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System Study: Auxiliary Feedwater 1998–2014

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ABSTRACT

This report presents an unreliability evaluation of the auxiliary feedwater (AFW) system at 69 U.S. commercial nuclear power plants. Demand, run hours, and failure data from fiscal year 1998 through 2014 for selected components were obtained from the Institute of Nuclear Power Operations (INPO) Consolidated Events Database (ICES). The unreliability results are trended for the most recent 10-year period while yearly estimates for system unreliability are provided for the entire active period. No statistically significant increasing or decreasing trends were identified in the AFW results.

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ACRONYMS

AFW	auxiliary feedwater
AOV	air-operated valve
CCF	common-cause failure
EPIX	Equipment Performance and Information Exchange
ESFAS	engineered safety features actuation system
FTLR	fail to load/run
FTOC	fail to open/close
FTOP	fail to operate
FTR	fail to run
FTR<1H	fail to run less than one hour (after start)
FTS	fail to start
FY	fiscal year
ICES	INPO Consolidated Events Database
INPO	Institute of Nuclear Power Operations
MDP	motor-driven pump
MOV	motor-operated valve
MSPI	Mitigating Systems Performance Index
PRA	probabilistic risk assessment
SO	spurious operation
SPAR	standardized plant analysis risk
SSU	safety system unavailability
TDP	turbine-driven pump
UA	unavailability (maintenance or state of another component)

System Study: Auxiliary Feedwater 1998–2014

1. INTRODUCTION

This report presents an unreliability evaluation of the auxiliary feedwater (AFW) system at 69 U.S. commercial nuclear power plants listed in Table 1. For each plant, the corresponding Standardized Plant Analysis Risk (SPAR) model (version model indicated in Table 1) was used in the yearly calculations. Demand, run hours, and failure data from fiscal year (FY)-98 through FY-14 for selected components in the AFW were obtained from the Institute of Nuclear Power Operations (INPO) Consolidated Events Database (ICES). Train unavailability data (outages from test or maintenance) were obtained from the Reactor Oversight Process Safety System Unavailability (SSU) database (FY-98 through FY-01) and the Mitigating Systems Performance Index (MSPI) database (FY-02 through FY-14). Common-cause failure (CCF) data used in the models are from the 2010 update to the CCF database. The system unreliability results are trended for the most recent 10-year period while yearly estimates for system unreliability are provided for the entire active period.

This report does not attempt to estimate basic event values for use in a probabilistic risk assessment (PRA). Suggested values for such use are presented in the 2010 Component Reliability Update (Reference 1), which is an update to Reference 2 (NUREG/CR-6928). Baseline AFW unreliability results using basic event values from that report are summarized in Section 3. Trend results for AFW (using system-specific data) are presented in Section 4. Similar to previous system study updates, Section 5 contains importance information (using the baseline results from Section 3), and Section 7 describes the AFW.

The AFW classes were categorized by number of pump trains (no specification on pump type) used in the SPAR models. Class 2 AFW includes configurations that effectively result in a success criterion of one of two pumps. Class 3 AFW includes configurations that effectively result in a success criterion of one of three pumps. AFW designs effectively resulting in a success criterion of one of four or more are included in Class 4. Table 1 summarizes the plants and their classes.

The AFW model is evaluated using the transient flag set in the SPAR model. The transient flag set assumes all support systems are available and that the AFW system is required to perform to mitigate the effects of the transient initiating event. All models include failures due to unavailability while in test or maintenance. Human error has not been included in the SPAR model logic. An overview of the trending methods, glossary of terms, and abbreviations can be found in the Overview and Reference document on the Reactor Operational Experience Results and Databases web page.

Two modes of the models for the AFW system are calculated. The AFW start-only model is the SPAR AFW model modified by setting all fail-to-run basic events to zero (False), setting all recovery events to False, setting all pump-ends events to False, and setting all cooling basic events to False. The 8-hour mission model includes all basic events in the SPAR AFW model.

Table 1. AFW design class summary.

Class	Plant	Version
Class 2	Arkansas 1	8.19
Class 2	Braidwood 1	8.21
Class 2	Braidwood 2	8.21
Class 2	Byron 1	8.21
Class 2	Byron 2	8.21
Class 2	Crystal River 3	8.16
Class 2	Prairie Island 1	8.19
Class 2	Prairie Island 2	8.19
Class 2	Seabrook	8.20
Class 3	Arkansas 2	8.21
Class 3	Beaver Valley 2	8.23
Class 3	Callaway	8.21
Class 3	Catawba 1	8.20
Class 3	Catawba 2	8.20
Class 3	Comanche Peak 1	8.21
Class 3	Comanche Peak 2	8.21
Class 3	Cook 1	8.20
Class 3	Cook 2	8.20
Class 3	Diablo Canyon 1	8.19
Class 3	Diablo Canyon 2	8.19
Class 3	Farley 1	8.18
Class 3	Farley 2	8.18
Class 3	Fort Calhoun	8.20
Class 3	Harris	8.23
Class 3	Indian Point 2	8.19
Class 3	Indian Point 3	8.20
Class 3	Kewaunee	8.20
Class 3	McGuire 1	8.20
Class 3	McGuire 2	8.20
Class 3	Millstone 2	8.17
Class 3	Millstone 3	8.20
Class 3	North Anna 1	8.20
Class 3	North Anna 2	8.20
Class 3	Oconee 1	8.19
Class 3	Oconee 2	8.19
Class 3	Oconee 3	8.19
Class 3	Palisades	8.20
Class 3	Palo Verde 1	8.20
Class 3	Palo Verde 2	8.20
Class 3	Palo Verde 3	8.20
Class 3	Point Beach 1	8.20
Class 3	Point Beach 2	8.20
Class 3	Robinson 2	8.17
Class 3	Salem 1	8.20
Class 3	Salem 2	8.20
Class 3	San Onofre 2	8.22
Class 3	San Onofre 3	8.22
Class 3	Sequoyah 1	8.16
Class 3	Sequoyah 2	8.16
Class 3	St. Lucie 1	8.19
Class 3	St. Lucie 2	8.19
Class 3	Summer	8.23
Class 3	Three Mile Isl 1	8.20
Class 3	Turkey Point 3	8.20
Class 3	Turkey Point 4	8.20
Class 3	Vogtle 1	8.21
Class 3	Vogtle 2	8.21
Class 3	Waterford 3	8.16
Class 3	Watts Bar 1	8.16
Class 3	Wolf Creek	8.20
Class 4	Beaver Valley 1	8.22
Class 4	Calvert Cliffs 1	8.22
Class 4	Calvert Cliffs 2	8.21
Class 4	Davis-Besse	8.19
Class 4	Ginna	8.23
Class 4	South Texas 1	8.17
Class 4	South Texas 2	8.17
Class 4	Surry 1	8.19
Class 4	Surry 2	8.15

2. SUMMARY OF FINDINGS

The results of this AFW system unreliability study are summarized in this section. Of particular interest is the existence of any statistically significant[a] increasing trends. In this update, no statistically significant increasing trends were identified in the AFW unreliability trend results. In addition, this update identified no statistically significant decreasing trends in the AFW results.

The industry-wide AFW start-only and 8-hour basic event group importances were evaluated and are shown in Figure 5:

- In the ***Start-Only*** case—the leading contributor is the injection flow path followed by the TDP and MDP components (only the fail-to-start failure mode).
- In the ***8-Hour*** case—the leading contributor to AFW system unreliability is the AFW motor-driven and turbine-driven pumps followed by recovery and the pump ends.

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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 that there is a trend in the data (reject the null hypothesis of no trend.) By convention, we use the "Michelin Guide" scale: p-value < 0.05 (statistically significant), p-value < 0.01 (highly statistically significant); p-value < 0.001 (extremely statistically significant).

3. INDUSTRY-WIDE UNRELIABILITY

The AFW fault trees from the SPAR models were evaluated for each of the 69 operating U.S. commercial pressurized water nuclear power plants with an AFW system.

The industry-wide unreliability of the AFW system has been estimated for two modes of operation. A start-only model and an 8-hour mission model were evaluated. The uncertainty distributions for AFW show both plant design variability and parameter uncertainty while using industry-wide component failure data (FY 1998–FY 2010).[a] Table 2 shows the percentiles and mean of the aggregated sample data (Latin hypercube, 1000 samples for each model) collected from the uncertainty calculations of the AFW fault trees in the SPAR models. In Figure 1 and Figure 2, the 5th and 95th percentiles and mean point estimates are shown for each class and for the industry.

In Figure 1 and Figure 2, the width of the distribution for a class is affected by the differences in the plant modeling and the parameter uncertainty used in the models. Because the width is affected by the plant modeling, the width is also affected by the number of different plant models in a class. For those classes with very few plants that share a design, the width can be very small.

Table 2. Industry-wide unreliability values.

Model	EPS Grouping	Lower (5%)	Median	Mean	Upper (95%)
Start-only	Industry	2.13E−08	1.47E−06	1.27E−05	3.08E−05
	Class 2	3.66E−07	9.10E−06	2.60E−05	1.07E−04
	Class 3	4.91E−08	1.34E−06	1.21E−05	1.62E−05
	Class 4	7.06E−09	5.22E−07	2.46E−06	1.08E−05
8-hour Mission	Industry	3.86E−07	7.39E−06	6.97E−05	5.02E−04
	Class 2	1.13E−06	4.48E−05	1.96E−04	9.49E−04
	Class 3	8.47E−07	7.35E−06	5.70E−05	5.03E−04
	Class 4	1.94E−08	1.59E−06	1.23E−05	5.24E−05

a. By using industry-wide component failure data, individual plant performance is not included in the distribution of results.

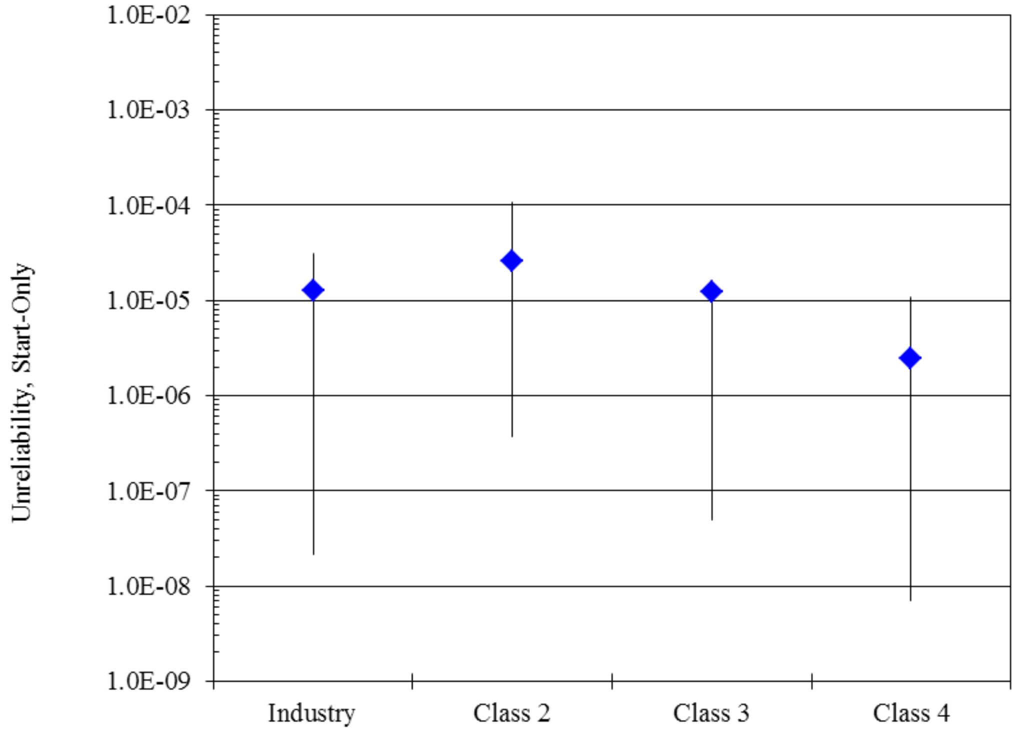

Figure 1. AFW start-only mission unreliability for Class 2, 3, and 4 and industry-wide groupings.

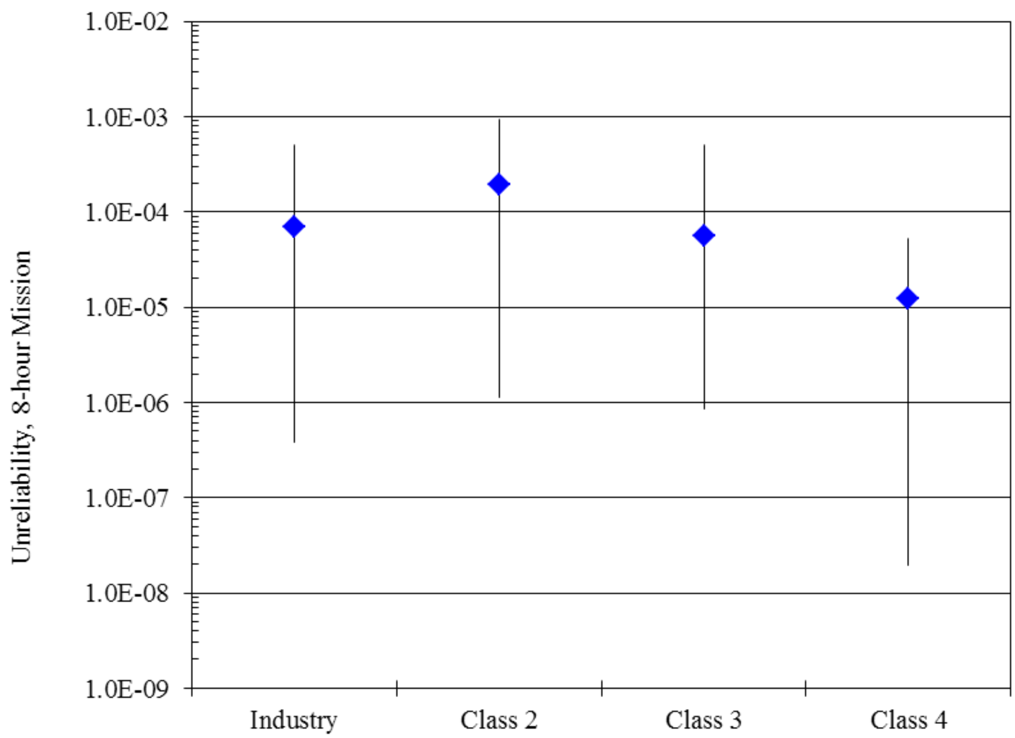

Figure 2. AFW 8-hour mission unreliability for Class 2, 3, and 4 and industry-wide groupings.

4. INDUSTRY-WIDE TRENDS

The yearly (FY-98 through FY-14) failure and demand or run time data were obtained from ICES for the AFW system. AFW train maintenance unavailability data for trending are from the same time period, as reported in the ROP and ICES. The component basic event uncertainty was calculated for the AFW system components using the trending methods described in Section 1 and 2 of the Overview and Reference document. Tables 6 and 7 show the yearly data values for each AFW system specific component and failure mode combination that was varied in the model. These data were loaded into the AFW system fault tree in each SPAR model with an AFW system (see Table 1).

The trend charts show the results of varying component reliability data over time and updating generic, relatively flat prior distributions using data for each year. In addition, the calculated industry-wide system reliability from this update (SPAR/ICES) is shown. Section 4 of the Overview and Reference link on the System Studies main web page provides more detailed discussion of the trending methods. In the lower left-hand corner of the trend figures, the regression method is reported.

The components that were varied in the AFW model are

- AFW motor-driven pump start, run, and test and maintenance.
- AFW turbine-driven pump start, run, and test and maintenance.
- Injection valves fail-to-open.

Figure 3 shows the trend in the AFW start-only model unreliability. Table 4 shows the data points for Figure 3. No statistically significant trends within the industry-wide estimates of AFW system start-only mission on a per fiscal year basis were identified. Figure 4 shows the trend in the 8-hour mission unreliability. No statistically significant trend within the industry-wide estimates of AFW system unreliability (8-hour mission) on a per fiscal year basis was identified. Table 5 shows the data points for Figure 4.

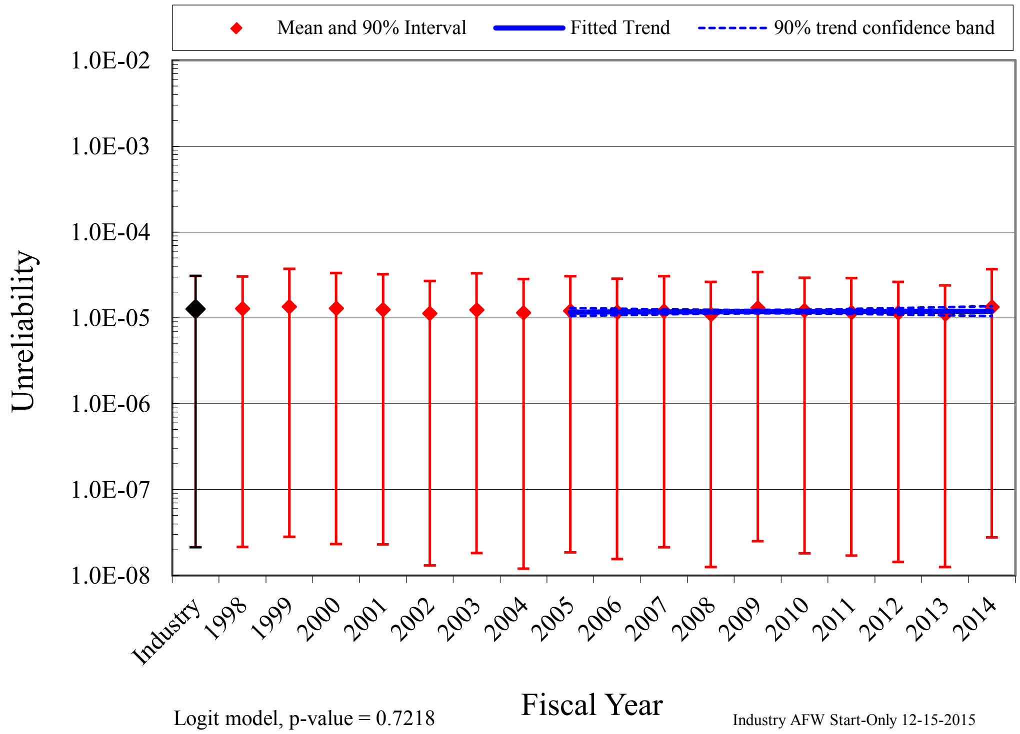

Figure 3. Trend of AFW system unreliability (start-only model), as a function of fiscal year.

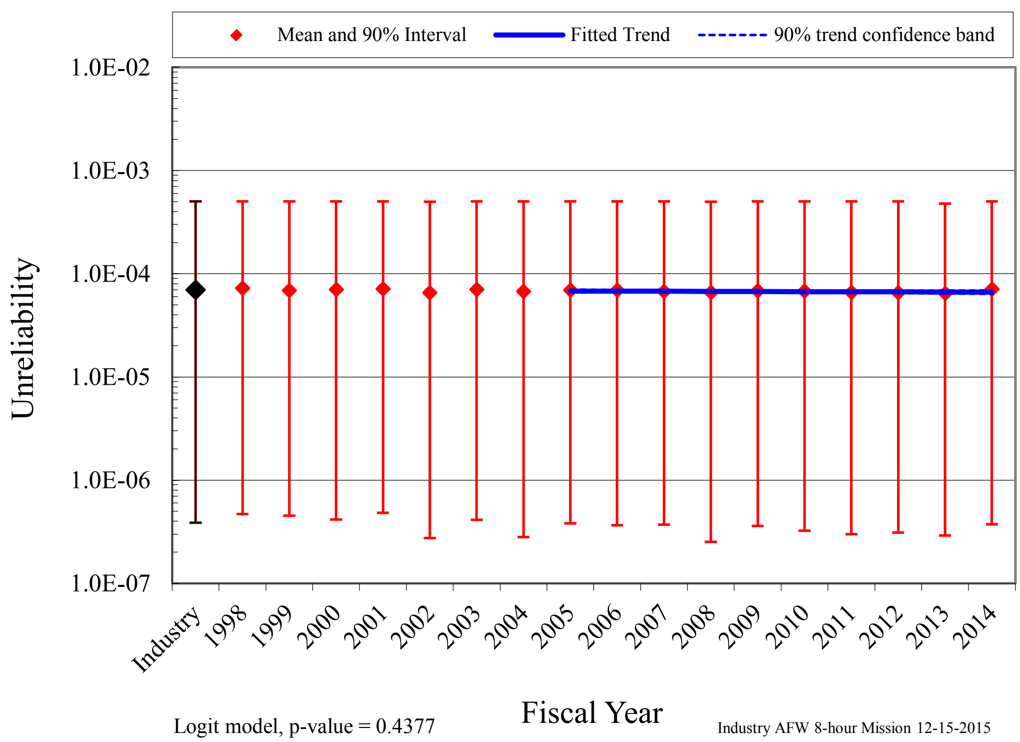

Figure 4. Trend of AFW system unreliability (8-hour model), as a function of fiscal year.

5. BASIC EVENT GROUP IMPORTANCES

The AFW basic event group Fussell-Vesely importances were calculated for the start-only and 8-hour modes for each plant using the industry-wide data (1998–2010). These basic event group importances were then averaged across all plants to represent an industry-wide basic event group importance.

The industry-wide AFW start-only and 8-hour basic event group importances are shown in Figure 5:

- In the **Start-Only** case—the leading contributor is the injection flow path followed by the TDP and MDP components (only the fail-to-start failure mode).
- In the **8-Hour** case—the leading contributor to AFW system unreliability is the AFW motor-driven and turbine-driven pumps followed by recovery and the pump ends.

For more discussion on the AFW motor/turbine-driven pumps, see the motor/turbine-driven pump component reliability studies at NRC Reactor Operational Experience Results and Databases. Table 3 shows the SPAR model AFW importance groups and their descriptions.

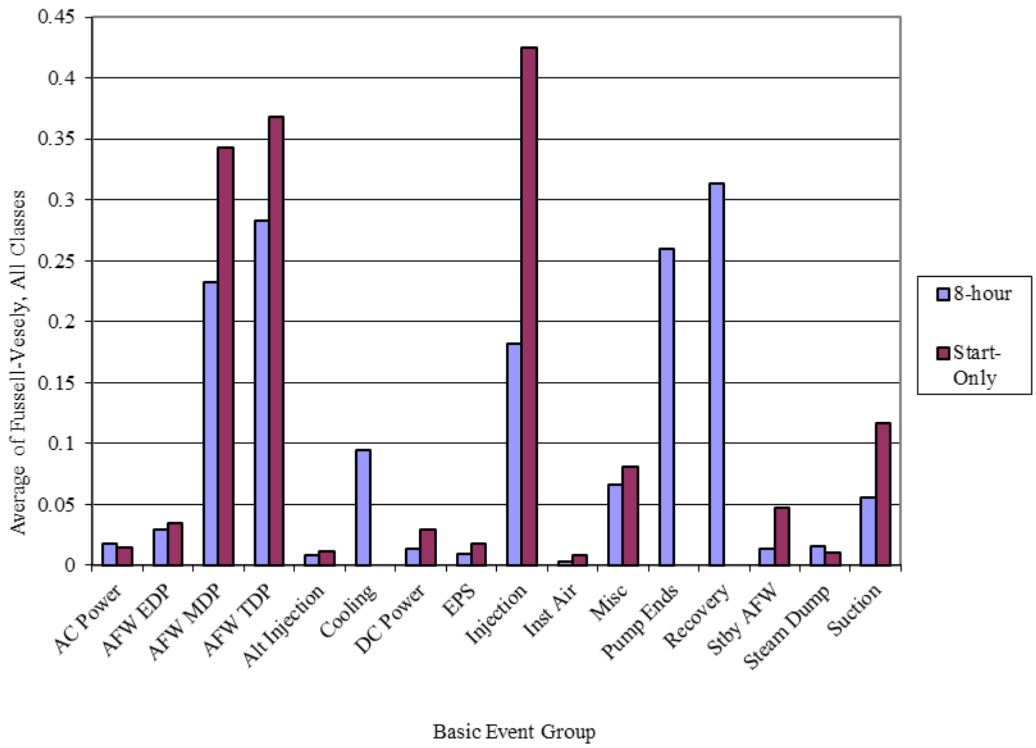

Figure 5. AFW industry-wide basic event group importances.

Table 3. AFW model basic event importance group descriptions.

Group	Description
AC Power	The ac buses and circuit breakers that supply power to the AFW pumps.
AFW EDP	All basic events associated with the diesel engine-driven pumps. The start, run, common-cause, and test and maintenance are included in this group of basic events.
AFW MDP	All basic events associated with the motor-driven pumps. The start, run, common-cause, and test and maintenance are included in this group of basic events.
AFW TDP	All basic events associated with the turbine-driven pumps. The start, run, common-cause, and test and maintenance are included in this group of basic events.
Alternate Injection	Alternate injection sources such as firewater.
Cooling	The pumps, valves, and heat exchangers that provide heat removal to the pumps. In addition, the pumps, valves, air-conditioning equipment that are modeled to provide room cooling to the AFW equipment
DC Power	The batteries and battery chargers that supply power to the pump control circuitry.
EPS	AFW dependency on the emergency power system.
Injection	The motor-operated valves and check valves in the injection path.
Inst Air	Instrument air support to the AFW model.
Misc	Other events that are not typically modeled or of very low importance.
Pump Ends	The common-cause failure of the pump ends. Used to model common-cause without the pump drivers.
Recovery	The operator recovery of the pump FTS, FTR, and other specialized modeled recovery events.
Special	Various events used in the models that are not directly associated with the AFW system.
Suction	The motor-operated valves and air-operated valves in the tank suction path. Includes the failure of the tank.
Stby AFW	Standby means of injecting water to the steam generators. Includes startup feedwater and cross-ties to adjacent units.

The basic event group importances were also averaged across plants of the same AFW class to represent class basic event group importances. The AFW class-specific start-only and 8-hour basic event group importances are shown in Figure 6 through Figure 8.

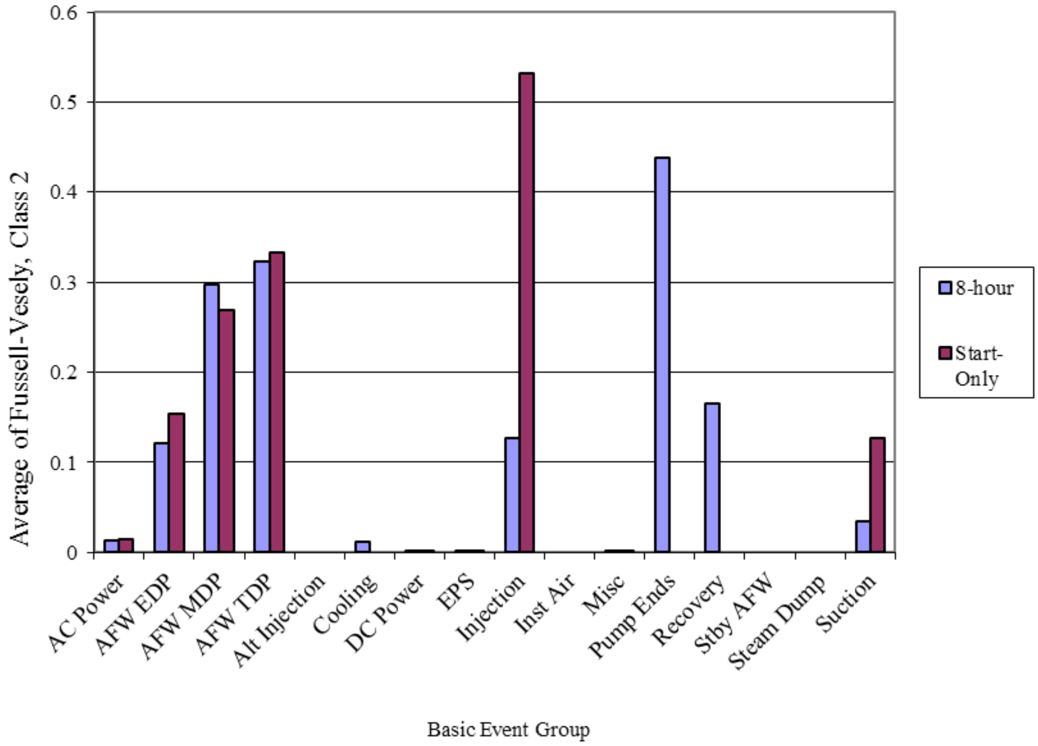

Figure 6. AFW Class 2 basic event group importances.

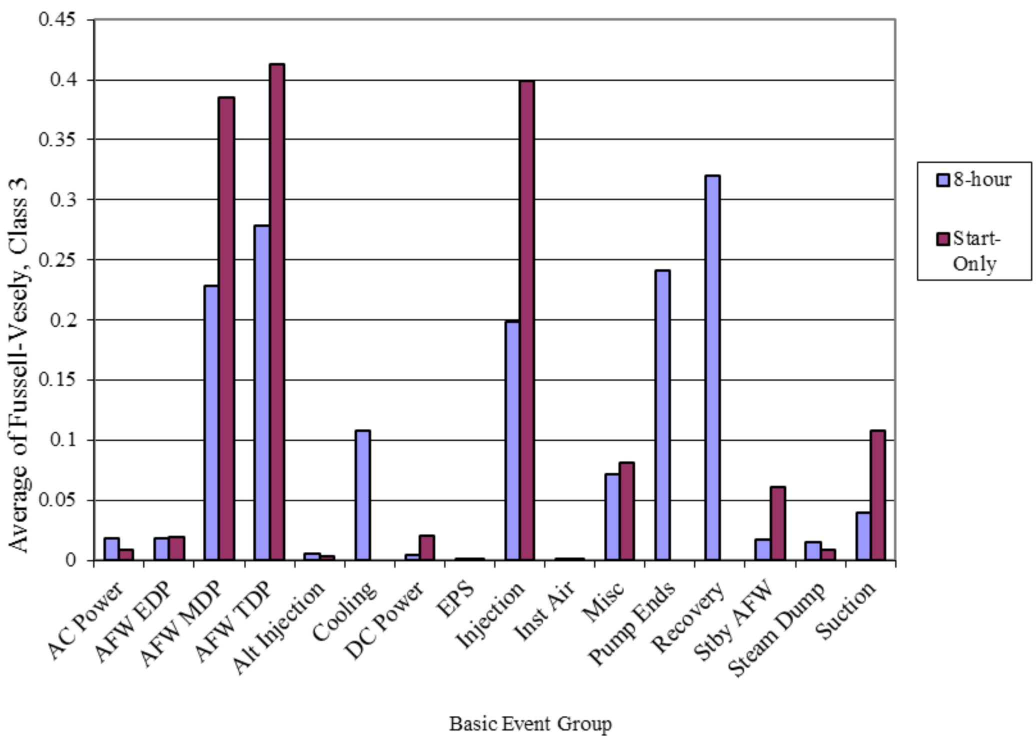

Figure 7. AFW Class 3 basic event group importances.

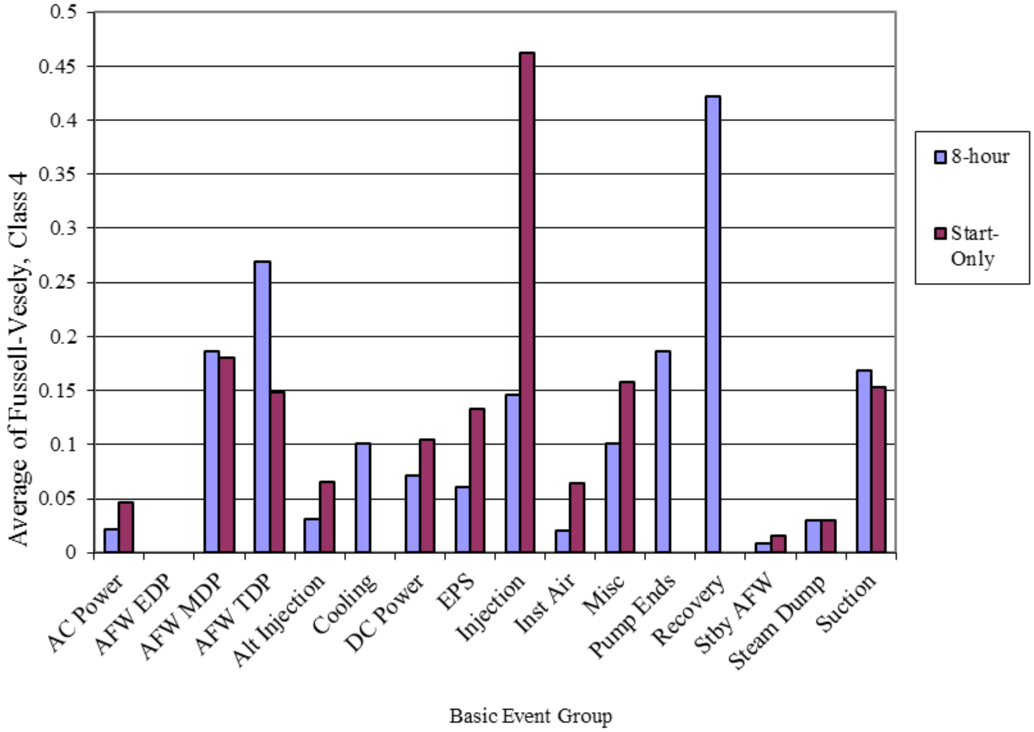

Figure 8. AFW Class 4 basic event group importances.

6. DATA TABLES

Table 4. Plot data for AFW start-only trend, Figure 3.

	Regression Curve Data Points			Annual Estimate Data Points		
FY/Source	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
SPAR/ICES				2.13E−08	3.08E−05	1.27E−05
1998				2.16E-08	3.05E-05	1.27E-05
1999				2.83E-08	3.73E-05	1.34E-05
2000				2.32E-08	3.35E-05	1.29E-05
2001				2.31E-08	3.23E-05	1.25E-05
2002				1.31E-08	2.70E-05	1.12E-05
2003				1.84E-08	3.31E-05	1.24E-05
2004				1.20E-08	2.83E-05	1.14E-05
2005	1.17E-05	1.05E-05	1.31E-05	1.87E-08	3.05E-05	1.20E-05
2006	1.17E-05	1.08E-05	1.28E-05	1.56E-08	2.85E-05	1.16E-05
2007	1.18E-05	1.10E-05	1.26E-05	2.14E-08	3.08E-05	1.19E-05
2008	1.18E-05	1.12E-05	1.25E-05	1.25E-08	2.64E-05	1.09E-05
2009	1.18E-05	1.13E-05	1.24E-05	2.50E-08	3.42E-05	1.30E-05
2010	1.19E-05	1.13E-05	1.25E-05	1.81E-08	2.94E-05	1.22E-05
2011	1.19E-05	1.11E-05	1.27E-05	1.70E-08	2.92E-05	1.15E-05
2012	1.19E-05	1.09E-05	1.30E-05	1.44E-08	2.62E-05	1.14E-05
2013	1.20E-05	1.07E-05	1.34E-05	1.26E-08	2.39E-05	1.10E-05
2014	1.20E-05	1.05E-05	1.37E-05	2.79E-08	3.70E-05	1.34E-05

Table 5. Plot data for AFW 8-hour trend, Figure 4.

FY/Source	Regression Curve Data Points			Annual Estimate Data Points		
	Mean	Lower (5%)	Upper (95%)	Lower (5%)	Upper (95%)	Mean
SPAR/ICES				3.86E−07	5.02E−04	6.97E−05
1998				4.69E-07	5.03E-04	7.23E-05
1999				4.51E-07	5.02E-04	6.86E-05
2000				4.16E-07	5.03E-04	7.00E-05
2001				4.81E-07	5.03E-04	7.10E-05
2002				2.74E-07	5.01E-04	6.53E-05
2003				4.11E-07	5.03E-04	7.00E-05
2004				2.80E-07	5.01E-04	6.71E-05
2005	6.80E-05	6.58E-05	7.02E-05	3.82E-07	5.02E-04	6.88E-05
2006	6.78E-05	6.60E-05	6.96E-05	3.66E-07	5.02E-04	6.91E-05
2007	6.76E-05	6.62E-05	6.90E-05	3.71E-07	5.02E-04	6.70E-05
2008	6.74E-05	6.64E-05	6.85E-05	2.52E-07	5.00E-04	6.55E-05
2009	6.72E-05	6.63E-05	6.82E-05	3.59E-07	5.02E-04	6.79E-05
2010	6.70E-05	6.60E-05	6.81E-05	3.24E-07	5.01E-04	6.76E-05
2011	6.69E-05	6.55E-05	6.82E-05	3.00E-07	5.01E-04	6.57E-05
2012	6.67E-05	6.50E-05	6.85E-05	3.09E-07	5.01E-04	6.52E-05
2013	6.65E-05	6.44E-05	6.87E-05	2.91E-07	4.77E-04	6.42E-05
2014	6.63E-05	6.37E-05	6.90E-05	3.74E-07	5.02E-04	7.04E-05

Table 6. Basic event reliability trending data.

Failure Mode	Component	Year	Number of Failures	Demands/ Run Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
FTOC	AOV	1998	5	1894.2	2.00E-03	6.112	3057.2	Beta
FTOC	AOV	1999	0	2153.18	3.35E-04	1.112	3321.18	Beta
FTOC	AOV	2000	2	1934.08	1.00E-03	3.112	3100.08	Beta
FTOC	AOV	2001	3	2069.1	1.27E-03	4.112	3234.1	Beta
FTOC	AOV	2002	3	2373	1.16E-03	4.112	3538	Beta
FTOC	AOV	2003	0	2068.39	3.43E-04	1.112	3236.39	Beta
FTOC	AOV	2004	0	2252.28	3.25E-04	1.112	3420.28	Beta
FTOC	AOV	2005	2	2370.23	8.79E-04	3.112	3536.23	Beta
FTOC	AOV	2006	2	1891.03	1.02E-03	3.112	3057.03	Beta
FTOC	AOV	2007	1	1871.68	6.95E-04	2.112	3038.68	Beta
FTOC	AOV	2008	0	1756.84	3.80E-04	1.112	2924.84	Beta
FTOC	AOV	2009	1	1724.76	7.30E-04	2.112	2891.76	Beta
FTOC	AOV	2010	3	1754.28	1.41E-03	4.112	2919.28	Beta
FTOC	AOV	2011	0	1761.44	3.79E-04	1.112	2929.44	Beta
FTOC	AOV	2012	0	1808.28	3.73E-04	1.112	2976.28	Beta
FTOC	AOV	2013	1	1821.56	7.06E-04	2.112	2988.56	Beta
FTOC	AOV	2014	0	1709.01	3.86E-04	1.112	2877.01	Beta
FTOC	MOV	1998	3	3600.36	8.81E-04	5.046	5720.36	Beta
FTOC	MOV	1999	5	3692.68	1.21E-03	7.046	5810.68	Beta
FTOC	MOV	2000	4	3909.47	1.00E-03	6.046	6028.47	Beta
FTOC	MOV	2001	6	3709.62	1.38E-03	8.046	5826.62	Beta
FTOC	MOV	2002	3	3944.27	8.31E-04	5.046	6064.27	Beta
FTOC	MOV	2003	0	3865.28	3.42E-04	2.046	5988.28	Beta
FTOC	MOV	2004	0	3966.71	3.36E-04	2.046	6089.71	Beta
FTOC	MOV	2005	3	4072.61	8.14E-04	5.046	6192.61	Beta
FTOC	MOV	2006	1	3698.37	5.23E-04	3.046	5820.37	Beta
FTOC	MOV	2007	5	3659.23	1.22E-03	7.046	5777.23	Beta
FTOC	MOV	2008	2	3739.31	6.90E-04	4.046	5860.31	Beta
FTOC	MOV	2009	5	3708.34	1.21E-03	7.046	5826.34	Beta
FTOC	MOV	2010	5	3712.61	1.21E-03	7.046	5830.61	Beta
FTOC	MOV	2011	3	3629.37	8.77E-04	5.046	5749.37	Beta
FTOC	MOV	2012	2	3455.59	7.25E-04	4.046	5576.59	Beta
FTOC	MOV	2013	0	3457.1	3.67E-04	2.046	5580.1	Beta
FTOC	MOV	2014	4	3475.67	1.08E-03	6.046	5594.67	Beta
FTOP	AOV	1998	0	1699440	1.92E-07	1.421	7418440	Gamma
FTOP	AOV	1999	0	1699440	1.92E-07	1.421	7418440	Gamma
FTOP	AOV	2000	1	1734480	3.25E-07	2.421	7453480	Gamma
FTOP	AOV	2001	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2002	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2003	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2004	0	1734480	1.91E-07	1.421	7453480	Gamma

Table 6. (continued).

Failure Mode	Component	Year	Number of Failures	Demands/ Run Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
FTOP	AOV	2005	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2006	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2007	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2008	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2009	0	1734480	1.91E-07	1.421	7453480	Gamma
FTOP	AOV	2010	1	1734480	3.25E-07	2.421	7453480	Gamma
FTOP	AOV	2011	0	1839600	1.88E-07	1.421	7558600	Gamma
FTOP	AOV	2012	0	1769520	1.90E-07	1.421	7.49E+06	Gamma
FTOP	AOV	2013	3	1769520	5.90E-07	4.421	7.49E+06	Gamma
FTOP	AOV	2014	1	1760760	3.24E-07	2.421	7.48E+06	Gamma
FTOP	MOV	1998	0	3942000	5.61E-08	1.458	2.60E+07	Gamma
FTOP	MOV	1999	0	3906960	5.62E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2000	1	3906960	9.47E-08	2.458	2.60E+07	Gamma
FTOP	MOV	2001	0	3906960	5.62E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2002	1	3906960	9.47E-08	2.458	2.60E+07	Gamma
FTOP	MOV	2003	1	3906960	9.47E-08	2.458	2.60E+07	Gamma
FTOP	MOV	2004	2	3906960	1.33E-07	3.458	2.60E+07	Gamma
FTOP	MOV	2005	0	3906960	5.62E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2006	0	3906960	5.62E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2007	0	3906960	5.62E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2008	1	3924480	9.46E-08	2.458	2.60E+07	Gamma
FTOP	MOV	2009	0	3994560	5.60E-08	1.458	2.60E+07	Gamma
FTOP	MOV	2010	1	3924480	9.46E-08	2.458	2.60E+07	Gamma
FTOP	MOV	2011	0	4047120	5.59E-08	1.458	2.61E+07	Gamma
FTOP	MOV	2012	1	3810600	9.50E-08	2.458	2.59E+07	Gamma
FTOP	MOV	2013	1	3828120	9.50E-08	2.458	2.59E+07	Gamma
FTOP	MOV	2014	0	3828120	5.63E-08	1.458	2.59E+07	Gamma
SO	AOV	1998	0	1699440	9.84E-08	0.6801	6910440	Gamma
SO	AOV	1999	0	1699440	9.84E-08	0.6801	6910440	Gamma
SO	AOV	2000	0	1734480	9.79E-08	0.6801	6945480	Gamma
SO	AOV	2001	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2002	0	1734480	9.79E-08	0.6801	6945480	Gamma
SO	AOV	2003	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2004	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2005	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2006	0	1734480	9.79E-08	0.6801	6945480	Gamma
SO	AOV	2007	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2008	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2009	1	1734480	2.42E-07	1.6801	6945480	Gamma
SO	AOV	2010	0	1734480	9.79E-08	0.6801	6945480	Gamma
SO	AOV	2011	1	1839600	2.38E-07	1.6801	7050600	Gamma

Table 6. (continued).

Failure Mode	Component	Year	Number of Failures	Demands/ Run Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
SO	AOV	2012	0	1769520	9.74E-08	0.6801	6980520	Gamma
SO	AOV	2013	0	1769520	9.74E-08	0.6801	6980520	Gamma
SO	AOV	2014	0	1760760	9.76E-08	0.6801	6971760	Gamma
SO	MOV	1998	1	3942000	7.56E-08	1.5703	2.08E+07	Gamma
SO	MOV	1999	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2000	1	3906960	7.57E-08	1.5703	2.07E+07	Gamma
SO	MOV	2001	1	3906960	7.57E-08	1.5703	2.07E+07	Gamma
SO	MOV	2002	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2003	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2004	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2005	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2006	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2007	0	3906960	2.75E-08	0.5703	2.07E+07	Gamma
SO	MOV	2008	0	3924480	2.75E-08	0.5703	2.08E+07	Gamma
SO	MOV	2009	0	3994560	2.74E-08	0.5703	2.08E+07	Gamma
SO	MOV	2010	0	3924480	2.75E-08	0.5703	2.08E+07	Gamma
SO	MOV	2011	0	4047120	2.73E-08	0.5703	2.09E+07	Gamma
SO	MOV	2012	0	3810600	2.76E-08	0.5703	2.07E+07	Gamma
SO	MOV	2013	0	3828120	2.76E-08	0.5703	2.07E+07	Gamma
SO	MOV	2014	0	3828120	2.76E-08	0.5703	2.07E+07	Gamma
FTR<1H	MDP	1998	1	1685.12	1.71E-04	2.82	1.65E+04	Gamma
FTR<1H	MDP	1999	2	1636.93	2.33E-04	3.82	1.64E+04	Gamma
FTR<1H	MDP	2000	1	1726.26	1.71E-04	2.82	1.65E+04	Gamma
FTR<1H	MDP	2001	0	1807.29	1.10E-04	1.82	1.66E+04	Gamma
FTR<1H	MDP	2002	2	1893.23	2.29E-04	3.82	1.67E+04	Gamma
FTR<1H	MDP	2003	0	2035.1	1.08E-04	1.82	1.68E+04	Gamma
FTR<1H	MDP	2004	1	2130.03	1.67E-04	2.82	1.69E+04	Gamma
FTR<1H	MDP	2005	2	2204.32	2.25E-04	3.82	1.70E+04	Gamma
FTR<1H	MDP	2006	0	1938.64	1.09E-04	1.82	1.67E+04	Gamma
FTR<1H	MDP	2007	1	2220.11	1.66E-04	2.82	1.70E+04	Gamma
FTR<1H	MDP	2008	0	2007.37	1.08E-04	1.82	1.68E+04	Gamma
FTR<1H	MDP	2009	0	1841.06	1.09E-04	1.82	1.66E+04	Gamma
FTR<1H	MDP	2010	1	2078.23	1.67E-04	2.82	1.69E+04	Gamma
FTR<1H	MDP	2011	0	2050.25	1.08E-04	1.82	1.68E+04	Gamma
FTR<1H	MDP	2012	0	1860.84	1.09E-04	1.82	1.67E+04	Gamma
FTR<1H	MDP	2013	2	2055.01	2.27E-04	3.82	1.68E+04	Gamma
FTR<1H	MDP	2014	0	1799.73	1.10E-04	1.82	1.66E+04	Gamma
FTR<1H	TDP	1998	2	1065.11	2.31E-03	2.9618	1.28E+03	Gamma
FTR<1H	TDP	1999	3	976.19	3.32E-03	3.9618	1.19E+03	Gamma
FTR<1H	TDP	2000	2	979.61	2.48E-03	2.9618	1.20E+03	Gamma
FTR<1H	TDP	2001	4	913.85	4.39E-03	4.9618	1.13E+03	Gamma

Table 6. (continued).

Failure Mode	Component	Year	Number of Failures	Demands/ Run Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
FTR<1H	TDP	2002	2	911.77	2.63E-03	2.9618	1.13E+03	Gamma
FTR<1H	TDP	2003	7	974.78	6.68E-03	7.9618	1.19E+03	Gamma
FTR<1H	TDP	2004	3	994.49	3.27E-03	3.9618	1.21E+03	Gamma
FTR<1H	TDP	2005	1	994.88	1.62E-03	1.9618	1.21E+03	Gamma
FTR<1H	TDP	2006	1	986.51	1.63E-03	1.9618	1.20E+03	Gamma
FTR<1H	TDP	2007	2	971.91	2.49E-03	2.9618	1188.31	Gamma
FTR<1H	TDP	2008	3	984.15	3.30E-03	3.9618	1200.55	Gamma
FTR<1H	TDP	2009	4	1089.29	3.80E-03	4.9618	1305.69	Gamma
FTR<1H	TDP	2010	2	1147.46	2.17E-03	2.9618	1363.86	Gamma
FTR<1H	TDP	2011	1	1122.68	1.47E-03	1.9618	1339.08	Gamma
FTR<1H	TDP	2012	2	1047.37	2.34E-03	2.9618	1263.77	Gamma
FTR<1H	TDP	2013	0	1129.13	7.15E-04	0.9618	1345.53	Gamma
FTR<1H	TDP	2014	0	1056.95	7.55E-04	0.9618	1273.35	Gamma
FTR>1H	MDP	1998	1	5836.18	2.20E-05	1.781	80846.18	Gamma
FTR>1H	MDP	1999	0	9198.12	9.27E-06	0.781	84208.12	Gamma
FTR>1H	MDP	2000	0	6576.42	9.57E-06	0.781	81586.42	Gamma
FTR>1H	MDP	2001	5	9611.46	6.83E-05	5.781	84621.46	Gamma
FTR>1H	MDP	2002	0	7900.25	9.42E-06	0.781	82910.25	Gamma
FTR>1H	MDP	2003	2	10600.86	3.25E-05	2.781	85610.86	Gamma
FTR>1H	MDP	2004	0	8980.49	9.30E-06	0.781	83990.49	Gamma
FTR>1H	MDP	2005	1	7681.39	2.15E-05	1.781	82691.39	Gamma
FTR>1H	MDP	2006	0	7864.61	9.42E-06	0.781	82874.61	Gamma
FTR>1H	MDP	2007	0	9252.11	9.27E-06	0.781	84262.11	Gamma
FTR>1H	MDP	2008	0	6867.46	9.54E-06	0.781	81877.46	Gamma
FTR>1H	MDP	2009	0	7435.46	9.47E-06	0.781	82445.46	Gamma
FTR>1H	MDP	2010	0	8978.86	9.30E-06	0.781	83988.86	Gamma
FTR>1H	MDP	2011	0	8896.77	9.31E-06	0.781	83906.77	Gamma
FTR>1H	MDP	2012	0	8136.92	9.39E-06	0.781	83146.92	Gamma
FTR>1H	MDP	2013	1	8807.85	2.12E-05	1.781	83817.85	Gamma
FTR>1H	MDP	2014	2	7880.31	3.36E-05	2.781	82890.31	Gamma
FTR>1H	TDP	1998	2	328.46	1.74E-03	14.5	8356.2	Gamma
FTR>1H	TDP	1999	0	2471.97	1.19E-03	12.5	10499.71	Gamma
FTR>1H	TDP	2000	0	524.78	1.46E-03	12.5	8552.52	Gamma
FTR>1H	TDP	2001	1	480.26	1.59E-03	13.5	8508	Gamma
FTR>1H	TDP	2002	0	1161.27	1.36E-03	12.5	9189.01	Gamma
FTR>1H	TDP	2003	0	1394.97	1.33E-03	12.5	9422.71	Gamma
FTR>1H	TDP	2004	3	299.85	1.86E-03	15.5	8327.59	Gamma
FTR>1H	TDP	2005	1	214.92	1.64E-03	13.5	8242.66	Gamma
FTR>1H	TDP	2006	2	186.97	1.77E-03	14.5	8214.71	Gamma
FTR>1H	TDP	2007	0	205.35	1.52E-03	12.5	8233.09	Gamma
FTR>1H	TDP	2008	1	222.2	1.64E-03	13.5	8249.94	Gamma

Table 6. (continued).

Failure Mode	Component	Year	Number of Failures	Demands/ Run Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
FTR>1H	TDP	2009	0	202.03	1.52E-03	12.5	8229.77	Gamma
FTR>1H	TDP	2010	0	216.05	1.52E-03	12.5	8243.79	Gamma
FTR>1H	TDP	2011	2	352.65	1.73E-03	14.5	8380.39	Gamma
FTR>1H	TDP	2012	3	194.53	1.89E-03	15.5	8222.27	Gamma
FTR>1H	TDP	2013	1	230.58	1.63E-03	13.5	8258.32	Gamma
FTR>1H	TDP	2014	2	208.23	1.76E-03	14.5	8235.97	Gamma
FTS	MDP	1998	4	1685.12	1.59E-03	5.948	3735.12	Beta
FTS	MDP	1999	5	1636.93	1.88E-03	6.948	3685.93	Beta
FTS	MDP	2000	3	1726.26	1.31E-03	4.948	3777.26	Beta
FTS	MDP	2001	3	1807.29	1.28E-03	4.948	3858.29	Beta
FTS	MDP	2002	0	1893.23	4.93E-04	1.948	3947.23	Beta
FTS	MDP	2003	4	2035.1	1.45E-03	5.948	4085.1	Beta
FTS	MDP	2004	0	2130.03	4.65E-04	1.948	4.18E+03	Beta
FTS	MDP	2005	3	2204.32	1.16E-03	4.948	4.26E+03	Beta
FTS	MDP	2006	4	1938.64	1.49E-03	5.948	3.99E+03	Beta
FTS	MDP	2007	4	2220.11	1.39E-03	5.948	4.27E+03	Beta
FTS	MDP	2008	0	2007.37	4.79E-04	1.948	4.06E+03	Beta
FTS	MDP	2009	1	1841.06	7.56E-04	2.948	3.89E+03	Beta
FTS	MDP	2010	1	2078.23	7.13E-04	2.948	4.13E+03	Beta
FTS	MDP	2011	2	2050.25	9.61E-04	3.948	4.10E+03	Beta
FTS	MDP	2012	3	1860.84	1.26E-03	4.948	3.91E+03	Beta
FTS	MDP	2013	4	2055.01	1.45E-03	5.948	4.11E+03	Beta
FTS	MDP	2014	2	1799.73	1.02E-03	3.948	3.85E+03	Beta
FTS	TDP	1998	1	1065.11	1.60E-03	1.9421	1.21E+03	Beta
FTS	TDP	1999	6	976.19	6.19E-03	6.9421	1.11E+03	Beta
FTS	TDP	2000	5	979.61	5.28E-03	5.9421	1.12E+03	Beta
FTS	TDP	2001	3	913.85	3.72E-03	3.9421	1.05E+03	Beta
FTS	TDP	2002	2	911.77	2.78E-03	2.9421	1.05E+03	Beta
FTS	TDP	2003	5	974.78	5.31E-03	5.9421	1113.88	Beta
FTS	TDP	2004	4	994.49	4.34E-03	4.9421	1134.59	Beta
FTS	TDP	2005	4	994.88	4.34E-03	4.9421	1134.98	Beta
FTS	TDP	2006	3	986.51	3.48E-03	3.9421	1127.61	Beta
FTS	TDP	2007	4	971.91	4.42E-03	4.9421	1112.01	Beta
FTS	TDP	2008	3	984.15	3.49E-03	3.9421	1125.25	Beta
FTS	TDP	2009	10	1089.29	8.86E-03	10.9421	1223.39	Beta
FTS	TDP	2010	4	1147.46	3.82E-03	4.9421	1287.56	Beta
FTS	TDP	2011	4	1122.68	3.90E-03	4.9421	1262.78	Beta
FTS	TDP	2012	2	1047.37	2.47E-03	2.9421	1189.47	Beta
FTS	TDP	2013	1	1129.13	1.52E-03	1.9421	1272.23	Beta
FTS	TDP	2014	12	1056.95	1.08E-02	12.9421	1189.05	Beta

Table 7. Basic event UA trending data.

Failure Mode	Component	Year	UA Hours	Critical Hours	Bayesian Update			
					Mean	Post A	Post B	Distribution
UA	MDP	1998	4180	655697	7.24E-03	0.594	81.5	Beta
UA	MDP	1999	4996	934480	5.15E-03	1.883	363.5	Beta
UA	MDP	2000	5146	963225	4.87E-03	1.315	268.4	Beta
UA	MDP	2001	4224	962348	4.39E-03	2.442	553.8	Beta
UA	MDP	2002	3818	988117	3.71E-03	2.621	703.7	Beta
UA	MDP	2003	4329	966360	4.03E-03	1.501	370.7	Beta
UA	MDP	2004	3885	990896	3.64E-03	2.315	633.9	Beta
UA	MDP	2005	3851	981394	3.68E-03	1.925	521.6	Beta
UA	MDP	2006	3495	993315	3.11E-03	1.287	412.6	Beta
UA	MDP	2007	3415	991570	3.31E-03	1.992	599.1	Beta
UA	MDP	2008	3667	988561	3.32E-03	1.218	365.9	Beta
UA	MDP	2009	2898	994989	2.61E-03	1.511	576.3	Beta
UA	MDP	2010	3144	976748	3.09E-03	1.782	574.3	Beta
UA	MDP	2011	3428	966489	3.43E-03	1.541	447.9	Beta
UA	MDP	2012	3183	926068	3.10E-03	1.078	346.5	Beta
UA	MDP	2013	3065	906883	3.10E-03	1.164	373.8	Beta
UA	MDP	2014	3043	904947	3.05E-03	1.452	474.0	Beta
UA	TDP	1998	3025	350430	8.72E-03	0.941	107.0	Beta
UA	TDP	1999	2699	503558	5.42E-03	1.366	250.7	Beta
UA	TDP	2000	2766	516118	5.33E-03	1.743	325.0	Beta
UA	TDP	2001	3081	514966	6.14E-03	1.153	186.6	Beta
UA	TDP	2002	2423	517926	4.70E-03	2.019	427.8	Beta
UA	TDP	2003	3029	505485	6.01E-03	1.434	237.1	Beta
UA	TDP	2004	2993	521680	5.95E-03	1.486	248.2	Beta
UA	TDP	2005	2928	523076	5.68E-03	2.968	519.4	Beta
UA	TDP	2006	2832	525399	5.35E-03	1.226	228.0	Beta
UA	TDP	2007	2290	529216	4.35E-03	1.041	238.5	Beta
UA	TDP	2008	2413	526129	4.59E-03	1.402	304.1	Beta
UA	TDP	2009	2704	530917	5.09E-03	0.990	193.5	Beta
UA	TDP	2010	3222	508310	6.48E-03	1.291	198.0	Beta
UA	TDP	2011	2790	512711	5.52E-03	0.839	151.2	Beta
UA	TDP	2012	2314	495453	4.66E-03	0.889	190.0	Beta
UA	TDP	2013	2204	489741	4.51E-03	1.241	273.7	Beta
UA	TDP	2014	2764	490066	5.67E-03	0.430	75.4	Beta

Table 8. Failure mode acronyms.

Failure Mode	Failure Mode Description
FTLR	Fail to load/run
FTOC	Fail to open/close
FTOP	Fail to operate
FTR	Fail to run
FTR<1H	Fail to run less than one hour (after start)
FTS	Fail to start
SO	Spurious operation
UA	Unavailability (maintenance or state of another component)

7. SYSTEM DESCRIPTION

The main purpose of the AFW system is to provide feedwater to the steam generators to maintain a heat sink in the event of (1) a loss of main feedwater, (2) a reactor trip and loss of offsite power, and (3) a small break loss of coolant accident. The system, at some plants, can also provide a source of feedwater to the steam generators during plant startup and shutdown. However, the system cannot supply sufficient feedwater flow during power operation. At most plants, the system can only supply adequate feedwater to the steam generators with steam loads less than 5% of rated flow.

The safety-related function of the AFW system is to maintain water inventory in the steam generators for reactor residual heat removal when the main feedwater system is unavailable. The system is designed to automatically start and supply sufficient feedwater to prevent the relief of primary coolant through the pressurizer safety valves. The AFW system, in conjunction with the steam generators and the main steam line atmospheric relief and/or safety valves, is used to cool the reactor coolant system to the residual heat removal cut-in temperature. At this temperature, the residual heat removal system is used to further cool the reactor coolant system. The AFW system may also be used to temporarily hold the plant in a hot standby condition while main feedwater flow is being restored, with the option of cooling the reactor coolant system to the residual heat removal system initiation temperature.

The AFW system typically consists of at least two independent divisions. The divisions consist of a number of different combinations of electric-motor-driven and/or turbine-driven pump trains or diesel-driven pump trains. Electrical power, control, and instrumentation associated with each division are independent from one another. Typically, the electric-motor-driven pump trains make up one division and the turbine-driven pump train the other. Some plants have a diesel-driven pump in place of the turbine-driven pump, or a second turbine-driven pump in place of the electric-motor-driven pumps.

The AFW system is typically started automatically by the engineered safety features actuation system (ESFAS) or equivalent, depending on plant design and terminology. The ESFAS system automatic start signals include a predetermined low water level condition in one or more steam generators, a loss of the operating main feedwater pumps, a loss of electrical power on safety-related buses, and a safety injection signal. There are additional start signals, but these four are the most common. There is significant variation among the plants in how the system responds given a start signal. However, in most cases, a low-level condition in one steam generator starts only the electric-motor-driven pumps, while a low-level condition in two or more steam generators starts both the electric and turbine-driven pumps. For the plants that have two divisions consisting of one train per division (i.e., an electric-motor and turbine-driven pump train), most start signals start both pumps.

Feedwater flow to each steam generator is normally controlled by a flow control valve that will modulate either open or closed to maintain steam generator level. The flow control valve can be controlled either automatically or manually. A flow recirculation line is provided downstream of each pump discharge. The recirculation line allows for continuous flow back to the suction source to provide minimum flow protection for the pump. In addition, a test return line is provided downstream of each pump discharge to allow for either full or partial testing of the pumps. To limit the flow, as steam generator pressure lowers during a cool down, the system utilizes several different methods depending on plant design. Some plants use a current limiter that acts to increase downstream pump pressure thereby reducing motor amps, others use flow restricting orifices or pipe design configurations, and others use the flow control valve that modulates closed when a flow reduction signal is received.

The turbine for each turbine-driven pump is classified as an atmospheric discharge, non-condensing turbine. Typically, driving steam is supplied from the main steam lines upstream of the main steam isolation valves from at least two steam generators. (Design class 11 turbine steam supply is from one steam generator.) Each steam supply line to the turbine contains a normally closed fail-open air operated steam isolation valve. Some plants have a dc-powered motor-operated valve. A bypass is provided around each of these isolation valves with a flow-restricting orifice and a normally closed fail-to-open air-operated bypass isolation valve. The bypass provides a small, controlled rate of steam flow to the AFW turbine for warming the steam lines and turbine. Steam drain traps are provided in the low points of the steam line to drain condensate from the lines as condensate present in the steam lines could have an adverse effect on turbine reliability during an unplanned demand.

Each turbine is supplied with a hydraulic governor control valve, and a trip and throttle valve with motor reset capability. The turbine is brought up to speed by governor control upon being supplied with steam by opening the steam supply isolation valve(s). The governor then controls the turbine speed at the pump rated speed by modulating the governor control valve. The governor controlled turbine speed can be adjusted from the control room, the remote shutdown panel, or manually at the governor.

The turbine is stopped by remotely closing the trip throttle valve from the control room or the remote shutdown panel. The trip and throttle valve is automatically (electrically) tripped on turbine overspeed at 115% of rated speed. The electric overspeed trip can be reset from either the control room or remote shutdown panel. A mechanical overspeed trip also provides automatic overspeed protection at 125% of rated speed. The mechanical overspeed trip can only be reset at the trip and throttle valve.

Feedwater is supplied to both divisions through either a single condensate storage tank with separate suction supply lines or two storage tanks with redundant supply lines. Each tank typically will have its level maintained above the minimum volume needed to provide a net positive suction head to the pumps and allow for 6 hours of system operation. For extended operation of the system or as a backup for the storage tanks, an ensured source of water is provided from a service water system. The switchover to the ensured source can be accomplished by either an automatic re-alignment of the suction valves based on a sensed, low-suction pressure condition or manually by operator action depending on the plant design (typical alignment at most plants is by manual capability).

The AFW systems analyzed can be grouped into three different design classes based on the effective redundancy of the pumps. Each system typically consists of at least two independent divisions. The divisions consist of a number of motor-, turbine-, and/or diesel-driven pumps. In addition, some SPAR models include other sources of emergency feed water such as the startup feedwater pump(s). The configurations are shown in Table 9.

Table 9. Listing of the AFW design classes.

Class	Plant	AFW EDP	AFW MDP	AFW TDP	Other
Class 2	Arkansas 1		1	1	
Class 2	Braidwood 1	1	1		
Class 2	Braidwood 2	1	1		
Class 2	Byron 1	1	1		
Class 2	Byron 2	1	1		
Class 2	Crystal River 3	1		1	
Class 2	Prairie Island 1		1	1	1[a]
Class 2	Prairie Island 2		1	1	1[a]
Class 2	Seabrook		1	1	1[b]
Class 3	Arkansas 2		1	1	1[b]
Class 3	Beaver Valley 2		2	1	
Class 3	Callaway		2	1	
Class 3	Catawba 1		2	1	
Class 3	Catawba 2		2	1	
Class 3	Comanche Peak 1		2	1	
Class 3	Comanche Peak 2		2	1	
Class 3	Cook 1		2	1	
Class 3	Cook 2		2	1	
Class 3	Diablo Canyon 1		2	1	
Class 3	Diablo Canyon 2		2	1	
Class 3	Farley 1		2	1	
Class 3	Farley 2		2	1	
Class 3	Fort Calhoun	1	1	1	
Class 3	Harris		2	1	
Class 3	Indian Point 2		2	1	
Class 3	Indian Point 3		2	1	
Class 3	Kewaunee		2	1	
Class 3	McGuire 1		2	1	
Class 3	McGuire 2		2	1	
Class 3	Millstone 2		2	1	
Class 3	Millstone 3		2	1	
Class 3	North Anna 1		2	1	
Class 3	North Anna 2		2	1	
Class 3	Oconee 1		2	1	
Class 3	Oconee 2		2	1	
Class 3	Oconee 3		2	1	
Class 3	Palisades		2	1	
Class 3	Palo Verde 1		2	1	
Class 3	Palo Verde 2		2	1	
Class 3	Palo Verde 3		2	1	
Class 3	Point Beach 1		2	1	
Class 3	Point Beach 2		2	1	
Class 3	Robinson 2		2	1	
Class 3	Salem 1		2	1	
Class 3	Salem 2		2	1	
Class 3	San Onofre 2		2	1	
Class 3	San Onofre 3		2	1	
Class 3	Sequoyah 1		2	1	
Class 3	Sequoyah 2		2	1	
Class 3	St. Lucie 1		2	1	
Class 3	St. Lucie 2		2	1	
Class 3	Summer		2	1	
Class 3	Three Mile Island 1		2	1	
Class 3	Turkey Point 3			3	
Class 3	Turkey Point 4			3	
Class 3	Vogtle 1		2	1	
Class 3	Vogtle 2		2	1	
Class 3	Waterford 3		2	1	
Class 3	Watts Bar 1		2	1	
Class 3	Wolf Creek		2	1	
Class 4	Beaver Valley 1		2	1	1
Class 4	Calvert Cliffs 1		2	2	
Class 4	Calvert Cliffs 2		2	2	
Class 4	Davis-Besse		1	2	1
Class 4	Ginna		2	1	2
Class 4	South Texas 1		3	1	
Class 4	South Texas 2		3	1	
Class 4	Surry 1		2	1	3
Class 4	Surry 2		2	1	3

a. Shares AFW pump with other unit.
b. Standby/Startup AFW pump.

8. REFERENCES

1. Nuclear Regulatory Commission, *Component Reliability Data Sheets Update 2010*, January 2012, http://nrcoe.inl.gov/resultsdb/publicdocs/AvgPerf/ComponentReliabilityDataSheets2010.pdf

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