 | 31.3% |
| Total | 134 | 100.0% | 0 | 1 | 4 | 4 | 0 | 3 | 0 | 1 | 2 | 1 | 16 | 100.0% |

Table 6. Summary of TDP failure counts for the FTR>1H and FTR failure modes over time by system.[a]

| System Code | TDP Count | TDP Percent | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Total | Percent of Failures |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AFW | 75 | 42.4% | 1 | 2 | 2 | | 1 | 2 | 1 | | | | 9 | 26.5% |
| HPCI | 28 | 15.8% | 1 | | | 1 | | | | | | | 2 | 5.9% |
| MFW | 43 | 24.3% | 4 | 2 | 5 | 2 | 3 | 2 | | 1 | | | 19 | 55.9% |
| RCIC | 31 | 17.5% | 1 | 1 | | 1 | 1 | | | | | | 4 | 11.8% |
| Total | 177 | 100.0% | 7 | 5 | 7 | 4 | 5 | 4 | 1 | 1 | 0 | 0 | 34 | 100.0% |

Note:

a. FTR>1H is a failure mode for standby components (e.g., TDPs in AFW, HPCI, and RCIC systems), while FTR is a failure mode for normally running components (TDPs in MFW system).

## 6.2 Normally Running TDP Engineering Trends

This section presents frequency trends for normally running TDP failures and demands.

Figure 15 to Figure 18 provide the plot for frequency (per reactor year) of normally running TDP start demands, run hours, FTS events, and FTR events:

- Figure 15 shows the trend for normally running TDP frequency of start demands
- Figure 16 shows the trend for normally running TDP run hours per reactor year
- Figure 17 shows the trend for normally running TDP frequency of FTS events
- Figure 18 shows the trend for normally running TDP FTR events per reactor year.

The data for the above figures are provided in Section 8. The normally running system (MFW) from Table 2 is trended for each figure.

In the lower left-hand corner of the trend figures, the regression p-values are reported along with the prior distribution used in the Bayesian update. A review of these p-values identified the following trend for normally running TDP for the most recent 10-year period:

- **Decreasing trend** in the **normally running TDP frequency of start demands** estimates, which is highly statistically significant with a p-value of 0.001 (see Figure 15). The same trend was observed in the *2020 TDP Update* study [2]
- **Decreasing trend** in the **normally running TDP frequency of run hours** estimates, which is extremely statistically significant with a p-value of 0.0009 (see Figure 16). The same trend was observed in the *2020 TDP Update* study.
- **Decreasing trend** in the **normally running TDP frequency of FTR events** estimates, which is highly statistically significant with a p-value of 0.0024 (see Figure 18). This is a new trend that was not observed in the *2020 TDP Update* study.

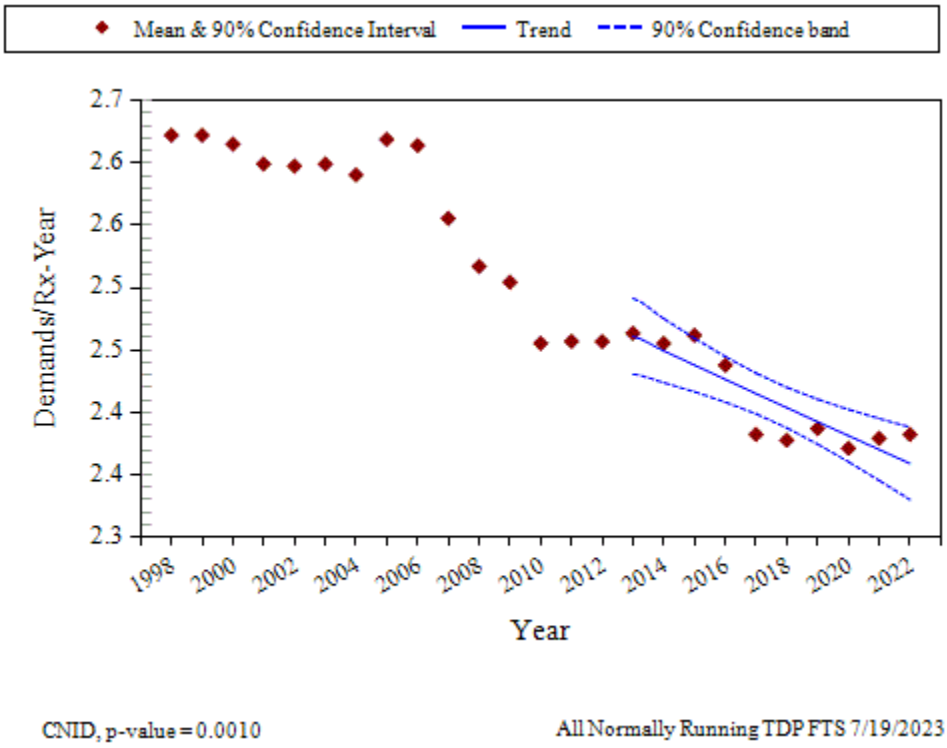


Figure 15. Frequency of start demands (demands per reactor year) trend for normally running TDPs.

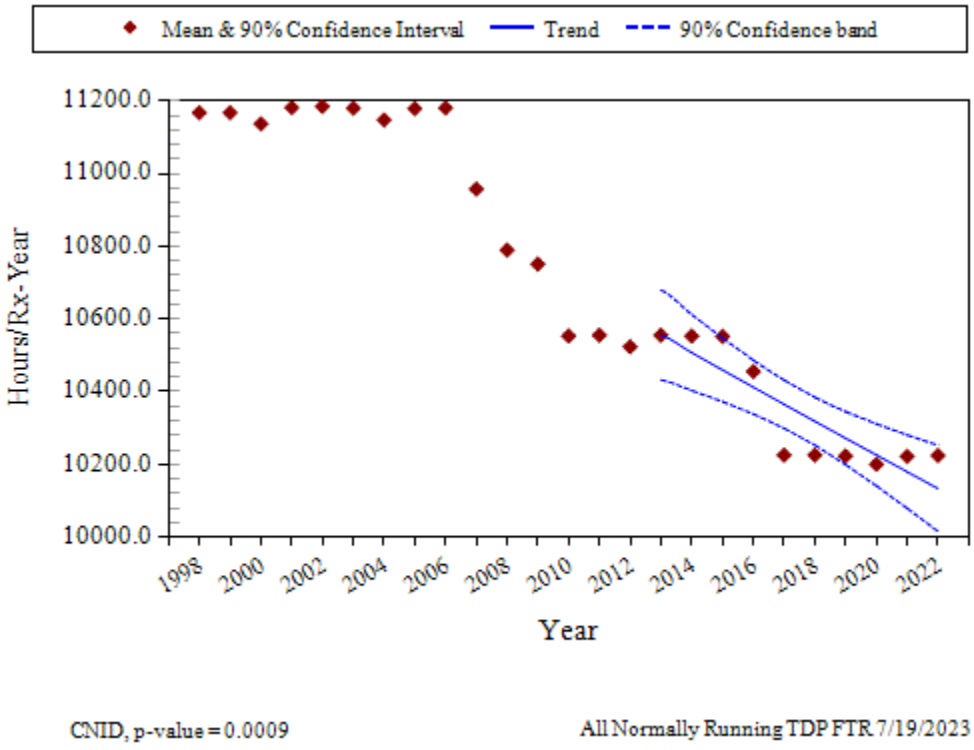


Figure 16. Frequency of run hours (hours per reactor year) trend for normally running TDPs.

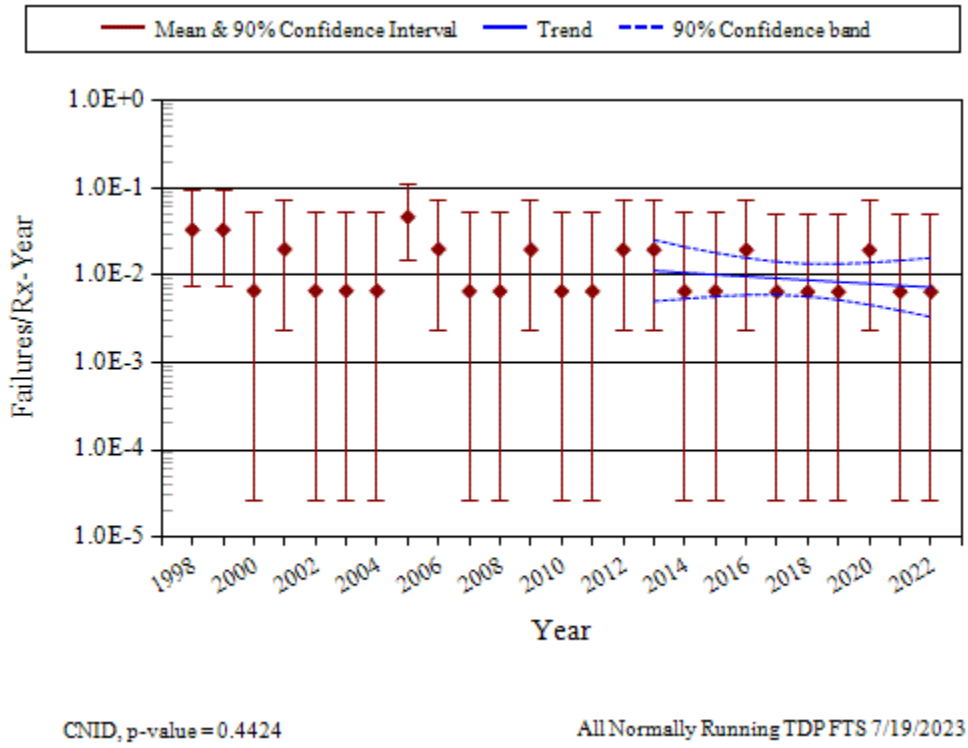


Figure 17. Frequency of FTS events (events per reactor year) trend for normally running TDPs.

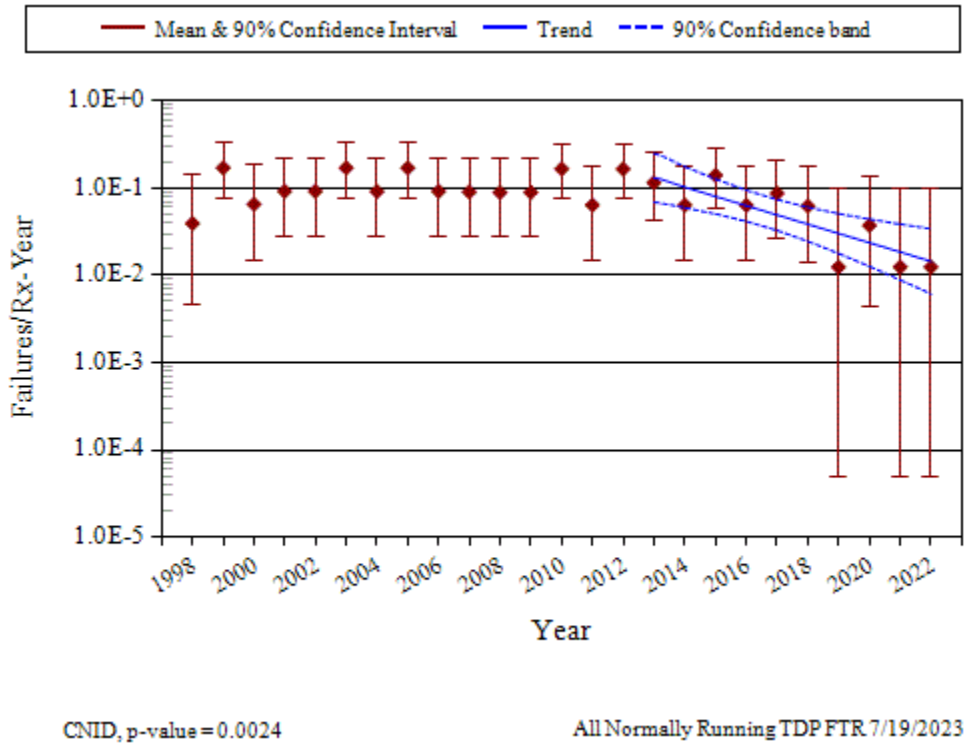


Figure 18. Frequency of FTR events (events per reactor year) trend for normally running TDPs.

## 6.3 Comparison of IRIS TDP Unplanned Demand Results with Industry Results

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

The standby TDP ESF unplanned demand data covering 2003 through 2022 are summarized in Table 7. Consistency between the unplanned demand data and the industry-average performance from *2020 Parameter Update* (Table 2) was evaluated using the predictive distribution approach outlined in NUREG/CR-6823, "Handbook of Parameter Estimation for PRA," Sections 6.2.3.5 and 6.3.3.4 [9].

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 1,000 times, each time obtaining a total number of predicted failures. The 1,000 sample results were ordered from high to low. Then the actual number of unplanned demand failures observed (listed in the Observed Failures column of Table 7) was compared with this 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 is consistent with the industry-average distribution obtained from the IRIS data analysis.

Table 7. Standby TDP unplanned demand performance comparison with industry-average performance.

| Failure Modes | Plants | Demands or Hours | Observed Failures | Expected Failures | Probability of ≥ Observed Failures | Consistent with Industry-Average Performance? [a] |
|---|---|---|---|---|---|---|
| FTS | 99 | 837 | 4 | 4.5 | 0.47 | Yes |
| FTR≤1H | 99 | 452 | 7 | 1.2 | 0.04 | No |
| FTR>1H | 99 | 1286 | 1 | 8.2 | 0.73 | Yes |

Note:

a. If the probability of observing the actual failures or greater is ≥ 0.05 and ≤ 0.95, then the observed performance is considered to be consistent with the industry-average performance estimate.

These consistency checks show that the FTS and FTR>1H failure observations in the non-test, operational ESF demand data lie within their corresponding industry-average failure estimate distributions, provided in the *2020 Parameter Update* (Table 2), that were based on both test and non-test operational ESF demands. However, the FTR≤1H failure observations are not consistent with the industry-average failure estimate distributions, and the TDP performs worse on a non-test, operational ESF demand than on a test demand.

## 6.4 TDP Engineering Analysis by Failure Modes

The engineering analysis of the TDP failure breakdown by failure modes and other factors such as subcomponents, failure causes, detection methods, and recovery possibility are presented in this section. First, each analysis divides the events into two categories: standby and normally running TDPs. Note that the FTR≤1H failure mode only applies to standby TDPs and therefore only shows the standby category data. Then the events are further divided by the failure modes and factors such as subcomponents, failure

causes, detection methods, and recovery possibility. The failure modes are determined after IRIS data review by Idaho National Laboratory (INL) staff. See Section 7 for further description of failure modes.

**TDP subcomponent** contributions to the three failure modes are presented in Figure 19. The subcomponent categories are similar to those used in the common-cause failure (CCF) database. The **driver** (specifically the governor) has the highest percentage contributions to failures for all the failure modes.

**TDP failure 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 8 shows the breakdown of the cause groups with the specific causes that were coded during the data collection. The most likely cause groups are **Human**, **Design**, and **Component**. The Human cause group is primarily influenced by maintenance and operating procedures and practices. The Component cause group includes the causes that were related to something internal to the component or an aging or worn-out part, which were categorized as the Internal cause group in previous studies [2]. The Design cause group is influenced by manufacturing, installation, and design issues.

**TDP failure detection methods** for the three failure modes are presented in Figure 21. A failure can be detected during inspection, testing, post maintenance testing (PMT), non-test demand, or engineered safety feature (ESF) demand. There are differences in the detection method based on the standby and normally running categories.

- **Standby**: the most likely detection method for all three failure modes is **test demand**. Inspection is also important for the FTS failure mode. The incidence of inspection for the FTS failure mode indicates that the equipment was observed to be unable to start without a demand (e.g., an alarmed condition, leaking oil, state of another component, etc.).
- **Normally running**: the most likely detection method for FTS and FTR is **non-test demand**.

**TDP recovery** fractions for the three failure modes are presented in Figure 22. The overall **non-recovery to recovery ratio** is approximately **6:1**, meaning that six of every seven failures were not recovered.

Table 8. Component failure cause groups.[b]

| Group | Specific Cause | Description |
|---|---|---|
| Component | 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. |
| | Set point drift | Used when the cause of a failure is the result of set point drift or adjustment. |
| | Age/wear | Used when the cause of the failure is a non-specific aging or wear issue. |
| 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 an incorrect component or material. |
| | Design error or inadequacy | Used when a design error is made. |
| | Manufacturing error or inadequacy | Used when a manufacturing error is made during component manufacture. |

b The cause groups have been re-arranged in order to align with those currently used in the CCF database.

| Group | Specific Cause | Description |
|---|---|---|
| Environment | Ambient environmental stress | Used when the cause of a failure is the result of an environmental condition from the location of the component. |
| | Internal environment | The internal environment led to the failure. Debris/foreign material as well as an operating medium chemistry issue. |
| | Extreme environmental stress | Used when the cause of a failure is the result of an environmental condition that places a higher-than-expected load on the equipment and is transitory in nature. |
| 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 action procedure | Used when the correct procedure is not followed, or the wrong procedure is followed, for example, when a missed step or incorrect step in a surveillance procedure results in a component failure. |
| | Inadequate maintenance | Used when a human error (during the performance of maintenance) results in an unintentional or undesired action. |
| | Inadequate procedure | Used when the cause of a failure is the result of an inadequate procedure operating or maintenance. |
| Other | 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 empty fuel storage tanks. |
| | 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. |
| | Unknown | Used when the cause of the failure is not known. |

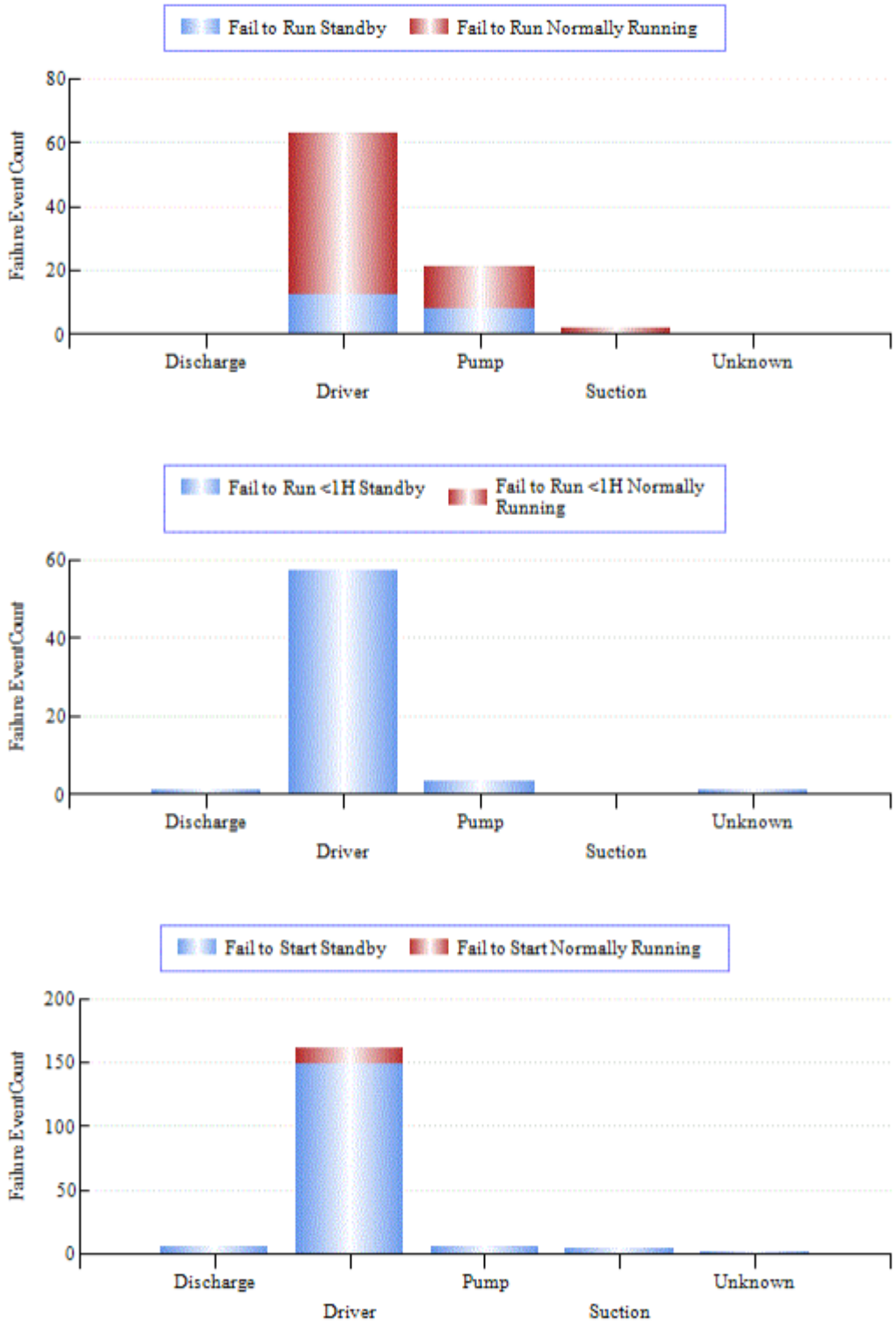


Figure 19. TDP failure event breakdown by subcomponent, failure mode, and operational status.

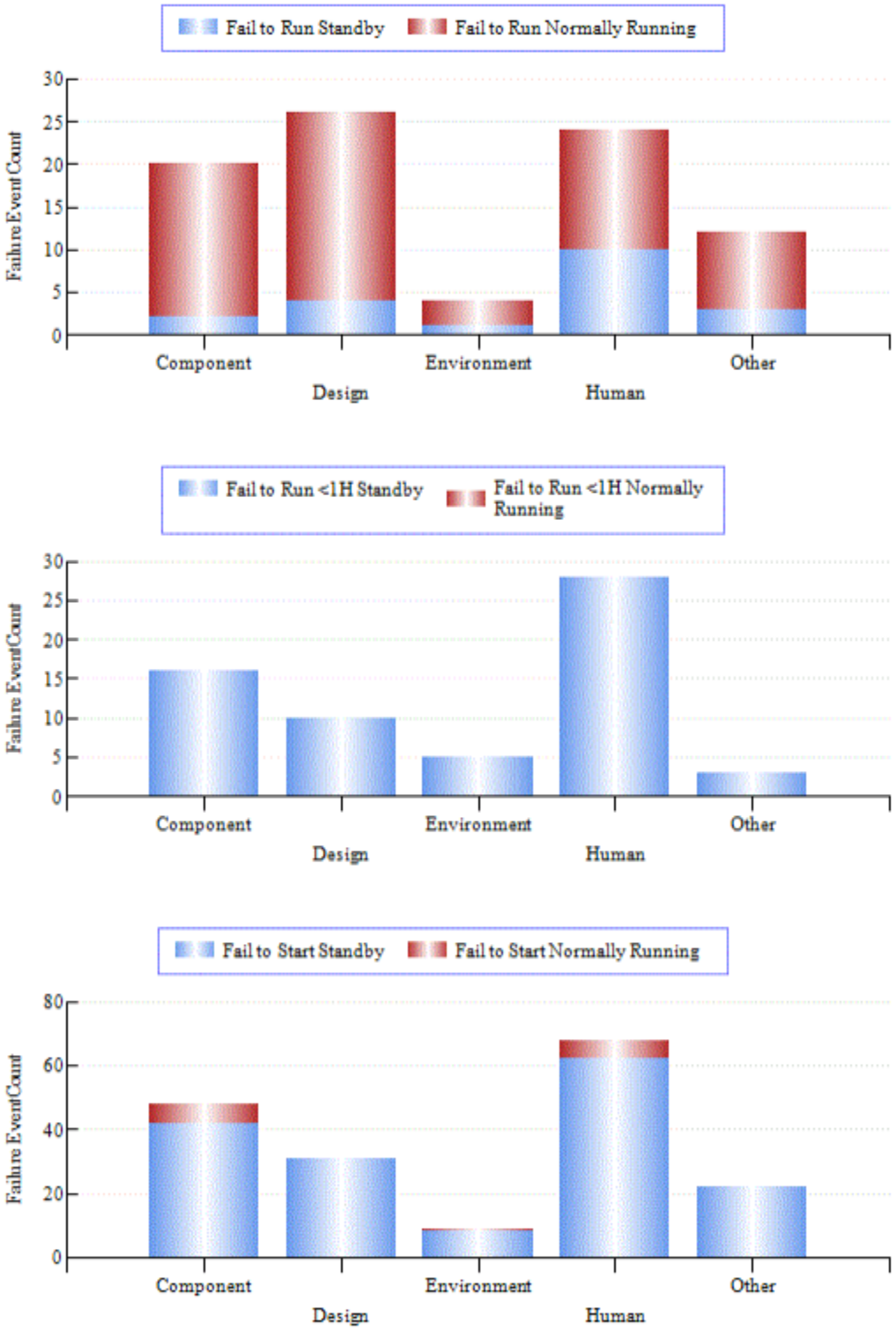


Figure 20. TDP failure event breakdown by cause group, failure mode, and operational status.

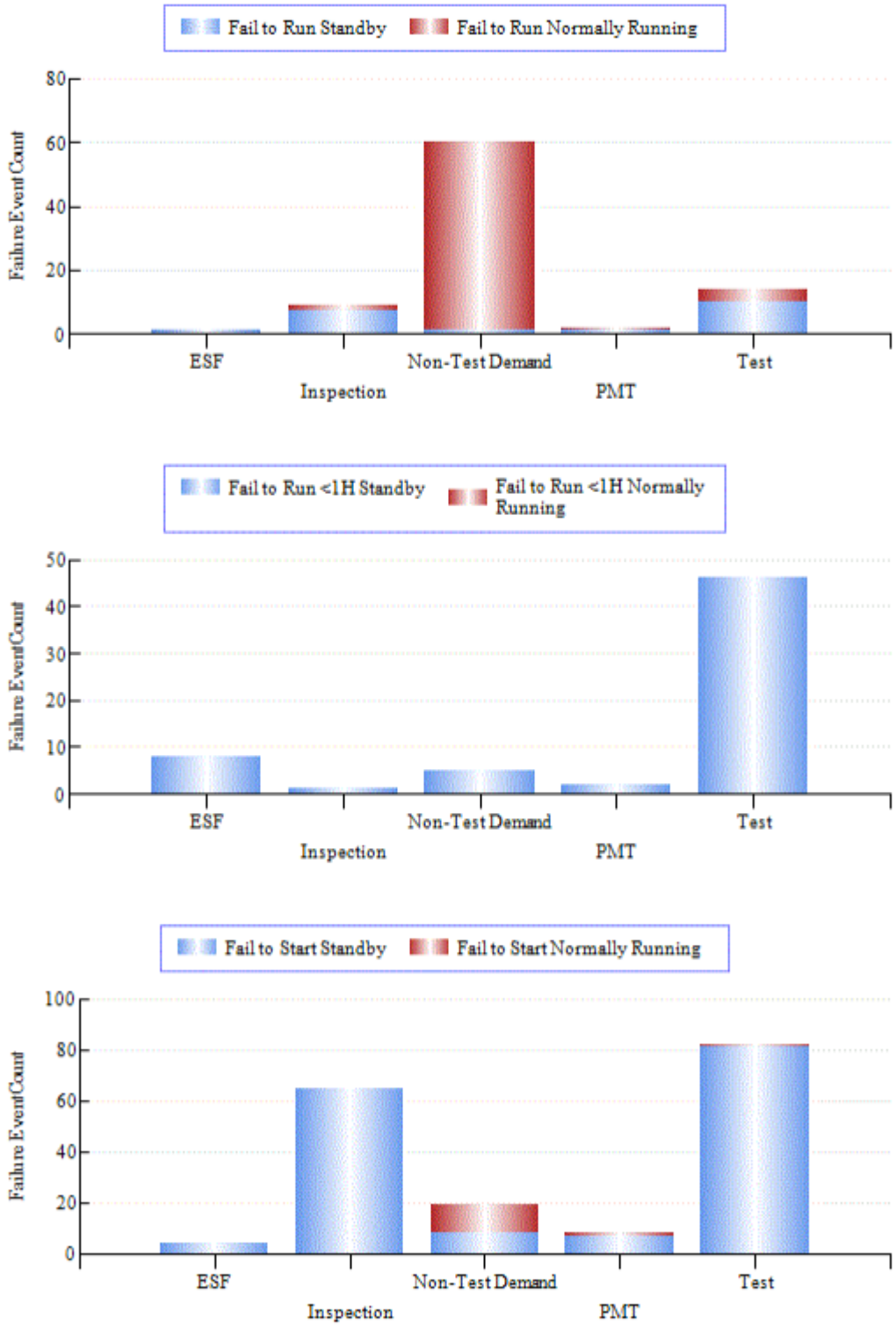


Figure 21. TDP failure event breakdown by failure detection method, failure mode, and operational status.

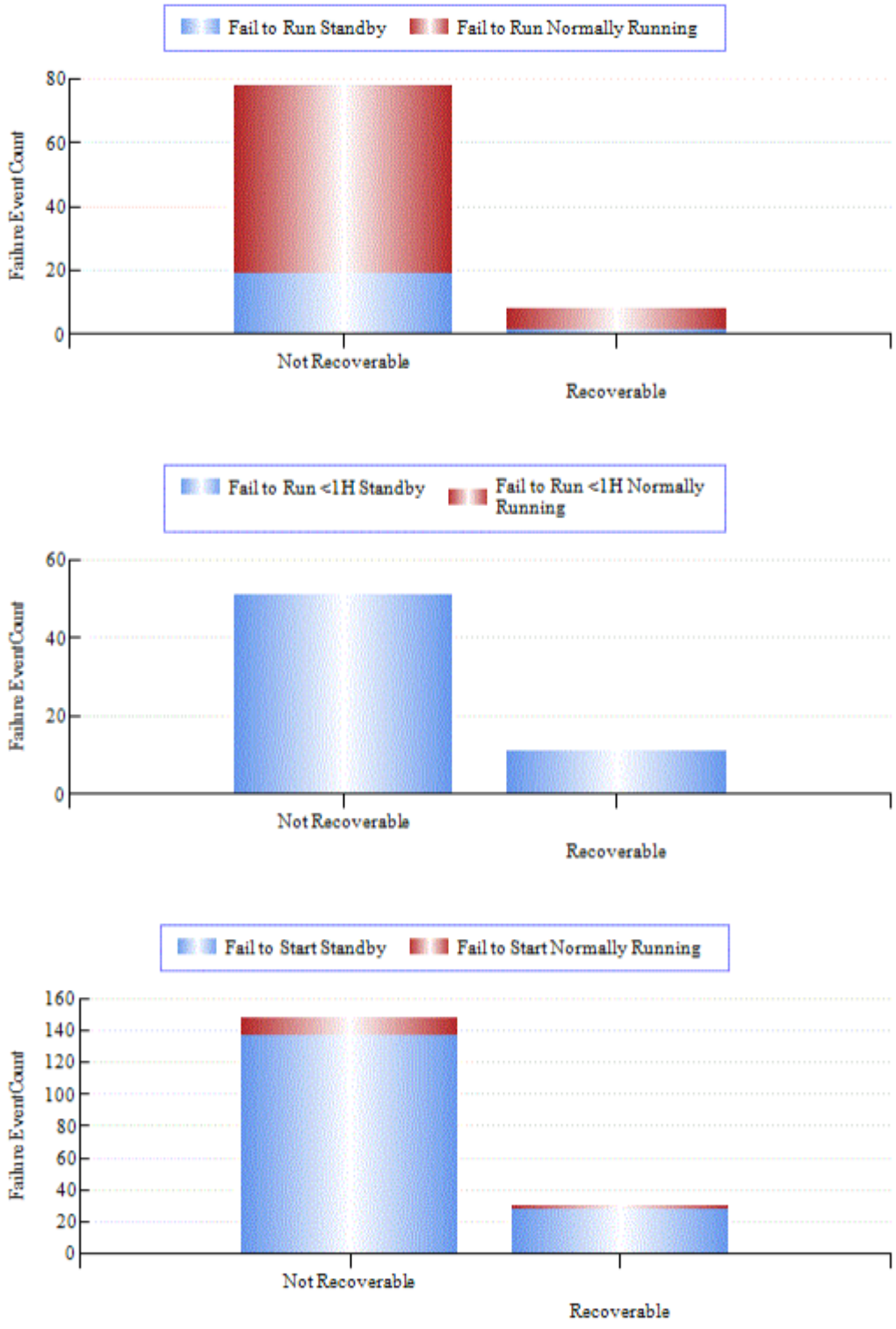


Figure 22. TDP failure event breakdown by recoverability determination, failure mode, and operational status.

# 7. TDP ASSEMBLY DESCRIPTION

The TDP is generally comprised of a pump, a turbine driver, and a governor. Most plant designs use a single stage "Terry Turbine," whose piece-parts include a turbine trip and throttle valve, a mechanical over speed trip mechanism, and a lubrication system. The various types of governors used for turbine speed control are mostly manufactured by the Woodward Corporation. For the AFW system TDP, the governors are predominantly mechanical/hydraulic, pressure-compensated, and have a pneumatic remote speed-setting capability. For the RCIC and HPCI systems, the TDPs typically have a Woodward type EG-M electric/electronic governor and EGR hydraulic actuators. Piece-parts of all governors include a turbine stop valve and a governor valve, while the EG-M usually includes a ramp generator/signal converter and other electrical controls.

The TDP failure modes include FTS, FTR≤1H, and FTR>1H. These failure modes were used in NUREG/CR-6928 [8] and are similar to those used in the MSPI program.

Guidelines for determining whether a component event reported in IRIS 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 PRA is counted. This includes conditions revealed through testing, operational demands, unplanned demands, or discovery. Run failures that occur beyond the typical 24-hour mission time in PRAs are included. However, certain events are excluded, e.g., events with slow starting times that do not exceed the PRA success criteria, events 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. Events occurring during maintenance or post maintenance testing that are related to the actual maintenance activities are excluded. All TDP events within IRIS 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, but exclude those during maintenance and post-maintenance.

# 8. DATA TABLES

In this section, the plot data for Figure 1 to Figure 18 in previous sections are provided in Table 9 to Table 26, respectively.

| Figure | Table | Analysis |
|---|---|---|
| Figure 1 | Table 9 | Failure probability estimate trend for standby TDP FTS |
| Figure 2 | Table 10 | Failure probability estimate trend for standby TDP FTR≤1H |
| Figure 3 | Table 11 | Failure rate estimate trend for standby TDP FTR>1H |
| Figure 4 | Table 12 | Failure probability estimate trend for normally running TDP FTS |
| Figure 5 | Table 13 | Failure rate estimate trend for normally running TDP FTR |
| Figure 6 | Table 14 | Pooled standby TDP UA trend |
| Figure 7 | Table 15 | Standby TDP unreliability trend (8-hour mission) |
| Figure 8 | Table 16 | Normally running TDP unreliability trend (8-hour mission) |
| Figure 9 | Table 17 | Frequency of start demands (demands per reactor year) trend for standby TDPs |
| Figure 10 | Table 18 | Frequency of run ≤ 1H hours (hours per reactor year) trend for standby TDPs |
| Figure 11 | Table 19 | Frequency of run > 1H hours (hours per reactor year) trend for standby TDPs |
| Figure 12 | Table 20 | Frequency of FTS events (events per reactor year) trend for standby TDPs |
| Figure 13 | Table 21 | Frequency of FTR≤1H events (events per reactor year) trend for standby TDPs |
| Figure 14 | Table 22 | Frequency of FTR>1H events (events per reactor year) trend for standby TDPs |
| Figure 15 | Table 23 | Frequency of start demands (demands per reactor year) trend for normally running TDPs |
| Figure 16 | Table 24 | Frequency of run hours (hours per reactor year) trend for normally running TDPs |
| Figure 17 | Table 25 | Frequency of FTS events (events per reactor year) trend for normally running TDPs |
| Figure 18 | Table 26 | Frequency of FTR events (events per reactor year) trend for normally running TDPs |

Table 9. Plot data for Figure 1, failure probability estimate trend for standby TDP FTS.

| Year | Failures | Demands | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 4.59E-04 | 1.47E-02 | 5.32E-03 |
| 1998 | 2 | 1,609 | -- | -- | -- | 3.33E-04 | 3.23E-03 | 1.46E-03 |
| 1999 | 12 | 1,513 | -- | -- | -- | 4.50E-03 | 1.16E-02 | 7.68E-03 |
| 2000 | 12 | 1,454 | -- | -- | -- | 4.67E-03 | 1.20E-02 | 7.98E-03 |
| 2001 | 5 | 1,431 | -- | -- | -- | 1.49E-03 | 6.39E-03 | 3.57E-03 |
| 2002 | 4 | 1,415 | -- | -- | -- | 1.09E-03 | 5.56E-03 | 2.96E-03 |
| 2003 | 8 | 1,539 | -- | -- | -- | 2.63E-03 | 8.36E-03 | 5.16E-03 |
| 2004 | 10 | 1,484 | -- | -- | -- | 3.64E-03 | 1.02E-02 | 6.58E-03 |
| 2005 | 6 | 1,462 | -- | -- | -- | 1.88E-03 | 7.11E-03 | 4.14E-03 |
| 2006 | 9 | 1,500 | -- | -- | -- | 3.14E-03 | 9.34E-03 | 5.90E-03 |
| 2007 | 7 | 1,421 | -- | -- | -- | 2.37E-03 | 8.16E-03 | 4.90E-03 |
| 2008 | 12 | 1,467 | -- | -- | -- | 4.63E-03 | 1.19E-02 | 7.91E-03 |
| 2009 | 12 | 1,547 | -- | -- | -- | 4.41E-03 | 1.13E-02 | 7.53E-03 |
| 2010 | 9 | 1,578 | -- | -- | -- | 3.00E-03 | 8.91E-03 | 5.63E-03 |
| 2011 | 9 | 1,576 | -- | -- | -- | 3.00E-03 | 8.93E-03 | 5.63E-03 |
| 2012 | 6 | 1,519 | -- | -- | -- | 1.81E-03 | 6.86E-03 | 3.99E-03 |
| 2013 | 8 | 1,556 | 5.66E-03 | 3.09E-03 | 1.03E-02 | 2.60E-03 | 8.27E-03 | 5.10E-03 |
| 2014 | 12 | 1,507 | 5.08E-03 | 3.06E-03 | 8.43E-03 | 4.52E-03 | 1.16E-02 | 7.71E-03 |
| 2015 | 3 | 1,528 | 4.56E-03 | 2.97E-03 | 6.99E-03 | 6.63E-04 | 4.30E-03 | 2.14E-03 |
| 2016 | 9 | 1,508 | 4.10E-03 | 2.81E-03 | 5.98E-03 | 3.13E-03 | 9.30E-03 | 5.87E-03 |
| 2017 | 7 | 1,502 | 3.68E-03 | 2.54E-03 | 5.33E-03 | 2.26E-03 | 7.75E-03 | 4.66E-03 |
| 2018 | 4 | 1,489 | 3.31E-03 | 2.20E-03 | 4.96E-03 | 1.04E-03 | 5.30E-03 | 2.82E-03 |
| 2019 | 8 | 1,448 | 2.97E-03 | 1.84E-03 | 4.79E-03 | 2.79E-03 | 8.84E-03 | 5.46E-03 |
| 2020 | 2 | 1,421 | 2.67E-03 | 1.51E-03 | 4.72E-03 | 3.74E-04 | 3.62E-03 | 1.64E-03 |
| 2021 | 4 | 1,413 | 2.39E-03 | 1.22E-03 | 4.71E-03 | 1.09E-03 | 5.56E-03 | 2.96E-03 |
| 2022 | 2 | 1,380 | 2.15E-03 | 9.74E-04 | 4.73E-03 | 3.84E-04 | 3.72E-03 | 1.68E-03 |
| Total | 182 | 37,267 | -- | -- | -- | -- | -- | -- |

Table 10. Plot data for Figure 2, failure probability estimate trend for standby TDP FTR≤1H.

| Year | Failures | Demands | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 5.17E-06 | 1.03E-02 | 2.56E-03 |
| 1998 | 2 | 1,609 | -- | -- | -- | 3.10E-04 | 3.00E-03 | 1.35E-03 |
| 1999 | 3 | 1,513 | -- | -- | -- | 6.19E-04 | 4.02E-03 | 2.00E-03 |
| 2000 | 10 | 1,454 | -- | -- | -- | 3.43E-03 | 9.66E-03 | 6.21E-03 |
| 2001 | 4 | 1,431 | -- | -- | -- | 9.96E-04 | 5.07E-03 | 2.70E-03 |
| 2002 | 5 | 1,415 | -- | -- | -- | 1.38E-03 | 5.95E-03 | 3.33E-03 |
| 2003 | 8 | 1,539 | -- | -- | -- | 2.44E-03 | 7.77E-03 | 4.79E-03 |
| 2004 | 0 | 1,484 | -- | -- | -- | 1.14E-06 | 1.12E-03 | 2.90E-04 |
| 2005 | 4 | 1,462 | -- | -- | -- | 9.78E-04 | 4.98E-03 | 2.65E-03 |
| 2006 | 2 | 1,500 | -- | -- | -- | 3.30E-04 | 3.19E-03 | 1.44E-03 |
| 2007 | 7 | 1,421 | -- | -- | -- | 2.19E-03 | 7.53E-03 | 4.52E-03 |
| 2008 | 4 | 1,467 | -- | -- | -- | 9.75E-04 | 4.96E-03 | 2.64E-03 |
| 2009 | 5 | 1,547 | -- | -- | -- | 1.28E-03 | 5.51E-03 | 3.08E-03 |
| 2010 | 3 | 1,578 | -- | -- | -- | 5.97E-04 | 3.87E-03 | 1.93E-03 |
| 2011 | 4 | 1,576 | -- | -- | -- | 9.17E-04 | 4.67E-03 | 2.48E-03 |
| 2012 | 1 | 1,519 | -- | -- | -- | 1.00E-04 | 2.22E-03 | 8.54E-04 |
| 2013 | 0 | 1,556 | 7.04E-04 | 1.78E-04 | 2.79E-03 | 1.10E-06 | 1.07E-03 | 2.79E-04 |
| 2014 | 1 | 1,507 | 7.25E-04 | 2.25E-04 | 2.33E-03 | 1.01E-04 | 2.24E-03 | 8.60E-04 |
| 2015 | 4 | 1,528 | 7.46E-04 | 2.79E-04 | 1.99E-03 | 9.42E-04 | 4.79E-03 | 2.55E-03 |
| 2016 | 4 | 1,508 | 7.68E-04 | 3.33E-04 | 1.77E-03 | 9.53E-04 | 4.85E-03 | 2.58E-03 |
| 2017 | 0 | 1,502 | 7.90E-04 | 3.74E-04 | 1.67E-03 | 1.13E-06 | 1.10E-03 | 2.87E-04 |
| 2018 | 3 | 1,489 | 8.13E-04 | 3.87E-04 | 1.71E-03 | 6.28E-04 | 4.07E-03 | 2.03E-03 |
| 2019 | 0 | 1,448 | 8.37E-04 | 3.68E-04 | 1.90E-03 | 1.17E-06 | 1.14E-03 | 2.97E-04 |
| 2020 | 1 | 1,421 | 8.61E-04 | 3.28E-04 | 2.26E-03 | 1.06E-04 | 2.36E-03 | 9.05E-04 |
| 2021 | 2 | 1,413 | 8.86E-04 | 2.81E-04 | 2.79E-03 | 3.47E-04 | 3.35E-03 | 1.51E-03 |
| 2022 | 1 | 1,380 | 9.12E-04 | 2.36E-04 | 3.53E-03 | 1.09E-04 | 2.42E-03 | 9.27E-04 |
| Total | 78 | 37,267 | -- | -- | -- | -- | -- | -- |

Table 11. Plot data for Figure 3, failure rate estimate trend for standby TDP FTR>1H.

| Year | Failures | Hours | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 1.23E-05 | 2.55E-02 | 6.35E-03 |
| 1998 | 0 | 2,129 | -- | -- | -- | 8.61E-07 | 8.41E-04 | 2.19E-04 |
| 1999 | 1 | 1,100 | -- | -- | -- | 1.40E-04 | 3.11E-03 | 1.20E-03 |
| 2000 | 3 | 508 | -- | -- | -- | 1.63E-03 | 1.06E-02 | 5.28E-03 |
| 2001 | 1 | 655 | -- | -- | -- | 2.17E-04 | 4.82E-03 | 1.85E-03 |
| 2002 | 0 | 1,174 | -- | -- | -- | 1.48E-06 | 1.44E-03 | 3.76E-04 |
| 2003 | 1 | 1,500 | -- | -- | -- | 1.06E-04 | 2.36E-03 | 9.06E-04 |
| 2004 | 4 | 366 | -- | -- | -- | 3.19E-03 | 1.62E-02 | 8.63E-03 |
| 2005 | 3 | 240 | -- | -- | -- | 2.74E-03 | 1.78E-02 | 8.84E-03 |
| 2006 | 0 | 240 | -- | -- | -- | 4.97E-06 | 4.86E-03 | 1.26E-03 |
| 2007 | 1 | 254 | -- | -- | -- | 4.30E-04 | 9.54E-03 | 3.66E-03 |
| 2008 | 2 | 279 | -- | -- | -- | 1.32E-03 | 1.27E-02 | 5.76E-03 |
| 2009 | 0 | 329 | -- | -- | -- | 4.05E-06 | 3.96E-03 | 1.03E-03 |
| 2010 | 1 | 318 | -- | -- | -- | 3.71E-04 | 8.25E-03 | 3.17E-03 |
| 2011 | 4 | 416 | -- | -- | -- | 2.91E-03 | 1.48E-02 | 7.88E-03 |
| 2012 | 4 | 298 | -- | -- | -- | 3.66E-03 | 1.86E-02 | 9.92E-03 |
| 2013 | 3 | 329 | 1.04E-02 | 6.50E-03 | 1.65E-02 | 2.24E-03 | 1.45E-02 | 7.23E-03 |
| 2014 | 3 | 314 | 8.48E-03 | 5.73E-03 | 1.26E-02 | 2.31E-03 | 1.50E-02 | 7.45E-03 |
| 2015 | 2 | 283 | 6.95E-03 | 4.98E-03 | 9.69E-03 | 1.31E-03 | 1.26E-02 | 5.70E-03 |
| 2016 | 2 | 366 | 5.69E-03 | 4.24E-03 | 7.65E-03 | 1.10E-03 | 1.06E-02 | 4.80E-03 |
| 2017 | 2 | 327 | 4.66E-03 | 3.49E-03 | 6.22E-03 | 1.19E-03 | 1.15E-02 | 5.19E-03 |
| 2018 | 2 | 220 | 3.82E-03 | 2.79E-03 | 5.23E-03 | 1.52E-03 | 1.47E-02 | 6.66E-03 |
| 2019 | 1 | 218 | 3.13E-03 | 2.17E-03 | 4.51E-03 | 4.71E-04 | 1.05E-02 | 4.01E-03 |
| 2020 | 0 | 266 | 2.56E-03 | 1.66E-03 | 3.96E-03 | 4.66E-06 | 4.56E-03 | 1.19E-03 |
| 2021 | 0 | 219 | 2.10E-03 | 1.25E-03 | 3.51E-03 | 5.25E-06 | 5.13E-03 | 1.34E-03 |
| 2022 | 0 | 251 | 1.72E-03 | 9.44E-04 | 3.13E-03 | 4.84E-06 | 4.73E-03 | 1.23E-03 |
| Total | 40 | 12,598 | -- | -- | -- | -- | -- | -- |

Table 12. Plot data for Figure 4, failure probability estimate trend for normally running TDP FTS.

| Year | Failures | Demands | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 5.45E-05 | 1.62E-02 | 4.60E-03 |
| 1998 | 2 | 79 | -- | -- | -- | 3.93E-03 | 3.76E-02 | 1.71E-02 |
| 1999 | 2 | 79 | -- | -- | -- | 3.93E-03 | 3.76E-02 | 1.71E-02 |
| 2000 | 0 | 79 | -- | -- | -- | 1.19E-05 | 1.31E-02 | 3.40E-03 |
| 2001 | 1 | 78 | -- | -- | -- | 1.21E-03 | 2.68E-02 | 1.03E-02 |
| 2002 | 0 | 78 | -- | -- | -- | 1.19E-05 | 1.32E-02 | 3.42E-03 |
| 2003 | 0 | 78 | -- | -- | -- | 1.19E-05 | 1.32E-02 | 3.41E-03 |
| 2004 | 0 | 78 | -- | -- | -- | 1.19E-05 | 1.32E-02 | 3.42E-03 |
| 2005 | 3 | 79 | -- | -- | -- | 7.43E-03 | 4.74E-02 | 2.38E-02 |
| 2006 | 1 | 78 | -- | -- | -- | 1.20E-03 | 2.68E-02 | 1.03E-02 |
| 2007 | 0 | 78 | -- | -- | -- | 1.19E-05 | 1.32E-02 | 3.41E-03 |
| 2008 | 0 | 78 | -- | -- | -- | 1.19E-05 | 1.32E-02 | 3.41E-03 |
| 2009 | 1 | 78 | -- | -- | -- | 1.21E-03 | 2.69E-02 | 1.04E-02 |
| 2010 | 0 | 76 | -- | -- | -- | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2011 | 0 | 76 | -- | -- | -- | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2012 | 1 | 76 | -- | -- | -- | 1.22E-03 | 2.72E-02 | 1.04E-02 |
| 2013 | 1 | 76 | 4.62E-03 | 2.05E-03 | 1.04E-02 | 1.22E-03 | 2.72E-02 | 1.04E-02 |
| 2014 | 0 | 76 | 4.41E-03 | 2.21E-03 | 8.77E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2015 | 0 | 76 | 4.21E-03 | 2.35E-03 | 7.51E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2016 | 1 | 76 | 4.01E-03 | 2.45E-03 | 6.57E-03 | 1.22E-03 | 2.72E-02 | 1.05E-02 |
| 2017 | 0 | 76 | 3.83E-03 | 2.47E-03 | 5.95E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2018 | 0 | 76 | 3.66E-03 | 2.37E-03 | 5.65E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2019 | 0 | 76 | 3.49E-03 | 2.16E-03 | 5.63E-03 | 1.21E-05 | 1.34E-02 | 3.45E-03 |
| 2020 | 1 | 76 | 3.33E-03 | 1.90E-03 | 5.84E-03 | 1.22E-03 | 2.72E-02 | 1.05E-02 |
| 2021 | 0 | 76 | 3.18E-03 | 1.63E-03 | 6.19E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| 2022 | 0 | 76 | 3.04E-03 | 1.38E-03 | 6.67E-03 | 1.21E-05 | 1.34E-02 | 3.46E-03 |
| Total | 14 | 1,930 | -- | -- | -- | -- | -- | -- |

Table 13. Plot data for Figure 5, failure rate estimate trend for normally running TDP FTR.

| Year | Failures | Hours | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 2.53E-07 | 2.71E-05 | 8.45E-06 |
| 1998 | 1 | 335,022 | -- | -- | -- | 4.51E-07 | 1.00E-05 | 3.85E-06 |
| 1999 | 6 | 335,022 | -- | -- | -- | 7.56E-06 | 2.87E-05 | 1.67E-05 |
| 2000 | 2 | 335,022 | -- | -- | -- | 1.47E-06 | 1.42E-05 | 6.41E-06 |
| 2001 | 3 | 335,448 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2002 | 3 | 335,539 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2003 | 6 | 335,402 | -- | -- | -- | 7.55E-06 | 2.87E-05 | 1.67E-05 |
| 2004 | 3 | 335,341 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2005 | 6 | 335,371 | -- | -- | -- | 7.55E-06 | 2.87E-05 | 1.67E-05 |
| 2006 | 3 | 335,417 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2007 | 3 | 335,448 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2008 | 3 | 335,387 | -- | -- | -- | 2.78E-06 | 1.80E-05 | 8.97E-06 |
| 2009 | 3 | 333,274 | -- | -- | -- | 2.79E-06 | 1.81E-05 | 9.02E-06 |
| 2010 | 6 | 327,150 | -- | -- | -- | 7.71E-06 | 2.93E-05 | 1.70E-05 |
| 2011 | 2 | 327,211 | -- | -- | -- | 1.50E-06 | 1.45E-05 | 6.54E-06 |
| 2012 | 6 | 327,120 | -- | -- | -- | 7.71E-06 | 2.93E-05 | 1.70E-05 |
| 2013 | 4 | 327,211 | 1.24E-05 | 6.53E-06 | 2.37E-05 | 4.35E-06 | 2.21E-05 | 1.18E-05 |
| 2014 | 2 | 327,135 | 9.77E-06 | 5.68E-06 | 1.68E-05 | 1.50E-06 | 1.45E-05 | 6.55E-06 |
| 2015 | 5 | 327,105 | 7.68E-06 | 4.85E-06 | 1.22E-05 | 5.99E-06 | 2.58E-05 | 1.44E-05 |
| 2016 | 2 | 327,120 | 6.04E-06 | 4.00E-06 | 9.11E-06 | 1.50E-06 | 1.45E-05 | 6.55E-06 |
| 2017 | 3 | 327,211 | 4.75E-06 | 3.16E-06 | 7.14E-06 | 2.84E-06 | 1.84E-05 | 9.16E-06 |
| 2018 | 2 | 327,211 | 3.73E-06 | 2.38E-06 | 5.85E-06 | 1.50E-06 | 1.45E-05 | 6.54E-06 |
| 2019 | 0 | 327,135 | 2.93E-06 | 1.73E-06 | 4.97E-06 | 5.15E-09 | 5.03E-06 | 1.31E-06 |
| 2020 | 1 | 327,302 | 2.31E-06 | 1.23E-06 | 4.32E-06 | 4.60E-07 | 1.02E-05 | 3.93E-06 |
| 2021 | 0 | 327,105 | 1.81E-06 | 8.65E-07 | 3.80E-06 | 5.15E-09 | 5.03E-06 | 1.31E-06 |
| 2022 | 0 | 327,181 | 1.43E-06 | 6.03E-07 | 3.37E-06 | 5.15E-09 | 5.03E-06 | 1.31E-06 |
| Total | 75 | 8,274,889 | -- | -- | -- | -- | -- | -- |

Table 14. Plot data for Figure 6, pooled standby TDP UA trend.

| Year | UA Hours | Critical Hours | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| SPAR 2020 | | -- | -- | -- | -- | 1.16E-05 | 1.46E-02 | 7.30E-03 |
| 1998 | 8,303 | 866,019 | -- | -- | -- | 1.06E-04 | 3.54E-02 | 9.96E-03 |
| 1999 | 8,368 | 932,827 | -- | -- | -- | 6.85E-04 | 2.55E-02 | 9.06E-03 |
| 2000 | 7,172 | 953,904 | -- | -- | -- | 8.55E-04 | 2.05E-02 | 7.77E-03 |
| 2001 | 7,895 | 960,556 | -- | -- | -- | 3.67E-04 | 2.56E-02 | 8.39E-03 |
| 2002 | 7,870 | 962,744 | -- | -- | -- | 5.37E-04 | 2.36E-02 | 8.19E-03 |
| 2003 | 8,371 | 939,190 | -- | -- | -- | 8.62E-04 | 2.42E-02 | 8.97E-03 |
| 2004 | 7,232 | 972,701 | -- | -- | -- | 5.32E-04 | 2.17E-02 | 7.62E-03 |
| 2005 | 6,152 | 962,533 | -- | -- | -- | 8.19E-04 | 1.66E-02 | 6.50E-03 |
| 2006 | 6,545 | 965,329 | -- | -- | -- | 9.07E-04 | 1.71E-02 | 6.78E-03 |
| 2007 | 7,838 | 976,725 | -- | -- | -- | 4.91E-05 | 3.07E-02 | 8.26E-03 |
| 2008 | 7,332 | 971,612 | -- | -- | -- | 5.97E-05 | 2.74E-02 | 7.53E-03 |
| 2009 | 7,832 | 954,932 | -- | -- | -- | 2.41E-05 | 3.26E-02 | 8.33E-03 |
| 2010 | 8,167 | 964,327 | -- | -- | -- | 8.02E-04 | 2.29E-02 | 8.46E-03 |
| 2011 | 8,041 | 937,926 | -- | -- | -- | 5.32E-04 | 2.58E-02 | 8.84E-03 |
| 2012 | 7,352 | 921,716 | -- | -- | -- | 4.34E-04 | 2.26E-02 | 7.68E-03 |
| 2013 | 8,161 | 927,540 | 8.19E-03 | 6.75E-03 | 9.64E-03 | 1.85E-08 | 4.32E-02 | 8.48E-03 |
| 2014 | 7,050 | 938,778 | 7.82E-03 | 6.70E-03 | 8.95E-03 | 4.90E-04 | 2.20E-02 | 7.61E-03 |
| 2015 | 6,365 | 924,172 | 7.45E-03 | 6.65E-03 | 8.26E-03 | 7.69E-04 | 1.80E-02 | 6.88E-03 |
| 2016 | 7,131 | 932,914 | 7.08E-03 | 6.60E-03 | 7.56E-03 | 6.79E-04 | 2.10E-02 | 7.66E-03 |
| 2017 | 6,750 | 926,540 | 6.71E-03 | 6.55E-03 | 6.87E-03 | 4.12E-04 | 2.15E-02 | 7.30E-03 |
| 2018 | 5,280 | 920,288 | 6.34E-03 | 6.18E-03 | 6.50E-03 | 2.77E-04 | 1.76E-02 | 5.81E-03 |
| 2019 | 5,371 | 916,107 | 5.97E-03 | 5.49E-03 | 6.45E-03 | 4.24E-04 | 1.70E-02 | 5.97E-03 |
| 2020 | 4,264 | 890,347 | 5.60E-03 | 4.80E-03 | 6.40E-03 | 2.19E-04 | 1.49E-02 | 4.89E-03 |
| 2021 | 4,760 | 872,242 | 5.23E-03 | 4.11E-03 | 6.35E-03 | 2.99E-04 | 1.64E-02 | 5.53E-03 |
| 2022 | 4,369 | 860,755 | 4.86E-03 | 3.42E-03 | 6.31E-03 | 2.81E-05 | 1.93E-02 | 5.14E-03 |
| Total | 173,973 | 23,352,723 | -- | -- | -- | -- | -- | -- |

Table 15. Plot data for Figure 7, standby TDP unreliability trend (8-hour mission).

| Year | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|
| | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | -- | -- | -- | 2.91E-03 | 4.00E-02 | 1.42E-02 |
| 1999 | -- | -- | -- | 1.28E-02 | 4.65E-02 | 2.67E-02 |
| 2000 | -- | -- | -- | 3.06E-02 | 9.49E-02 | 5.74E-02 |
| 2001 | -- | -- | -- | 1.02E-02 | 5.76E-02 | 2.74E-02 |
| 2002 | -- | -- | -- | 6.63E-03 | 3.45E-02 | 1.67E-02 |
| 2003 | -- | -- | -- | 1.31E-02 | 4.32E-02 | 2.52E-02 |
| 2004 | -- | -- | -- | 3.43E-02 | 1.17E-01 | 7.00E-02 |
| 2005 | -- | -- | -- | 3.02E-02 | 1.25E-01 | 7.08E-02 |
| 2006 | -- | -- | -- | 8.94E-03 | 5.14E-02 | 2.31E-02 |
| 2007 | -- | -- | -- | 1.52E-02 | 8.74E-02 | 4.25E-02 |
| 2008 | -- | -- | -- | 2.31E-02 | 1.01E-01 | 5.58E-02 |
| 2009 | -- | -- | -- | 9.96E-03 | 5.69E-02 | 2.62E-02 |
| 2010 | -- | -- | -- | 1.45E-02 | 7.36E-02 | 3.79E-02 |
| 2011 | -- | -- | -- | 3.45E-02 | 1.17E-01 | 6.85E-02 |
| 2012 | -- | -- | -- | 3.56E-02 | 1.27E-01 | 7.55E-02 |
| 2013 | 7.60E-02 | 5.37E-02 | 1.08E-01 | 2.37E-02 | 1.18E-01 | 6.10E-02 |
| 2014 | 6.47E-02 | 4.82E-02 | 8.68E-02 | 3.01E-02 | 1.13E-01 | 6.48E-02 |
| 2015 | 5.51E-02 | 4.30E-02 | 7.05E-02 | 1.83E-02 | 1.02E-01 | 4.99E-02 |
| 2016 | 4.69E-02 | 3.80E-02 | 5.78E-02 | 2.17E-02 | 8.53E-02 | 4.73E-02 |
| 2017 | 3.99E-02 | 3.30E-02 | 4.82E-02 | 1.79E-02 | 8.77E-02 | 4.65E-02 |
| 2018 | 3.39E-02 | 2.81E-02 | 4.10E-02 | 2.04E-02 | 1.05E-01 | 5.53E-02 |
| 2019 | 2.89E-02 | 2.34E-02 | 3.57E-02 | 1.17E-02 | 8.32E-02 | 3.84E-02 |
| 2020 | 2.46E-02 | 1.92E-02 | 3.15E-02 | 3.77E-03 | 4.09E-02 | 1.60E-02 |
| 2021 | 2.09E-02 | 1.56E-02 | 2.81E-02 | 5.07E-03 | 4.70E-02 | 1.89E-02 |
| 2022 | 1.78E-02 | 1.26E-02 | 2.52E-02 | 3.00E-03 | 4.38E-02 | 1.64E-02 |

Table 16. Plot data for Figure 8, normally running TDP unreliability trend (8-hour mission).

| | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|
| Year | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | -- | -- | -- | 4.40E-03 | 4.08E-02 | 1.76E-02 |
| 1999 | -- | -- | -- | 4.35E-03 | 3.77E-02 | 1.76E-02 |
| 2000 | -- | -- | -- | 1.33E-04 | 1.43E-02 | 3.55E-03 |
| 2001 | -- | -- | -- | 1.41E-03 | 2.65E-02 | 1.06E-02 |
| 2002 | -- | -- | -- | 1.94E-04 | 1.39E-02 | 3.64E-03 |
| 2003 | -- | -- | -- | 3.68E-04 | 1.27E-02 | 3.71E-03 |
| 2004 | -- | -- | -- | 1.82E-04 | 1.38E-02 | 3.77E-03 |
| 2005 | -- | -- | -- | 7.99E-03 | 4.88E-02 | 2.44E-02 |
| 2006 | -- | -- | -- | 1.40E-03 | 2.53E-02 | 1.03E-02 |
| 2007 | -- | -- | -- | 1.72E-04 | 1.36E-02 | 3.63E-03 |
| 2008 | -- | -- | -- | 1.95E-04 | 1.33E-02 | 3.56E-03 |
| 2009 | -- | -- | -- | 1.25E-03 | 2.70E-02 | 1.01E-02 |
| 2010 | -- | -- | -- | 3.45E-04 | 1.46E-02 | 3.99E-03 |
| 2011 | -- | -- | -- | 1.24E-04 | 1.31E-02 | 3.62E-03 |
| 2012 | -- | -- | -- | 1.67E-03 | 2.78E-02 | 1.12E-02 |
| 2013 | 6.10E-03 | 3.07E-03 | 1.21E-02 | 1.45E-03 | 2.65E-02 | 1.06E-02 |
| 2014 | 5.81E-03 | 3.24E-03 | 1.04E-02 | 1.36E-04 | 1.43E-02 | 3.56E-03 |
| 2015 | 5.53E-03 | 3.39E-03 | 9.03E-03 | 3.00E-04 | 1.32E-02 | 3.60E-03 |
| 2016 | 5.27E-03 | 3.47E-03 | 8.00E-03 | 1.28E-03 | 2.70E-02 | 1.02E-02 |
| 2017 | 5.02E-03 | 3.45E-03 | 7.31E-03 | 2.14E-04 | 1.48E-02 | 3.84E-03 |
| 2018 | 4.78E-03 | 3.28E-03 | 6.96E-03 | 1.47E-04 | 1.27E-02 | 3.43E-03 |
| 2019 | 4.55E-03 | 3.00E-03 | 6.91E-03 | 3.48E-05 | 1.25E-02 | 3.23E-03 |
| 2020 | 4.34E-03 | 2.66E-03 | 7.08E-03 | 1.50E-03 | 2.74E-02 | 1.10E-02 |
| 2021 | 4.13E-03 | 2.31E-03 | 7.40E-03 | 3.47E-05 | 1.42E-02 | 3.52E-03 |
| 2022 | 3.94E-03 | 1.98E-03 | 7.83E-03 | 3.74E-05 | 1.29E-02 | 3.49E-03 |

Table 17. Plot data for Figure 9, frequency of start demands (demands per reactor year) trend for standby TDPs.

| Year | Demands | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 1,609 | 97.0 | -- | -- | -- | 1.59E+01 | 1.73E+01 | 1.66E+01 |
| 1999 | 1,513 | 97.0 | -- | -- | -- | 1.49E+01 | 1.63E+01 | 1.56E+01 |
| 2000 | 1,454 | 97.3 | -- | -- | -- | 1.43E+01 | 1.56E+01 | 1.49E+01 |
| 2001 | 1,431 | 97.0 | -- | -- | -- | 1.41E+01 | 1.54E+01 | 1.48E+01 |
| 2002 | 1,415 | 97.0 | -- | -- | -- | 1.40E+01 | 1.52E+01 | 1.46E+01 |
| 2003 | 1,539 | 97.0 | -- | -- | -- | 1.52E+01 | 1.65E+01 | 1.59E+01 |
| 2004 | 1,484 | 97.3 | -- | -- | -- | 1.46E+01 | 1.59E+01 | 1.53E+01 |
| 2005 | 1,462 | 97.0 | -- | -- | -- | 1.44E+01 | 1.57E+01 | 1.51E+01 |
| 2006 | 1,500 | 97.0 | -- | -- | -- | 1.48E+01 | 1.61E+01 | 1.55E+01 |
| 2007 | 1,421 | 97.6 | -- | -- | -- | 1.39E+01 | 1.52E+01 | 1.46E+01 |
| 2008 | 1,467 | 98.3 | -- | -- | -- | 1.43E+01 | 1.56E+01 | 1.49E+01 |
| 2009 | 1,547 | 98.0 | -- | -- | -- | 1.51E+01 | 1.65E+01 | 1.58E+01 |
| 2010 | 1,578 | 98.0 | -- | -- | -- | 1.54E+01 | 1.68E+01 | 1.61E+01 |
| 2011 | 1,576 | 98.0 | -- | -- | -- | 1.54E+01 | 1.68E+01 | 1.61E+01 |
| 2012 | 1,519 | 98.3 | -- | -- | -- | 1.48E+01 | 1.61E+01 | 1.55E+01 |
| 2013 | 1,556 | 95.6 | 1.63E+01 | 1.61E+01 | 1.65E+01 | 1.56E+01 | 1.70E+01 | 1.63E+01 |
| 2014 | 1,507 | 94.0 | 1.62E+01 | 1.60E+01 | 1.64E+01 | 1.54E+01 | 1.67E+01 | 1.60E+01 |
| 2015 | 1,528 | 93.0 | 1.62E+01 | 1.60E+01 | 1.63E+01 | 1.57E+01 | 1.71E+01 | 1.64E+01 |
| 2016 | 1,508 | 93.2 | 1.61E+01 | 1.60E+01 | 1.63E+01 | 1.55E+01 | 1.69E+01 | 1.62E+01 |
| 2017 | 1,502 | 93.0 | 1.61E+01 | 1.59E+01 | 1.62E+01 | 1.55E+01 | 1.69E+01 | 1.61E+01 |
| 2018 | 1,489 | 93.0 | 1.60E+01 | 1.59E+01 | 1.61E+01 | 1.53E+01 | 1.67E+01 | 1.60E+01 |
| 2019 | 1,448 | 92.0 | 1.59E+01 | 1.58E+01 | 1.61E+01 | 1.51E+01 | 1.64E+01 | 1.57E+01 |
| 2020 | 1,421 | 90.2 | 1.59E+01 | 1.57E+01 | 1.61E+01 | 1.51E+01 | 1.64E+01 | 1.57E+01 |
| 2021 | 1,413 | 88.3 | 1.58E+01 | 1.56E+01 | 1.60E+01 | 1.53E+01 | 1.67E+01 | 1.60E+01 |
| 2022 | 1,380 | 87.4 | 1.58E+01 | 1.55E+01 | 1.60E+01 | 1.51E+01 | 1.65E+01 | 1.58E+01 |
| Total | 37,267 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 18. Plot data for Figure 10, frequency of run ≤ 1H hours (hours per reactor year) trend for standby TDPs.

| Year | Hours | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 1,609 | 97.0 | -- | -- | -- | 1.59E+01 | 1.73E+01 | 1.66E+01 |
| 1999 | 1,513 | 97.0 | -- | -- | -- | 1.49E+01 | 1.63E+01 | 1.56E+01 |
| 2000 | 1,454 | 97.3 | -- | -- | -- | 1.43E+01 | 1.56E+01 | 1.49E+01 |
| 2001 | 1,431 | 97.0 | -- | -- | -- | 1.41E+01 | 1.54E+01 | 1.48E+01 |
| 2002 | 1,415 | 97.0 | -- | -- | -- | 1.40E+01 | 1.52E+01 | 1.46E+01 |
| 2003 | 1,539 | 97.0 | -- | -- | -- | 1.52E+01 | 1.65E+01 | 1.59E+01 |
| 2004 | 1,484 | 97.3 | -- | -- | -- | 1.46E+01 | 1.59E+01 | 1.53E+01 |
| 2005 | 1,462 | 97.0 | -- | -- | -- | 1.44E+01 | 1.57E+01 | 1.51E+01 |
| 2006 | 1,500 | 97.0 | -- | -- | -- | 1.48E+01 | 1.61E+01 | 1.55E+01 |
| 2007 | 1,421 | 97.6 | -- | -- | -- | 1.39E+01 | 1.52E+01 | 1.46E+01 |
| 2008 | 1,467 | 98.3 | -- | -- | -- | 1.43E+01 | 1.56E+01 | 1.49E+01 |
| 2009 | 1,547 | 98.0 | -- | -- | -- | 1.51E+01 | 1.65E+01 | 1.58E+01 |
| 2010 | 1,578 | 98.0 | -- | -- | -- | 1.54E+01 | 1.68E+01 | 1.61E+01 |
| 2011 | 1,576 | 98.0 | -- | -- | -- | 1.54E+01 | 1.68E+01 | 1.61E+01 |
| 2012 | 1,519 | 98.3 | -- | -- | -- | 1.48E+01 | 1.61E+01 | 1.55E+01 |
| 2013 | 1,556 | 95.6 | 1.63E+01 | 1.61E+01 | 1.65E+01 | 1.56E+01 | 1.70E+01 | 1.63E+01 |
| 2014 | 1,507 | 94.0 | 1.62E+01 | 1.60E+01 | 1.64E+01 | 1.54E+01 | 1.67E+01 | 1.60E+01 |
| 2015 | 1,528 | 93.0 | 1.62E+01 | 1.60E+01 | 1.63E+01 | 1.57E+01 | 1.71E+01 | 1.64E+01 |
| 2016 | 1,508 | 93.2 | 1.61E+01 | 1.60E+01 | 1.63E+01 | 1.55E+01 | 1.69E+01 | 1.62E+01 |
| 2017 | 1,502 | 93.0 | 1.61E+01 | 1.59E+01 | 1.62E+01 | 1.55E+01 | 1.69E+01 | 1.61E+01 |
| 2018 | 1,489 | 93.0 | 1.60E+01 | 1.59E+01 | 1.61E+01 | 1.53E+01 | 1.67E+01 | 1.60E+01 |
| 2019 | 1,448 | 92.0 | 1.59E+01 | 1.58E+01 | 1.61E+01 | 1.51E+01 | 1.64E+01 | 1.57E+01 |
| 2020 | 1,421 | 90.2 | 1.59E+01 | 1.57E+01 | 1.61E+01 | 1.51E+01 | 1.64E+01 | 1.57E+01 |
| 2021 | 1,413 | 88.3 | 1.58E+01 | 1.56E+01 | 1.60E+01 | 1.53E+01 | 1.67E+01 | 1.60E+01 |
| 2022 | 1,380 | 87.4 | 1.58E+01 | 1.55E+01 | 1.60E+01 | 1.51E+01 | 1.65E+01 | 1.58E+01 |
| Total | 37,267 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 19. Plot data for Figure 11, frequency of run > 1H hours (hours per reactor year) trend for standby TDPs.

| Year | Run Hours | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 2,129 | 97.0 | -- | -- | -- | 2.11E+01 | 2.27E+01 | 2.19E+01 |
| 1999 | 1,100 | 97.0 | -- | -- | -- | 1.08E+01 | 1.19E+01 | 1.13E+01 |
| 2000 | 508 | 97.3 | -- | -- | -- | 4.84E+00 | 5.61E+00 | 5.22E+00 |
| 2001 | 655 | 97.0 | -- | -- | -- | 6.32E+00 | 7.20E+00 | 6.75E+00 |
| 2002 | 1,174 | 97.0 | -- | -- | -- | 1.15E+01 | 1.27E+01 | 1.21E+01 |
| 2003 | 1,500 | 97.0 | -- | -- | -- | 1.48E+01 | 1.61E+01 | 1.54E+01 |
| 2004 | 366 | 97.3 | -- | -- | -- | 3.44E+00 | 4.10E+00 | 3.76E+00 |
| 2005 | 240 | 97.0 | -- | -- | -- | 2.22E+00 | 2.76E+00 | 2.48E+00 |
| 2006 | 240 | 97.0 | -- | -- | -- | 2.22E+00 | 2.75E+00 | 2.47E+00 |
| 2007 | 254 | 97.6 | -- | -- | -- | 2.34E+00 | 2.89E+00 | 2.60E+00 |
| 2008 | 279 | 98.3 | -- | -- | -- | 2.56E+00 | 3.13E+00 | 2.84E+00 |
| 2009 | 329 | 98.0 | -- | -- | -- | 3.06E+00 | 3.68E+00 | 3.36E+00 |
| 2010 | 318 | 98.0 | -- | -- | -- | 2.95E+00 | 3.56E+00 | 3.25E+00 |
| 2011 | 416 | 98.0 | -- | -- | -- | 3.91E+00 | 4.60E+00 | 4.24E+00 |
| 2012 | 298 | 98.3 | -- | -- | -- | 2.75E+00 | 3.34E+00 | 3.03E+00 |
| 2013 | 329 | 95.6 | 3.51E+00 | 2.86E+00 | 4.30E+00 | 3.13E+00 | 3.77E+00 | 3.44E+00 |
| 2014 | 314 | 94.0 | 3.38E+00 | 2.85E+00 | 4.02E+00 | 3.04E+00 | 3.67E+00 | 3.34E+00 |
| 2015 | 283 | 93.0 | 3.27E+00 | 2.83E+00 | 3.77E+00 | 2.75E+00 | 3.36E+00 | 3.05E+00 |
| 2016 | 366 | 93.2 | 3.15E+00 | 2.78E+00 | 3.57E+00 | 3.59E+00 | 4.28E+00 | 3.92E+00 |
| 2017 | 327 | 93.0 | 3.04E+00 | 2.71E+00 | 3.41E+00 | 3.20E+00 | 3.85E+00 | 3.51E+00 |
| 2018 | 220 | 93.0 | 2.93E+00 | 2.60E+00 | 3.31E+00 | 2.11E+00 | 2.65E+00 | 2.37E+00 |
| 2019 | 218 | 92.0 | 2.83E+00 | 2.47E+00 | 3.25E+00 | 2.12E+00 | 2.66E+00 | 2.37E+00 |
| 2020 | 266 | 90.2 | 2.73E+00 | 2.32E+00 | 3.22E+00 | 2.66E+00 | 3.26E+00 | 2.95E+00 |
| 2021 | 219 | 88.3 | 2.64E+00 | 2.17E+00 | 3.20E+00 | 2.21E+00 | 2.77E+00 | 2.48E+00 |
| 2022 | 251 | 87.4 | 2.54E+00 | 2.02E+00 | 3.20E+00 | 2.58E+00 | 3.18E+00 | 2.87E+00 |
| Total | 12,598 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 20. Plot data for Figure 12, frequency of FTS events (events per reactor year) trend for standby TDPs.

| Year | Failures | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 2 | 97.0 | -- | -- | -- | 5.47E-03 | 6.72E-02 | 2.39E-02 |
| 1999 | 12 | 97.0 | -- | -- | -- | 6.98E-02 | 1.92E-01 | 1.19E-01 |
| 2000 | 12 | 97.3 | -- | -- | -- | 6.96E-02 | 1.91E-01 | 1.19E-01 |
| 2001 | 5 | 97.0 | -- | -- | -- | 2.18E-02 | 1.07E-01 | 5.25E-02 |
| 2002 | 4 | 97.0 | -- | -- | -- | 1.59E-02 | 9.39E-02 | 4.30E-02 |
| 2003 | 8 | 97.0 | -- | -- | -- | 4.14E-02 | 1.44E-01 | 8.12E-02 |
| 2004 | 10 | 97.3 | -- | -- | -- | 5.52E-02 | 1.67E-01 | 1.00E-01 |
| 2005 | 6 | 97.0 | -- | -- | -- | 2.81E-02 | 1.19E-01 | 6.21E-02 |
| 2006 | 9 | 97.0 | -- | -- | -- | 4.83E-02 | 1.56E-01 | 9.07E-02 |
| 2007 | 7 | 97.6 | -- | -- | -- | 3.45E-02 | 1.31E-01 | 7.12E-02 |
| 2008 | 12 | 98.3 | -- | -- | -- | 6.89E-02 | 1.89E-01 | 1.18E-01 |
| 2009 | 12 | 98.0 | -- | -- | -- | 6.91E-02 | 1.90E-01 | 1.18E-01 |
| 2010 | 9 | 98.0 | -- | -- | -- | 4.78E-02 | 1.54E-01 | 8.99E-02 |
| 2011 | 9 | 98.0 | -- | -- | -- | 4.78E-02 | 1.54E-01 | 8.99E-02 |
| 2012 | 6 | 98.3 | -- | -- | -- | 2.78E-02 | 1.18E-01 | 6.13E-02 |
| 2013 | 8 | 95.6 | 9.24E-02 | 5.07E-02 | 1.68E-01 | 4.20E-02 | 1.46E-01 | 8.23E-02 |
| 2014 | 12 | 94.0 | 8.27E-02 | 4.99E-02 | 1.37E-01 | 7.18E-02 | 1.97E-01 | 1.23E-01 |
| 2015 | 3 | 93.0 | 7.40E-02 | 4.84E-02 | 1.13E-01 | 1.08E-02 | 8.40E-02 | 3.47E-02 |
| 2016 | 9 | 93.2 | 6.62E-02 | 4.55E-02 | 9.62E-02 | 5.01E-02 | 1.62E-01 | 9.41E-02 |
| 2017 | 7 | 93.0 | 5.92E-02 | 4.11E-02 | 8.53E-02 | 3.60E-02 | 1.37E-01 | 7.45E-02 |
| 2018 | 4 | 93.0 | 5.30E-02 | 3.55E-02 | 7.90E-02 | 1.65E-02 | 9.77E-02 | 4.47E-02 |
| 2019 | 8 | 92.0 | 4.74E-02 | 2.96E-02 | 7.57E-02 | 4.35E-02 | 1.51E-01 | 8.52E-02 |
| 2020 | 2 | 90.2 | 4.24E-02 | 2.42E-02 | 7.42E-02 | 5.85E-03 | 7.18E-02 | 2.55E-02 |
| 2021 | 4 | 88.3 | 3.79E-02 | 1.95E-02 | 7.36E-02 | 1.73E-02 | 1.02E-01 | 4.68E-02 |
| 2022 | 2 | 87.4 | 3.39E-02 | 1.56E-02 | 7.37E-02 | 6.02E-03 | 7.39E-02 | 2.63E-02 |
| Total | 182 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 21. Plot data for Figure 13, frequency of FTR≤1H events (events per reactor year) trend for standby TDPs.

| Year | Failures | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 2 | 97.0 | -- | -- | -- | 4.59E-03 | 5.63E-02 | 2.00E-02 |
| 1999 | 3 | 97.0 | -- | -- | -- | 8.68E-03 | 6.77E-02 | 2.80E-02 |
| 2000 | 10 | 97.3 | -- | -- | -- | 4.63E-02 | 1.41E-01 | 8.39E-02 |
| 2001 | 4 | 97.0 | -- | -- | -- | 1.33E-02 | 7.88E-02 | 3.60E-02 |
| 2002 | 5 | 97.0 | -- | -- | -- | 1.83E-02 | 8.95E-02 | 4.40E-02 |
| 2003 | 8 | 97.0 | -- | -- | -- | 3.47E-02 | 1.21E-01 | 6.81E-02 |
| 2004 | 0 | 97.3 | -- | -- | -- | 1.57E-05 | 3.12E-02 | 4.00E-03 |
| 2005 | 4 | 97.0 | -- | -- | -- | 1.33E-02 | 7.88E-02 | 3.60E-02 |
| 2006 | 2 | 97.0 | -- | -- | -- | 4.59E-03 | 5.63E-02 | 2.00E-02 |
| 2007 | 7 | 97.6 | -- | -- | -- | 2.89E-02 | 1.10E-01 | 5.98E-02 |
| 2008 | 4 | 98.3 | -- | -- | -- | 1.32E-02 | 7.80E-02 | 3.57E-02 |
| 2009 | 5 | 98.0 | -- | -- | -- | 1.82E-02 | 8.88E-02 | 4.37E-02 |
| 2010 | 3 | 98.0 | -- | -- | -- | 8.61E-03 | 6.72E-02 | 2.78E-02 |
| 2011 | 4 | 98.0 | -- | -- | -- | 1.32E-02 | 7.82E-02 | 3.58E-02 |
| 2012 | 1 | 98.3 | -- | -- | -- | 1.39E-03 | 4.39E-02 | 1.19E-02 |
| 2013 | 0 | 95.6 | 1.14E-02 | 2.87E-03 | 4.55E-02 | 1.59E-05 | 3.17E-02 | 4.05E-03 |
| 2014 | 1 | 94.0 | 1.17E-02 | 3.63E-03 | 3.79E-02 | 1.44E-03 | 4.54E-02 | 1.23E-02 |
| 2015 | 4 | 93.0 | 1.20E-02 | 4.49E-03 | 3.23E-02 | 1.38E-02 | 8.14E-02 | 3.72E-02 |
| 2016 | 4 | 93.2 | 1.23E-02 | 5.34E-03 | 2.85E-02 | 1.37E-02 | 8.13E-02 | 3.72E-02 |
| 2017 | 0 | 93.0 | 1.27E-02 | 5.98E-03 | 2.68E-02 | 1.63E-05 | 3.23E-02 | 4.14E-03 |
| 2018 | 3 | 93.0 | 1.30E-02 | 6.17E-03 | 2.74E-02 | 8.97E-03 | 7.00E-02 | 2.90E-02 |
| 2019 | 0 | 92.0 | 1.33E-02 | 5.85E-03 | 3.04E-02 | 1.64E-05 | 3.26E-02 | 4.17E-03 |
| 2020 | 1 | 90.2 | 1.37E-02 | 5.21E-03 | 3.60E-02 | 1.49E-03 | 4.69E-02 | 1.27E-02 |
| 2021 | 2 | 88.3 | 1.41E-02 | 4.45E-03 | 4.44E-02 | 4.93E-03 | 6.05E-02 | 2.15E-02 |
| 2022 | 1 | 87.4 | 1.44E-02 | 3.71E-03 | 5.61E-02 | 1.53E-03 | 4.80E-02 | 1.30E-02 |
| Total | 78 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 22. Plot data for Figure 14, frequency of FTR>1H events (events per reactor year) trend for standby TDPs.

| Year | Failures | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 0 | 97.0 | -- | -- | -- | 1.55E-05 | 3.08E-02 | 3.95E-03 |
| 1999 | 1 | 97.0 | -- | -- | -- | 1.39E-03 | 4.37E-02 | 1.18E-02 |
| 2000 | 3 | 97.3 | -- | -- | -- | 8.54E-03 | 6.66E-02 | 2.76E-02 |
| 2001 | 1 | 97.0 | -- | -- | -- | 1.39E-03 | 4.37E-02 | 1.18E-02 |
| 2002 | 0 | 97.0 | -- | -- | -- | 1.55E-05 | 3.08E-02 | 3.95E-03 |
| 2003 | 1 | 97.0 | -- | -- | -- | 1.39E-03 | 4.37E-02 | 1.18E-02 |
| 2004 | 4 | 97.3 | -- | -- | -- | 1.31E-02 | 7.75E-02 | 3.55E-02 |
| 2005 | 3 | 97.0 | -- | -- | -- | 8.56E-03 | 6.68E-02 | 2.76E-02 |
| 2006 | 0 | 97.0 | -- | -- | -- | 1.55E-05 | 3.08E-02 | 3.95E-03 |
| 2007 | 1 | 97.6 | -- | -- | -- | 1.38E-03 | 4.35E-02 | 1.18E-02 |
| 2008 | 2 | 98.3 | -- | -- | -- | 4.48E-03 | 5.50E-02 | 1.95E-02 |
| 2009 | 0 | 98.0 | -- | -- | -- | 1.54E-05 | 3.06E-02 | 3.92E-03 |
| 2010 | 1 | 98.0 | -- | -- | -- | 1.38E-03 | 4.34E-02 | 1.17E-02 |
| 2011 | 4 | 98.0 | -- | -- | -- | 1.30E-02 | 7.71E-02 | 3.52E-02 |
| 2012 | 4 | 98.3 | -- | -- | -- | 1.30E-02 | 7.69E-02 | 3.52E-02 |
| 2013 | 3 | 95.6 | 3.51E-02 | 2.29E-02 | 5.40E-02 | 8.65E-03 | 6.75E-02 | 2.79E-02 |
| 2014 | 3 | 94.0 | 2.81E-02 | 1.95E-02 | 4.03E-02 | 8.76E-03 | 6.84E-02 | 2.83E-02 |
| 2015 | 2 | 93.0 | 2.24E-02 | 1.65E-02 | 3.05E-02 | 4.67E-03 | 5.73E-02 | 2.04E-02 |
| 2016 | 2 | 93.2 | 1.79E-02 | 1.36E-02 | 2.35E-02 | 4.66E-03 | 5.72E-02 | 2.03E-02 |
| 2017 | 2 | 93.0 | 1.43E-02 | 1.10E-02 | 1.86E-02 | 4.67E-03 | 5.73E-02 | 2.04E-02 |
| 2018 | 2 | 93.0 | 1.14E-02 | 8.56E-03 | 1.52E-02 | 4.67E-03 | 5.73E-02 | 2.04E-02 |
| 2019 | 1 | 92.0 | 9.12E-03 | 6.52E-03 | 1.28E-02 | 1.45E-03 | 4.55E-02 | 1.23E-02 |
| 2020 | 0 | 90.2 | 7.29E-03 | 4.90E-03 | 1.08E-02 | 1.64E-05 | 3.26E-02 | 4.17E-03 |
| 2021 | 0 | 88.3 | 5.82E-03 | 3.64E-03 | 9.31E-03 | 1.67E-05 | 3.31E-02 | 4.24E-03 |
| 2022 | 0 | 87.4 | 4.65E-03 | 2.69E-03 | 8.03E-03 | 1.68E-05 | 3.34E-02 | 4.27E-03 |
| Total | 40 | 2,381.4 | -- | -- | -- | -- | -- | -- |

Table 23. Plot data for Figure 15, frequency of start demands (demands per reactor year) trend for normally running TDPs.

| Year | Demands | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 79 | 30.0 | -- | -- | -- | 2.16E+00 | 3.16E+00 | 2.62E+00 |
| 1999 | 79 | 30.0 | -- | -- | -- | 2.16E+00 | 3.16E+00 | 2.62E+00 |
| 2000 | 79 | 30.1 | -- | -- | -- | 2.15E+00 | 3.15E+00 | 2.62E+00 |
| 2001 | 78 | 30.0 | -- | -- | -- | 2.14E+00 | 3.14E+00 | 2.60E+00 |
| 2002 | 78 | 30.0 | -- | -- | -- | 2.13E+00 | 3.13E+00 | 2.60E+00 |
| 2003 | 78 | 30.0 | -- | -- | -- | 2.14E+00 | 3.14E+00 | 2.60E+00 |
| 2004 | 78 | 30.1 | -- | -- | -- | 2.13E+00 | 3.13E+00 | 2.59E+00 |
| 2005 | 79 | 30.0 | -- | -- | -- | 2.15E+00 | 3.16E+00 | 2.62E+00 |
| 2006 | 78 | 30.0 | -- | -- | -- | 2.15E+00 | 3.15E+00 | 2.61E+00 |
| 2007 | 78 | 30.6 | -- | -- | -- | 2.10E+00 | 3.08E+00 | 2.56E+00 |
| 2008 | 78 | 31.1 | -- | -- | -- | 2.07E+00 | 3.04E+00 | 2.52E+00 |
| 2009 | 78 | 31.0 | -- | -- | -- | 2.06E+00 | 3.02E+00 | 2.50E+00 |
| 2010 | 76 | 31.0 | -- | -- | -- | 2.01E+00 | 2.97E+00 | 2.46E+00 |
| 2011 | 76 | 31.0 | -- | -- | -- | 2.01E+00 | 2.97E+00 | 2.46E+00 |
| 2012 | 76 | 31.1 | -- | -- | -- | 2.01E+00 | 2.97E+00 | 2.46E+00 |
| 2013 | 76 | 31.0 | 2.46E+00 | 2.43E+00 | 2.49E+00 | 2.02E+00 | 2.98E+00 | 2.46E+00 |
| 2014 | 76 | 31.0 | 2.45E+00 | 2.42E+00 | 2.48E+00 | 2.01E+00 | 2.97E+00 | 2.46E+00 |
| 2015 | 76 | 31.0 | 2.44E+00 | 2.42E+00 | 2.46E+00 | 2.02E+00 | 2.98E+00 | 2.46E+00 |
| 2016 | 76 | 31.3 | 2.43E+00 | 2.41E+00 | 2.44E+00 | 2.00E+00 | 2.95E+00 | 2.44E+00 |
| 2017 | 76 | 32.0 | 2.42E+00 | 2.40E+00 | 2.43E+00 | 1.95E+00 | 2.88E+00 | 2.38E+00 |
| 2018 | 76 | 32.0 | 2.40E+00 | 2.39E+00 | 2.42E+00 | 1.95E+00 | 2.88E+00 | 2.38E+00 |
| 2019 | 76 | 32.0 | 2.39E+00 | 2.37E+00 | 2.41E+00 | 1.96E+00 | 2.89E+00 | 2.39E+00 |
| 2020 | 76 | 32.1 | 2.38E+00 | 2.36E+00 | 2.40E+00 | 1.94E+00 | 2.87E+00 | 2.37E+00 |
| 2021 | 76 | 32.0 | 2.37E+00 | 2.35E+00 | 2.40E+00 | 1.95E+00 | 2.88E+00 | 2.38E+00 |
| 2022 | 76 | 32.0 | 2.36E+00 | 2.33E+00 | 2.39E+00 | 1.95E+00 | 2.88E+00 | 2.38E+00 |
| Total | 1,930 | 772.3 | -- | -- | -- | -- | -- | -- |

Table 24. Plot data for Figure 16, frequency of run hours (hours per reactor year) trend for normally running TDPs.

| Year | Run Hours | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 335,022 | 30.0 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.12E+04 |
| 1999 | 335,022 | 30.0 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.12E+04 |
| 2000 | 335,022 | 30.1 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.11E+04 |
| 2001 | 335,448 | 30.0 | -- | -- | -- | 1.12E+04 | 1.12E+04 | 1.12E+04 |
| 2002 | 335,539 | 30.0 | -- | -- | -- | 1.12E+04 | 1.12E+04 | 1.12E+04 |
| 2003 | 335,402 | 30.0 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.12E+04 |
| 2004 | 335,341 | 30.1 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.11E+04 |
| 2005 | 335,371 | 30.0 | -- | -- | -- | 1.11E+04 | 1.12E+04 | 1.12E+04 |
| 2006 | 335,417 | 30.0 | -- | -- | -- | 1.12E+04 | 1.12E+04 | 1.12E+04 |
| 2007 | 335,448 | 30.6 | -- | -- | -- | 1.09E+04 | 1.10E+04 | 1.10E+04 |
| 2008 | 335,387 | 31.1 | -- | -- | -- | 1.08E+04 | 1.08E+04 | 1.08E+04 |
| 2009 | 333,274 | 31.0 | -- | -- | -- | 1.07E+04 | 1.08E+04 | 1.08E+04 |
| 2010 | 327,150 | 31.0 | -- | -- | -- | 1.05E+04 | 1.06E+04 | 1.06E+04 |
| 2011 | 327,211 | 31.0 | -- | -- | -- | 1.05E+04 | 1.06E+04 | 1.06E+04 |
| 2012 | 327,120 | 31.1 | -- | -- | -- | 1.05E+04 | 1.06E+04 | 1.05E+04 |
| 2013 | 327,211 | 31.0 | 1.06E+04 | 1.04E+04 | 1.07E+04 | 1.05E+04 | 1.06E+04 | 1.06E+04 |
| 2014 | 327,135 | 31.0 | 1.05E+04 | 1.04E+04 | 1.06E+04 | 1.05E+04 | 1.06E+04 | 1.06E+04 |
| 2015 | 327,105 | 31.0 | 1.05E+04 | 1.04E+04 | 1.05E+04 | 1.05E+04 | 1.06E+04 | 1.06E+04 |
| 2016 | 327,120 | 31.3 | 1.04E+04 | 1.03E+04 | 1.05E+04 | 1.04E+04 | 1.05E+04 | 1.05E+04 |
| 2017 | 327,211 | 32.0 | 1.04E+04 | 1.03E+04 | 1.04E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 |
| 2018 | 327,211 | 32.0 | 1.03E+04 | 1.03E+04 | 1.04E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 |
| 2019 | 327,135 | 32.0 | 1.03E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 |
| 2020 | 327,302 | 32.1 | 1.02E+04 | 1.01E+04 | 1.03E+04 | 1.02E+04 | 1.02E+04 | 1.02E+04 |
| 2021 | 327,105 | 32.0 | 1.02E+04 | 1.01E+04 | 1.03E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 |
| 2022 | 327,181 | 32.0 | 1.01E+04 | 1.00E+04 | 1.03E+04 | 1.02E+04 | 1.03E+04 | 1.02E+04 |
| Total | 8,274,889 | 772.3 | -- | -- | -- | -- | -- | -- |

Table 25. Plot data for Figure 17, frequency of FTS events (events per reactor year) trend for normally running TDPs.

| Year | Failures | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 2 | 30.0 | -- | -- | -- | 7.62E-03 | 9.35E-02 | 3.32E-02 |
| 1999 | 2 | 30.0 | -- | -- | -- | 7.62E-03 | 9.35E-02 | 3.32E-02 |
| 2000 | 0 | 30.1 | -- | -- | -- | 2.61E-05 | 5.19E-02 | 6.64E-03 |
| 2001 | 1 | 30.0 | -- | -- | -- | 2.34E-03 | 7.36E-02 | 1.99E-02 |
| 2002 | 0 | 30.0 | -- | -- | -- | 2.61E-05 | 5.20E-02 | 6.65E-03 |
| 2003 | 0 | 30.0 | -- | -- | -- | 2.61E-05 | 5.20E-02 | 6.65E-03 |
| 2004 | 0 | 30.1 | -- | -- | -- | 2.61E-05 | 5.19E-02 | 6.64E-03 |
| 2005 | 3 | 30.0 | -- | -- | -- | 1.44E-02 | 1.12E-01 | 4.65E-02 |
| 2006 | 1 | 30.0 | -- | -- | -- | 2.34E-03 | 7.36E-02 | 1.99E-02 |
| 2007 | 0 | 30.6 | -- | -- | -- | 2.59E-05 | 5.15E-02 | 6.60E-03 |
| 2008 | 0 | 31.1 | -- | -- | -- | 2.58E-05 | 5.12E-02 | 6.55E-03 |
| 2009 | 1 | 31.0 | -- | -- | -- | 2.31E-03 | 7.26E-02 | 1.97E-02 |
| 2010 | 0 | 31.0 | -- | -- | -- | 2.58E-05 | 5.13E-02 | 6.56E-03 |
| 2011 | 0 | 31.0 | -- | -- | -- | 2.58E-05 | 5.13E-02 | 6.56E-03 |
| 2012 | 1 | 31.1 | -- | -- | -- | 2.31E-03 | 7.26E-02 | 1.97E-02 |
| 2013 | 1 | 31.0 | 1.12E-02 | 5.02E-03 | 2.51E-02 | 2.31E-03 | 7.26E-02 | 1.97E-02 |
| 2014 | 0 | 31.0 | 1.07E-02 | 5.41E-03 | 2.12E-02 | 2.58E-05 | 5.13E-02 | 6.56E-03 |
| 2015 | 0 | 31.0 | 1.02E-02 | 5.74E-03 | 1.81E-02 | 2.58E-05 | 5.13E-02 | 6.56E-03 |
| 2016 | 1 | 31.3 | 9.73E-03 | 5.97E-03 | 1.58E-02 | 2.30E-03 | 7.24E-02 | 1.96E-02 |
| 2017 | 0 | 32.0 | 9.27E-03 | 5.99E-03 | 1.43E-02 | 2.55E-05 | 5.06E-02 | 6.48E-03 |
| 2018 | 0 | 32.0 | 8.84E-03 | 5.74E-03 | 1.36E-02 | 2.55E-05 | 5.06E-02 | 6.48E-03 |
| 2019 | 0 | 32.0 | 8.42E-03 | 5.24E-03 | 1.35E-02 | 2.55E-05 | 5.06E-02 | 6.48E-03 |
| 2020 | 1 | 32.1 | 8.03E-03 | 4.60E-03 | 1.40E-02 | 2.28E-03 | 7.16E-02 | 1.94E-02 |
| 2021 | 0 | 32.0 | 7.65E-03 | 3.95E-03 | 1.48E-02 | 2.55E-05 | 5.06E-02 | 6.48E-03 |
| 2022 | 0 | 32.0 | 7.29E-03 | 3.34E-03 | 1.59E-02 | 2.55E-05 | 5.06E-02 | 6.48E-03 |
| Total | 14 | 772.3 | -- | -- | -- | -- | -- | -- |

Table 26. Plot data for Figure 18, frequency of FTR events (events per reactor year) trend for normally running TDPs.

| Year | Failures | Reactor Years | Regression Curve Data Points | | | Yearly Estimate Data Points | | |
|---|---|---|---|---|---|---|---|---|
| | | | Mean | Lower (5%) | Upper (95%) | Lower (5%) | Upper (95%) | Mean |
| 1998 | 1 | 30.0 | -- | -- | -- | 4.62E-03 | 1.45E-01 | 3.94E-02 |
| 1999 | 6 | 30.0 | -- | -- | -- | 7.73E-02 | 3.28E-01 | 1.71E-01 |
| 2000 | 2 | 30.1 | -- | -- | -- | 1.50E-02 | 1.84E-01 | 6.55E-02 |
| 2001 | 3 | 30.0 | -- | -- | -- | 2.84E-02 | 2.22E-01 | 9.18E-02 |
| 2002 | 3 | 30.0 | -- | -- | -- | 2.84E-02 | 2.22E-01 | 9.18E-02 |
| 2003 | 6 | 30.0 | -- | -- | -- | 7.73E-02 | 3.28E-01 | 1.71E-01 |
| 2004 | 3 | 30.1 | -- | -- | -- | 2.84E-02 | 2.21E-01 | 9.16E-02 |
| 2005 | 6 | 30.0 | -- | -- | -- | 7.73E-02 | 3.28E-01 | 1.71E-01 |
| 2006 | 3 | 30.0 | -- | -- | -- | 2.84E-02 | 2.22E-01 | 9.18E-02 |
| 2007 | 3 | 30.6 | -- | -- | -- | 2.80E-02 | 2.18E-01 | 9.04E-02 |
| 2008 | 3 | 31.1 | -- | -- | -- | 2.76E-02 | 2.16E-01 | 8.93E-02 |
| 2009 | 3 | 31.0 | -- | -- | -- | 2.77E-02 | 2.16E-01 | 8.95E-02 |
| 2010 | 6 | 31.0 | -- | -- | -- | 7.53E-02 | 3.20E-01 | 1.66E-01 |
| 2011 | 2 | 31.0 | -- | -- | -- | 1.46E-02 | 1.80E-01 | 6.39E-02 |
| 2012 | 6 | 31.1 | -- | -- | -- | 7.52E-02 | 3.19E-01 | 1.66E-01 |
| 2013 | 4 | 31.0 | 1.31E-01 | 6.88E-02 | 2.49E-01 | 4.25E-02 | 2.52E-01 | 1.15E-01 |
| 2014 | 2 | 31.0 | 1.02E-01 | 5.96E-02 | 1.76E-01 | 1.46E-02 | 1.80E-01 | 6.39E-02 |
| 2015 | 5 | 31.0 | 8.02E-02 | 5.07E-02 | 1.27E-01 | 5.85E-02 | 2.86E-01 | 1.41E-01 |
| 2016 | 2 | 31.3 | 6.28E-02 | 4.17E-02 | 9.48E-02 | 1.45E-02 | 1.79E-01 | 6.35E-02 |
| 2017 | 3 | 32.0 | 4.92E-02 | 3.28E-02 | 7.39E-02 | 2.70E-02 | 2.11E-01 | 8.73E-02 |
| 2018 | 2 | 32.0 | 3.85E-02 | 2.46E-02 | 6.04E-02 | 1.43E-02 | 1.75E-01 | 6.23E-02 |
| 2019 | 0 | 32.0 | 3.02E-02 | 1.78E-02 | 5.11E-02 | 4.90E-05 | 9.74E-02 | 1.25E-02 |
| 2020 | 1 | 32.1 | 2.36E-02 | 1.27E-02 | 4.41E-02 | 4.38E-03 | 1.38E-01 | 3.73E-02 |
| 2021 | 0 | 32.0 | 1.85E-02 | 8.86E-03 | 3.87E-02 | 4.90E-05 | 9.74E-02 | 1.25E-02 |
| 2022 | 0 | 32.0 | 1.45E-02 | 6.15E-03 | 3.42E-02 | 4.90E-05 | 9.74E-02 | 1.25E-02 |
| Total | 75 | 772.3 | -- | -- | -- | -- | -- | -- |

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