# CCF Parameter Estimations 2010

U.S. Nuclear Regulatory Commission, "CCF Parameter Estimations, 2010 Update"

This report documents the quantitative results of the common-cause failure (CCF) data collection effort and summarizes the results of the parameter estimation quantification process, performed on CCF data in the U.S. NRC CCF database.

**1/26/2012**

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This report documents the quantitative results of the common-cause failure (CCF) data collection effort and summarizes the results of the parameter estimation quantification process, performed on CCF data in the U.S. NRC CCF database.

These results are appropriate for use in Probabilistic Risk Assessment studies of commercial nuclear power plants in the U.S.

Included in these results are the applications to be used in the SPAR Version greater than 3.45 models. This is the 2010 update to NUREG/CR-5496, updating data and parameter estimations.

This release, CCF Parameter Estimation for 2010, reflects the CCF data contained within the CCF database, Version 4.5.2010. This version of the CCF database contains data from 1997 to 2010.

The applications contained within were created with a starting date of 1/1/1997. This date was selected in order to use as much of the CCF data as possible, but to avoid using the large number of CCF events in the 1980 to 1996 period since the trend is decreasing significantly from 1980 to 1996.

The way to provide a reference for this update is:

U.S. Nuclear Regulatory Commission, "CCF Parameter Estimations, 2010 Update", http://nrcoe.inl.gov/results/CCF/ParamEst2010/ccfparamest.htm, January 2012.

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## *General CCF Information*

A general conclusion from probabilistic risk assessments (PRAs) of commercial nuclear power plants is that common cause failures (CCFs) are significant contributors to the unavailability of safety systems. A CCF event consists of component failures that meet the following four criteria: (1) two or more components fail or are degraded at the same plant and in the same system, (2) component failures occur within a selected period of time such that success of the PRA mission would be uncertain, (3) the component failures result from a single shared cause and are linked by a coupling mechanism such that other components in the group are susceptible to the same cause and failure mode and, (4) the equipment failures are not caused by the failure of equipment outside the established component boundary.

In response to these deficiencies, the Idaho National Laboratory (INL) staff and the Nuclear Regulatory Commission's (NRC) Office of Nuclear Regulatory Research have developed a CCF data collection and analysis system that includes a method for identifying CCF events, coding and classifying those events for use in CCF studies, and a computer system for storing and analyzing the data. The system is based, in part, on previous CCF methods and models and is designed to run on a personal computer (PC). The data collection effort has collected CCF events from 1980 through 2010 for use in CCF analyses. The current data collection effort has separated the data by system. The principal products of this CCF data collection and analysis system (CCF database) are the method for identifying and classifying CCF events, the CCF database containing both CCF events and independent failure counts, and the CCF parameter estimation software.

Three data sources are used to select equipment failure reports to be reviewed for CCF event identification: the Nuclear Plant Reliability Data System (NPRDS), which contained component failure information prior to 1997; the Equipment Performance and Information Exchange (EPIX), which contains component failure information since 1997; and the Sequence Coding and Search System (SCSS), which contains Licensee Event Reports (LERs). All events that meet the above criteria are identified as CCF events and included in the CCF database.

# 1 Industry Component CCF Introduction

This section contains CCF applications created for components pooled at various levels. The first level presented is the industry-wide component specific pooled distribution. The pooled distribution represents the pooling of the more specific distributions shown under the pooled distribution. Typically, the pooling takes place across systems.

It is up to the user to decide the level of pooling that is appropriate to the intended use. If data exist at the system/component level most appropriate to the intended use, and are not sparse, it is recommended to use the more specific data. Otherwise, it is recommended to use the industry level pooled component data. If no pooled components are listed that are similar to the intended use, the use of the Generic Demand, Generic Rate, or the No Data (Prior Only) pooled distribution may be appropriate.

This update to the parameter estimation report includes the SPAR alpha factor basic event name to facilitate the cross reference of this report to the SPAR models. The SPAR basic event name can be found in the title of the application report and in the topic text if SPAR uses the parameter estimate.

# 1.1 Motor Driven Pumps

## 1.1.1 Pooled Motor Driven Pump Distributions

### 1.1.1.1 MOTOR DRIVEN PUMP FAIL TO START ALL SYSTEMS SPAR: MDP-FS

**Component :** Motor Driven Pump
**Failure Mode :** Fail to start
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 557.40
Total Number of Common-Cause Failure Events: 23

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9608200 | 0.9750580 | 0.9758710 | 0.9865300 | 0.9755030 | 3.7868E+02 | 9.6868E+00 |
| $\alpha_2$ | 1.35E-02 | 2.49E-02 | 2.41E-02 | 3.92E-02 | 2.45E-02 | 9.6868E+00 | 3.7868E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9650900 | 0.9762240 | 0.9767570 | 0.9855350 | 0.9768880 | 5.7666E+02 | 1.4045E+01 |
| $\alpha_2$ | 7.22E-03 | 1.42E-02 | 1.36E-02 | 2.30E-02 | 1.35E-02 | 8.3706E+00 | 5.8233E+02 |
| $\alpha_3$ | 4.08E-03 | 9.61E-03 | 9.06E-03 | 1.70E-02 | 9.65E-03 | 5.6739E+00 | 5.8503E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9667980 | 0.9763300 | 0.9767290 | 0.9844910 | 0.9773010 | 7.7044E+02 | 1.8678E+01 |
| $\alpha_2$ | 7.37E-03 | 1.33E-02 | 1.29E-02 | 2.06E-02 | 1.25E-02 | 1.0495E+01 | 7.7862E+02 |
| $\alpha_3$ | 2.72E-03 | 6.68E-03 | 6.26E-03 | 1.20E-02 | 6.56E-03 | 5.2679E+00 | 7.8385E+02 |
| $\alpha_4$ | 9.84E-04 | 3.69E-03 | 3.28E-03 | 7.81E-03 | 3.63E-03 | 2.9155E+00 | 7.8620E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9710010 | 0.9788930 | 0.9792070 | 0.9857150 | 0.9804490 | 1.0000E+03 | 2.1563E+01 |
| $\alpha_2$ | 4.88E-03 | 9.18E-03 | 8.86E-03 | 1.46E-02 | 7.88E-03 | 9.3749E+00 | 1.0122E+03 |
| $\alpha_3$ | 2.99E-03 | 6.51E-03 | 6.19E-03 | 1.11E-02 | 6.16E-03 | 6.6546E+00 | 1.0149E+03 |
| $\alpha_4$ | 1.41E-03 | 4.03E-03 | 3.71E-03 | 7.74E-03 | 4.06E-03 | 4.1161E+00 | 1.0174E+03 |
| $\alpha_5$ | 1.48E-04 | 1.39E-03 | 1.08E-03 | 3.68E-03 | 1.46E-03 | 1.4170E+00 | 1.0201E+03 |

Pooled Motor Driven Pump Distributions

MOTOR DRIVEN PUMP FAIL TO START ALL SYSTEMS SPAR: MDP-FS

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9739920 | 0.9808480 | 0.9811070 | 0.9868090 | 0.9826230 | 1.2002E+03 | 2.3435E+01 |
| $\alpha_2$ | 3.48E-03 | 6.85E-03 | 6.58E-03 | 1.11E-02 | 5.57E-03 | 8.3787E+00 | 1.2153E+03 |
| $\alpha_3$ | 2.48E-03 | 5.41E-03 | 5.14E-03 | 9.25E-03 | 4.97E-03 | 6.6207E+00 | 1.2170E+03 |
| $\alpha_4$ | 1.57E-03 | 4.02E-03 | 3.76E-03 | 7.38E-03 | 3.93E-03 | 4.9226E+00 | 1.2187E+03 |
| $\alpha_5$ | 5.70E-04 | 2.25E-03 | 1.99E-03 | 4.84E-03 | 2.30E-03 | 2.7582E+00 | 1.2209E+03 |
| $\alpha_6$ | 1.40E-05 | 6.17E-04 | 3.75E-04 | 2.04E-03 | 6.10E-04 | 7.5524E-01 | 1.2229E+03 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9755030 | 0.9768880 | 0.9773010 | 0.9804490 | 0.9826230 |
| $\alpha_2$ | 2.45E-02 | 1.35E-02 | 1.25E-02 | 7.88E-03 | 5.57E-03 |
| $\alpha_3$ | | 9.65E-03 | 6.56E-03 | 6.16E-03 | 4.97E-03 |
| $\alpha_4$ | | | 3.63E-03 | 4.06E-03 | 3.93E-03 |
| $\alpha_5$ | | | | 1.46E-03 | 2.30E-03 |
| $\alpha_6$ | | | | | 6.10E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.76E-01 | 9.77E-01 | 9.77E-01 | 9.80E-01 | 9.83E-01 |
| Beta | 2.45E-02 | 2.31E-02 | 2.27E-02 | 1.96E-02 | 1.74E-02 |
| Gamma | | 4.18E-01 | 4.49E-01 | 5.97E-01 | 6.80E-01 |
| Delta | | | 3.56E-01 | 4.73E-01 | 5.79E-01 |
| Epsilon | | | | 2.64E-01 | 4.26E-01 |
| Mu | | | | | 2.09E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 356.17 | 534.25 | 712.33 | 890.42 | 1068.50 |
| $N_1$ | 12.2620 | 12.8561 | 11.9692 | 13.4597 | 14.7926 |
| $N_2$ | 9.2523 | 7.5369 | 9.2664 | 7.2607 | 6.1395 |
| $N_3$ | | 5.4067 | 4.8636 | 5.6772 | 5.4789 |
| $N_4$ | | | 2.6928 | 3.7417 | 4.3304 |
| $N_5$ | | | | 1.3447 | 2.5360 |
| $N_6$ | | | | | 0.6720 |

## 1.1.1.2 MOTOR DRIVEN PUMP FTR LESS THAN 1H ALL SYSTEMS

**Component :** Motor Driven Pump
**Failure Mode :** Fail to Run less than 1 Hour
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 42.80
Total Number of Common-Cause Failure Events: 4

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8985690 | 0.9573340 | 0.9641160 | 0.9928560 | 0.9566930 | 4.1909E+01 | 1.8678E+00 |
| $\alpha_2$ | 7.15E-03 | 4.27E-02 | 3.59E-02 | 1.01E-01 | 4.33E-02 | 1.8678E+00 | 4.1909E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9147280 | 0.9572930 | 0.9610980 | 0.9868490 | 0.9529990 | 7.5785E+01 | 3.3809E+00 |
| $\alpha_2$ | 8.00E-03 | 3.29E-02 | 2.90E-02 | 7.10E-02 | 3.65E-02 | 2.6037E+00 | 7.6562E+01 |
| $\alpha_3$ | 2.48E-04 | 9.82E-03 | 6.11E-03 | 3.20E-02 | 1.05E-02 | 7.7722E-01 | 7.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9145520 | 0.9517650 | 0.9544500 | 0.9798040 | 0.9445280 | 1.0612E+02 | 5.3781E+00 |
| $\alpha_2$ | 1.23E-02 | 3.56E-02 | 3.28E-02 | 6.82E-02 | 4.31E-02 | 3.9641E+00 | 1.0753E+02 |
| $\alpha_3$ | 3.72E-04 | 8.43E-03 | 5.73E-03 | 2.57E-02 | 8.44E-03 | 9.4031E-01 | 1.1056E+02 |
| $\alpha_4$ | 1.25E-05 | 4.25E-03 | 1.85E-03 | 1.66E-02 | 3.95E-03 | 4.7367E-01 | 1.1102E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9316870 | 0.9587200 | 0.9604300 | 0.9799160 | 0.9513600 | 1.7077E+02 | 7.3529E+00 |
| $\alpha_2$ | 8.76E-03 | 2.41E-02 | 2.24E-02 | 4.56E-02 | 2.79E-02 | 4.3015E+00 | 1.7382E+02 |
| $\alpha_3$ | 2.24E-03 | 1.18E-02 | 1.00E-02 | 2.74E-02 | 1.43E-02 | 2.1001E+00 | 1.7602E+02 |
| $\alpha_4$ | 9.59E-05 | 4.23E-03 | 2.58E-03 | 1.40E-02 | 4.84E-03 | 7.5389E-01 | 1.7737E+02 |
| $\alpha_5$ | 9.40E-10 | 1.11E-03 | 1.11E-04 | 5.73E-03 | 1.60E-03 | 1.9738E-01 | 1.7793E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9368060 | 0.9607400 | 0.9621630 | 0.9798080 | 0.9555920 | 2.0608E+02 | 8.4212E+00 |
| $\alpha_2$ | 6.91E-03 | 1.95E-02 | 1.80E-02 | 3.71E-02 | 2.07E-02 | 4.1747E+00 | 2.1033E+02 |
| $\alpha_3$ | 2.53E-03 | 1.13E-02 | 9.83E-03 | 2.52E-02 | 1.38E-02 | 2.4265E+00 | 2.1207E+02 |
| $\alpha_4$ | 4.38E-04 | 5.60E-03 | 4.16E-03 | 1.57E-02 | 6.53E-03 | 1.2016E+00 | 2.1330E+02 |
| $\alpha_5$ | 6.41E-06 | 2.20E-03 | 9.55E-04 | 8.63E-03 | 2.69E-03 | 4.7270E-01 | 2.1403E+02 |
| $\alpha_6$ | 3.47E-12 | 6.79E-04 | 2.54E-05 | 3.76E-03 | 6.70E-04 | 1.4574E-01 | 2.1436E+02 |

Pooled Motor Driven Pump Distributions

MOTOR DRIVEN PUMP FTR LESS THAN 1H ALL SYSTEMS

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9566930 | 0.9529990 | 0.9445280 | 0.9513600 | 0.9555920 |
| $\alpha_2$ | 4.33E-02 | 3.65E-02 | 4.31E-02 | 2.79E-02 | 2.07E-02 |
| $\alpha_3$ | | 1.05E-02 | 8.44E-03 | 1.43E-02 | 1.38E-02 |
| $\alpha_4$ | | | 3.95E-03 | 4.84E-03 | 6.53E-03 |
| $\alpha_5$ | | | | 1.60E-03 | 2.69E-03 |
| $\alpha_6$ | | | | | 6.70E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.57E-01 | 9.53E-01 | 9.45E-01 | 9.51E-01 | 9.56E-01 |
| Beta | 4.33E-02 | 4.70E-02 | 5.55E-02 | 4.86E-02 | 4.44E-02 |
| Gamma | | 2.24E-01 | 2.23E-01 | 4.27E-01 | 5.33E-01 |
| Delta | | | 3.19E-01 | 3.10E-01 | 4.18E-01 |
| Epsilon | | | | 2.48E-01 | 3.39E-01 |
| Mu | | | | | 2.00E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 28.53 | 42.80 | 57.07 | 71.33 | 85.60 |
| $N_1$ | 3.1333 | 3.4300 | 2.9160 | 3.2805 | 3.5429 |
| $N_2$ | 1.4333 | 1.7700 | 2.7360 | 2.1873 | 1.9355 |
| $N_3$ | | 0.5100 | 0.5360 | 1.1227 | 1.2847 |
| $N_4$ | | | 0.2510 | 0.3795 | 0.6094 |
| $N_5$ | | | | 0.1251 | 0.2505 |
| $N_6$ | | | | | 0.0625 |

## 1.1.1.3 MOTOR DRIVEN PUMP FAIL TO RUN >1H ALL SYSTEMS

**Component :** Motor Driven Pump
**Failure Mode :** Fail to Run >1 Hour (Standby equipment)
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 128.20
Total Number of Common-Cause Failure Events: 8

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9340410 | 0.9687610 | 0.9721660 | 0.9918260 | 0.9700320 | 8.7273E+01 | 2.8142E+00 |
| $\alpha_2$ | 8.18E-03 | 3.12E-02 | 2.78E-02 | 6.60E-02 | 3.00E-02 | 2.8142E+00 | 8.7273E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9320010 | 0.9611610 | 0.9632330 | 0.9832490 | 0.9603910 | 1.4173E+02 | 5.7271E+00 |
| $\alpha_2$ | 1.23E-02 | 3.19E-02 | 2.98E-02 | 5.87E-02 | 3.31E-02 | 4.7035E+00 | 1.4275E+02 |
| $\alpha_3$ | 3.80E-04 | 6.94E-03 | 4.88E-03 | 2.06E-02 | 6.48E-03 | 1.0236E+00 | 1.4643E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9370740 | 0.9615800 | 0.9630990 | 0.9808990 | 0.9616540 | 1.9399E+02 | 7.7510E+00 |
| $\alpha_2$ | 8.88E-03 | 2.32E-02 | 2.17E-02 | 4.29E-02 | 2.25E-02 | 4.6842E+00 | 1.9706E+02 |
| $\alpha_3$ | 3.08E-03 | 1.29E-02 | 1.13E-02 | 2.80E-02 | 1.42E-02 | 2.5933E+00 | 1.9915E+02 |
| $\alpha_4$ | 6.89E-06 | 2.35E-03 | 1.02E-03 | 9.18E-03 | 1.63E-03 | 4.7347E-01 | 2.0127E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9476420 | 0.9665910 | 0.9676550 | 0.9818990 | 0.9676800 | 2.8065E+02 | 9.7003E+00 |
| $\alpha_2$ | 5.97E-03 | 1.58E-02 | 1.47E-02 | 2.95E-02 | 1.30E-02 | 4.5989E+00 | 2.8575E+02 |
| $\alpha_3$ | 3.15E-03 | 1.09E-02 | 9.85E-03 | 2.25E-02 | 1.15E-02 | 3.1788E+00 | 2.8717E+02 |
| $\alpha_4$ | 8.69E-04 | 5.94E-03 | 4.85E-03 | 1.47E-02 | 7.09E-03 | 1.7252E+00 | 2.8863E+02 |
| $\alpha_5$ | 5.76E-10 | 6.80E-04 | 6.82E-05 | 3.52E-03 | 6.56E-04 | 1.9738E-01 | 2.9015E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9528690 | 0.9693930 | 0.9702890 | 0.9828700 | 0.9718920 | 3.3805E+02 | 1.0673E+01 |
| $\alpha_2$ | 4.13E-03 | 1.18E-02 | 1.09E-02 | 2.26E-02 | 8.25E-03 | 4.1164E+00 | 3.4461E+02 |
| $\alpha_3$ | 2.66E-03 | 9.18E-03 | 8.26E-03 | 1.88E-02 | 9.05E-03 | 3.2010E+00 | 3.4552E+02 |
| $\alpha_4$ | 1.20E-03 | 6.16E-03 | 5.25E-03 | 1.43E-02 | 6.84E-03 | 2.1495E+00 | 3.4657E+02 |
| $\alpha_5$ | 1.80E-04 | 3.04E-03 | 2.16E-03 | 8.91E-03 | 3.69E-03 | 1.0608E+00 | 3.4766E+02 |
| $\alpha_6$ | 2.13E-12 | 4.18E-04 | 1.56E-05 | 2.31E-03 | 2.75E-04 | 1.4574E-01 | 3.4858E+02 |

Pooled Motor Driven Pump Distributions

MOTOR DRIVEN PUMP FAIL TO RUN >1H ALL SYSTEMS

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9700320 | 0.9603910 | 0.9616540 | 0.9676800 | 0.9718920 |
| $\alpha_2$ | 3.00E-02 | 3.31E-02 | 2.25E-02 | 1.30E-02 | 8.25E-03 |
| $\alpha_3$ | | 6.48E-03 | 1.42E-02 | 1.15E-02 | 9.05E-03 |
| $\alpha_4$ | | | 1.63E-03 | 7.09E-03 | 6.84E-03 |
| $\alpha_5$ | | | | 6.56E-04 | 3.69E-03 |
| $\alpha_6$ | | | | | 2.75E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.70E-01 | 9.60E-01 | 9.62E-01 | 9.68E-01 | 9.72E-01 |
| Beta | 3.00E-02 | 3.96E-02 | 3.83E-02 | 3.23E-02 | 2.81E-02 |
| Gamma | | 1.64E-01 | 4.14E-01 | 5.97E-01 | 7.06E-01 |
| Delta | | | 1.03E-01 | 4.01E-01 | 5.44E-01 |
| Epsilon | | | | 8.48E-02 | 3.67E-01 |
| Mu | | | | | 6.94E-02 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 73.26 | 109.89 | 146.51 | 183.14 | 219.77 |
| $N_1$ | 3.7673 | 2.2812 | 1.3486 | 1.3532 | 1.3444 |
| $N_2$ | 2.3797 | 3.8698 | 3.4561 | 2.4847 | 1.8772 |
| $N_3$ | | 0.7564 | 2.1890 | 2.2014 | 2.0592 |
| $N_4$ | | | 0.2508 | 1.3508 | 1.5573 |
| $N_5$ | | | | 0.1251 | 0.8386 |
| $N_6$ | | | | | 0.0625 |

## 1.1.1.4 MOTOR DRIVEN PUMP FAIL TO RUN ALL SYSTEMS SPAR: MDP-FR

**Component :** Motor Driven Pump
**Failure Mode :** Fail to Run >1 Hour (Standby equipment)
Fail to Run less than 1 Hour
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 171.00
Total Number of Common-Cause Failure Events: 12

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9354480 | 0.9657730 | 0.9682500 | 0.9876320 | 0.9663800 | 1.1985E+02 | 4.2475E+00 |
| $\alpha_2$ | 1.24E-02 | 3.42E-02 | 3.18E-02 | 6.46E-02 | 3.36E-02 | 4.2475E+00 | 1.1985E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9340330 | 0.9594220 | 0.9609680 | 0.9795370 | 0.9585630 | 1.8932E+02 | 8.0071E+00 |
| $\alpha_2$ | 1.50E-02 | 3.28E-02 | 3.12E-02 | 5.60E-02 | 3.38E-02 | 6.4735E+00 | 1.9085E+02 |
| $\alpha_3$ | 9.51E-04 | 7.77E-03 | 6.18E-03 | 2.00E-02 | 7.60E-03 | 1.5336E+00 | 1.9579E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9358230 | 0.9577890 | 0.9589260 | 0.9758660 | 0.9570100 | 2.5581E+02 | 1.1274E+01 |
| $\alpha_2$ | 1.35E-02 | 2.78E-02 | 2.66E-02 | 4.61E-02 | 2.83E-02 | 7.4202E+00 | 2.5966E+02 |
| $\alpha_3$ | 3.33E-03 | 1.17E-02 | 1.05E-02 | 2.42E-02 | 1.24E-02 | 3.1293E+00 | 2.6395E+02 |
| $\alpha_4$ | 5.35E-05 | 2.71E-03 | 1.61E-03 | 9.11E-03 | 2.29E-03 | 7.2447E-01 | 2.6636E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9463100 | 0.9635780 | 0.9644110 | 0.9780160 | 0.9632360 | 3.5755E+02 | 1.3515E+01 |
| $\alpha_2$ | 8.51E-03 | 1.83E-02 | 1.74E-02 | 3.10E-02 | 1.72E-02 | 6.7862E+00 | 3.6428E+02 |
| $\alpha_3$ | 4.18E-03 | 1.16E-02 | 1.07E-02 | 2.20E-02 | 1.22E-02 | 4.3015E+00 | 3.6676E+02 |
| $\alpha_4$ | 1.08E-03 | 5.67E-03 | 4.81E-03 | 1.32E-02 | 6.38E-03 | 2.1047E+00 | 3.6896E+02 |
| $\alpha_5$ | 1.76E-07 | 8.69E-04 | 2.38E-04 | 3.88E-03 | 9.22E-04 | 3.2248E-01 | 3.7074E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9516120 | 0.9666870 | 0.9673830 | 0.9793760 | 0.9674300 | 4.2994E+02 | 1.4816E+01 |
| $\alpha_2$ | 5.98E-03 | 1.36E-02 | 1.29E-02 | 2.37E-02 | 1.18E-02 | 6.0520E+00 | 4.3870E+02 |
| $\alpha_3$ | 3.73E-03 | 1.01E-02 | 9.36E-03 | 1.89E-02 | 1.03E-02 | 4.4857E+00 | 4.4027E+02 |
| $\alpha_4$ | 1.57E-03 | 6.20E-03 | 5.48E-03 | 1.33E-02 | 6.70E-03 | 2.7589E+00 | 4.4200E+02 |
| $\alpha_5$ | 2.73E-04 | 2.95E-03 | 2.25E-03 | 8.03E-03 | 3.37E-03 | 1.3114E+00 | 4.4344E+02 |
| $\alpha_6$ | 8.35E-10 | 4.68E-04 | 5.40E-05 | 2.39E-03 | 3.86E-04 | 2.0824E-01 | 4.4455E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9663800 | 0.9585630 | 0.9570100 | 0.9632360 | 0.9674300 |
| $\alpha_2$ | 3.36E-02 | 3.38E-02 | 2.83E-02 | 1.72E-02 | 1.18E-02 |
| $\alpha_3$ | | 7.60E-03 | 1.24E-02 | 1.22E-02 | 1.03E-02 |
| $\alpha_4$ | | | 2.29E-03 | 6.38E-03 | 6.70E-03 |
| $\alpha_5$ | | | | 9.22E-04 | 3.37E-03 |
| $\alpha_6$ | | | | | 3.86E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.66E-01 | 9.59E-01 | 9.57E-01 | 9.63E-01 | 9.67E-01 |
| Beta | 3.36E-02 | 4.14E-02 | 4.30E-02 | 3.68E-02 | 3.26E-02 |
| Gamma | | 1.83E-01 | 3.43E-01 | 5.32E-01 | 6.38E-01 |
| Delta | | | 1.56E-01 | 3.73E-01 | 5.03E-01 |
| Epsilon | | | | 1.26E-01 | 3.59E-01 |
| Mu | | | | | 1.03E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 102.70 | 154.05 | 205.41 | 256.76 | 308.11 |
| $N_1$ | 6.9007 | 5.7112 | 4.2646 | 4.6337 | 4.8873 |
| $N_2$ | 3.8130 | 5.6398 | 6.1921 | 4.6720 | 3.8128 |
| $N_3$ | | 1.2664 | 2.7250 | 3.3241 | 3.3439 |
| $N_4$ | | | 0.5018 | 1.7303 | 2.1667 |
| $N_5$ | | | | 0.2502 | 1.0892 |
| $N_6$ | | | | | 0.1250 |

## 1.1.2 Pooled Pump Volutes

### 1.1.2.1 CLEAN SYSTEM PUMP VOLUTES FAIL TO RUN SPAR: PMP-FR

| | |
|---|---|
| **System :** | Chemical and volume control<br>Component cooling water<br>Auxiliary feedwater<br>Containment spray recirculation<br>Low pressure core spray<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs)<br>Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Subcomponent :** | Pump |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 97.00
Total Number of Common-Cause Failure Events: 3

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9575160 | 0.9818490 | 0.9846320 | 0.9966690 | 0.9842210 | 1.1005E+02 | 2.0345E+00 |
| $\alpha_2$ | 3.33E-03 | 1.82E-02 | 1.54E-02 | 4.25E-02 | 1.58E-02 | 2.0345E+00 | 1.1005E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9624930 | 0.9813850 | 0.9831210 | 0.9943370 | 0.9848970 | 1.7824E+02 | 3.3809E+00 |
| $\alpha_2$ | 2.81E-03 | 1.30E-02 | 1.12E-02 | 2.91E-02 | 1.01E-02 | 2.3537E+00 | 1.7927E+02 |
| $\alpha_3$ | 3.12E-04 | 5.66E-03 | 3.98E-03 | 1.67E-02 | 5.03E-03 | 1.0272E+00 | 1.8059E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9647320 | 0.9808580 | 0.9821320 | 0.9926260 | 0.9855330 | 2.4355E+02 | 4.7531E+00 |
| $\alpha_2$ | 2.73E-03 | 1.09E-02 | 9.65E-03 | 2.35E-02 | 7.42E-03 | 2.7141E+00 | 2.4559E+02 |
| $\alpha_3$ | 6.38E-04 | 5.80E-03 | 4.54E-03 | 1.53E-02 | 5.17E-03 | 1.4403E+00 | 2.4686E+02 |
| $\alpha_4$ | 2.25E-05 | 2.41E-03 | 1.27E-03 | 8.67E-03 | 1.88E-03 | 5.9867E-01 | 2.4770E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9842210 | 0.9848970 | 0.9855330 |
| $\alpha_2$ | 1.58E-02 | 1.01E-02 | 7.42E-03 |
| $\alpha_3$ | | 5.03E-03 | 5.17E-03 |
| $\alpha_4$ | | | 1.88E-03 |

Pooled Pump Volutes

CLEAN SYSTEM PUMP VOLUTES FAIL TO RUN SPAR: PMP-FR

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.84E-01 | 9.85E-01 | 9.86E-01 |
| Beta | 1.58E-02 | 1.51E-02 | 1.45E-02 |
| Gamma | | 3.33E-01 | 4.87E-01 |
| Delta | | | 2.66E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 97.00 | 145.50 | 194.00 |
| $N_1$ | 2.8000 | 3.1800 | 3.4160 |
| $N_2$ | 1.6000 | 1.5200 | 1.4860 |
| $N_3$ | | 0.7600 | 1.0360 |
| $N_4$ | | | 0.3760 |

## 1.1.3 Pooled Clean System Motor Driven Pump Distributions

### 1.1.3.1 CLEAN SYSTEM MOTOR DRIVEN PUMPS FAIL TO START SPAR: MDP-FS

| | |
|---|---|
| **System :** | Chemical and volume control<br>Component cooling water<br>Auxiliary feedwater<br>Containment spray recirculation<br>High pressure core spray<br>High pressure coolant injection<br>High pressure injection<br>Low pressure core spray<br>Reactor core isolation<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs)<br>Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 381.00
Total Number of Common-Cause Failure Events: 15

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9552730 | 0.9721350 | 0.9731390 | 0.9855530 | 0.9725900 | 3.0228E+02 | 8.6645E+00 |
| $\alpha_2$ | 1.44E-02 | 2.79E-02 | 2.69E-02 | 4.47E-02 | 2.74E-02 | 8.6645E+00 | 3.0228E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9639610 | 0.9764120 | 0.9770780 | 0.9866010 | 0.9772600 | 4.6476E+02 | 1.1228E+01 |
| $\alpha_2$ | 5.07E-03 | 1.19E-02 | 1.13E-02 | 2.11E-02 | 1.09E-02 | 5.6787E+00 | 4.7031E+02 |
| $\alpha_3$ | 4.89E-03 | 1.17E-02 | 1.10E-02 | 2.07E-02 | 1.19E-02 | 5.5489E+00 | 4.7044E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9670490 | 0.9774790 | 0.9779790 | 0.9862160 | 0.9787930 | 6.2324E+02 | 1.4359E+01 |
| $\alpha_2$ | 5.16E-03 | 1.10E-02 | 1.05E-02 | 1.85E-02 | 9.77E-03 | 6.9894E+00 | 6.3061E+02 |
| $\alpha_3$ | 2.63E-03 | 7.08E-03 | 6.58E-03 | 1.33E-02 | 6.97E-03 | 4.5167E+00 | 6.3308E+02 |
| $\alpha_4$ | 1.17E-03 | 4.47E-03 | 3.97E-03 | 9.51E-03 | 4.46E-03 | 2.8530E+00 | 6.3475E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9711420 | 0.9797600 | 0.9801400 | 0.9870710 | 0.9818320 | 8.1651E+02 | 1.6868E+01 |
| $\alpha_2$ | 3.69E-03 | 8.02E-03 | 7.63E-03 | 1.37E-02 | 6.23E-03 | 6.6839E+00 | 8.2669E+02 |
| $\alpha_3$ | 2.44E-03 | 6.11E-03 | 5.72E-03 | 1.11E-02 | 5.60E-03 | 5.0884E+00 | 8.2829E+02 |
| $\alpha_4$ | 1.44E-03 | 4.45E-03 | 4.06E-03 | 8.79E-03 | 4.55E-03 | 3.7099E+00 | 8.2967E+02 |
| $\alpha_5$ | 1.70E-04 | 1.66E-03 | 1.29E-03 | 4.44E-03 | 1.79E-03 | 1.3857E+00 | 8.3199E+02 |

Pooled Clean System Motor Driven Pump Distributions

CLEAN SYSTEM MOTOR DRIVEN PUMPS FAIL TO START SPAR: MDP-FS

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9740970 | 0.9815920 | 0.9819100 | 0.9879940 | 0.9839250 | 9.8042E+02 | 1.8386E+01 |
| $\alpha_2$ | 2.73E-03 | 6.17E-03 | 5.84E-03 | 1.07E-02 | 4.47E-03 | 6.1598E+00 | 9.9265E+02 |
| $\alpha_3$ | 1.90E-03 | 4.88E-03 | 4.55E-03 | 8.97E-03 | 4.25E-03 | 4.8699E+00 | 9.9394E+02 |
| $\alpha_4$ | 1.42E-03 | 4.08E-03 | 3.76E-03 | 7.86E-03 | 3.97E-03 | 4.0769E+00 | 9.9473E+02 |
| $\alpha_5$ | 5.93E-04 | 2.54E-03 | 2.22E-03 | 5.60E-03 | 2.64E-03 | 2.5395E+00 | 9.9627E+02 |
| $\alpha_6$ | 1.57E-05 | 7.41E-04 | 4.45E-04 | 2.47E-03 | 7.48E-04 | 7.3964E-01 | 9.9807E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9725900 | 0.9772600 | 0.9787930 | 0.9818320 | 0.9839250 |
| $\alpha_2$ | 2.74E-02 | 1.09E-02 | 9.77E-03 | 6.23E-03 | 4.47E-03 |
| $\alpha_3$ | | 1.19E-02 | 6.97E-03 | 5.60E-03 | 4.25E-03 |
| $\alpha_4$ | | | 4.46E-03 | 4.55E-03 | 3.97E-03 |
| $\alpha_5$ | | | | 1.79E-03 | 2.64E-03 |
| $\alpha_6$ | | | | | 7.48E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.73E-01 | 9.77E-01 | 9.79E-01 | 9.82E-01 | 9.84E-01 |
| Beta | 2.74E-02 | 2.27E-02 | 2.12E-02 | 1.82E-02 | 1.61E-02 |
| Gamma | | 5.22E-01 | 5.39E-01 | 6.57E-01 | 7.22E-01 |
| Delta | | | 3.90E-01 | 5.31E-01 | 6.34E-01 |
| Epsilon | | | | 2.83E-01 | 4.60E-01 |
| Mu | | | | | 2.21E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 285.39 | 428.09 | 570.79 | 713.48 | 856.18 |
| $N_1$ | 6.6400 | 7.1150 | 6.3171 | 6.8643 | 7.3041 |
| $N_2$ | 8.2300 | 4.8450 | 5.7613 | 4.5697 | 3.9206 |
| $N_3$ | | 5.2817 | 4.1124 | 4.1110 | 3.7281 |
| $N_4$ | | | 2.6303 | 3.3355 | 3.4847 |
| $N_5$ | | | | 1.3134 | 2.3173 |
| $N_6$ | | | | | 0.6564 |

## 1.1.3.2 CLEAN SYSTEM MDP-FTR LESS THAN 1 HOUR

| | |
|---|---|
| **System :** | Chemical and volume control<br>Component cooling water<br>Auxiliary feedwater<br>Containment spray recirculation<br>High pressure core spray<br>High pressure coolant injection<br>High pressure injection<br>Low pressure core spray<br>Reactor core isolation<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs)<br>Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 23.20
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8696580 | 0.9464930 | 0.9556130 | 0.9920580 | 0.9400050 | 3.0093E+01 | 1.7012E+00 |
| $\alpha_2$ | 7.94E-03 | 5.35E-02 | 4.44E-02 | 1.30E-01 | 6.00E-02 | 1.7012E+00 | 3.0093E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9022760 | 0.9531070 | 0.9579560 | 0.9873490 | 0.9421700 | 5.8555E+01 | 2.8809E+00 |
| $\alpha_2$ | 6.62E-03 | 3.42E-02 | 2.93E-02 | 7.87E-02 | 4.13E-02 | 2.1037E+00 | 5.9332E+01 |
| $\alpha_3$ | 3.20E-04 | 1.27E-02 | 7.89E-03 | 4.12E-02 | 1.66E-02 | 7.7722E-01 | 6.0659E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9075840 | 0.9503560 | 0.9537340 | 0.9815800 | 0.9372370 | 8.3812E+01 | 4.3781E+00 |
| $\alpha_2$ | 9.23E-03 | 3.36E-02 | 3.01E-02 | 6.99E-02 | 4.32E-02 | 2.9641E+00 | 8.5226E+01 |
| $\alpha_3$ | 4.72E-04 | 1.07E-02 | 7.26E-03 | 3.25E-02 | 1.33E-02 | 9.4031E-01 | 8.7250E+01 |
| $\alpha_4$ | 1.59E-05 | 5.37E-03 | 2.34E-03 | 2.10E-02 | 6.24E-03 | 4.7367E-01 | 8.7716E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9272970 | 0.9574330 | 0.9594610 | 0.9806310 | 0.9431910 | 1.4289E+02 | 6.3529E+00 |
| $\alpha_2$ | 7.85E-03 | 2.44E-02 | 2.23E-02 | 4.80E-02 | 3.07E-02 | 3.6349E+00 | 1.4561E+02 |
| $\alpha_3$ | 1.80E-03 | 1.18E-02 | 9.74E-03 | 2.91E-02 | 1.59E-02 | 1.7667E+00 | 1.4748E+02 |
| $\alpha_4$ | 1.15E-04 | 5.05E-03 | 3.08E-03 | 1.67E-02 | 7.66E-03 | 7.5389E-01 | 1.4849E+02 |
| $\alpha_5$ | 1.12E-09 | 1.32E-03 | 1.33E-04 | 6.84E-03 | 2.52E-03 | 1.9738E-01 | 1.4905E+02 |

Pooled Clean System Motor Driven Pump Distributions

CLEAN SYSTEM MDP-FTR LESS THAN 1 HOUR

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9319160 | 0.9587780 | 0.9604700 | 0.9798640 | 0.9465690 | 1.7261E+02 | 7.4212E+00 |
| $\alpha_2$ | 6.80E-03 | 2.07E-02 | 1.90E-02 | 4.06E-02 | 2.54E-02 | 3.7303E+00 | 1.7630E+02 |
| $\alpha_3$ | 1.95E-03 | 1.10E-02 | 9.26E-03 | 2.61E-02 | 1.43E-02 | 1.9820E+00 | 1.7805E+02 |
| $\alpha_4$ | 3.84E-04 | 6.06E-03 | 4.35E-03 | 1.75E-02 | 8.47E-03 | 1.0905E+00 | 1.7894E+02 |
| $\alpha_5$ | 7.64E-06 | 2.63E-03 | 1.14E-03 | 1.03E-02 | 4.26E-03 | 4.7270E-01 | 1.7956E+02 |
| $\alpha_6$ | 4.14E-12 | 8.10E-04 | 3.02E-05 | 4.48E-03 | 1.06E-03 | 1.4574E-01 | 1.7989E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9400050 | 0.9421700 | 0.9372370 | 0.9431910 | 0.9465690 |
| $\alpha_2$ | 6.00E-02 | 4.13E-02 | 4.32E-02 | 3.07E-02 | 2.54E-02 |
| $\alpha_3$ | | 1.66E-02 | 1.33E-02 | 1.59E-02 | 1.43E-02 |
| $\alpha_4$ | | | 6.24E-03 | 7.66E-03 | 8.47E-03 |
| $\alpha_5$ | | | | 2.52E-03 | 4.26E-03 |
| $\alpha_6$ | | | | | 1.06E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.40E-01 | 9.42E-01 | 9.37E-01 | 9.43E-01 | 9.47E-01 |
| Beta | 6.00E-02 | 5.78E-02 | 6.28E-02 | 5.68E-02 | 5.34E-02 |
| Gamma | | 2.87E-01 | 3.12E-01 | 4.60E-01 | 5.26E-01 |
| Delta | | | 3.19E-01 | 3.90E-01 | 4.91E-01 |
| Epsilon | | | | 2.48E-01 | 3.86E-01 |
| Mu | | | | | 2.00E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 17.38 | 26.07 | 34.76 | 43.45 | 52.13 |
| $N_1$ | 2.4667 | 2.9300 | 2.9160 | 3.2805 | 3.5429 |
| $N_2$ | 1.2667 | 1.2700 | 1.7360 | 1.5207 | 1.4911 |
| $N_3$ | | 0.5100 | 0.5360 | 0.7893 | 0.8402 |
| $N_4$ | | | 0.2510 | 0.3795 | 0.4983 |
| $N_5$ | | | | 0.1251 | 0.2505 |
| $N_6$ | | | | | 0.0625 |

### 1.1.3.3 CLEAN SYSTEM MDP-FTR LESS THAN AND > 1 HOUR SPAR: MDP-FR

| | |
|---|---|
| **System :** | Chemical and volume control<br>Component cooling water<br>Auxiliary feedwater<br>Containment spray recirculation<br>High pressure core spray<br>High pressure coolant injection<br>High pressure injection<br>Low pressure core spray<br>Reactor core isolation<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs)<br>Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 246.60
Total Number of Common-Cause Failure Events: 11

## *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9530200 | 0.9739780 | 0.9755720 | 0.9895000 | 0.9748200 | 1.9157E+02 | 5.1182E+00 |
| $\alpha_2$ | 1.05E-02 | 2.60E-02 | 2.44E-02 | 4.70E-02 | 2.52E-02 | 5.1182E+00 | 1.9157E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9546770 | 0.9717820 | 0.9728020 | 0.9853900 | 0.9726390 | 2.9727E+02 | 8.6319E+00 |
| $\alpha_2$ | 8.83E-03 | 2.00E-02 | 1.89E-02 | 3.46E-02 | 1.91E-02 | 6.1047E+00 | 2.9980E+02 |
| $\alpha_3$ | 1.92E-03 | 8.26E-03 | 7.22E-03 | 1.82E-02 | 8.21E-03 | 2.5272E+00 | 3.0337E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9593140 | 0.9734890 | 0.9742500 | 0.9850600 | 0.9750900 | 4.0105E+02 | 1.0922E+01 |
| $\alpha_2$ | 6.32E-03 | 1.45E-02 | 1.37E-02 | 2.53E-02 | 1.30E-02 | 5.9661E+00 | 4.0601E+02 |
| $\alpha_3$ | 2.79E-03 | 8.76E-03 | 7.97E-03 | 1.74E-02 | 8.80E-03 | 3.6070E+00 | 4.0836E+02 |
| $\alpha_4$ | 3.20E-04 | 3.27E-03 | 2.51E-03 | 8.83E-03 | 3.09E-03 | 1.3487E+00 | 4.1062E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9639460 | 0.9756190 | 0.9761890 | 0.9853440 | 0.9780670 | 5.3872E+02 | 1.3463E+01 |
| $\alpha_2$ | 4.69E-03 | 1.08E-02 | 1.02E-02 | 1.89E-02 | 8.48E-03 | 5.9530E+00 | 5.4623E+02 |
| $\alpha_3$ | 2.89E-03 | 7.93E-03 | 7.34E-03 | 1.50E-02 | 7.52E-03 | 4.3779E+00 | 5.4780E+02 |
| $\alpha_4$ | 1.04E-03 | 4.52E-03 | 3.94E-03 | 1.00E-02 | 4.69E-03 | 2.4970E+00 | 5.4969E+02 |
| $\alpha_5$ | 1.37E-05 | 1.15E-03 | 6.30E-04 | 4.05E-03 | 1.24E-03 | 6.3488E-01 | 5.5155E+02 |

Pooled Clean System Motor Driven Pump Distributions

CLEAN SYSTEM MDP-FTR LESS THAN AND > 1 HOUR SPAR: MDP-FR

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9671180 | 0.9773650 | 0.9778460 | 0.9859820 | 0.9802020 | 6.4708E+02 | 1.4986E+01 |
| $\alpha_2$ | 3.58E-03 | 8.49E-03 | 8.00E-03 | 1.51E-02 | 6.25E-03 | 5.6206E+00 | 6.5645E+02 |
| $\alpha_3$ | 2.29E-03 | 6.41E-03 | 5.92E-03 | 1.22E-02 | 5.74E-03 | 4.2444E+00 | 6.5782E+02 |
| $\alpha_4$ | 1.40E-03 | 4.84E-03 | 4.35E-03 | 9.95E-03 | 4.83E-03 | 3.2027E+00 | 6.5886E+02 |
| $\alpha_5$ | 2.92E-04 | 2.35E-03 | 1.87E-03 | 6.04E-03 | 2.46E-03 | 1.5538E+00 | 6.6051E+02 |
| $\alpha_6$ | 2.96E-07 | 5.51E-04 | 1.78E-04 | 2.36E-03 | 5.20E-04 | 3.6454E-01 | 6.6170E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9748200 | 0.9726390 | 0.9750900 | 0.9780670 | 0.9802020 |
| $\alpha_2$ | 2.52E-02 | 1.91E-02 | 1.30E-02 | 8.48E-03 | 6.25E-03 |
| $\alpha_3$ | | 8.21E-03 | 8.80E-03 | 7.52E-03 | 5.74E-03 |
| $\alpha_4$ | | | 3.09E-03 | 4.69E-03 | 4.83E-03 |
| $\alpha_5$ | | | | 1.24E-03 | 2.46E-03 |
| $\alpha_6$ | | | | | 5.20E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.75E-01 | 9.73E-01 | 9.75E-01 | 9.78E-01 | 9.80E-01 |
| Beta | 2.52E-02 | 2.74E-02 | 2.49E-02 | 2.19E-02 | 1.98E-02 |
| Gamma | | 3.00E-01 | 4.77E-01 | 6.13E-01 | 6.84E-01 |
| Delta | | | 2.60E-01 | 4.41E-01 | 5.76E-01 |
| Epsilon | | | | 2.10E-01 | 3.82E-01 |
| Mu | | | | | 1.74E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 174.89 | 262.34 | 349.79 | 437.23 | 524.68 |
| $N_1$ | 6.4327 | 5.3780 | 5.1231 | 5.3317 | 5.4585 |
| $N_2$ | 4.6837 | 5.2710 | 4.7380 | 3.8388 | 3.3814 |
| $N_3$ | | 2.2600 | 3.2027 | 3.4005 | 3.1026 |
| $N_4$ | | | 1.1260 | 2.1226 | 2.6105 |
| $N_5$ | | | | 0.5626 | 1.3316 |
| $N_6$ | | | | | 0.2813 |

## 1.1.3.4 CLEAN SYSTEM MDP-FTR > 1 HOUR

| | |
|---|---|
| **System :** | Chemical and volume control<br>Component cooling water<br>Auxiliary feedwater<br>Containment spray recirculation<br>High pressure core spray<br>High pressure coolant injection<br>High pressure injection<br>Low pressure core spray<br>Reactor core isolation<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs)<br>Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 46.50
Total Number of Common-Cause Failure Events: 4

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040790 | 0.9592390 | 0.9655290 | 0.9928640 | 0.9592160 | 4.5532E+01 | 1.9348E+00 |
| $\alpha_2$ | 7.14E-03 | 4.08E-02 | 3.45E-02 | 9.59E-02 | 4.08E-02 | 1.9348E+00 | 4.5532E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9164040 | 0.9574170 | 0.9609770 | 0.9862360 | 0.9536240 | 8.0983E+01 | 3.6019E+00 |
| $\alpha_2$ | 8.84E-03 | 3.35E-02 | 2.99E-02 | 7.05E-02 | 3.71E-02 | 2.8347E+00 | 8.1750E+01 |
| $\alpha_3$ | 2.19E-04 | 9.07E-03 | 5.60E-03 | 2.97E-02 | 9.27E-03 | 7.6722E-01 | 8.3818E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9295320 | 0.9619860 | 0.9645480 | 0.9856740 | 0.9624210 | 1.1448E+02 | 4.5238E+00 |
| $\alpha_2$ | 4.79E-03 | 2.08E-02 | 1.82E-02 | 4.59E-02 | 1.76E-02 | 2.4801E+00 | 1.1652E+02 |
| $\alpha_3$ | 1.69E-03 | 1.32E-02 | 1.06E-02 | 3.37E-02 | 1.64E-02 | 1.5710E+00 | 1.1743E+02 |
| $\alpha_4$ | 1.16E-05 | 3.97E-03 | 1.73E-03 | 1.55E-02 | 3.52E-03 | 4.7267E-01 | 1.1853E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9420430 | 0.9661470 | 0.9677880 | 0.9846360 | 0.9679990 | 1.8141E+02 | 6.3565E+00 |
| $\alpha_2$ | 4.32E-03 | 1.58E-02 | 1.42E-02 | 3.31E-02 | 9.76E-03 | 2.9740E+00 | 1.8479E+02 |
| $\alpha_3$ | 2.19E-03 | 1.13E-02 | 9.66E-03 | 2.63E-02 | 1.31E-02 | 2.1302E+00 | 1.8564E+02 |
| $\alpha_4$ | 3.30E-04 | 5.62E-03 | 3.99E-03 | 1.65E-02 | 7.73E-03 | 1.0550E+00 | 1.8671E+02 |
| $\alpha_5$ | 8.85E-10 | 1.05E-03 | 1.05E-04 | 5.44E-03 | 1.42E-03 | 1.9728E-01 | 1.8757E+02 |

Pooled Clean System Motor Driven Pump Distributions

CLEAN SYSTEM MDP-FTR > 1 HOUR

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9468510 | 0.9680880 | 0.9694560 | 0.9846480 | 0.9719910 | 2.1908E+02 | 7.2218E+00 |
| $\alpha_2$ | 3.36E-03 | 1.27E-02 | 1.13E-02 | 2.69E-02 | 6.06E-03 | 2.8761E+00 | 2.2343E+02 |
| $\alpha_3$ | 1.78E-03 | 9.33E-03 | 7.93E-03 | 2.17E-02 | 9.24E-03 | 2.1125E+00 | 2.2419E+02 |
| $\alpha_4$ | 7.43E-04 | 6.50E-03 | 5.12E-03 | 1.70E-02 | 8.37E-03 | 1.4718E+00 | 2.2483E+02 |
| $\alpha_5$ | 2.87E-05 | 2.72E-03 | 1.46E-03 | 9.69E-03 | 3.74E-03 | 6.1570E-01 | 2.2569E+02 |
| $\alpha_6$ | 3.29E-12 | 6.44E-04 | 2.40E-05 | 3.57E-03 | 5.95E-04 | 1.4574E-01 | 2.2616E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9592160 | 0.9536240 | 0.9624210 | 0.9679990 | 0.9719910 |
| $\alpha_2$ | 4.08E-02 | 3.71E-02 | 1.76E-02 | 9.76E-03 | 6.06E-03 |
| $\alpha_3$ | | 9.27E-03 | 1.64E-02 | 1.31E-02 | 9.24E-03 |
| $\alpha_4$ | | | 3.52E-03 | 7.73E-03 | 8.37E-03 |
| $\alpha_5$ | | | | 1.42E-03 | 3.74E-03 |
| $\alpha_6$ | | | | | 5.95E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.59E-01 | 9.54E-01 | 9.62E-01 | 9.68E-01 | 9.72E-01 |
| Beta | 4.08E-02 | 4.64E-02 | 3.76E-02 | 3.20E-02 | 2.80E-02 |
| Gamma | | 2.00E-01 | 5.31E-01 | 6.95E-01 | 7.84E-01 |
| Delta | | | 1.76E-01 | 4.11E-01 | 5.79E-01 |
| Epsilon | | | | 1.55E-01 | 3.41E-01 |
| Mu | | | | | 1.37E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 33.82 | 50.73 | 67.64 | 84.55 | 101.45 |
| $N_1$ | 1.4660 | 0.6980 | 0.7071 | 0.6971 | 0.6864 |
| $N_2$ | 1.5003 | 2.0010 | 1.2520 | 0.8598 | 0.6369 |
| $N_3$ | | 0.5000 | 1.1667 | 1.1528 | 0.9707 |
| $N_4$ | | | 0.2500 | 0.6806 | 0.8796 |
| $N_5$ | | | | 0.1250 | 0.3935 |
| $N_6$ | | | | | 0.0625 |

# 1.1.4 PWR Containment Spray Pumps

## 1.1.4.1 CONTAINMENT SPRAY MDP-FS

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 29.00
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8766840 | 0.9430560 | 0.9497220 | 0.9865860 | 0.9377850 | 4.1146E+01 | 2.4845E+00 |
| $\alpha_2$ | 1.34E-02 | 5.69E-02 | 5.03E-02 | 1.23E-01 | 6.22E-02 | 2.4845E+00 | 4.1146E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 0.9377850 |
| $\alpha_2$ | 6.22E-02 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 9.38E-01 |
| Beta | 6.22E-02 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 29.00 |
| $N_1$ | 1.9000 |
| $N_2$ | 2.0500 |

## 1.1.4.2 CONTAINMENT SPRAY FTR LESS THAN 1H MDP-FH

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9017830 | 0.9754240 | 0.9898730 | 0.9999510 | 1.0000000 | 1.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.52E-05 | 2.46E-02 | 1.01E-02 | 9.82E-02 | 0.00E+00 | 4.3452E-01 | 1.7246E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 7.00 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

## 1.1.4.3 CONTAINMENT SPRAY MDP-FTR LESS THAN AND > 1 HOUR

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 12.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9252160 | 0.9813350 | 0.9923820 | 0.9999630 | 1.0000000 | 2.2846E+01 | 4.3452E-01 |
| $\alpha_2$ | 3.40E-05 | 1.87E-02 | 7.62E-03 | 7.48E-02 | 0.00E+00 | 4.3452E-01 | 2.2846E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 12.60 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

## 1.1.4.4 CONTAINMENT SPRAY >1H MDP-FR

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 5.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8934440 | 0.9733100 | 0.9889680 | 0.9999470 | 1.0000000 | 1.5846E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.93E-05 | 2.67E-02 | 1.10E-02 | 1.07E-01 | 0.00E+00 | 4.3452E-01 | 1.5846E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 5.60 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

# 1.1.5 BWR Residual Heat Removal Pumps

## 1.1.5.1 BWR RHR MDP FAIL TO START

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 30.00
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9089010 | 0.9719230 | 0.9823640 | 0.9993020 | 0.9800020 | 2.6579E+01 | 7.6782E-01 |
| $\alpha_2$ | 6.95E-04 | 2.81E-02 | 1.76E-02 | 9.11E-02 | 2.00E-02 | 7.6782E-01 | 2.6579E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9125190 | 0.9619090 | 0.9673600 | 0.9926310 | 0.9591840 | 5.3055E+01 | 2.1009E+00 |
| $\alpha_2$ | 5.40E-03 | 3.32E-02 | 2.78E-02 | 7.98E-02 | 4.08E-02 | 1.8337E+00 | 5.3322E+01 |
| $\alpha_3$ | 1.69E-07 | 4.84E-03 | 9.75E-04 | 2.30E-02 | 0.00E+00 | 2.6722E-01 | 5.4889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9072690 | 0.9518060 | 0.9555360 | 0.9835910 | 0.9375000 | 7.6136E+01 | 3.8551E+00 |
| $\alpha_2$ | 1.20E-02 | 4.04E-02 | 3.66E-02 | 8.17E-02 | 6.25E-02 | 3.2281E+00 | 7.6763E+01 |
| $\alpha_3$ | 5.68E-06 | 5.05E-03 | 1.87E-03 | 2.09E-02 | 0.00E+00 | 4.0431E-01 | 7.9587E+01 |
| $\alpha_4$ | 1.20E-08 | 2.78E-03 | 3.80E-04 | 1.39E-02 | 0.00E+00 | 2.2267E-01 | 7.9768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9800020 | 0.9591840 | 0.9375000 |
| $\alpha_2$ | 2.00E-02 | 4.08E-02 | 6.25E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.80E-01 | 9.59E-01 | 9.38E-01 |
| Beta | 2.00E-02 | 4.08E-02 | 6.25E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 15.00 | 22.50 | 30.00 |
| $N_1$ | 1.3333 | 1.0000 | 0.0000 |
| $N_2$ | 0.3333 | 1.0000 | 2.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.5.2 BWR RHR MDP FTR LESS THAN 1H

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Op. Mode :** | |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.5.3 BWR RHR MDP FAIL TO RUN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 8.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9093850 | 0.9773460 | 0.9906920 | 0.9999550 | 1.0000000 | 1.8746E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.16E-05 | 2.27E-02 | 9.31E-03 | 9.06E-02 | 0.00E+00 | 4.3452E-01 | 1.8746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9197350 | 0.9718850 | 0.9794540 | 0.9981430 | 1.0000000 | 3.8055E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.78E-04 | 2.13E-02 | 1.39E-02 | 6.73E-02 | 0.00E+00 | 8.3366E-01 | 3.8322E+01 |
| $\alpha_3$ | 2.40E-07 | 6.82E-03 | 1.38E-03 | 3.24E-02 | 0.00E+00 | 2.6722E-01 | 3.8889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9214020 | 0.9671620 | 0.9725130 | 0.9945900 | 1.0000000 | 5.4636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.80E-03 | 2.17E-02 | 1.64E-02 | 6.00E-02 | 0.00E+00 | 1.2281E+00 | 5.5263E+01 |
| $\alpha_3$ | 8.07E-06 | 7.16E-03 | 2.66E-03 | 2.96E-02 | 0.00E+00 | 4.0431E-01 | 5.6087E+01 |
| $\alpha_4$ | 1.70E-08 | 3.94E-03 | 5.40E-04 | 1.97E-02 | 0.00E+00 | 2.2267E-01 | 5.6268E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 8.50 | 8.50 | 8.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.5.4 BWR RHR MDP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 5.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8927940 | 0.9731450 | 0.9888970 | 0.9999460 | 1.0000000 | 1.5746E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.96E-05 | 2.69E-02 | 1.11E-02 | 1.07E-01 | 0.00E+00 | 4.3452E-01 | 1.5746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9131810 | 0.9695520 | 0.9777180 | 0.9979800 | 1.0000000 | 3.5055E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.35E-04 | 2.31E-02 | 1.50E-02 | 7.28E-02 | 0.00E+00 | 8.3366E-01 | 3.5322E+01 |
| $\alpha_3$ | 2.60E-07 | 7.39E-03 | 1.50E-03 | 3.51E-02 | 0.00E+00 | 2.6722E-01 | 3.5889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9170660 | 0.9653200 | 0.9709530 | 0.9942790 | 1.0000000 | 5.1636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.91E-03 | 2.30E-02 | 1.73E-02 | 6.33E-02 | 0.00E+00 | 1.2281E+00 | 5.2263E+01 |
| $\alpha_3$ | 8.53E-06 | 7.56E-03 | 2.81E-03 | 3.12E-02 | 0.00E+00 | 4.0431E-01 | 5.3087E+01 |
| $\alpha_4$ | 1.80E-08 | 4.16E-03 | 5.71E-04 | 2.09E-02 | 0.00E+00 | 2.2267E-01 | 5.3268E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 5.50 | 5.50 | 5.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.6 AFW Motor-Driven Pumps

### 1.1.6.1 AFW MOTOR DRIVEN PUMP FAIL TO START SPAR: AFW-MDP-FS

**System :** Auxiliary feedwater
**Component :** Motor Driven Pump
**Failure Mode :** Fail to start
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 32.70
Total Number of Common-Cause Failure Events: 2

#### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8847320 | 0.9508270 | 0.9582900 | 0.9913360 | 0.9476620 | 3.7406E+01 | 1.9345E+00 |
| $\alpha_2$ | 8.66E-03 | 4.92E-02 | 4.17E-02 | 1.15E-01 | 5.23E-02 | 1.9345E+00 | 3.7406E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9127180 | 0.9573150 | 0.9614560 | 0.9877510 | 0.9523700 | 6.9545E+01 | 3.1009E+00 |
| $\alpha_2$ | 2.84E-03 | 2.18E-02 | 1.76E-02 | 5.52E-02 | 1.79E-02 | 1.5837E+00 | 7.1062E+01 |
| $\alpha_3$ | 2.54E-03 | 2.09E-02 | 1.67E-02 | 5.37E-02 | 2.98E-02 | 1.5172E+00 | 7.1129E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9227900 | 0.9590050 | 0.9619400 | 0.9851810 | 0.9569710 | 9.8956E+01 | 4.2301E+00 |
| $\alpha_2$ | 3.40E-03 | 1.92E-02 | 1.62E-02 | 4.52E-02 | 1.36E-02 | 1.9781E+00 | 1.0121E+02 |
| $\alpha_3$ | 1.44E-03 | 1.36E-02 | 1.06E-02 | 3.60E-02 | 1.81E-02 | 1.4043E+00 | 1.0178E+02 |
| $\alpha_4$ | 2.71E-04 | 8.21E-03 | 5.33E-03 | 2.60E-02 | 1.13E-02 | 8.4767E-01 | 1.0234E+02 |

#### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9476620 | 0.9523700 | 0.9569710 |
| $\alpha_2$ | 5.23E-02 | 1.79E-02 | 1.36E-02 |
| $\alpha_3$ | | 2.98E-02 | 1.81E-02 |
| $\alpha_4$ | | | 1.13E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.48E-01 | 9.52E-01 | 9.57E-01 |
| Beta | 5.23E-02 | 4.76E-02 | 4.30E-02 |
| Gamma | | 6.25E-01 | 6.84E-01 |
| Delta | | | 3.85E-01 |

AFW MOTOR DRIVEN PUMP FAIL TO START SPAR: AFW-MDP-FS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 26.16 | 39.24 | 52.32 |
| $N_1$ | 1.0000 | 0.7500 | 0.5000 |
| $N_2$ | 1.5000 | 0.7500 | 0.7500 |
| $N_3$ | | 1.2500 | 1.0000 |
| $N_4$ | | | 0.6250 |

### 1.1.6.2 AFW MOTOR DRIVEN PUMP FTR LESS THAN 1H SPAR: AFW-MDP-FH

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.50
Total Number of Common-Cause Failure Events: 2

## *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8683400 | 0.9604820 | 0.9761100 | 0.9992710 | 0.9622420 | 1.7043E+01 | 7.0122E-01 |
| $\alpha_2$ | 7.26E-04 | 3.95E-02 | 2.39E-02 | 1.32E-01 | 3.78E-02 | 7.0122E-01 | 1.7043E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8909990 | 0.9539730 | 0.9612000 | 0.9922030 | 0.9236040 | 3.8985E+01 | 1.8809E+00 |
| $\alpha_2$ | 5.28E-03 | 3.92E-02 | 3.20E-02 | 9.81E-02 | 7.54E-02 | 1.6037E+00 | 3.9262E+01 |
| $\alpha_3$ | 3.46E-07 | 6.78E-03 | 1.47E-03 | 3.18E-02 | 9.79E-04 | 2.7722E-01 | 4.0589E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8901110 | 0.9447120 | 0.9495170 | 0.9828820 | 0.8838200 | 5.7722E+01 | 3.3781E+00 |
| $\alpha_2$ | 1.13E-02 | 4.44E-02 | 3.95E-02 | 9.43E-02 | 1.13E-01 | 2.7141E+00 | 5.8386E+01 |
| $\alpha_3$ | 1.40E-05 | 7.21E-03 | 2.93E-03 | 2.89E-02 | 2.75E-03 | 4.4031E-01 | 6.0660E+01 |
| $\alpha_4$ | 1.67E-08 | 3.66E-03 | 5.07E-04 | 1.83E-02 | 7.63E-05 | 2.2367E-01 | 6.0876E+01 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9622420 | 0.9236040 | 0.8838200 |
| $\alpha_2$ | 3.78E-02 | 7.54E-02 | 1.13E-01 |
| $\alpha_3$ | | 9.79E-04 | 2.75E-03 |
| $\alpha_4$ | | | 7.63E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.62E-01 | 9.24E-01 | 8.84E-01 |
| Beta | 3.78E-02 | 7.64E-02 | 1.16E-01 |
| Gamma | | 1.28E-02 | 2.43E-02 |
| Delta | | | 2.70E-02 |

AFW MOTOR DRIVEN PUMP FTR LESS THAN 1H SPAR: AFW-MDP-FH

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 4.33 | 6.50 | 8.67 |
| $N_1$ | 2.4667 | 2.9300 | 2.9160 |
| $N_2$ | 0.2667 | 0.7700 | 1.4860 |
| $N_3$ | | 0.0100 | 0.0360 |
| $N_4$ | | | 0.0010 |

## 1.1.6.3 AFW MOTOR DRIVEN PUMP FAIL TO RUN SPAR: AFW-MDP-FR

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 14.20
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8974100 | 0.9693580 | 0.9816310 | 0.9994410 | 0.9781450 | 2.2183E+01 | 7.0122E-01 |
| $\alpha_2$ | 5.56E-04 | 3.06E-02 | 1.84E-02 | 1.03E-01 | 2.19E-02 | 7.0122E-01 | 2.2183E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9079610 | 0.9612710 | 0.9674320 | 0.9934740 | 0.9564490 | 4.6685E+01 | 1.8809E+00 |
| $\alpha_2$ | 4.42E-03 | 3.30E-02 | 2.68E-02 | 8.28E-02 | 4.30E-02 | 1.6037E+00 | 4.6962E+01 |
| $\alpha_3$ | 2.91E-07 | 5.71E-03 | 1.23E-03 | 2.68E-02 | 5.58E-04 | 2.7722E-01 | 4.8289E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9056260 | 0.9526620 | 0.9568380 | 0.9853980 | 0.9348280 | 6.7982E+01 | 3.3781E+00 |
| $\alpha_2$ | 9.66E-03 | 3.80E-02 | 3.38E-02 | 8.09E-02 | 6.36E-02 | 2.7141E+00 | 6.8646E+01 |
| $\alpha_3$ | 1.19E-05 | 6.17E-03 | 2.51E-03 | 2.47E-02 | 1.54E-03 | 4.4031E-01 | 7.0920E+01 |
| $\alpha_4$ | 1.43E-08 | 3.13E-03 | 4.33E-04 | 1.57E-02 | 4.28E-05 | 2.2367E-01 | 7.1136E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9781450 | 0.9564490 | 0.9348280 |
| $\alpha_2$ | 2.19E-02 | 4.30E-02 | 6.36E-02 |
| $\alpha_3$ | | 5.58E-04 | 1.54E-03 |
| $\alpha_4$ | | | 4.28E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.78E-01 | 9.56E-01 | 9.35E-01 |
| Beta | 2.19E-02 | 4.36E-02 | 6.52E-02 |
| Gamma | | 1.28E-02 | 2.43E-02 |
| Delta | | | 2.70E-02 |

AFW MOTOR DRIVEN PUMP FAIL TO RUN SPAR: AFW-MDP-FR

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 9.47 | 14.20 | 18.93 |
| $N_1$ | 2.4667 | 2.9300 | 2.9160 |
| $N_2$ | 0.2667 | 0.7700 | 1.4860 |
| $N_3$ | | 0.0100 | 0.0360 |
| $N_4$ | | | 0.0010 |

## 1.1.6.4 AFW MOTOR DRIVEN PUMP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.70
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9054820 | 0.9763600 | 0.9902730 | 0.9999530 | 1.0000000 | 1.7946E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.34E-05 | 2.36E-02 | 9.73E-03 | 9.45E-02 | 0.00E+00 | 4.3452E-01 | 1.7946E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9180860 | 0.9712980 | 0.9790180 | 0.9981030 | 1.0000000 | 3.7255E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.92E-04 | 2.17E-02 | 1.41E-02 | 6.87E-02 | 0.00E+00 | 8.3366E-01 | 3.7522E+01 |
| $\alpha_3$ | 2.45E-07 | 6.97E-03 | 1.41E-03 | 3.30E-02 | 0.00E+00 | 2.6722E-01 | 3.8089E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9202950 | 0.9666900 | 0.9721130 | 0.9945110 | 1.0000000 | 5.3836E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.83E-03 | 2.21E-02 | 1.66E-02 | 6.08E-02 | 0.00E+00 | 1.2281E+00 | 5.4463E+01 |
| $\alpha_3$ | 8.19E-06 | 7.26E-03 | 2.70E-03 | 3.00E-02 | 0.00E+00 | 4.0431E-01 | 5.5287E+01 |
| $\alpha_4$ | 1.73E-08 | 4.00E-03 | 5.48E-04 | 2.00E-02 | 0.00E+00 | 2.2267E-01 | 5.5468E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

AFW Motor-Driven Pumps

AFW MOTOR DRIVEN PUMP FAIL TO RUN >1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 7.70 | 7.70 | 7.70 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.7 AFW Pump Volutes

### 1.1.7.1 AFW PUMP VOLUTES (MDP,TDP,EDP) FAIL TO RUN SPAR: AFW-PMP-FR

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Driven Pump<br>Turbine Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Subcomponent :** | Pump |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 17.10
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9330100 | 0.9819910 | 0.9911350 | 0.9999000 | 0.9947370 | 2.9146E+01 | 5.3452E-01 |
| $\alpha_2$ | 1.02E-04 | 1.80E-02 | 8.86E-03 | 6.70E-02 | 5.26E-03 | 5.3452E-01 | 2.9146E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9380380 | 0.9766010 | 0.9817430 | 0.9975760 | 0.9901270 | 5.7635E+01 | 1.3809E+00 |
| $\alpha_2$ | 1.23E-03 | 1.87E-02 | 1.36E-02 | 5.36E-02 | 9.52E-03 | 1.1037E+00 | 5.7912E+01 |
| $\alpha_3$ | 2.39E-07 | 4.70E-03 | 1.01E-03 | 2.20E-02 | 3.53E-04 | 2.7722E-01 | 5.8739E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9382970 | 0.9722280 | 0.9758250 | 0.9938590 | 0.9861050 | 8.3252E+01 | 2.3781E+00 |
| $\alpha_2$ | 2.93E-03 | 2.00E-02 | 1.64E-02 | 4.94E-02 | 1.29E-02 | 1.7141E+00 | 8.3916E+01 |
| $\alpha_3$ | 9.93E-06 | 5.14E-03 | 2.09E-03 | 2.06E-02 | 9.56E-04 | 4.4031E-01 | 8.5190E+01 |
| $\alpha_4$ | 1.19E-08 | 2.61E-03 | 3.61E-04 | 1.31E-02 | 2.66E-05 | 2.2367E-01 | 8.5406E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9947370 | 0.9901270 | 0.9861050 |
| $\alpha_2$ | 5.26E-03 | 9.52E-03 | 1.29E-02 |
| $\alpha_3$ | | 3.53E-04 | 9.56E-04 |
| $\alpha_4$ | | | 2.66E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.95E-01 | 9.90E-01 | 9.86E-01 |
| Beta | 5.26E-03 | 9.87E-03 | 1.39E-02 |
| Gamma | | 3.57E-02 | 7.07E-02 |
| Delta | | | 2.70E-02 |

AFW PUMP VOLUTES (MDP,TDP,EDP) FAIL TO RUN SPAR: AFW-PMP-FR

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 17.10 | 25.65 | 34.20 |
| $N_1$ | 1.8000 | 2.4300 | 2.9160 |
| $N_2$ | 0.1000 | 0.2700 | 0.4860 |
| $N_3$ | | 0.0100 | 0.0360 |
| $N_4$ | | | 0.0010 |

# 1.1.8 Emergency Service Water Pump

## 1.1.8.1 NORMALLY RUNNING SERVICE WATER MDP FAIL TO START

**System :** Normally operating service water
**Component :** Motor Driven Pump
**Failure Mode :** Fail to start
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 73.70
Total Number of Common-Cause Failure Events: 5

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9506320 | 0.9836610 | 0.9887650 | 0.9992430 | 0.9891160 | 5.7392E+01 | 9.5332E-01 |
| $\alpha_2$ | 7.54E-04 | 1.63E-02 | 1.12E-02 | 4.94E-02 | 1.09E-02 | 9.5332E-01 | 5.7392E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9474110 | 0.9762850 | 0.9793440 | 0.9947050 | 0.9815620 | 9.9098E+01 | 2.4072E+00 |
| $\alpha_2$ | 3.61E-03 | 1.99E-02 | 1.68E-02 | 4.66E-02 | 1.67E-02 | 2.0150E+00 | 9.9490E+01 |
| $\alpha_3$ | 3.53E-06 | 3.86E-03 | 1.38E-03 | 1.61E-02 | 1.76E-03 | 3.9222E-01 | 1.0111E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9443140 | 0.9706920 | 0.9728830 | 0.9895900 | 0.9754800 | 1.3754E+02 | 4.1527E+00 |
| $\alpha_2$ | 6.63E-03 | 2.27E-02 | 2.05E-02 | 4.63E-02 | 2.12E-02 | 3.2119E+00 | 1.3848E+02 |
| $\alpha_3$ | 6.31E-05 | 4.63E-03 | 2.60E-03 | 1.61E-02 | 2.68E-03 | 6.5561E-01 | 1.4104E+02 |
| $\alpha_4$ | 1.34E-07 | 2.01E-03 | 4.52E-04 | 9.35E-03 | 6.67E-04 | 2.8517E-01 | 1.4141E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9505580 | 0.9713290 | 0.9727740 | 0.9871780 | 0.9771660 | 2.0996E+02 | 6.1974E+00 |
| $\alpha_2$ | 5.98E-03 | 1.78E-02 | 1.64E-02 | 3.47E-02 | 1.49E-02 | 3.8528E+00 | 2.1230E+02 |
| $\alpha_3$ | 1.14E-03 | 7.91E-03 | 6.45E-03 | 1.97E-02 | 6.29E-03 | 1.7103E+00 | 2.1445E+02 |
| $\alpha_4$ | 1.31E-05 | 2.46E-03 | 1.18E-03 | 9.22E-03 | 1.34E-03 | 5.3069E-01 | 2.1563E+02 |
| $\alpha_5$ | 7.77E-16 | 4.79E-04 | 3.51E-06 | 2.78E-03 | 2.69E-04 | 1.0358E-01 | 2.1605E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9534900 | 0.9720600 | 0.9732580 | 0.9865290 | 0.9784690 | 2.5310E+02 | 7.2748E+00 |
| $\alpha_2$ | 4.92E-03 | 1.47E-02 | 1.35E-02 | 2.87E-02 | 1.15E-02 | 3.8351E+00 | 2.5654E+02 |
| $\alpha_3$ | 1.49E-03 | 7.96E-03 | 6.74E-03 | 1.86E-02 | 6.69E-03 | 2.0731E+00 | 2.5830E+02 |
| $\alpha_4$ | 1.66E-04 | 3.66E-03 | 2.49E-03 | 1.11E-02 | 2.58E-03 | 9.5172E-01 | 2.5942E+02 |
| $\alpha_5$ | 2.07E-07 | 1.21E-03 | 3.22E-04 | 5.46E-03 | 6.74E-04 | 3.1600E-01 | 2.6006E+02 |
| $\alpha_6$ | 1.60E-16 | 3.80E-04 | 2.10E-06 | 2.21E-03 | 1.12E-04 | 9.8837E-02 | 2.6028E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9891160 | 0.9815620 | 0.9754800 | 0.9771660 | 0.9784690 |
| $\alpha_2$ | 1.09E-02 | 1.67E-02 | 2.12E-02 | 1.49E-02 | 1.15E-02 |
| $\alpha_3$ | | 1.76E-03 | 2.68E-03 | 6.29E-03 | 6.69E-03 |
| $\alpha_4$ | | | 6.67E-04 | 1.34E-03 | 2.58E-03 |
| $\alpha_5$ | | | | 2.69E-04 | 6.74E-04 |
| $\alpha_6$ | | | | | 1.12E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.89E-01 | 9.82E-01 | 9.75E-01 | 9.77E-01 | 9.78E-01 |
| Beta | 1.09E-02 | 1.84E-02 | 2.45E-02 | 2.28E-02 | 2.15E-02 |
| Gamma | | 9.57E-02 | 1.37E-01 | 3.46E-01 | 4.67E-01 |
| Delta | | | 1.99E-01 | 2.04E-01 | 3.35E-01 |
| Epsilon | | | | 1.67E-01 | 2.33E-01 |
| Mu | | | | | 1.43E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 43.35 | 65.03 | 86.71 | 108.38 | 130.06 |
| $N_1$ | 3.7958 | 4.5125 | 4.6950 | 5.4168 | 6.0957 |
| $N_2$ | 0.5188 | 1.1813 | 1.9838 | 1.7386 | 1.5959 |
| $N_3$ | | 0.1250 | 0.2513 | 0.7329 | 0.9313 |
| $N_4$ | | | 0.0625 | 0.1563 | 0.3595 |
| $N_5$ | | | | 0.0313 | 0.0938 |
| $N_6$ | | | | | 0.0156 |

## 1.1.8.2 NORMALLY RUNNING SERVICE WATER MDP FAIL TO RUN

**System :** Normally operating service water
**Component :** Motor Driven Pump
**Failure Mode :** Fail to Run (Normally running equipment)
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 54.60
Total Number of Common-Cause Failure Events: 6

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8947800 | 0.9557440 | 0.9627810 | 0.9926080 | 0.9545300 | 4.0229E+01 | 1.8628E+00 |
| $\alpha_2$ | 7.39E-03 | 4.43E-02 | 3.72E-02 | 1.05E-01 | 4.55E-02 | 1.8628E+00 | 4.0229E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9121510 | 0.9560180 | 0.9599380 | 0.9864810 | 0.9506370 | 7.3263E+01 | 3.3705E+00 |
| $\alpha_2$ | 5.24E-03 | 2.73E-02 | 2.33E-02 | 6.32E-02 | 2.74E-02 | 2.0955E+00 | 7.4538E+01 |
| $\alpha_3$ | 1.48E-03 | 1.66E-02 | 1.27E-02 | 4.54E-02 | 2.19E-02 | 1.2750E+00 | 7.5358E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9183780 | 0.9550630 | 0.9578450 | 0.9822520 | 0.9500640 | 1.0342E+02 | 4.8661E+00 |
| $\alpha_2$ | 7.48E-03 | 2.73E-02 | 2.45E-02 | 5.70E-02 | 2.87E-02 | 2.9611E+00 | 1.0532E+02 |
| $\alpha_3$ | 8.28E-04 | 1.09E-02 | 8.08E-03 | 3.07E-02 | 1.29E-02 | 1.1813E+00 | 1.0710E+02 |
| $\alpha_4$ | 1.32E-04 | 6.68E-03 | 3.99E-03 | 2.24E-02 | 8.31E-03 | 7.2367E-01 | 1.0756E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9302890 | 0.9578900 | 0.9596360 | 0.9795310 | 0.9490200 | 1.6680E+02 | 7.3327E+00 |
| $\alpha_2$ | 8.88E-03 | 2.46E-02 | 2.28E-02 | 4.64E-02 | 2.91E-02 | 4.2769E+00 | 1.6986E+02 |
| $\alpha_3$ | 1.59E-03 | 1.03E-02 | 8.48E-03 | 2.52E-02 | 1.09E-02 | 1.7910E+00 | 1.7234E+02 |
| $\alpha_4$ | 2.39E-04 | 5.41E-03 | 3.67E-03 | 1.65E-02 | 7.63E-03 | 9.4229E-01 | 1.7319E+02 |
| $\alpha_5$ | 3.77E-07 | 1.85E-03 | 5.07E-04 | 8.27E-03 | 3.36E-03 | 3.2248E-01 | 1.7381E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9326490 | 0.9576840 | 0.9591360 | 0.9777710 | 0.9480590 | 2.0074E+02 | 8.8698E+00 |
| $\alpha_2$ | 8.84E-03 | 2.28E-02 | 2.13E-02 | 4.19E-02 | 2.88E-02 | 4.7844E+00 | 2.0483E+02 |
| $\alpha_3$ | 1.92E-03 | 1.01E-02 | 8.55E-03 | 2.34E-02 | 1.09E-02 | 2.1090E+00 | 2.0750E+02 |
| $\alpha_4$ | 3.96E-04 | 5.51E-03 | 4.04E-03 | 1.56E-02 | 6.36E-03 | 1.1543E+00 | 2.0846E+02 |
| $\alpha_5$ | 3.05E-05 | 2.93E-03 | 1.57E-03 | 1.04E-02 | 4.43E-03 | 6.1390E-01 | 2.0900E+02 |
| $\alpha_6$ | 1.77E-09 | 9.93E-04 | 1.15E-04 | 5.07E-03 | 1.41E-03 | 2.0824E-01 | 2.0940E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9545300 | 0.9506370 | 0.9500640 | 0.9490200 | 0.9480590 |
| $\alpha_2$ | 4.55E-02 | 2.74E-02 | 2.87E-02 | 2.91E-02 | 2.88E-02 |
| $\alpha_3$ | | 2.19E-02 | 1.29E-02 | 1.09E-02 | 1.09E-02 |
| $\alpha_4$ | | | 8.31E-03 | 7.63E-03 | 6.36E-03 |
| $\alpha_5$ | | | | 3.36E-03 | 4.43E-03 |
| $\alpha_6$ | | | | | 1.41E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.55E-01 | 9.51E-01 | 9.50E-01 | 9.49E-01 | 9.48E-01 |
| Beta | 4.55E-02 | 4.94E-02 | 4.99E-02 | 5.10E-02 | 5.19E-02 |
| Gamma | | 4.44E-01 | 4.24E-01 | 4.30E-01 | 4.46E-01 |
| Delta | | | 3.92E-01 | 5.01E-01 | 5.27E-01 |
| Epsilon | | | | 3.06E-01 | 4.79E-01 |
| Mu | | | | | 2.42E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 26.19 | 39.28 | 52.37 | 65.47 | 78.56 |
| $N_1$ | 3.7933 | 4.4283 | 4.9157 | 5.1654 | 5.2422 |
| $N_2$ | 1.4283 | 1.2618 | 1.7330 | 2.1627 | 2.5452 |
| $N_3$ | | 1.0078 | 0.7770 | 0.8136 | 0.9672 |
| $N_4$ | | | 0.5010 | 0.5679 | 0.5621 |
| $N_5$ | | | | 0.2502 | 0.3917 |
| $N_6$ | | | | | 0.1250 |

## 1.1.8.3 STANDBY SERVICE WATER MDP FAIL TO START

| | |
|---|---|
| **System :** | Standby service water |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 69.20
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9301870 | 0.9769450 | 0.9841820 | 0.9989710 | 0.9832190 | 3.9752E+01 | 9.3812E-01 |
| $\alpha_2$ | 1.03E-03 | 2.31E-02 | 1.58E-02 | 6.98E-02 | 1.68E-02 | 9.3812E-01 | 3.9752E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9248970 | 0.9651390 | 0.9692040 | 0.9914850 | 0.9658670 | 7.2304E+01 | 2.6116E+00 |
| $\alpha_2$ | 6.83E-03 | 3.13E-02 | 2.72E-02 | 6.97E-02 | 3.41E-02 | 2.3444E+00 | 7.2571E+01 |
| $\alpha_3$ | 1.24E-07 | 3.57E-03 | 7.16E-04 | 1.69E-02 | 0.00E+00 | 2.6722E-01 | 7.4648E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9296490 | 0.9635420 | 0.9664170 | 0.9876070 | 0.9653500 | 1.0245E+02 | 3.8765E+00 |
| $\alpha_2$ | 6.60E-03 | 2.59E-02 | 2.29E-02 | 5.51E-02 | 2.61E-02 | 2.7495E+00 | 1.0358E+02 |
| $\alpha_3$ | 3.38E-04 | 8.51E-03 | 5.69E-03 | 2.63E-02 | 8.57E-03 | 9.0431E-01 | 1.0542E+02 |
| $\alpha_4$ | 9.00E-09 | 2.09E-03 | 2.86E-04 | 1.05E-02 | 0.00E+00 | 2.2267E-01 | 1.0610E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9428250 | 0.9676150 | 0.9694100 | 0.9862660 | 0.9718880 | 1.6654E+02 | 5.5740E+00 |
| $\alpha_2$ | 5.00E-03 | 1.78E-02 | 1.60E-02 | 3.69E-02 | 1.32E-02 | 3.0666E+00 | 1.6905E+02 |
| $\alpha_3$ | 1.65E-03 | 1.05E-02 | 8.69E-03 | 2.56E-02 | 1.15E-02 | 1.8107E+00 | 1.7030E+02 |
| $\alpha_4$ | 4.06E-05 | 3.63E-03 | 1.97E-03 | 1.28E-02 | 3.45E-03 | 6.2439E-01 | 1.7149E+02 |
| $\alpha_5$ | 3.46E-21 | 4.20E-04 | 2.37E-07 | 2.43E-03 | 0.00E+00 | 7.2277E-02 | 1.7204E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9477100 | 0.9695130 | 0.9710070 | 0.9862100 | 0.9762560 | 2.0137E+02 | 6.3321E+00 |
| $\alpha_2$ | 3.63E-03 | 1.38E-02 | 1.23E-02 | 2.92E-02 | 7.20E-03 | 2.8622E+00 | 2.0484E+02 |
| $\alpha_3$ | 1.65E-03 | 9.44E-03 | 7.92E-03 | 2.24E-02 | 9.47E-03 | 1.9612E+00 | 2.0574E+02 |
| $\alpha_4$ | 3.21E-04 | 5.19E-03 | 3.71E-03 | 1.51E-02 | 5.62E-03 | 1.0783E+00 | 2.0662E+02 |
| $\alpha_5$ | 6.21E-07 | 1.67E-03 | 5.09E-04 | 7.29E-03 | 1.45E-03 | 3.4720E-01 | 2.0735E+02 |
| $\alpha_6$ | 6.78E-19 | 4.01E-04 | 7.00E-07 | 2.34E-03 | 0.00E+00 | 8.3237E-02 | 2.0762E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9832190 | 0.9658670 | 0.9653500 | 0.9718880 | 0.9762560 |
| $\alpha_2$ | 1.68E-02 | 3.41E-02 | 2.61E-02 | 1.32E-02 | 7.20E-03 |
| $\alpha_3$ | | 0.00E+00 | 8.57E-03 | 1.15E-02 | 9.47E-03 |
| $\alpha_4$ | | | 0.00E+00 | 3.45E-03 | 5.62E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 1.45E-03 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.83E-01 | 9.66E-01 | 9.65E-01 | 9.72E-01 | 9.76E-01 |
| Beta | 1.68E-02 | 3.41E-02 | 3.46E-02 | 2.81E-02 | 2.37E-02 |
| Gamma | | 0.00E+00 | 2.47E-01 | 5.32E-01 | 6.97E-01 |
| Delta | | | 0.00E+00 | 2.31E-01 | 4.27E-01 |
| Epsilon | | | | 0.00E+00 | 2.05E-01 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 27.68 | 41.52 | 55.36 | 69.20 | 83.04 |
| $N_1$ | 1.8262 | 1.2286 | 0.9571 | 1.1786 | 1.3929 |
| $N_2$ | 0.5036 | 1.5107 | 1.5214 | 0.9524 | 0.6230 |
| $N_3$ | | 0.0000 | 0.5000 | 0.8333 | 0.8194 |
| $N_4$ | | | 0.0000 | 0.2500 | 0.4861 |
| $N_5$ | | | | 0.0000 | 0.1250 |
| $N_6$ | | | | | 0.0000 |

## 1.1.8.4 STANDBY SERVICE WATER MDP FAIL TO RUN

**System :** Standby service water
**Component :** Motor Driven Pump
**Failure Mode :** Fail to Run (Normally running equipment)
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 6.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8959650 | 0.9739500 | 0.9892430 | 0.9999480 | 1.0000000 | 1.6246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.81E-05 | 2.60E-02 | 1.08E-02 | 1.04E-01 | 0.00E+00 | 4.3452E-01 | 1.6246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9143470 | 0.9699670 | 0.9780280 | 0.9980130 | 1.0000000 | 3.5555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.25E-04 | 2.27E-02 | 1.48E-02 | 7.18E-02 | 0.00E+00 | 8.3366E-01 | 3.5822E+01 |
| $\alpha_3$ | 2.56E-07 | 7.29E-03 | 1.48E-03 | 3.46E-02 | 0.00E+00 | 2.6722E-01 | 3.6389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9178250 | 0.9656410 | 0.9712250 | 0.9943340 | 1.0000000 | 5.2136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.89E-03 | 2.27E-02 | 1.72E-02 | 6.27E-02 | 0.00E+00 | 1.2281E+00 | 5.2763E+01 |
| $\alpha_3$ | 8.45E-06 | 7.49E-03 | 2.78E-03 | 3.09E-02 | 0.00E+00 | 4.0431E-01 | 5.3587E+01 |
| $\alpha_4$ | 1.78E-08 | 4.12E-03 | 5.66E-04 | 2.07E-02 | 0.00E+00 | 2.2267E-01 | 5.3768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9337450 | 0.9665250 | 0.9694270 | 0.9893730 | 1.0000000 | 1.0216E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.85E-03 | 2.00E-02 | 1.71E-02 | 4.62E-02 | 0.00E+00 | 2.1142E+00 | 1.0358E+02 |
| $\alpha_3$ | 4.52E-04 | 9.25E-03 | 6.39E-03 | 2.78E-02 | 0.00E+00 | 9.7738E-01 | 1.0472E+02 |
| $\alpha_4$ | 2.33E-06 | 3.54E-03 | 1.19E-03 | 1.50E-02 | 0.00E+00 | 3.7439E-01 | 1.0532E+02 |
| $\alpha_5$ | 5.65E-21 | 6.84E-04 | 3.87E-07 | 3.96E-03 | 0.00E+00 | 7.2277E-02 | 1.0563E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366750 | 0.9663680 | 0.9687880 | 0.9877920 | 1.0000000 | 1.2294E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.62E-03 | 1.76E-02 | 1.51E-02 | 4.00E-02 | 0.00E+00 | 2.2392E+00 | 1.2498E+02 |
| $\alpha_3$ | 6.32E-04 | 8.98E-03 | 6.57E-03 | 2.55E-02 | 0.00E+00 | 1.1418E+00 | 1.2608E+02 |
| $\alpha_4$ | 4.16E-05 | 4.66E-03 | 2.44E-03 | 1.68E-02 | 0.00E+00 | 5.9222E-01 | 1.2663E+02 |
| $\alpha_5$ | 7.30E-09 | 1.75E-03 | 2.37E-04 | 8.75E-03 | 0.00E+00 | 2.2220E-01 | 1.2700E+02 |
| $\alpha_6$ | 1.11E-18 | 6.54E-04 | 1.14E-06 | 3.82E-03 | 0.00E+00 | 8.3237E-02 | 1.2714E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.1.8.5 SERVICE WATER MDP FAIL TO START SPAR:ESW-MDP-FS

| | |
|---|---|
| **System :** | Normally operating service water<br>Standby service water |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 142.90
Total Number of Common-Cause Failure Events: 8

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9571730 | 0.9835900 | 0.9870600 | 0.9981410 | 0.9869090 | 8.7318E+01 | 1.4568E+00 |
| $\alpha_2$ | 1.86E-03 | 1.64E-02 | 1.29E-02 | 4.28E-02 | 1.31E-02 | 1.4568E+00 | 8.7318E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9483280 | 0.9732380 | 0.9753680 | 0.9908770 | 0.9756610 | 1.4248E+02 | 3.9179E+00 |
| $\alpha_2$ | 7.59E-03 | 2.41E-02 | 2.19E-02 | 4.79E-02 | 2.33E-02 | 3.5257E+00 | 1.4287E+02 |
| $\alpha_3$ | 2.44E-06 | 2.68E-03 | 9.54E-04 | 1.12E-02 | 1.08E-03 | 3.9222E-01 | 1.4601E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9469800 | 0.9692620 | 0.9708060 | 0.9862680 | 0.9717470 | 1.9469E+02 | 6.1741E+00 |
| $\alpha_2$ | 9.07E-03 | 2.36E-02 | 2.20E-02 | 4.34E-02 | 2.29E-02 | 4.7333E+00 | 1.9613E+02 |
| $\alpha_3$ | 4.15E-04 | 5.75E-03 | 4.22E-03 | 1.63E-02 | 4.91E-03 | 1.1556E+00 | 1.9971E+02 |
| $\alpha_4$ | 9.45E-08 | 1.42E-03 | 3.19E-04 | 6.60E-03 | 4.09E-04 | 2.8517E-01 | 2.0058E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9539000 | 0.9715730 | 0.9726500 | 0.9855560 | 0.9752800 | 2.8139E+02 | 8.2331E+00 |
| $\alpha_2$ | 6.43E-03 | 1.66E-02 | 1.55E-02 | 3.05E-02 | 1.42E-02 | 4.8052E+00 | 2.8482E+02 |
| $\alpha_3$ | 2.06E-03 | 8.78E-03 | 7.68E-03 | 1.93E-02 | 8.25E-03 | 2.5436E+00 | 2.8708E+02 |
| $\alpha_4$ | 6.84E-05 | 2.70E-03 | 1.67E-03 | 8.81E-03 | 2.14E-03 | 7.8069E-01 | 2.8884E+02 |
| $\alpha_5$ | 5.79E-16 | 3.58E-04 | 2.62E-06 | 2.07E-03 | 1.65E-04 | 1.0358E-01 | 2.8952E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9576120 | 0.9732030 | 0.9741020 | 0.9857150 | 0.9777440 | 3.3878E+02 | 9.3283E+00 |
| $\alpha_2$ | 4.73E-03 | 1.28E-02 | 1.19E-02 | 2.40E-02 | 9.78E-03 | 4.4581E+00 | 3.4365E+02 |
| $\alpha_3$ | 2.20E-03 | 8.31E-03 | 7.39E-03 | 1.76E-02 | 7.72E-03 | 2.8926E+00 | 3.4522E+02 |
| $\alpha_4$ | 4.52E-04 | 4.13E-03 | 3.23E-03 | 1.09E-02 | 3.73E-03 | 1.4378E+00 | 3.4667E+02 |
| $\alpha_5$ | 2.45E-06 | 1.27E-03 | 5.12E-04 | 5.09E-03 | 9.64E-04 | 4.4100E-01 | 3.4767E+02 |
| $\alpha_6$ | 1.20E-16 | 2.84E-04 | 1.57E-06 | 1.65E-03 | 6.88E-05 | 9.8837E-02 | 3.4801E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9869090 | 0.9756610 | 0.9717470 | 0.9752800 | 0.9777440 |
| $\alpha_2$ | 1.31E-02 | 2.33E-02 | 2.29E-02 | 1.42E-02 | 9.78E-03 |
| $\alpha_3$ | | 1.08E-03 | 4.91E-03 | 8.25E-03 | 7.72E-03 |
| $\alpha_4$ | | | 4.09E-04 | 2.14E-03 | 3.73E-03 |
| $\alpha_5$ | | | | 1.65E-04 | 9.64E-04 |
| $\alpha_6$ | | | | | 6.88E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.87E-01 | 9.76E-01 | 9.72E-01 | 9.75E-01 | 9.78E-01 |
| Beta | 1.31E-02 | 2.43E-02 | 2.83E-02 | 2.47E-02 | 2.23E-02 |
| Gamma | | 4.44E-02 | 1.88E-01 | 4.27E-01 | 5.61E-01 |
| Delta | | | 7.68E-02 | 2.18E-01 | 3.82E-01 |
| Epsilon | | | | 7.15E-02 | 2.17E-01 |
| Mu | | | | | 6.66E-02 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 71.45 | 107.18 | 142.90 | 178.63 | 214.35 |
| $N_1$ | 5.6220 | 5.7411 | 5.6521 | 6.5954 | 7.4886 |
| $N_2$ | 1.0223 | 2.6920 | 3.5052 | 2.6910 | 2.2189 |
| $N_3$ | | 0.1250 | 0.7513 | 1.5662 | 1.7508 |
| $N_4$ | | | 0.0625 | 0.4063 | 0.8456 |
| $N_5$ | | | | 0.0313 | 0.2188 |
| $N_6$ | | | | | 0.0156 |

## 1.1.8.6 SERVICE WATER MDP FAIL TO RUN SPAR:ESW-MDP-FR

| | |
|---|---|
| **System :** | Normally operating service water<br>Standby service water |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 60.60
Total Number of Common-Cause Failure Events: 6

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9013690 | 0.9585690 | 0.9651890 | 0.9930940 | 0.9583360 | 4.3099E+01 | 1.8628E+00 |
| $\alpha_2$ | 6.91E-03 | 4.14E-02 | 3.48E-02 | 9.86E-02 | 4.17E-02 | 1.8628E+00 | 4.3099E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9167600 | 0.9583650 | 0.9620940 | 0.9872180 | 0.9548770 | 7.7583E+01 | 3.3705E+00 |
| $\alpha_2$ | 4.95E-03 | 2.59E-02 | 2.21E-02 | 5.98E-02 | 2.51E-02 | 2.0955E+00 | 7.8858E+01 |
| $\alpha_3$ | 1.40E-03 | 1.57E-02 | 1.20E-02 | 4.30E-02 | 2.00E-02 | 1.2750E+00 | 7.9678E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9224430 | 0.9573320 | 0.9599820 | 0.9831640 | 0.9544180 | 1.0918E+02 | 4.8661E+00 |
| $\alpha_2$ | 7.09E-03 | 2.60E-02 | 2.32E-02 | 5.41E-02 | 2.62E-02 | 2.9611E+00 | 1.1108E+02 |
| $\alpha_3$ | 7.85E-04 | 1.04E-02 | 7.67E-03 | 2.91E-02 | 1.18E-02 | 1.1813E+00 | 1.1286E+02 |
| $\alpha_4$ | 1.25E-04 | 6.35E-03 | 3.79E-03 | 2.13E-02 | 7.58E-03 | 7.2367E-01 | 1.1332E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9330220 | 0.9595600 | 0.9612380 | 0.9803540 | 0.9535110 | 1.7399E+02 | 7.3327E+00 |
| $\alpha_2$ | 8.52E-03 | 2.36E-02 | 2.19E-02 | 4.46E-02 | 2.65E-02 | 4.2769E+00 | 1.7705E+02 |
| $\alpha_3$ | 1.53E-03 | 9.88E-03 | 8.14E-03 | 2.42E-02 | 9.97E-03 | 1.7910E+00 | 1.7953E+02 |
| $\alpha_4$ | 2.30E-04 | 5.20E-03 | 3.53E-03 | 1.59E-02 | 6.96E-03 | 9.4229E-01 | 1.8038E+02 |
| $\alpha_5$ | 3.62E-07 | 1.78E-03 | 4.87E-04 | 7.94E-03 | 3.07E-03 | 3.2248E-01 | 1.8100E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9352880 | 0.9593570 | 0.9607570 | 0.9786600 | 0.9526790 | 2.0937E+02 | 8.8698E+00 |
| $\alpha_2$ | 8.49E-03 | 2.19E-02 | 2.05E-02 | 4.03E-02 | 2.62E-02 | 4.7844E+00 | 2.1346E+02 |
| $\alpha_3$ | 1.84E-03 | 9.66E-03 | 8.21E-03 | 2.24E-02 | 9.97E-03 | 2.1090E+00 | 2.1613E+02 |
| $\alpha_4$ | 3.80E-04 | 5.29E-03 | 3.88E-03 | 1.50E-02 | 5.79E-03 | 1.1543E+00 | 2.1709E+02 |
| $\alpha_5$ | 2.93E-05 | 2.81E-03 | 1.51E-03 | 1.00E-02 | 4.04E-03 | 6.1390E-01 | 2.1763E+02 |
| $\alpha_6$ | 1.70E-09 | 9.54E-04 | 1.10E-04 | 4.87E-03 | 1.29E-03 | 2.0824E-01 | 2.1803E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9583360 | 0.9548770 | 0.9544180 | 0.9535110 | 0.9526790 |
| $\alpha_2$ | 4.17E-02 | 2.51E-02 | 2.62E-02 | 2.65E-02 | 2.62E-02 |
| $\alpha_3$ | | 2.00E-02 | 1.18E-02 | 9.97E-03 | 9.97E-03 |
| $\alpha_4$ | | | 7.58E-03 | 6.96E-03 | 5.79E-03 |
| $\alpha_5$ | | | | 3.07E-03 | 4.04E-03 |
| $\alpha_6$ | | | | | 1.29E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.58E-01 | 9.55E-01 | 9.54E-01 | 9.54E-01 | 9.53E-01 |
| Beta | 4.17E-02 | 4.51E-02 | 4.56E-02 | 4.65E-02 | 4.73E-02 |
| Gamma | | 4.44E-01 | 4.24E-01 | 4.30E-01 | 4.46E-01 |
| Delta | | | 3.92E-01 | 5.01E-01 | 5.27E-01 |
| Epsilon | | | | 3.06E-01 | 4.79E-01 |
| Mu | | | | | 2.42E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 29.06 | 43.60 | 58.13 | 72.66 | 87.19 |
| $N_1$ | 3.7933 | 4.4283 | 4.9157 | 5.1654 | 5.2422 |
| $N_2$ | 1.4283 | 1.2618 | 1.7330 | 2.1627 | 2.5452 |
| $N_3$ | | 1.0078 | 0.7770 | 0.8136 | 0.9672 |
| $N_4$ | | | 0.5010 | 0.5679 | 0.5621 |
| $N_5$ | | | | 0.2502 | 0.3917 |
| $N_6$ | | | | | 0.1250 |

# 1.1.9 PWR High Pressure Safety Injection Pump

## 1.1.9.1 HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO START

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 143.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9756040 | 0.9907320 | 0.9927470 | 0.9989830 | 0.9930600 | 1.5335E+02 | 1.4345E+00 |
| $\alpha_2$ | 1.02E-03 | 9.27E-03 | 7.26E-03 | 2.44E-02 | 6.94E-03 | 1.4345E+00 | 1.5335E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9801560 | 0.9914700 | 0.9927560 | 0.9983840 | 0.9953630 | 2.4421E+02 | 2.1009E+00 |
| $\alpha_2$ | 5.19E-04 | 5.41E-03 | 4.15E-03 | 1.46E-02 | 2.32E-03 | 1.3337E+00 | 2.4498E+02 |
| $\alpha_3$ | 7.47E-05 | 3.11E-03 | 1.91E-03 | 1.02E-02 | 2.32E-03 | 7.6722E-01 | 2.4554E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9819300 | 0.9914820 | 0.9924410 | 0.9977720 | 0.9965180 | 3.3234E+02 | 2.8551E+00 |
| $\alpha_2$ | 5.06E-04 | 4.41E-03 | 3.47E-03 | 1.15E-02 | 8.70E-04 | 1.4781E+00 | 3.3372E+02 |
| $\alpha_3$ | 1.06E-04 | 2.70E-03 | 1.80E-03 | 8.36E-03 | 1.74E-03 | 9.0431E-01 | 3.3429E+02 |
| $\alpha_4$ | 4.09E-06 | 1.41E-03 | 6.10E-04 | 5.52E-03 | 8.70E-04 | 4.7267E-01 | 3.3472E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9930600 | 0.9953630 | 0.9965180 |
| $\alpha_2$ | 6.94E-03 | 2.32E-03 | 8.70E-04 |
| $\alpha_3$ | | 2.32E-03 | 1.74E-03 |
| $\alpha_4$ | | | 8.70E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.93E-01 | 9.95E-01 | 9.97E-01 |
| Beta | 6.94E-03 | 4.64E-03 | 3.48E-03 |
| Gamma | | 5.00E-01 | 7.50E-01 |
| Delta | | | 3.33E-01 |

PWR High Pressure Safety Injection Pump

HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO START

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 143.10 | 214.65 | 286.20 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.5000 | 0.2500 |
| $N_3$ | | 0.5000 | 0.5000 |
| $N_4$ | | | 0.2500 |

## 1.1.9.2 HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FTR LESS THAN 1H

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8687700 | 0.9670330 | 0.9862440 | 0.9999400 | 1.0000000 | 1.2746E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.16E-05 | 3.30E-02 | 1.38E-02 | 1.31E-01 | 0.00E+00 | 4.3452E-01 | 1.2746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9054640 | 0.9667970 | 0.9756610 | 0.9977910 | 1.0000000 | 3.2055E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.04E-04 | 2.51E-02 | 1.64E-02 | 7.93E-02 | 0.00E+00 | 8.3366E-01 | 3.2322E+01 |
| $\alpha_3$ | 2.84E-07 | 8.06E-03 | 1.63E-03 | 3.82E-02 | 0.00E+00 | 2.6722E-01 | 3.2889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9122220 | 0.9632590 | 0.9692100 | 0.9939300 | 1.0000000 | 4.8636E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.02E-03 | 2.43E-02 | 1.84E-02 | 6.70E-02 | 0.00E+00 | 1.2281E+00 | 4.9263E+01 |
| $\alpha_3$ | 9.04E-06 | 8.01E-03 | 2.98E-03 | 3.31E-02 | 0.00E+00 | 4.0431E-01 | 5.0087E+01 |
| $\alpha_4$ | 1.91E-08 | 4.41E-03 | 6.05E-04 | 2.21E-02 | 0.00E+00 | 2.2267E-01 | 5.0268E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FTR LESS THAN 1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 2.50 | 2.50 | 2.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.1.9.3 HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO RUN

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 135.80
Total Number of Common-Cause Failure Events: 5

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9549480 | 0.9796430 | 0.9822570 | 0.9954100 | 0.9816360 | 1.1717E+02 | 2.4348E+00 |
| $\alpha_2$ | 4.59E-03 | 2.04E-02 | 1.77E-02 | 4.51E-02 | 1.84E-02 | 2.4348E+00 | 1.1717E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9556200 | 0.9760680 | 0.9777040 | 0.9909440 | 0.9783410 | 1.8769E+02 | 4.6019E+00 |
| $\alpha_2$ | 5.93E-03 | 1.86E-02 | 1.70E-02 | 3.70E-02 | 1.70E-02 | 3.5847E+00 | 1.8871E+02 |
| $\alpha_3$ | 2.84E-04 | 5.29E-03 | 3.70E-03 | 1.57E-02 | 4.64E-03 | 1.0172E+00 | 1.9127E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9606790 | 0.9774990 | 0.9787020 | 0.9902030 | 0.9811190 | 2.5626E+02 | 5.8988E+00 |
| $\alpha_2$ | 3.60E-03 | 1.23E-02 | 1.11E-02 | 2.52E-02 | 9.35E-03 | 3.2301E+00 | 2.5893E+02 |
| $\alpha_3$ | 1.47E-03 | 7.90E-03 | 6.69E-03 | 1.85E-02 | 7.78E-03 | 2.0710E+00 | 2.6009E+02 |
| $\alpha_4$ | 2.12E-05 | 2.28E-03 | 1.20E-03 | 8.21E-03 | 1.75E-03 | 5.9767E-01 | 2.6156E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9816360 | 0.9783410 | 0.9811190 |
| $\alpha_2$ | 1.84E-02 | 1.70E-02 | 9.35E-03 |
| $\alpha_3$ | | 4.64E-03 | 7.78E-03 |
| $\alpha_4$ | | | 1.75E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.82E-01 | 9.78E-01 | 9.81E-01 |
| Beta | 1.84E-02 | 2.17E-02 | 1.89E-02 |
| Gamma | | 2.14E-01 | 5.05E-01 |
| Delta | | | 1.84E-01 |

PWR High Pressure Safety Injection Pump

HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO RUN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 104.46 | 156.69 | 208.92 |
| $N_1$ | 2.4660 | 1.4480 | 1.2071 |
| $N_2$ | 2.0003 | 2.7510 | 2.0020 |
| $N_3$ | | 0.7500 | 1.6667 |
| $N_4$ | | | 0.3750 |

## 1.1.9.4 HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 133.30
Total Number of Common-Cause Failure Events: 5

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9542190 | 0.9793110 | 0.9819660 | 0.9953340 | 0.9813070 | 1.1525E+02 | 2.4348E+00 |
| $\alpha_2$ | 4.67E-03 | 2.07E-02 | 1.80E-02 | 4.58E-02 | 1.87E-02 | 2.4348E+00 | 1.1525E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9549510 | 0.9757040 | 0.9773630 | 0.9908050 | 0.9779480 | 1.8481E+02 | 4.6019E+00 |
| $\alpha_2$ | 6.02E-03 | 1.89E-02 | 1.73E-02 | 3.75E-02 | 1.73E-02 | 3.5847E+00 | 1.8583E+02 |
| $\alpha_3$ | 2.89E-04 | 5.37E-03 | 3.76E-03 | 1.59E-02 | 4.72E-03 | 1.0172E+00 | 1.8839E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9600980 | 0.9771650 | 0.9783890 | 0.9900560 | 0.9807750 | 2.5242E+02 | 5.8988E+00 |
| $\alpha_2$ | 3.65E-03 | 1.25E-02 | 1.13E-02 | 2.56E-02 | 9.52E-03 | 3.2301E+00 | 2.5509E+02 |
| $\alpha_3$ | 1.50E-03 | 8.02E-03 | 6.79E-03 | 1.87E-02 | 7.92E-03 | 2.0710E+00 | 2.5625E+02 |
| $\alpha_4$ | 2.15E-05 | 2.31E-03 | 1.22E-03 | 8.33E-03 | 1.78E-03 | 5.9767E-01 | 2.5772E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9813070 | 0.9779480 | 0.9807750 |
| $\alpha_2$ | 1.87E-02 | 1.73E-02 | 9.52E-03 |
| $\alpha_3$ | | 4.72E-03 | 7.92E-03 |
| $\alpha_4$ | | | 1.78E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.81E-01 | 9.78E-01 | 9.81E-01 |
| Beta | 1.87E-02 | 2.21E-02 | 1.92E-02 |
| Gamma | | 2.14E-01 | 5.05E-01 |
| Delta | | | 1.84E-01 |

PWR High Pressure Safety Injection Pump

HIGH PRESSURE INJECTION MOTOR DRIVEN PUMP FAIL TO RUN >1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 102.54 | 153.81 | 205.08 |
| $N_1$ | 2.4660 | 1.4480 | 1.2071 |
| $N_2$ | 2.0003 | 2.7510 | 2.0020 |
| $N_3$ | | 0.7500 | 1.6667 |
| $N_4$ | | | 0.3750 |

# 1.1.10 PWR Residual Heat Removal Pump

## 1.1.10.1 PWR RHR MDP FAIL TO START

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 33.50
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9048220 | 0.9619520 | 0.9690180 | 0.9948830 | 0.9628450 | 4.0566E+01 | 1.6045E+00 |
| $\alpha_2$ | 5.12E-03 | 3.80E-02 | 3.10E-02 | 9.52E-02 | 3.72E-02 | 1.6045E+00 | 4.0566E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9281530 | 0.9668900 | 0.9708430 | 0.9920950 | 0.9687360 | 7.4600E+01 | 2.5546E+00 |
| $\alpha_2$ | 3.47E-03 | 2.28E-02 | 1.88E-02 | 5.58E-02 | 1.99E-02 | 1.7592E+00 | 7.5395E+01 |
| $\alpha_3$ | 2.80E-04 | 1.03E-02 | 6.50E-03 | 3.33E-02 | 1.14E-02 | 7.9542E-01 | 7.6359E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9344890 | 0.9666210 | 0.9694270 | 0.9891500 | 0.9707450 | 1.0574E+02 | 3.6514E+00 |
| $\alpha_2$ | 3.94E-03 | 1.98E-02 | 1.70E-02 | 4.55E-02 | 1.53E-02 | 2.1700E+00 | 1.0722E+02 |
| $\alpha_3$ | 4.79E-04 | 9.17E-03 | 6.41E-03 | 2.73E-02 | 9.76E-03 | 1.0036E+00 | 1.0839E+02 |
| $\alpha_4$ | 1.35E-05 | 4.37E-03 | 1.92E-03 | 1.70E-02 | 4.15E-03 | 4.7777E-01 | 1.0891E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9628450 | 0.9687360 | 0.9707450 |
| $\alpha_2$ | 3.72E-02 | 1.99E-02 | 1.53E-02 |
| $\alpha_3$ | | 1.14E-02 | 9.76E-03 |
| $\alpha_4$ | | | 4.15E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.63E-01 | 9.69E-01 | 9.71E-01 |
| Beta | 3.72E-02 | 3.13E-02 | 2.93E-02 |
| Gamma | | 3.63E-01 | 4.76E-01 |
| Delta | | | 2.99E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 28.76 | 43.13 | 57.51 |
| $N_1$ | 1.5600 | 1.9145 | 2.0960 |
| $N_2$ | 1.1700 | 0.9255 | 0.9419 |
| $N_3$ | | 0.5282 | 0.5993 |
| $N_4$ | | | 0.2551 |

## 1.1.10.2 PWR RHR MDP FTR LESS THAN 1H

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 3.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.7559040 | 0.9029460 | 0.9208280 | 0.9885570 | 0.7560980 | 1.3346E+01 | 1.4345E+00 |
| $\alpha_2$ | 1.14E-02 | 9.71E-02 | 7.92E-02 | 2.44E-01 | 2.44E-01 | 1.4345E+00 | 1.3346E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8683020 | 0.9421330 | 0.9501000 | 0.9886510 | 0.8230090 | 3.4205E+01 | 2.1009E+00 |
| $\alpha_2$ | 3.62E-03 | 3.67E-02 | 2.86E-02 | 9.78E-02 | 8.85E-02 | 1.3337E+00 | 3.4972E+01 |
| $\alpha_3$ | 5.18E-04 | 2.11E-02 | 1.32E-02 | 6.88E-02 | 8.85E-02 | 7.6722E-01 | 3.5539E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8921340 | 0.9482690 | 0.9536140 | 0.9861190 | 0.8611110 | 5.2336E+01 | 2.8551E+00 |
| $\alpha_2$ | 3.13E-03 | 2.68E-02 | 2.13E-02 | 6.92E-02 | 3.47E-02 | 1.4781E+00 | 5.3713E+01 |
| $\alpha_3$ | 6.56E-04 | 1.64E-02 | 1.10E-02 | 5.04E-02 | 6.94E-02 | 9.0431E-01 | 5.4287E+01 |
| $\alpha_4$ | 2.51E-05 | 8.56E-03 | 3.74E-03 | 3.34E-02 | 3.47E-02 | 4.7267E-01 | 5.4718E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.7560980 | 0.8230090 | 0.8611110 |
| $\alpha_2$ | 2.44E-01 | 8.85E-02 | 3.47E-02 |
| $\alpha_3$ | | 8.85E-02 | 6.94E-02 |
| $\alpha_4$ | | | 3.47E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 7.56E-01 | 8.23E-01 | 8.61E-01 |
| Beta | 2.44E-01 | 1.77E-01 | 1.39E-01 |
| Gamma | | 5.00E-01 | 7.50E-01 |
| Delta | | | 3.33E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 3.10 | 4.65 | 6.20 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.5000 | 0.2500 |
| $N_3$ | | 0.5000 | 0.5000 |
| $N_4$ | | | 0.2500 |

## 1.1.10.3 PWR RHR MDP FAIL TO RUN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 10.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8315110 | 0.9341380 | 0.9470550 | 0.9924380 | 0.9099100 | 2.0346E+01 | 1.4345E+00 |
| $\alpha_2$ | 7.56E-03 | 6.59E-02 | 5.29E-02 | 1.68E-01 | 9.01E-02 | 1.4345E+00 | 2.0346E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8972310 | 0.9551140 | 0.9614590 | 0.9912720 | 0.9380800 | 4.4705E+01 | 2.1009E+00 |
| $\alpha_2$ | 2.79E-03 | 2.85E-02 | 2.21E-02 | 7.62E-02 | 3.10E-02 | 1.3337E+00 | 4.5472E+01 |
| $\alpha_3$ | 3.99E-04 | 1.64E-02 | 1.02E-02 | 5.35E-02 | 3.10E-02 | 7.6722E-01 | 4.6039E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9135850 | 0.9587360 | 0.9630890 | 0.9889930 | 0.9528300 | 6.6336E+01 | 2.8551E+00 |
| $\alpha_2$ | 2.49E-03 | 2.14E-02 | 1.69E-02 | 5.54E-02 | 1.18E-02 | 1.4781E+00 | 6.7713E+01 |
| $\alpha_3$ | 5.22E-04 | 1.31E-02 | 8.77E-03 | 4.03E-02 | 2.36E-02 | 9.0431E-01 | 6.8287E+01 |
| $\alpha_4$ | 2.00E-05 | 6.83E-03 | 2.98E-03 | 2.67E-02 | 1.18E-02 | 4.7267E-01 | 6.8718E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9099100 | 0.9380800 | 0.9528300 |
| $\alpha_2$ | 9.01E-02 | 3.10E-02 | 1.18E-02 |
| $\alpha_3$ | | 3.10E-02 | 2.36E-02 |
| $\alpha_4$ | | | 1.18E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.10E-01 | 9.38E-01 | 9.53E-01 |
| Beta | 9.01E-02 | 6.19E-02 | 4.72E-02 |
| Gamma | | 5.00E-01 | 7.50E-01 |
| Delta | | | 3.33E-01 |

PWR Residual Heat Removal Pump

PWR RHR MDP FAIL TO RUN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 10.10 | 15.15 | 20.20 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.5000 | 0.2500 |
| $N_3$ | | 0.5000 | 0.5000 |
| $N_4$ | | | 0.2500 |

## 1.1.10.4 PWR RHR MDP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9017830 | 0.9754240 | 0.9898730 | 0.9999510 | 1.0000000 | 1.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.52E-05 | 2.46E-02 | 1.01E-02 | 9.82E-02 | 0.00E+00 | 4.3452E-01 | 1.7246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9165860 | 0.9707650 | 0.9786210 | 0.9980670 | 1.0000000 | 3.6555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.05E-04 | 2.21E-02 | 1.44E-02 | 7.00E-02 | 0.00E+00 | 8.3366E-01 | 3.6822E+01 |
| $\alpha_3$ | 2.49E-07 | 7.10E-03 | 1.44E-03 | 3.37E-02 | 0.00E+00 | 2.6722E-01 | 3.7389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9192920 | 0.9662660 | 0.9717540 | 0.9944390 | 1.0000000 | 5.3136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.85E-03 | 2.23E-02 | 1.68E-02 | 6.16E-02 | 0.00E+00 | 1.2281E+00 | 5.3763E+01 |
| $\alpha_3$ | 8.29E-06 | 7.35E-03 | 2.73E-03 | 3.04E-02 | 0.00E+00 | 4.0431E-01 | 5.4587E+01 |
| $\alpha_4$ | 1.75E-08 | 4.05E-03 | 5.55E-04 | 2.03E-02 | 0.00E+00 | 2.2267E-01 | 5.4768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 7.00 | 7.00 | 7.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

# 1.1.11 BWR Standby Liquid Control Pump

## 1.1.11.1 STANDBY LIQUID CONTROL MDP FAIL TO START SPAR: SLC-MDP-FS

| | |
|---|---|
| **System :** | Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 14.50
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9303290 | 0.9824790 | 0.9926940 | 0.9999600 | 0.9993190 | 2.4926E+01 | 4.4452E-01 |
| $\alpha_2$ | 3.66E-05 | 1.75E-02 | 7.31E-03 | 6.97E-02 | 6.81E-04 | 4.4452E-01 | 2.4926E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 0.9993190 |
| $\alpha_2$ | 6.81E-04 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 9.99E-01 |
| Beta | 6.81E-04 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 14.50 |
| $N_1$ | 0.1800 |
| $N_2$ | 0.0100 |

## 1.1.11.2 STANDBY LIQUID CONTROL MDP FAIL TO RUN SPAR: SLC-MDP-FR

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Op. Mode :** | CCF Event Can Only Happen During Power Operation<br>CCF Event May Occur During Both Power Operation & Shutdown |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 10.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8315110 | 0.9341380 | 0.9470550 | 0.9924380 | 0.9099100 | 2.0346E+01 | 1.4345E+00 |
| $\alpha_2$ | 7.56E-03 | 6.59E-02 | 5.29E-02 | 1.68E-01 | 9.01E-02 | 1.4345E+00 | 2.0346E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 0.9099100 |
| $\alpha_2$ | 9.01E-02 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 9.10E-01 |
| Beta | 9.01E-02 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 10.10 |
| $N_1$ | 0.0000 |
| $N_2$ | 1.0000 |

## 1.1.11.3 STANDBY LIQUID CONTROL MDP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Standby liquid control |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.20
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8657670 | 0.9662650 | 0.9859070 | 0.9999390 | 1.0000000 | 1.2446E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.31E-05 | 3.37E-02 | 1.41E-02 | 1.34E-01 | 0.00E+00 | 4.3452E-01 | 1.2446E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 2.20 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

## 1.1.12 Component Cooling Water Pumps

### 1.1.12.1 CCW MOTOR DRIVEN PUMP FAIL TO START SPAR: CCW-MDP-FS

| | |
|---|---|
| **System :** | Component cooling water |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 79.70
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9806290 | 0.9951920 | 0.9980790 | 0.9999920 | 1.0000000 | 8.9946E+01 | 4.3452E-01 |
| $\alpha_2$ | 8.56E-06 | 4.81E-03 | 1.92E-03 | 1.94E-02 | 0.00E+00 | 4.3452E-01 | 8.9946E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9712540 | 0.9900240 | 0.9927850 | 0.9993480 | 1.0000000 | 1.0925E+02 | 1.1009E+00 |
| $\alpha_2$ | 2.37E-04 | 7.55E-03 | 4.86E-03 | 2.41E-02 | 0.00E+00 | 8.3366E-01 | 1.0952E+02 |
| $\alpha_3$ | 8.42E-08 | 2.42E-03 | 4.85E-04 | 1.15E-02 | 0.00E+00 | 2.6722E-01 | 1.1008E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 |
|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 |
|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 |
|---|---|---|
| Adj. Ind. Events | 79.70 | 79.70 |
| $N_1$ | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 |

## 1.1.12.2 CCW MOTOR DRIVEN PUMP FAIL TO RUN SPAR: CCW-MDP-FR

| | |
|---|---|
| **System :** | Component cooling water |
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 54.50
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9114470 | 0.9652970 | 0.9721280 | 0.9957350 | 0.9672290 | 4.2219E+01 | 1.5178E+00 |
| $\alpha_2$ | 4.26E-03 | 3.47E-02 | 2.79E-02 | 8.86E-02 | 3.28E-02 | 1.5178E+00 | 4.2219E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9342170 | 0.9704720 | 0.9743250 | 0.9935480 | 0.9744690 | 7.7265E+01 | 2.3509E+00 |
| $\alpha_2$ | 8.57E-04 | 1.36E-02 | 9.81E-03 | 3.94E-02 | 5.11E-03 | 1.0837E+00 | 7.8532E+01 |
| $\alpha_3$ | 1.40E-03 | 1.59E-02 | 1.21E-02 | 4.36E-02 | 2.04E-02 | 1.2672E+00 | 7.8349E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 |
|---|---|---|
| $\alpha_1$ | 0.9672290 | 0.9744690 |
| $\alpha_2$ | 3.28E-02 | 5.11E-03 |
| $\alpha_3$ | | 2.04E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 |
|---|---|---|
| 1-Beta | 9.67E-01 | 9.74E-01 |
| Beta | 3.28E-02 | 2.55E-02 |
| Gamma | | 8.00E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 |
|---|---|---|
| Adj. Ind. Events | 31.14 | 46.71 |
| $N_1$ | 0.8333 | 1.0000 |
| $N_2$ | 1.0833 | 0.2500 |
| $N_3$ | | 1.0000 |

# 1.1.13 Positive Displacement Pumps

## 1.1.13.1 POSITIVE DISPLACEMENT PUMP FAIL TO START

| | |
|---|---|
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to start |
| **Component Group :** | Positive Displacement |
| **Start Date :** | 1998/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 89.60
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9823140 | 0.9955760 | 0.9981920 | 0.9999920 | 0.9998890 | 1.0003E+02 | 4.4452E-01 |
| $\alpha_2$ | 9.04E-06 | 4.42E-03 | 1.81E-03 | 1.77E-02 | 1.11E-04 | 4.4452E-01 | 1.0003E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9804610 | 0.9931720 | 0.9950280 | 0.9995290 | 0.9997920 | 1.6420E+02 | 1.1289E+00 |
| $\alpha_2$ | 1.79E-04 | 5.21E-03 | 3.39E-03 | 1.64E-02 | 2.00E-04 | 8.6066E-01 | 1.6447E+02 |
| $\alpha_3$ | 5.85E-08 | 1.62E-03 | 3.26E-04 | 7.69E-03 | 7.43E-06 | 2.6822E-01 | 1.6506E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9798920 | 0.9916170 | 0.9930050 | 0.9985880 | 0.9997090 | 2.2563E+02 | 1.9074E+00 |
| $\alpha_2$ | 4.95E-04 | 5.61E-03 | 4.25E-03 | 1.54E-02 | 2.71E-04 | 1.2767E+00 | 2.2626E+02 |
| $\alpha_3$ | 2.12E-06 | 1.79E-03 | 6.67E-04 | 7.39E-03 | 2.01E-05 | 4.0791E-01 | 2.2713E+02 |
| $\alpha_4$ | 4.22E-09 | 9.79E-04 | 1.33E-04 | 4.90E-03 | 5.57E-07 | 2.2277E-01 | 2.2731E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9998890 | 0.9997920 | 0.9997090 |
| $\alpha_2$ | 1.11E-04 | 2.00E-04 | 2.71E-04 |
| $\alpha_3$ | | 7.43E-06 | 2.01E-05 |
| $\alpha_4$ | | | 5.57E-07 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 1.11E-04 | 2.08E-04 | 2.91E-04 |
| Gamma | | 3.57E-02 | 7.07E-02 |
| Delta | | | 2.70E-02 |

POSITIVE DISPLACEMENT PUMP FAIL TO START

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 89.60 | 134.40 | 179.20 |
| $N_1$ | 0.1800 | 0.2430 | 0.2916 |
| $N_2$ | 0.0100 | 0.0270 | 0.0486 |
| $N_3$ | | 0.0010 | 0.0036 |
| $N_4$ | | | 0.0001 |

## 1.1.13.2 POSITIVE DISPLACEMENT PUMP FAIL TO RUN

| | |
|---|---|
| **Component :** | Motor Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment) |
| **Component Group :** | Positive Displacement |
| **Start Date :** | 1998/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 86.20
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9577590 | 0.9845660 | 0.9882850 | 0.9986410 | 0.9883390 | 8.0873E+01 | 1.2678E+00 |
| $\alpha_2$ | 1.36E-03 | 1.54E-02 | 1.17E-02 | 4.22E-02 | 1.17E-02 | 1.2678E+00 | 8.0873E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9532970 | 0.9773390 | 0.9796280 | 0.9935700 | 0.9811660 | 1.3374E+02 | 3.1009E+00 |
| $\alpha_2$ | 4.52E-03 | 1.89E-02 | 1.66E-02 | 4.11E-02 | 1.65E-02 | 2.5837E+00 | 1.3426E+02 |
| $\alpha_3$ | 1.78E-05 | 3.78E-03 | 1.78E-03 | 1.43E-02 | 2.35E-03 | 5.1722E-01 | 1.3632E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9575280 | 0.9775940 | 0.9792580 | 0.9919720 | 0.9831320 | 1.8456E+02 | 4.2301E+00 |
| $\alpha_2$ | 3.00E-03 | 1.31E-02 | 1.14E-02 | 2.90E-02 | 8.88E-03 | 2.4781E+00 | 1.8631E+02 |
| $\alpha_3$ | 7.84E-04 | 7.44E-03 | 5.79E-03 | 1.97E-02 | 7.10E-03 | 1.4043E+00 | 1.8739E+02 |
| $\alpha_4$ | 6.92E-07 | 1.84E-03 | 5.62E-04 | 8.02E-03 | 8.88E-04 | 3.4767E-01 | 1.8844E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9883390 | 0.9811660 | 0.9831320 |
| $\alpha_2$ | 1.17E-02 | 1.65E-02 | 8.88E-03 |
| $\alpha_3$ | | 2.35E-03 | 7.10E-03 |
| $\alpha_4$ | | | 8.88E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.88E-01 | 9.81E-01 | 9.83E-01 |
| Beta | 1.17E-02 | 1.88E-02 | 1.69E-02 |
| Gamma | | 1.25E-01 | 4.74E-01 |
| Delta | | | 1.11E-01 |

POSITIVE DISPLACEMENT PUMP FAIL TO RUN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 68.96 | 103.44 | 137.92 |
| $N_1$ | 1.6667 | 0.7500 | 0.5000 |
| $N_2$ | 0.8333 | 1.7500 | 1.2500 |
| $N_3$ | | 0.2500 | 1.0000 |
| $N_4$ | | | 0.1250 |

# 1.2 Turbine Driven Pumps

## 1.2.1 Pooled Turbine Driven Pumps

### 1.2.1.1 TURBINE DRIVEN PUMP FAIL TO START SPAR: TDP-FS

| | |
|---|---|
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 167.90
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9789610 | 0.9920120 | 0.9937470 | 0.9991230 | 0.9940790 | 1.7815E+02 | 1.4345E+00 |
| $\alpha_2$ | 8.74E-04 | 7.99E-03 | 6.25E-03 | 2.10E-02 | 5.92E-03 | 1.4345E+00 | 1.7815E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9827500 | 0.9925890 | 0.9937130 | 0.9985920 | 0.9960450 | 2.8140E+02 | 2.1009E+00 |
| $\alpha_2$ | 4.51E-04 | 4.70E-03 | 3.60E-03 | 1.27E-02 | 1.98E-03 | 1.3337E+00 | 2.8217E+02 |
| $\alpha_3$ | 6.49E-05 | 2.71E-03 | 1.66E-03 | 8.90E-03 | 1.98E-03 | 7.6722E-01 | 2.8273E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9842490 | 0.9925800 | 0.9934180 | 0.9980610 | 0.9970310 | 3.8194E+02 | 2.8551E+00 |
| $\alpha_2$ | 4.41E-04 | 3.84E-03 | 3.02E-03 | 1.00E-02 | 7.42E-04 | 1.4781E+00 | 3.8332E+02 |
| $\alpha_3$ | 9.27E-05 | 2.35E-03 | 1.56E-03 | 7.29E-03 | 1.48E-03 | 9.0431E-01 | 3.8389E+02 |
| $\alpha_4$ | 3.56E-06 | 1.23E-03 | 5.32E-04 | 4.81E-03 | 7.42E-04 | 4.7267E-01 | 3.8432E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9940790 | 0.9960450 | 0.9970310 |
| $\alpha_2$ | 5.92E-03 | 1.98E-03 | 7.42E-04 |
| $\alpha_3$ | | 1.98E-03 | 1.48E-03 |
| $\alpha_4$ | | | 7.42E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.94E-01 | 9.96E-01 | 9.97E-01 |
| Beta | 5.92E-03 | 3.95E-03 | 2.97E-03 |
| Gamma | | 5.00E-01 | 7.50E-01 |
| Delta | | | 3.33E-01 |

Pooled Turbine Driven Pumps

TURBINE DRIVEN PUMP FAIL TO START SPAR: TDP-FS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 167.90 | 251.85 | 335.80 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.5000 | 0.2500 |
| $N_3$ | | 0.5000 | 0.5000 |
| $N_4$ | | | 0.2500 |

## 1.2.1.2 TURBINE DRIVEN PUMP FTR LESS THAN 1H

| | |
|---|---|
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 62.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9761140 | 0.9940700 | 0.9976270 | 0.9999880 | 1.0000000 | 7.2846E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.06E-05 | 5.93E-03 | 2.38E-03 | 2.39E-02 | 0.00E+00 | 4.3452E-01 | 7.2846E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9660150 | 0.9881950 | 0.9914590 | 0.9992280 | 1.0000000 | 9.2155E+01 | 1.1009E+00 |
| $\alpha_2$ | 2.81E-04 | 8.94E-03 | 5.76E-03 | 2.84E-02 | 0.00E+00 | 8.3366E-01 | 9.2422E+01 |
| $\alpha_3$ | 9.97E-08 | 2.87E-03 | 5.74E-04 | 1.36E-02 | 0.00E+00 | 2.6722E-01 | 9.2989E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9595530 | 0.9832260 | 0.9860440 | 0.9972690 | 1.0000000 | 1.0874E+02 | 1.8551E+00 |
| $\alpha_2$ | 9.12E-04 | 1.11E-02 | 8.33E-03 | 3.08E-02 | 0.00E+00 | 1.2281E+00 | 1.0937E+02 |
| $\alpha_3$ | 4.10E-06 | 3.66E-03 | 1.35E-03 | 1.51E-02 | 0.00E+00 | 4.0431E-01 | 1.1019E+02 |
| $\alpha_4$ | 8.65E-09 | 2.01E-03 | 2.75E-04 | 1.01E-02 | 0.00E+00 | 2.2267E-01 | 1.1037E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

Pooled Turbine Driven Pumps
TURBINE DRIVEN PUMP FTR LESS THAN 1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 62.60 | 62.60 | 62.60 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.2.1.3 TDP FTR LESS THAN AND > 1 HOUR ALL SYSTEMS SPAR: TDP-FR

**Component :** Turbine Driven Pump
**Failure Mode :** Fail to Run (Normally running equipment)
Fail to Run >1 Hour (Standby equipment)
Fail to Run less than 1 Hour
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 130.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9876020 | 0.9969250 | 0.9987700 | 0.9999890 | 1.0000000 | 1.4085E+02 | 4.3452E-01 |
| $\alpha_2$ | 5.46E-06 | 3.08E-03 | 1.23E-03 | 1.24E-02 | 0.00E+00 | 4.3452E-01 | 1.4085E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9802920 | 0.9931730 | 0.9950720 | 0.9995550 | 1.0000000 | 1.6015E+02 | 1.1009E+00 |
| $\alpha_2$ | 1.62E-04 | 5.17E-03 | 3.32E-03 | 1.65E-02 | 0.00E+00 | 8.3366E-01 | 1.6042E+02 |
| $\alpha_3$ | 5.75E-08 | 1.66E-03 | 3.31E-04 | 7.86E-03 | 0.00E+00 | 2.6722E-01 | 1.6098E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9748790 | 0.9896130 | 0.9913740 | 0.9983130 | 1.0000000 | 1.7674E+02 | 1.8551E+00 |
| $\alpha_2$ | 5.63E-04 | 6.88E-03 | 5.14E-03 | 1.91E-02 | 0.00E+00 | 1.2281E+00 | 1.7737E+02 |
| $\alpha_3$ | 2.53E-06 | 2.26E-03 | 8.34E-04 | 9.36E-03 | 0.00E+00 | 4.0431E-01 | 1.7819E+02 |
| $\alpha_4$ | 5.35E-09 | 1.25E-03 | 1.70E-04 | 6.24E-03 | 0.00E+00 | 2.2267E-01 | 1.7837E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9693910 | 0.9846360 | 0.9860200 | 0.9951690 | 1.0000000 | 2.2676E+02 | 3.5382E+00 |
| $\alpha_2$ | 1.76E-03 | 9.18E-03 | 7.80E-03 | 2.13E-02 | 0.00E+00 | 2.1142E+00 | 2.2818E+02 |
| $\alpha_3$ | 2.06E-04 | 4.24E-03 | 2.92E-03 | 1.28E-02 | 0.00E+00 | 9.7738E-01 | 2.2932E+02 |
| $\alpha_4$ | 1.07E-06 | 1.63E-03 | 5.46E-04 | 6.91E-03 | 0.00E+00 | 3.7439E-01 | 2.2992E+02 |
| $\alpha_5$ | 2.58E-21 | 3.14E-04 | 1.77E-07 | 1.81E-03 | 0.00E+00 | 7.2277E-02 | 2.3023E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9678230 | 0.9830090 | 0.9842690 | 0.9938810 | 1.0000000 | 2.4754E+02 | 4.2787E+00 |
| $\alpha_2$ | 1.82E-03 | 8.89E-03 | 7.63E-03 | 2.03E-02 | 0.00E+00 | 2.2392E+00 | 2.4958E+02 |
| $\alpha_3$ | 3.18E-04 | 4.53E-03 | 3.31E-03 | 1.29E-02 | 0.00E+00 | 1.1418E+00 | 2.5068E+02 |
| $\alpha_4$ | 2.10E-05 | 2.35E-03 | 1.23E-03 | 8.49E-03 | 0.00E+00 | 5.9222E-01 | 2.5123E+02 |
| $\alpha_5$ | 3.68E-09 | 8.82E-04 | 1.19E-04 | 4.42E-03 | 0.00E+00 | 2.2220E-01 | 2.5160E+02 |
| $\alpha_6$ | 5.59E-19 | 3.31E-04 | 5.77E-07 | 1.93E-03 | 0.00E+00 | 8.3237E-02 | 2.5174E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 130.60 | 130.60 | 130.60 | 130.60 | 130.60 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.2.1.4 TURBINE DRIVEN PUMP FAIL TO RUN >1H

| | |
|---|---|
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run (Normally running equipment)<br>Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 68.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9777550 | 0.9944770 | 0.9977910 | 0.9999910 | 1.0000000 | 7.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 9.84E-06 | 5.52E-03 | 2.21E-03 | 2.22E-02 | 0.00E+00 | 4.3452E-01 | 7.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9678650 | 0.9888410 | 0.9919290 | 0.9992710 | 1.0000000 | 9.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 2.65E-04 | 8.45E-03 | 5.44E-03 | 2.69E-02 | 0.00E+00 | 8.3366E-01 | 9.7822E+01 |
| $\alpha_3$ | 9.42E-08 | 2.71E-03 | 5.42E-04 | 1.28E-02 | 0.00E+00 | 2.6722E-01 | 9.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9614270 | 0.9840070 | 0.9866970 | 0.9973970 | 1.0000000 | 1.1414E+02 | 1.8551E+00 |
| $\alpha_2$ | 8.70E-04 | 1.06E-02 | 7.94E-03 | 2.94E-02 | 0.00E+00 | 1.2281E+00 | 1.1477E+02 |
| $\alpha_3$ | 3.91E-06 | 3.49E-03 | 1.29E-03 | 1.44E-02 | 0.00E+00 | 4.0431E-01 | 1.1559E+02 |
| $\alpha_4$ | 8.25E-09 | 1.92E-03 | 2.62E-04 | 9.61E-03 | 0.00E+00 | 2.2267E-01 | 1.1577E+02 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

Pooled Turbine Driven Pumps

TURBINE DRIVEN PUMP FAIL TO RUN >1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 68.00 | 68.00 | 68.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.2.2 AFW Turbine-Driven Pumps

### 1.2.2.1 AFW TURBINE DRIVEN PUMP FAIL TO START SPAR: AFW-TDP-FS

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 66.90
Total Number of Common-Cause Failure Events: 0

#### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9774400 | 0.9943990 | 0.9977600 | 0.9999910 | 1.0000000 | 7.7146E+01 | 4.3452E-01 |
| $\alpha_2$ | 9.98E-06 | 5.60E-03 | 2.24E-03 | 2.26E-02 | 0.00E+00 | 4.3452E-01 | 7.7146E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9675050 | 0.9887150 | 0.9918380 | 0.9992620 | 1.0000000 | 9.6455E+01 | 1.1009E+00 |
| $\alpha_2$ | 2.68E-04 | 8.55E-03 | 5.50E-03 | 2.72E-02 | 0.00E+00 | 8.3366E-01 | 9.6722E+01 |
| $\alpha_3$ | 9.53E-08 | 2.74E-03 | 5.49E-04 | 1.30E-02 | 0.00E+00 | 2.6722E-01 | 9.7289E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9610610 | 0.9838540 | 0.9865690 | 0.9973720 | 1.0000000 | 1.1304E+02 | 1.8551E+00 |
| $\alpha_2$ | 8.78E-04 | 1.07E-02 | 8.01E-03 | 2.96E-02 | 0.00E+00 | 1.2281E+00 | 1.1367E+02 |
| $\alpha_3$ | 3.94E-06 | 3.52E-03 | 1.30E-03 | 1.45E-02 | 0.00E+00 | 4.0431E-01 | 1.1449E+02 |
| $\alpha_4$ | 8.33E-09 | 1.94E-03 | 2.64E-04 | 9.70E-03 | 0.00E+00 | 2.2267E-01 | 1.1467E+02 |

#### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

AFW TURBINE DRIVEN PUMP FAIL TO START SPAR: AFW-TDP-FS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 66.90 | 66.90 | 66.90 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

### 1.2.2.2 AFW TURBINE DRIVEN PUMP FTR LESS THAN 1H SPAR: AFW-TDP-FH

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 40.00
Total Number of Common-Cause Failure Events: 0

## *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9655000 | 0.9914260 | 0.9965530 | 0.9999830 | 1.0000000 | 5.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.54E-05 | 8.57E-03 | 3.45E-03 | 3.45E-02 | 0.00E+00 | 4.3452E-01 | 5.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9552250 | 0.9844190 | 0.9886960 | 0.9989790 | 1.0000000 | 6.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.72E-04 | 1.18E-02 | 7.62E-03 | 3.75E-02 | 0.00E+00 | 8.3366E-01 | 6.9822E+01 |
| $\alpha_3$ | 1.32E-07 | 3.78E-03 | 7.59E-04 | 1.79E-02 | 0.00E+00 | 2.6722E-01 | 7.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9492630 | 0.9789170 | 0.9824320 | 0.9965570 | 1.0000000 | 8.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.15E-03 | 1.40E-02 | 1.05E-02 | 3.86E-02 | 0.00E+00 | 1.2281E+00 | 8.6763E+01 |
| $\alpha_3$ | 5.16E-06 | 4.59E-03 | 1.70E-03 | 1.90E-02 | 0.00E+00 | 4.0431E-01 | 8.7587E+01 |
| $\alpha_4$ | 1.09E-08 | 2.53E-03 | 3.46E-04 | 1.27E-02 | 0.00E+00 | 2.2267E-01 | 8.7768E+01 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

AFW Turbine-Driven Pumps

AFW TURBINE DRIVEN PUMP FTR LESS THAN 1H SPAR: AFW-TDP-FH

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 40.00 | 40.00 | 40.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.2.2.3 AFW TURBINE DRIVEN PUMP FAIL TO RUN SPAR: AFW-TDP-FR

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 48.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9701940 | 0.9925950 | 0.9970290 | 0.9999850 | 1.0000000 | 5.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.32E-05 | 7.40E-03 | 2.97E-03 | 2.98E-02 | 0.00E+00 | 4.3452E-01 | 5.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9597510 | 0.9860040 | 0.9898550 | 0.9990840 | 1.0000000 | 7.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.33E-04 | 1.06E-02 | 6.84E-03 | 3.37E-02 | 0.00E+00 | 8.3366E-01 | 7.7822E+01 |
| $\alpha_3$ | 1.18E-07 | 3.40E-03 | 6.81E-04 | 1.61E-02 | 0.00E+00 | 2.6722E-01 | 7.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9534540 | 0.9806740 | 0.9839060 | 0.9968480 | 1.0000000 | 9.4136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.05E-03 | 1.28E-02 | 9.60E-03 | 3.54E-02 | 0.00E+00 | 1.2281E+00 | 9.4763E+01 |
| $\alpha_3$ | 4.73E-06 | 4.21E-03 | 1.56E-03 | 1.74E-02 | 0.00E+00 | 4.0431E-01 | 9.5587E+01 |
| $\alpha_4$ | 9.98E-09 | 2.32E-03 | 3.17E-04 | 1.16E-02 | 0.00E+00 | 2.2267E-01 | 9.5768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

AFW Turbine-Driven Pumps

AFW TURBINE DRIVEN PUMP FAIL TO RUN SPAR: AFW-TDP-FR

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 48.00 | 48.00 | 48.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.2.2.4 AFW TURBINE DRIVEN PUMP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 8.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9069840 | 0.9767390 | 0.9904340 | 0.9999540 | 1.0000000 | 1.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.27E-05 | 2.33E-02 | 9.56E-03 | 9.30E-02 | 0.00E+00 | 4.3452E-01 | 1.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9187120 | 0.9715210 | 0.9791840 | 0.9981180 | 1.0000000 | 3.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.87E-04 | 2.16E-02 | 1.40E-02 | 6.82E-02 | 0.00E+00 | 8.3366E-01 | 3.7822E+01 |
| $\alpha_3$ | 2.43E-07 | 6.91E-03 | 1.40E-03 | 3.28E-02 | 0.00E+00 | 2.6722E-01 | 3.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9207150 | 0.9668680 | 0.9722640 | 0.9945410 | 1.0000000 | 5.4136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.82E-03 | 2.19E-02 | 1.65E-02 | 6.05E-02 | 0.00E+00 | 1.2281E+00 | 5.4763E+01 |
| $\alpha_3$ | 8.14E-06 | 7.22E-03 | 2.68E-03 | 2.98E-02 | 0.00E+00 | 4.0431E-01 | 5.5587E+01 |
| $\alpha_4$ | 1.72E-08 | 3.98E-03 | 5.45E-04 | 1.99E-02 | 0.00E+00 | 2.2267E-01 | 5.5768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

AFW Turbine-Driven Pumps

AFW TURBINE DRIVEN PUMP FAIL TO RUN >1H

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 8.00 | 8.00 | 8.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.2.3 BWR High Pressure Coolant Injection and Reactor Core Isolation Cooling Pumps

### 1.2.3.1 COMBINED HPCI AND RCIC TDP FAIL TO START

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to start |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 88.00
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9622100 | 0.9856090 | 0.9887030 | 0.9984190 | 0.9887640 | 9.8246E+01 | 1.4345E+00 |
| $\alpha_2$ | 1.58E-03 | 1.44E-02 | 1.13E-02 | 3.78E-02 | 1.12E-02 | 1.4345E+00 | 9.8246E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 0.9887640 |
| $\alpha_2$ | 1.12E-02 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 9.89E-01 |
| Beta | 1.12E-02 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 88.00 |
| $N_1$ | 0.0000 |
| $N_2$ | 1.0000 |

## 1.2.3.2 COMBINED HPCI AND RCIC TDP FTR LESS THAN 1H

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 22.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9475590 | 0.9869440 | 0.9947100 | 0.9999740 | 1.0000000 | 3.2846E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.36E-05 | 1.31E-02 | 5.29E-03 | 5.24E-02 | 0.00E+00 | 4.3452E-01 | 3.2846E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 22.60 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

## 1.2.3.3 COMBINED HPCI AND RCIC TDP FAIL TO RUN

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment)<br>Fail to Run less than 1 Hour |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 25.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9518730 | 0.9880230 | 0.9951600 | 0.9999760 | 1.0000000 | 3.5846E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.16E-05 | 1.20E-02 | 4.84E-03 | 4.81E-02 | 0.00E+00 | 4.3452E-01 | 3.5846E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 25.60 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

## 1.2.3.4 COMBINED HPCI AND RCIC TDP FAIL TO RUN >1H

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Turbine Driven Pump |
| **Failure Mode :** | Fail to Run >1 Hour (Standby equipment) |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 3.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8734960 | 0.9682380 | 0.9867710 | 0.9999360 | 1.0000000 | 1.3246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.92E-05 | 3.18E-02 | 1.32E-02 | 1.27E-01 | 0.00E+00 | 4.3452E-01 | 1.3246E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 3.00 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

# 1.3 Motor Operated Valves

## 1.3.1 Pooled Motor Operated Valve Distributions

### 1.3.1.1 MOV FAIL TO OPEN/CLOSE ALL SYSTEMS SPAR: MOV-FO

**Component :** Motor Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 486.70
Total Number of Common-Cause Failure Events: 8

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9733330 | 0.9886710 | 0.9904450 | 0.9979480 | 0.9905450 | 1.7598E+02 | 2.0165E+00 |
| $\alpha_2$ | 2.05E-03 | 1.13E-02 | 9.56E-03 | 2.67E-02 | 9.46E-03 | 2.0165E+00 | 1.7598E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9738350 | 0.9866890 | 0.9878310 | 0.9956450 | 0.9894640 | 2.7659E+02 | 3.7313E+00 |
| $\alpha_2$ | 2.76E-03 | 1.04E-02 | 9.23E-03 | 2.19E-02 | 8.30E-03 | 2.9063E+00 | 2.7742E+02 |
| $\alpha_3$ | 8.89E-05 | 2.94E-03 | 1.88E-03 | 9.43E-03 | 2.23E-03 | 8.2502E-01 | 2.7950E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9728200 | 0.9844870 | 0.9853280 | 0.9932690 | 0.9878370 | 3.7364E+02 | 5.8877E+00 |
| $\alpha_2$ | 4.06E-03 | 1.13E-02 | 1.04E-02 | 2.14E-02 | 9.21E-03 | 4.2825E+00 | 3.7525E+02 |
| $\alpha_3$ | 2.05E-04 | 2.98E-03 | 2.17E-03 | 8.54E-03 | 2.19E-03 | 1.1315E+00 | 3.7840E+02 |
| $\alpha_4$ | 3.66E-06 | 1.25E-03 | 5.41E-04 | 4.88E-03 | 7.57E-04 | 4.7367E-01 | 3.7905E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9735460 | 0.9836850 | 0.9843070 | 0.9916900 | 0.9883110 | 5.0454E+02 | 8.3683E+00 |
| $\alpha_2$ | 3.96E-03 | 9.91E-03 | 9.28E-03 | 1.80E-02 | 7.18E-03 | 5.0829E+00 | 5.0783E+02 |
| $\alpha_3$ | 9.71E-04 | 4.55E-03 | 3.92E-03 | 1.03E-02 | 3.28E-03 | 2.3331E+00 | 5.1058E+02 |
| $\alpha_4$ | 3.34E-05 | 1.47E-03 | 8.95E-04 | 4.87E-03 | 9.21E-04 | 7.5479E-01 | 5.1215E+02 |
| $\alpha_5$ | 3.28E-10 | 3.85E-04 | 3.86E-05 | 1.99E-03 | 3.03E-04 | 1.9748E-01 | 5.1271E+02 |

Pooled Motor Operated Valve Distributions

MOV FAIL TO OPEN/CLOSE ALL SYSTEMS SPAR: MOV-FO

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9750180 | 0.9840990 | 0.9846180 | 0.9914020 | 0.9888510 | 6.0618E+02 | 9.7944E+00 |
| $\alpha_2$ | 3.16E-03 | 8.05E-03 | 7.52E-03 | 1.47E-02 | 5.49E-03 | 4.9562E+00 | 6.1102E+02 |
| $\alpha_3$ | 1.43E-03 | 5.05E-03 | 4.53E-03 | 1.05E-02 | 3.98E-03 | 3.1118E+00 | 6.1286E+02 |
| $\alpha_4$ | 1.18E-04 | 1.80E-03 | 1.30E-03 | 5.19E-03 | 1.04E-03 | 1.1074E+00 | 6.1487E+02 |
| $\alpha_5$ | 2.24E-06 | 7.68E-04 | 3.33E-04 | 3.01E-03 | 5.08E-04 | 4.7330E-01 | 6.1550E+02 |
| $\alpha_6$ | 1.21E-12 | 2.37E-04 | 8.82E-06 | 1.31E-03 | 1.26E-04 | 1.4574E-01 | 6.1583E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9758200 | 0.9839290 | 0.9843450 | 0.9906090 | 0.9898010 | 7.5441E+02 | 1.2322E+01 |
| $\alpha_2$ | 3.08E-03 | 7.31E-03 | 6.89E-03 | 1.30E-02 | 4.37E-03 | 5.6080E+00 | 7.6112E+02 |
| $\alpha_3$ | 1.37E-03 | 4.49E-03 | 4.06E-03 | 9.04E-03 | 3.14E-03 | 3.4398E+00 | 7.6329E+02 |
| $\alpha_4$ | 4.61E-04 | 2.60E-03 | 2.18E-03 | 6.17E-03 | 1.74E-03 | 1.9939E+00 | 7.6474E+02 |
| $\alpha_5$ | 4.14E-05 | 1.14E-03 | 7.50E-04 | 3.59E-03 | 6.17E-04 | 8.7707E-01 | 7.6585E+02 |
| $\alpha_6$ | 1.50E-07 | 4.47E-04 | 1.33E-04 | 1.96E-03 | 2.72E-04 | 3.4278E-01 | 7.6639E+02 |
| $\alpha_7$ | 2.16E-25 | 7.87E-05 | 7.94E-09 | 4.42E-04 | 5.43E-05 | 6.0371E-02 | 7.6667E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9771010 | 0.9845000 | 0.9848610 | 0.9906520 | 0.9905140 | 8.7015E+02 | 1.3700E+01 |
| $\alpha_2$ | 2.78E-03 | 6.51E-03 | 6.14E-03 | 1.15E-02 | 3.66E-03 | 5.7527E+00 | 8.7810E+02 |
| $\alpha_3$ | 1.20E-03 | 3.90E-03 | 3.53E-03 | 7.86E-03 | 2.60E-03 | 3.4466E+00 | 8.8040E+02 |
| $\alpha_4$ | 5.58E-04 | 2.63E-03 | 2.26E-03 | 5.95E-03 | 1.79E-03 | 2.3238E+00 | 8.8153E+02 |
| $\alpha_5$ | 1.33E-04 | 1.47E-03 | 1.11E-03 | 4.01E-03 | 8.94E-04 | 1.2962E+00 | 8.8255E+02 |
| $\alpha_6$ | 7.27E-06 | 6.96E-04 | 3.73E-04 | 2.48E-03 | 3.77E-04 | 6.1486E-01 | 8.8323E+02 |
| $\alpha_7$ | 7.44E-10 | 2.45E-04 | 3.12E-05 | 1.24E-03 | 1.43E-04 | 2.1677E-01 | 8.8363E+02 |
| $\alpha_8$ | 1.31E-30 | 5.51E-05 | 4.38E-10 | 2.91E-04 | 2.37E-05 | 4.8724E-02 | 8.8380E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9905450 | 0.9894640 | 0.9878370 | 0.9883110 | 0.9888510 | 0.9898010 | 0.9905140 |
| $\alpha_2$ | 9.46E-03 | 8.30E-03 | 9.21E-03 | 7.18E-03 | 5.49E-03 | 4.37E-03 | 3.66E-03 |
| $\alpha_3$ | | 2.23E-03 | 2.19E-03 | 3.28E-03 | 3.98E-03 | 3.14E-03 | 2.60E-03 |
| $\alpha_4$ | | | 7.57E-04 | 9.21E-04 | 1.04E-03 | 1.74E-03 | 1.79E-03 |
| $\alpha_5$ | | | | 3.03E-04 | 5.08E-04 | 6.17E-04 | 8.94E-04 |
| $\alpha_6$ | | | | | 1.26E-04 | 2.72E-04 | 3.77E-04 |
| $\alpha_7$ | | | | | | 5.43E-05 | 1.43E-04 |
| $\alpha_8$ | | | | | | | 2.37E-05 |

Pooled Motor Operated Valve Distributions

MOV FAIL TO OPEN/CLOSE ALL SYSTEMS SPAR: MOV-FO

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.91E-01 | 9.89E-01 | 9.88E-01 | 9.88E-01 | 9.89E-01 | 9.90E-01 | 9.91E-01 |
| Beta | 9.46E-03 | 1.05E-02 | 1.22E-02 | 1.17E-02 | 1.11E-02 | 1.02E-02 | 9.49E-03 |
| Gamma | | 2.12E-01 | 2.43E-01 | 3.85E-01 | 5.07E-01 | 5.71E-01 | 6.14E-01 |
| Delta | | | 2.57E-01 | 2.72E-01 | 2.96E-01 | 4.61E-01 | 5.54E-01 |
| Epsilon | | | | 2.48E-01 | 3.78E-01 | 3.51E-01 | 4.45E-01 |
| Mu | | | | | 1.99E-01 | 3.46E-01 | 3.78E-01 |
| Upsilon | | | | | | 1.67E-01 | 3.06E-01 |
| Sigma | | | | | | | 1.43E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 162.23 | 243.35 | 324.47 | 405.58 | 486.70 | 567.82 | 648.93 |
| $N_1$ | 3.5027 | 3.6814 | 3.0389 | 2.8019 | 2.5394 | 2.5414 | 2.4909 |
| $N_2$ | 1.5820 | 2.0726 | 3.0544 | 2.9687 | 2.7170 | 2.5202 | 2.4080 |
| $N_3$ | | 0.5578 | 0.7272 | 1.3557 | 1.9700 | 1.8086 | 1.7082 |
| $N_4$ | | | 0.2510 | 0.3804 | 0.5152 | 1.0050 | 1.1773 |
| $N_5$ | | | | 0.1252 | 0.2511 | 0.3553 | 0.5879 |
| $N_6$ | | | | | 0.0625 | 0.1565 | 0.2479 |
| $N_7$ | | | | | | 0.0313 | 0.0938 |
| $N_8$ | | | | | | | 0.0156 |

## 1.3.1.2 MOV FAIL TO OPEN ALL SYSTEMS SPAR: MOV-CC

| | |
|---|---|
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 272.80
Total Number of Common-Cause Failure Events: 4

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9518680 | 0.9807780 | 0.9843850 | 0.9973570 | 0.9838390 | 8.3925E+01 | 1.6448E+00 |
| $\alpha_2$ | 2.65E-03 | 1.92E-02 | 1.56E-02 | 4.81E-02 | 1.62E-02 | 1.6448E+00 | 8.3925E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9599550 | 0.9814940 | 0.9837050 | 0.9954900 | 0.9862770 | 1.3959E+02 | 2.6319E+00 |
| $\alpha_2$ | 2.01E-03 | 1.28E-02 | 1.06E-02 | 3.10E-02 | 8.79E-03 | 1.8146E+00 | 1.4041E+02 |
| $\alpha_3$ | 1.69E-04 | 5.75E-03 | 3.66E-03 | 1.84E-02 | 4.93E-03 | 8.1732E-01 | 1.4140E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9627900 | 0.9810490 | 0.9826580 | 0.9938060 | 0.9874330 | 1.9240E+02 | 3.7167E+00 |
| $\alpha_2$ | 2.12E-03 | 1.09E-02 | 9.30E-03 | 2.52E-02 | 6.15E-03 | 2.1395E+00 | 1.9398E+02 |
| $\alpha_3$ | 3.67E-04 | 5.63E-03 | 4.07E-03 | 1.62E-02 | 4.73E-03 | 1.1045E+00 | 1.9501E+02 |
| $\alpha_4$ | 7.01E-06 | 2.41E-03 | 1.04E-03 | 9.44E-03 | 1.69E-03 | 4.7267E-01 | 1.9564E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9649400 | 0.9801630 | 0.9812760 | 0.9915710 | 0.9886140 | 2.7870E+02 | 5.6406E+00 |
| $\alpha_2$ | 2.61E-03 | 9.99E-03 | 8.87E-03 | 2.12E-02 | 3.94E-03 | 2.8410E+00 | 2.8150E+02 |
| $\alpha_3$ | 1.05E-03 | 6.52E-03 | 5.40E-03 | 1.58E-02 | 4.74E-03 | 1.8529E+00 | 2.8249E+02 |
| $\alpha_4$ | 5.84E-05 | 2.64E-03 | 1.60E-03 | 8.74E-03 | 2.03E-03 | 7.4939E-01 | 2.8359E+02 |
| $\alpha_5$ | 5.83E-10 | 6.94E-04 | 6.95E-05 | 3.59E-03 | 6.77E-04 | 1.9728E-01 | 2.8414E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9677770 | 0.9812130 | 0.9821410 | 0.9914700 | 0.9902640 | 3.3592E+02 | 6.4317E+00 |
| $\alpha_2$ | 1.62E-03 | 7.17E-03 | 6.23E-03 | 1.59E-02 | 9.70E-04 | 2.4537E+00 | 3.3990E+02 |
| $\alpha_3$ | 1.54E-03 | 6.99E-03 | 6.06E-03 | 1.56E-02 | 5.66E-03 | 2.3928E+00 | 3.3996E+02 |
| $\alpha_4$ | 1.34E-04 | 2.83E-03 | 1.94E-03 | 8.55E-03 | 1.70E-03 | 9.6722E-01 | 3.4138E+02 |
| $\alpha_5$ | 3.98E-06 | 1.38E-03 | 5.97E-04 | 5.40E-03 | 1.13E-03 | 4.7220E-01 | 3.4188E+02 |
| $\alpha_6$ | 2.17E-12 | 4.26E-04 | 1.59E-05 | 2.36E-03 | 2.83E-04 | 1.4574E-01 | 3.4221E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9689200 | 0.9806800 | 0.9813880 | 0.9900170 | 0.9914110 | 4.3946E+02 | 8.6578E+00 |
| $\alpha_2$ | 2.22E-03 | 7.43E-03 | 6.71E-03 | 1.51E-02 | 9.39E-04 | 3.3297E+00 | 4.4479E+02 |
| $\alpha_3$ | 1.17E-03 | 5.33E-03 | 4.62E-03 | 1.19E-02 | 2.94E-03 | 2.3895E+00 | 4.4573E+02 |
| $\alpha_4$ | 5.43E-04 | 3.80E-03 | 3.09E-03 | 9.47E-03 | 2.77E-03 | 1.7014E+00 | 4.4642E+02 |
| $\alpha_5$ | 5.81E-05 | 1.86E-03 | 1.19E-03 | 5.94E-03 | 1.21E-03 | 8.3427E-01 | 4.4728E+02 |
| $\alpha_6$ | 2.55E-07 | 7.64E-04 | 2.28E-04 | 3.35E-03 | 6.07E-04 | 3.4258E-01 | 4.4778E+02 |
| $\alpha_7$ | 3.71E-25 | 1.35E-04 | 1.36E-08 | 7.57E-04 | 1.21E-04 | 6.0371E-02 | 4.4806E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9705700 | 0.9812740 | 0.9818850 | 0.9898850 | 0.9922410 | 5.1055E+02 | 9.7430E+00 |
| $\alpha_2$ | 2.24E-03 | 6.99E-03 | 6.37E-03 | 1.39E-02 | 1.00E-03 | 3.6388E+00 | 5.1665E+02 |
| $\alpha_3$ | 8.41E-04 | 4.22E-03 | 3.60E-03 | 9.70E-03 | 1.55E-03 | 2.1955E+00 | 5.1810E+02 |
| $\alpha_4$ | 5.80E-04 | 3.58E-03 | 2.96E-03 | 8.67E-03 | 2.43E-03 | 1.8610E+00 | 5.1843E+02 |
| $\alpha_5$ | 1.71E-04 | 2.27E-03 | 1.67E-03 | 6.41E-03 | 1.61E-03 | 1.1808E+00 | 5.1911E+02 |
| $\alpha_6$ | 1.10E-05 | 1.16E-03 | 6.10E-04 | 4.15E-03 | 7.97E-04 | 6.0136E-01 | 5.1969E+02 |
| $\alpha_7$ | 1.26E-09 | 4.17E-04 | 5.31E-05 | 2.10E-03 | 3.19E-04 | 2.1677E-01 | 5.2008E+02 |
| $\alpha_8$ | 2.23E-30 | 9.36E-05 | 7.45E-10 | 4.94E-04 | 5.30E-05 | 4.8724E-02 | 5.2024E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9838390 | 0.9862770 | 0.9874330 | 0.9886140 | 0.9902640 | 0.9914110 | 0.9922410 |
| $\alpha_2$ | 1.62E-02 | 8.79E-03 | 6.15E-03 | 3.94E-03 | 9.70E-04 | 9.39E-04 | 1.00E-03 |
| $\alpha_3$ | | 4.93E-03 | 4.73E-03 | 4.74E-03 | 5.66E-03 | 2.94E-03 | 1.55E-03 |
| $\alpha_4$ | | | 1.69E-03 | 2.03E-03 | 1.70E-03 | 2.77E-03 | 2.43E-03 |
| $\alpha_5$ | | | | 6.77E-04 | 1.13E-03 | 1.21E-03 | 1.61E-03 |
| $\alpha_6$ | | | | | 2.83E-04 | 6.07E-04 | 7.97E-04 |
| $\alpha_7$ | | | | | | 1.21E-04 | 3.19E-04 |
| $\alpha_8$ | | | | | | | 5.30E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.84E-01 | 9.86E-01 | 9.87E-01 | 9.89E-01 | 9.90E-01 | 9.91E-01 | 9.92E-01 |
| Beta | 1.62E-02 | 1.37E-02 | 1.26E-02 | 1.14E-02 | 9.74E-03 | 8.59E-03 | 7.76E-03 |
| Gamma | | 3.59E-01 | 5.10E-01 | 6.54E-01 | 9.00E-01 | 8.91E-01 | 8.71E-01 |
| Delta | | | 2.63E-01 | 3.64E-01 | 3.55E-01 | 6.15E-01 | 7.70E-01 |
| Epsilon | | | | 2.50E-01 | 4.55E-01 | 4.12E-01 | 5.33E-01 |
| Mu | | | | | 2.00E-01 | 3.75E-01 | 4.21E-01 |
| Upsilon | | | | | | 1.67E-01 | 3.18E-01 |
| Sigma | | | | | | | 1.43E-01 |

Pooled Motor Operated Valve Distributions

MOV FAIL TO OPEN ALL SYSTEMS SPAR: MOV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 72.75 | 109.12 | 145.49 | 181.87 | 218.24 | 254.61 | 290.99 |
| $N_1$ | 0.9293 | 0.9132 | 0.7766 | 0.6698 | 0.7430 | 0.7972 | 0.8319 |
| $N_2$ | 1.2103 | 0.9809 | 0.9114 | 0.7268 | 0.2145 | 0.2419 | 0.2941 |
| $N_3$ | | 0.5501 | 0.7002 | 0.8755 | 1.2510 | 0.7583 | 0.4571 |
| $N_4$ | | | 0.2500 | 0.3750 | 0.3750 | 0.7125 | 0.7145 |
| $N_5$ | | | | 0.1250 | 0.2500 | 0.3125 | 0.4725 |
| $N_6$ | | | | | 0.0625 | 0.1563 | 0.2344 |
| $N_7$ | | | | | | 0.0313 | 0.0938 |
| $N_8$ | | | | | | | 0.0156 |

### 1.3.1.3 MOV FAIL TO CLOSE ALL SYSTEMS SPAR: MOV-OO

| | |
|---|---|
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 195.90
Total Number of Common-Cause Failure Events: 4

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9742010 | 0.9919930 | 0.9949270 | 0.9997760 | 0.9958710 | 9.9889E+01 | 8.0622E-01 |
| $\alpha_2$ | 2.27E-04 | 8.01E-03 | 5.07E-03 | 2.58E-02 | 4.13E-03 | 8.0622E-01 | 9.9889E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9694990 | 0.9866730 | 0.9885800 | 0.9973230 | 0.9918230 | 1.6292E+02 | 2.2005E+00 |
| $\alpha_2$ | 1.99E-03 | 1.17E-02 | 9.76E-03 | 2.79E-02 | 8.12E-03 | 1.9255E+00 | 1.6320E+02 |
| $\alpha_3$ | 7.76E-08 | 1.67E-03 | 3.51E-04 | 7.83E-03 | 5.80E-05 | 2.7502E-01 | 1.6485E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9658200 | 0.9822290 | 0.9836270 | 0.9938550 | 0.9878420 | 2.2253E+02 | 4.0261E+00 |
| $\alpha_2$ | 4.51E-03 | 1.49E-02 | 1.35E-02 | 3.00E-02 | 1.20E-02 | 3.3711E+00 | 2.2318E+02 |
| $\alpha_3$ | 3.22E-06 | 1.90E-03 | 7.53E-04 | 7.70E-03 | 1.51E-04 | 4.3131E-01 | 2.2612E+02 |
| $\alpha_4$ | 4.48E-09 | 9.87E-04 | 1.36E-04 | 4.94E-03 | 5.60E-06 | 2.2367E-01 | 2.2633E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9664550 | 0.9805540 | 0.9815380 | 0.9912860 | 0.9877420 | 3.1596E+02 | 6.2660E+00 |
| $\alpha_2$ | 4.92E-03 | 1.35E-02 | 1.25E-02 | 2.55E-02 | 1.01E-02 | 4.3561E+00 | 3.1787E+02 |
| $\alpha_3$ | 5.07E-04 | 4.52E-03 | 3.55E-03 | 1.19E-02 | 2.16E-03 | 1.4576E+00 | 3.2077E+02 |
| $\alpha_4$ | 8.55E-07 | 1.18E-03 | 4.03E-04 | 4.98E-03 | 2.43E-05 | 3.7979E-01 | 3.2185E+02 |
| $\alpha_5$ | 2.07E-21 | 2.25E-04 | 1.30E-07 | 1.30E-03 | 8.99E-07 | 7.2477E-02 | 3.2215E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9674510 | 0.9802840 | 0.9811030 | 0.9903190 | 0.9873750 | 3.7994E+02 | 7.6415E+00 |
| $\alpha_2$ | 4.69E-03 | 1.22E-02 | 1.14E-02 | 2.26E-02 | 9.40E-03 | 4.7417E+00 | 3.8284E+02 |
| $\alpha_3$ | 7.79E-04 | 4.80E-03 | 3.98E-03 | 1.16E-02 | 2.70E-03 | 1.8608E+00 | 3.8572E+02 |
| $\alpha_4$ | 3.87E-05 | 1.89E-03 | 1.13E-03 | 6.32E-03 | 5.26E-04 | 7.3242E-01 | 3.8685E+02 |
| $\alpha_5$ | 2.56E-09 | 5.76E-04 | 7.88E-05 | 2.88E-03 | 4.13E-06 | 2.2330E-01 | 3.8736E+02 |
| $\alpha_6$ | 3.63E-19 | 2.15E-04 | 3.75E-07 | 1.25E-03 | 0.00E+00 | 8.3237E-02 | 3.8750E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9685020 | 0.9798070 | 0.9804410 | 0.9889430 | 0.9881860 | 4.9052E+02 | 1.0109E+01 |
| $\alpha_2$ | 4.42E-03 | 1.07E-02 | 1.01E-02 | 1.92E-02 | 7.35E-03 | 5.3661E+00 | 4.9526E+02 |
| $\alpha_3$ | 1.32E-03 | 5.36E-03 | 4.71E-03 | 1.16E-02 | 3.39E-03 | 2.6815E+00 | 4.9795E+02 |
| $\alpha_4$ | 2.27E-04 | 2.56E-03 | 1.94E-03 | 7.02E-03 | 9.43E-04 | 1.2814E+00 | 4.9935E+02 |
| $\alpha_5$ | 8.09E-06 | 1.13E-03 | 5.68E-04 | 4.15E-03 | 1.38E-04 | 5.6457E-01 | 5.0006E+02 |
| $\alpha_6$ | 1.36E-10 | 3.72E-04 | 3.18E-05 | 1.95E-03 | 6.45E-07 | 1.8648E-01 | 5.0044E+02 |
| $\alpha_7$ | 0.00E+00 | 5.81E-05 | 5.08E-14 | 2.18E-04 | 0.00E+00 | 2.9071E-02 | 5.0060E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9699900 | 0.9803170 | 0.9808650 | 0.9887690 | 0.9888200 | 5.6866E+02 | 1.1418E+01 |
| $\alpha_2$ | 3.91E-03 | 9.41E-03 | 8.85E-03 | 1.68E-02 | 5.97E-03 | 5.4586E+00 | 5.7462E+02 |
| $\alpha_3$ | 1.40E-03 | 5.15E-03 | 4.60E-03 | 1.08E-02 | 3.54E-03 | 2.9894E+00 | 5.7709E+02 |
| $\alpha_4$ | 3.65E-04 | 2.77E-03 | 2.23E-03 | 7.05E-03 | 1.31E-03 | 1.6093E+00 | 5.7847E+02 |
| $\alpha_5$ | 4.26E-05 | 1.42E-03 | 9.04E-04 | 4.56E-03 | 3.26E-04 | 8.2373E-01 | 5.7925E+02 |
| $\alpha_6$ | 4.81E-07 | 6.56E-04 | 2.24E-04 | 2.77E-03 | 3.81E-05 | 3.8046E-01 | 5.7970E+02 |
| $\alpha_7$ | 2.80E-14 | 2.12E-04 | 3.81E-06 | 1.21E-03 | 0.00E+00 | 1.2297E-01 | 5.7995E+02 |
| $\alpha_8$ | 5.25E-43 | 5.71E-05 | 8.13E-13 | 2.41E-04 | 0.00E+00 | 3.3124E-02 | 5.8004E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9958710 | 0.9918230 | 0.9878420 | 0.9877420 | 0.9873750 | 0.9881860 | 0.9888200 |
| $\alpha_2$ | 4.13E-03 | 8.12E-03 | 1.20E-02 | 1.01E-02 | 9.40E-03 | 7.35E-03 | 5.97E-03 |
| $\alpha_3$ | | 5.80E-05 | 1.51E-04 | 2.16E-03 | 2.70E-03 | 3.39E-03 | 3.54E-03 |
| $\alpha_4$ | | | 5.60E-06 | 2.43E-05 | 5.26E-04 | 9.43E-04 | 1.31E-03 |
| $\alpha_5$ | | | | 8.99E-07 | 4.13E-06 | 1.38E-04 | 3.26E-04 |
| $\alpha_6$ | | | | | 0.00E+00 | 6.45E-07 | 3.81E-05 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.96E-01 | 9.92E-01 | 9.88E-01 | 9.88E-01 | 9.87E-01 | 9.88E-01 | 9.89E-01 |
| Beta | 4.13E-03 | 8.18E-03 | 1.22E-02 | 1.23E-02 | 1.26E-02 | 1.18E-02 | 1.12E-02 |
| Gamma | | 7.09E-03 | 1.29E-02 | 1.78E-01 | 2.56E-01 | 3.78E-01 | 4.66E-01 |
| Delta | | | 3.57E-02 | 1.15E-02 | 1.64E-01 | 2.42E-01 | 3.21E-01 |
| Epsilon | | | | 3.57E-02 | 7.78E-03 | 1.28E-01 | 2.18E-01 |
| Mu | | | | | 0.00E+00 | 4.65E-03 | 1.05E-01 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

Pooled Motor Operated Valve Distributions

MOV FAIL TO CLOSE ALL SYSTEMS SPAR: MOV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 87.07 | 130.60 | 174.13 | 217.67 | 261.20 | 304.73 | 348.27 |
| $N_1$ | 2.5733 | 2.7683 | 2.2623 | 2.1320 | 1.7964 | 1.7442 | 1.6590 |
| $N_2$ | 0.3717 | 1.0918 | 2.1430 | 2.2419 | 2.5025 | 2.2783 | 2.1139 |
| $N_3$ | | 0.0078 | 0.0270 | 0.4802 | 0.7190 | 1.0503 | 1.2510 |
| $N_4$ | | | 0.0010 | 0.0054 | 0.1402 | 0.2925 | 0.4628 |
| $N_5$ | | | | 0.0002 | 0.0011 | 0.0428 | 0.1154 |
| $N_6$ | | | | | 0.0000 | 0.0002 | 0.0135 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.1.4 MOV SPURIOUS OPERATION ALL SYSTEMS SPAR: MOV-CO

| | |
|---|---|
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Spurious operation open or close |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 24.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8725230 | 0.9628520 | 0.9785950 | 0.9994900 | 0.9684190 | 1.6817E+01 | 6.4882E-01 |
| $\alpha_2$ | 5.07E-04 | 3.71E-02 | 2.14E-02 | 1.27E-01 | 3.16E-02 | 6.4882E-01 | 1.6817E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9013250 | 0.9605540 | 0.9678750 | 0.9947070 | 0.9496400 | 3.8984E+01 | 1.6009E+00 |
| $\alpha_2$ | 2.75E-03 | 3.11E-02 | 2.38E-02 | 8.46E-02 | 4.32E-02 | 1.2623E+00 | 3.9323E+01 |
| $\alpha_3$ | 2.57E-06 | 8.34E-03 | 2.48E-03 | 3.66E-02 | 7.19E-03 | 3.3862E-01 | 4.0246E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9080180 | 0.9571600 | 0.9620750 | 0.9894800 | 0.9416900 | 5.8365E+01 | 2.6123E+00 |
| $\alpha_2$ | 4.31E-03 | 2.86E-02 | 2.36E-02 | 6.99E-02 | 3.96E-02 | 1.7424E+00 | 5.9235E+01 |
| $\alpha_3$ | 1.24E-04 | 1.04E-02 | 5.73E-03 | 3.65E-02 | 1.76E-02 | 6.3291E-01 | 6.0344E+01 |
| $\alpha_4$ | 3.59E-08 | 3.89E-03 | 6.13E-04 | 1.91E-02 | 1.10E-03 | 2.3697E-01 | 6.0740E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9282170 | 0.9613920 | 0.9640230 | 0.9855610 | 0.9419630 | 1.1123E+02 | 4.4669E+00 |
| $\alpha_2$ | 5.19E-03 | 2.20E-02 | 1.93E-02 | 4.80E-02 | 2.68E-02 | 2.5428E+00 | 1.1315E+02 |
| $\alpha_3$ | 1.29E-03 | 1.22E-02 | 9.48E-03 | 3.22E-02 | 2.68E-02 | 1.4060E+00 | 1.1429E+02 |
| $\alpha_4$ | 8.00E-06 | 3.85E-03 | 1.58E-03 | 1.54E-02 | 4.46E-03 | 4.4579E-01 | 1.1525E+02 |
| $\alpha_5$ | 5.16E-21 | 6.25E-04 | 3.53E-07 | 3.62E-03 | 0.00E+00 | 7.2277E-02 | 1.1562E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9327880 | 0.9623540 | 0.9645330 | 0.9844680 | 0.9473680 | 1.3494E+02 | 5.2787E+00 |
| $\alpha_2$ | 3.97E-03 | 1.75E-02 | 1.53E-02 | 3.87E-02 | 1.13E-02 | 2.4535E+00 | 1.3777E+02 |
| $\alpha_3$ | 1.78E-03 | 1.22E-02 | 9.99E-03 | 3.03E-02 | 3.01E-02 | 1.7132E+00 | 1.3851E+02 |
| $\alpha_4$ | 1.63E-04 | 5.75E-03 | 3.64E-03 | 1.86E-02 | 1.13E-02 | 8.0652E-01 | 1.3941E+02 |
| $\alpha_5$ | 6.62E-09 | 1.58E-03 | 2.15E-04 | 7.94E-03 | 0.00E+00 | 2.2220E-01 | 1.4000E+02 |
| $\alpha_6$ | 1.01E-18 | 5.94E-04 | 1.04E-06 | 3.46E-03 | 0.00E+00 | 8.3237E-02 | 1.4014E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9684190 | 0.9496400 | 0.9416900 | 0.9419630 | 0.9473680 |
| $\alpha_2$ | 3.16E-02 | 4.32E-02 | 3.96E-02 | 2.68E-02 | 1.13E-02 |
| $\alpha_3$ | | 7.19E-03 | 1.76E-02 | 2.68E-02 | 3.01E-02 |
| $\alpha_4$ | | | 1.10E-03 | 4.46E-03 | 1.13E-02 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.68E-01 | 9.50E-01 | 9.42E-01 | 9.42E-01 | 9.47E-01 |
| Beta | 3.16E-02 | 5.04E-02 | 5.83E-02 | 5.80E-02 | 5.26E-02 |
| Gamma | | 1.43E-01 | 3.21E-01 | 5.38E-01 | 7.86E-01 |
| Delta | | | 5.89E-02 | 1.43E-01 | 2.73E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 6.00 | 9.00 | 12.00 | 15.00 | 18.00 |
| $N_1$ | 0.5714 | 0.4286 | 0.2286 | 0.0714 | 0.0000 |
| $N_2$ | 0.2143 | 0.4286 | 0.5143 | 0.4286 | 0.2143 |
| $N_3$ | | 0.0714 | 0.2286 | 0.4286 | 0.5714 |
| $N_4$ | | | 0.0143 | 0.0714 | 0.2143 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.3.2 PWR Containment Spray Motor Operated Valves

## 1.3.2.1 CONTAINMENT SPRAY MOV FAIL TO OPEN/CLOSE

**System :** Containment spray recirculation
**Component :** Motor Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 23.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9489320 | 0.9872880 | 0.9948520 | 0.9999750 | 1.0000000 | 3.3746E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.29E-05 | 1.27E-02 | 5.15E-03 | 5.11E-02 | 0.00E+00 | 4.3452E-01 | 3.3746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9417320 | 0.9796720 | 0.9852150 | 0.9986630 | 1.0000000 | 5.3055E+01 | 1.1009E+00 |
| $\alpha_2$ | 4.87E-04 | 1.54E-02 | 9.97E-03 | 4.88E-02 | 0.00E+00 | 8.3366E-01 | 5.3322E+01 |
| $\alpha_3$ | 1.73E-07 | 4.93E-03 | 9.93E-04 | 2.34E-02 | 0.00E+00 | 2.6722E-01 | 5.3889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9376940 | 0.9740520 | 0.9783390 | 0.9957420 | 1.0000000 | 6.9636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.42E-03 | 1.72E-02 | 1.29E-02 | 4.75E-02 | 0.00E+00 | 1.2281E+00 | 7.0263E+01 |
| $\alpha_3$ | 6.36E-06 | 5.66E-03 | 2.09E-03 | 2.34E-02 | 0.00E+00 | 4.0431E-01 | 7.1087E+01 |
| $\alpha_4$ | 1.34E-08 | 3.11E-03 | 4.26E-04 | 1.56E-02 | 0.00E+00 | 2.2267E-01 | 7.1268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9430560 | 0.9712800 | 0.9737970 | 0.9909040 | 1.0000000 | 1.1966E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.30E-03 | 1.72E-02 | 1.46E-02 | 3.97E-02 | 0.00E+00 | 2.1142E+00 | 1.2108E+02 |
| $\alpha_3$ | 3.87E-04 | 7.93E-03 | 5.48E-03 | 2.39E-02 | 0.00E+00 | 9.7738E-01 | 1.2222E+02 |
| $\alpha_4$ | 2.00E-06 | 3.04E-03 | 1.02E-03 | 1.29E-02 | 0.00E+00 | 3.7439E-01 | 1.2282E+02 |
| $\alpha_5$ | 4.84E-21 | 5.87E-04 | 3.32E-07 | 3.40E-03 | 0.00E+00 | 7.2277E-02 | 1.2313E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9442590 | 0.9704350 | 0.9725790 | 0.9892870 | 1.0000000 | 1.4044E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.18E-03 | 1.55E-02 | 1.33E-02 | 3.52E-02 | 0.00E+00 | 2.2392E+00 | 1.4248E+02 |
| $\alpha_3$ | 5.55E-04 | 7.89E-03 | 5.77E-03 | 2.25E-02 | 0.00E+00 | 1.1418E+00 | 1.4358E+02 |
| $\alpha_4$ | 3.66E-05 | 4.09E-03 | 2.14E-03 | 1.48E-02 | 0.00E+00 | 5.9222E-01 | 1.4413E+02 |
| $\alpha_5$ | 6.42E-09 | 1.54E-03 | 2.08E-04 | 7.69E-03 | 0.00E+00 | 2.2220E-01 | 1.4450E+02 |
| $\alpha_6$ | 9.74E-19 | 5.75E-04 | 1.01E-06 | 3.36E-03 | 0.00E+00 | 8.3237E-02 | 1.4464E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 23.50 | 23.50 | 23.50 | 23.50 | 23.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.3.2.2 CONTAINMENT SPRAY MOV-CC

**System :** Containment spray recirculation
**Component :** Motor Operated Valve
**Failure Mode :** Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 16.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9358690 | 0.9840140 | 0.9935000 | 0.9999680 | 1.0000000 | 2.6746E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.90E-05 | 1.60E-02 | 6.50E-03 | 6.41E-02 | 0.00E+00 | 4.3452E-01 | 2.6746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9331860 | 0.9766540 | 0.9829890 | 0.9984660 | 1.0000000 | 4.6055E+01 | 1.1009E+00 |
| $\alpha_2$ | 5.60E-04 | 1.77E-02 | 1.15E-02 | 5.60E-02 | 0.00E+00 | 8.3366E-01 | 4.6322E+01 |
| $\alpha_3$ | 1.99E-07 | 5.67E-03 | 1.14E-03 | 2.69E-02 | 0.00E+00 | 2.6722E-01 | 4.6889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9310250 | 0.9712350 | 0.9759630 | 0.9952700 | 1.0000000 | 6.2636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.58E-03 | 1.90E-02 | 1.43E-02 | 5.26E-02 | 0.00E+00 | 1.2281E+00 | 6.3263E+01 |
| $\alpha_3$ | 7.06E-06 | 6.27E-03 | 2.32E-03 | 2.59E-02 | 0.00E+00 | 4.0431E-01 | 6.4087E+01 |
| $\alpha_4$ | 1.49E-08 | 3.45E-03 | 4.73E-04 | 1.73E-02 | 0.00E+00 | 2.2267E-01 | 6.4268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9396640 | 0.9695500 | 0.9722090 | 0.9903480 | 1.0000000 | 1.1266E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.50E-03 | 1.82E-02 | 1.55E-02 | 4.21E-02 | 0.00E+00 | 2.1142E+00 | 1.1408E+02 |
| $\alpha_3$ | 4.11E-04 | 8.41E-03 | 5.81E-03 | 2.53E-02 | 0.00E+00 | 9.7738E-01 | 1.1522E+02 |
| $\alpha_4$ | 2.12E-06 | 3.22E-03 | 1.08E-03 | 1.37E-02 | 0.00E+00 | 3.7439E-01 | 1.1582E+02 |
| $\alpha_5$ | 5.13E-21 | 6.22E-04 | 3.52E-07 | 3.60E-03 | 0.00E+00 | 7.2277E-02 | 1.1613E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9414510 | 0.9689320 | 0.9711740 | 0.9887350 | 1.0000000 | 1.3344E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.34E-03 | 1.63E-02 | 1.40E-02 | 3.70E-02 | 0.00E+00 | 2.2392E+00 | 1.3548E+02 |
| $\alpha_3$ | 5.84E-04 | 8.29E-03 | 6.06E-03 | 2.36E-02 | 0.00E+00 | 1.1418E+00 | 1.3658E+02 |
| $\alpha_4$ | 3.84E-05 | 4.30E-03 | 2.25E-03 | 1.55E-02 | 0.00E+00 | 5.9222E-01 | 1.3713E+02 |
| $\alpha_5$ | 6.74E-09 | 1.61E-03 | 2.19E-04 | 8.08E-03 | 0.00E+00 | 2.2220E-01 | 1.3750E+02 |
| $\alpha_6$ | 1.02E-18 | 6.04E-04 | 1.06E-06 | 3.53E-03 | 0.00E+00 | 8.3237E-02 | 1.3764E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 16.50 | 16.50 | 16.50 | 16.50 | 16.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.3.2.3 CONTAINMENT SPRAY MOV-OO

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9017830 | 0.9754240 | 0.9898730 | 0.9999510 | 1.0000000 | 1.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.52E-05 | 2.46E-02 | 1.01E-02 | 9.82E-02 | 0.00E+00 | 4.3452E-01 | 1.7246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9165860 | 0.9707650 | 0.9786210 | 0.9980670 | 1.0000000 | 3.6555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.05E-04 | 2.21E-02 | 1.44E-02 | 7.00E-02 | 0.00E+00 | 8.3366E-01 | 3.6822E+01 |
| $\alpha_3$ | 2.49E-07 | 7.10E-03 | 1.44E-03 | 3.37E-02 | 0.00E+00 | 2.6722E-01 | 3.7389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9192920 | 0.9662660 | 0.9717540 | 0.9944390 | 1.0000000 | 5.3136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.85E-03 | 2.23E-02 | 1.68E-02 | 6.16E-02 | 0.00E+00 | 1.2281E+00 | 5.3763E+01 |
| $\alpha_3$ | 8.29E-06 | 7.35E-03 | 2.73E-03 | 3.04E-02 | 0.00E+00 | 4.0431E-01 | 5.4587E+01 |
| $\alpha_4$ | 1.75E-08 | 4.05E-03 | 5.55E-04 | 2.03E-02 | 0.00E+00 | 2.2267E-01 | 5.4768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9343580 | 0.9668390 | 0.9697150 | 0.9894740 | 1.0000000 | 1.0316E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.82E-03 | 1.98E-02 | 1.69E-02 | 4.58E-02 | 0.00E+00 | 2.1142E+00 | 1.0458E+02 |
| $\alpha_3$ | 4.48E-04 | 9.16E-03 | 6.33E-03 | 2.75E-02 | 0.00E+00 | 9.7738E-01 | 1.0572E+02 |
| $\alpha_4$ | 2.31E-06 | 3.51E-03 | 1.18E-03 | 1.49E-02 | 0.00E+00 | 3.7439E-01 | 1.0632E+02 |
| $\alpha_5$ | 5.59E-21 | 6.77E-04 | 3.83E-07 | 3.92E-03 | 0.00E+00 | 7.2277E-02 | 1.0663E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9371630 | 0.9666300 | 0.9690330 | 0.9878880 | 1.0000000 | 1.2394E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.59E-03 | 1.75E-02 | 1.50E-02 | 3.97E-02 | 0.00E+00 | 2.2392E+00 | 1.2598E+02 |
| $\alpha_3$ | 6.27E-04 | 8.91E-03 | 6.51E-03 | 2.54E-02 | 0.00E+00 | 1.1418E+00 | 1.2708E+02 |
| $\alpha_4$ | 4.13E-05 | 4.62E-03 | 2.42E-03 | 1.67E-02 | 0.00E+00 | 5.9222E-01 | 1.2763E+02 |
| $\alpha_5$ | 7.25E-09 | 1.73E-03 | 2.35E-04 | 8.68E-03 | 0.00E+00 | 2.2220E-01 | 1.2800E+02 |
| $\alpha_6$ | 1.10E-18 | 6.49E-04 | 1.14E-06 | 3.79E-03 | 0.00E+00 | 8.3237E-02 | 1.2814E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 7.00 | 7.00 | 7.00 | 7.00 | 7.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.3.3 BWR Residual Heat Removal Motor-Operated Valves

## 1.3.3.1 BWR RHR MOV FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 123.50
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9588300 | 0.9840110 | 0.9872660 | 0.9980620 | 0.9871410 | 9.3409E+01 | 1.5178E+00 |
| $\alpha_2$ | 1.94E-03 | 1.60E-02 | 1.27E-02 | 4.12E-02 | 1.29E-02 | 1.5178E+00 | 9.3409E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9663090 | 0.9849690 | 0.9869850 | 0.9967460 | 0.9900600 | 1.5405E+02 | 2.3509E+00 |
| $\alpha_2$ | 1.31E-03 | 1.01E-02 | 8.13E-03 | 2.58E-02 | 5.96E-03 | 1.5837E+00 | 1.5482E+02 |
| $\alpha_3$ | 1.18E-04 | 4.91E-03 | 3.02E-03 | 1.61E-02 | 3.98E-03 | 7.6722E-01 | 1.5563E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9684800 | 0.9844070 | 0.9858850 | 0.9952960 | 0.9910270 | 2.1181E+02 | 3.3551E+00 |
| $\alpha_2$ | 1.62E-03 | 9.19E-03 | 7.72E-03 | 2.18E-02 | 4.49E-03 | 1.9781E+00 | 2.1319E+02 |
| $\alpha_3$ | 1.66E-04 | 4.20E-03 | 2.80E-03 | 1.30E-02 | 2.99E-03 | 9.0431E-01 | 2.1426E+02 |
| $\alpha_4$ | 6.38E-06 | 2.20E-03 | 9.52E-04 | 8.60E-03 | 1.50E-03 | 4.7267E-01 | 2.1469E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9695490 | 0.9831140 | 0.9841460 | 0.9931420 | 0.9920080 | 3.0303E+02 | 5.2049E+00 |
| $\alpha_2$ | 2.37E-03 | 9.16E-03 | 8.12E-03 | 1.95E-02 | 3.40E-03 | 2.8225E+00 | 3.0541E+02 |
| $\alpha_3$ | 5.09E-04 | 4.66E-03 | 3.64E-03 | 1.23E-02 | 2.20E-03 | 1.4357E+00 | 3.0680E+02 |
| $\alpha_4$ | 5.39E-05 | 2.43E-03 | 1.47E-03 | 8.06E-03 | 1.80E-03 | 7.4939E-01 | 3.0749E+02 |
| $\alpha_5$ | 5.38E-10 | 6.40E-04 | 6.41E-05 | 3.31E-03 | 5.99E-04 | 1.9728E-01 | 3.0804E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9713760 | 0.9835110 | 0.9843700 | 0.9927070 | 0.9926350 | 3.6498E+02 | 6.1190E+00 |
| $\alpha_2$ | 2.16E-03 | 7.98E-03 | 7.11E-03 | 1.68E-02 | 2.89E-03 | 2.9614E+00 | 3.6814E+02 |
| $\alpha_3$ | 5.26E-04 | 4.20E-03 | 3.35E-03 | 1.08E-02 | 1.67E-03 | 1.5585E+00 | 3.6954E+02 |
| $\alpha_4$ | 1.30E-04 | 2.64E-03 | 1.82E-03 | 7.96E-03 | 1.56E-03 | 9.8112E-01 | 3.7012E+02 |
| $\alpha_5$ | 3.67E-06 | 1.27E-03 | 5.50E-04 | 4.99E-03 | 1.00E-03 | 4.7220E-01 | 3.7063E+02 |
| $\alpha_6$ | 2.01E-12 | 3.93E-04 | 1.46E-05 | 2.17E-03 | 2.50E-04 | 1.4574E-01 | 3.7095E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9716030 | 0.9824390 | 0.9831000 | 0.9910140 | 0.9930840 | 4.7323E+02 | 8.4590E+00 |
| $\alpha_2$ | 2.66E-03 | 7.98E-03 | 7.31E-03 | 1.56E-02 | 2.59E-03 | 3.8424E+00 | 4.7785E+02 |
| $\alpha_3$ | 7.70E-04 | 4.23E-03 | 3.56E-03 | 9.95E-03 | 1.39E-03 | 2.0363E+00 | 4.7965E+02 |
| $\alpha_4$ | 2.69E-04 | 2.78E-03 | 2.13E-03 | 7.52E-03 | 1.21E-03 | 1.3408E+00 | 4.8035E+02 |
| $\alpha_5$ | 5.47E-05 | 1.74E-03 | 1.11E-03 | 5.54E-03 | 1.08E-03 | 8.3657E-01 | 4.8085E+02 |
| $\alpha_6$ | 2.37E-07 | 7.11E-04 | 2.12E-04 | 3.11E-03 | 5.37E-04 | 3.4258E-01 | 4.8135E+02 |
| $\alpha_7$ | 3.45E-25 | 1.25E-04 | 1.26E-08 | 7.04E-04 | 1.07E-04 | 6.0371E-02 | 4.8163E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9728060 | 0.9827380 | 0.9833080 | 0.9907150 | 0.9934350 | 5.4902E+02 | 9.6437E+00 |
| $\alpha_2$ | 2.59E-03 | 7.40E-03 | 6.82E-03 | 1.42E-02 | 2.37E-03 | 4.1319E+00 | 5.5453E+02 |
| $\alpha_3$ | 7.56E-04 | 3.87E-03 | 3.29E-03 | 8.94E-03 | 1.27E-03 | 2.1601E+00 | 5.5650E+02 |
| $\alpha_4$ | 2.91E-04 | 2.60E-03 | 2.04E-03 | 6.85E-03 | 9.28E-04 | 1.4551E+00 | 5.5721E+02 |
| $\alpha_5$ | 1.02E-04 | 1.84E-03 | 1.29E-03 | 5.46E-03 | 9.65E-04 | 1.0293E+00 | 5.5763E+02 |
| $\alpha_6$ | 1.03E-05 | 1.08E-03 | 5.69E-04 | 3.87E-03 | 7.06E-04 | 6.0176E-01 | 5.5806E+02 |
| $\alpha_7$ | 1.18E-09 | 3.88E-04 | 4.94E-05 | 1.96E-03 | 2.82E-04 | 2.1677E-01 | 5.5845E+02 |
| $\alpha_8$ | 2.08E-30 | 8.72E-05 | 6.94E-10 | 4.60E-04 | 4.69E-05 | 4.8724E-02 | 5.5861E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9871410 | 0.9900600 | 0.9910270 | 0.9920080 | 0.9926350 | 0.9930840 | 0.9934350 |
| $\alpha_2$ | 1.29E-02 | 5.96E-03 | 4.49E-03 | 3.40E-03 | 2.89E-03 | 2.59E-03 | 2.37E-03 |
| $\alpha_3$ | | 3.98E-03 | 2.99E-03 | 2.20E-03 | 1.67E-03 | 1.39E-03 | 1.27E-03 |
| $\alpha_4$ | | | 1.50E-03 | 1.80E-03 | 1.56E-03 | 1.21E-03 | 9.28E-04 |
| $\alpha_5$ | | | | 5.99E-04 | 1.00E-03 | 1.08E-03 | 9.65E-04 |
| $\alpha_6$ | | | | | 2.50E-04 | 5.37E-04 | 7.06E-04 |
| $\alpha_7$ | | | | | | 1.07E-04 | 2.82E-04 |
| $\alpha_8$ | | | | | | | 4.69E-05 |

BWR RHR MOV FAIL TO OPEN/CLOSE

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.87E-01 | 9.90E-01 | 9.91E-01 | 9.92E-01 | 9.93E-01 | 9.93E-01 | 9.93E-01 |
| Beta | 1.29E-02 | 9.94E-03 | 8.97E-03 | 7.99E-03 | 7.36E-03 | 6.92E-03 | 6.56E-03 |
| Gamma | | 4.00E-01 | 5.00E-01 | 5.75E-01 | 6.08E-01 | 6.25E-01 | 6.39E-01 |
| Delta | | | 3.33E-01 | 5.22E-01 | 6.27E-01 | 6.78E-01 | 6.98E-01 |
| Epsilon | | | | 2.50E-01 | 4.46E-01 | 5.88E-01 | 6.83E-01 |
| Mu | | | | | 2.00E-01 | 3.73E-01 | 5.17E-01 |
| Upsilon | | | | | | 1.67E-01 | 3.18E-01 |
| Sigma | | | | | | | 1.43E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 82.33 | 123.50 | 164.67 | 205.83 | 247.00 | 288.17 | 329.33 |
| $N_1$ | 0.8333 | 1.0000 | 1.0000 | 1.0417 | 1.0417 | 1.0127 | 0.9645 |
| $N_2$ | 1.0833 | 0.7500 | 0.7500 | 0.7083 | 0.7222 | 0.7546 | 0.7872 |
| $N_3$ | | 0.5000 | 0.5000 | 0.4583 | 0.4167 | 0.4051 | 0.4217 |
| $N_4$ | | | 0.2500 | 0.3750 | 0.3889 | 0.3519 | 0.3086 |
| $N_5$ | | | | 0.1250 | 0.2500 | 0.3148 | 0.3210 |
| $N_6$ | | | | | 0.0625 | 0.1563 | 0.2348 |
| $N_7$ | | | | | | 0.0313 | 0.0938 |
| $N_8$ | | | | | | | 0.0156 |

## 1.3.3.2 BWR RHR MOV FAIL TO OPEN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 74.20
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9561880 | 0.9832970 | 0.9868790 | 0.9981570 | 0.9867020 | 8.4446E+01 | 1.4345E+00 |
| $\alpha_2$ | 1.84E-03 | 1.67E-02 | 1.31E-02 | 4.38E-02 | 1.33E-02 | 1.4345E+00 | 8.4446E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9658970 | 0.9853030 | 0.9875020 | 0.9972020 | 0.9910950 | 1.4085E+02 | 2.1009E+00 |
| $\alpha_2$ | 8.98E-04 | 9.33E-03 | 7.16E-03 | 2.52E-02 | 4.45E-03 | 1.3337E+00 | 1.4162E+02 |
| $\alpha_3$ | 1.29E-04 | 5.37E-03 | 3.31E-03 | 1.76E-02 | 4.45E-03 | 7.6722E-01 | 1.4218E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9693850 | 0.9855360 | 0.9871450 | 0.9962020 | 0.9933070 | 1.9454E+02 | 2.8551E+00 |
| $\alpha_2$ | 8.62E-04 | 7.49E-03 | 5.90E-03 | 1.95E-02 | 1.67E-03 | 1.4781E+00 | 1.9592E+02 |
| $\alpha_3$ | 1.81E-04 | 4.58E-03 | 3.05E-03 | 1.42E-02 | 3.35E-03 | 9.0431E-01 | 1.9649E+02 |
| $\alpha_4$ | 6.96E-06 | 2.39E-03 | 1.04E-03 | 9.37E-03 | 1.67E-03 | 4.7267E-01 | 1.9692E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9704120 | 0.9841430 | 0.9852550 | 0.9940720 | 0.9946380 | 2.8166E+02 | 4.5383E+00 |
| $\alpha_2$ | 1.60E-03 | 7.82E-03 | 6.71E-03 | 1.79E-02 | 6.70E-04 | 2.2392E+00 | 2.8396E+02 |
| $\alpha_3$ | 4.65E-04 | 4.73E-03 | 3.63E-03 | 1.27E-02 | 2.01E-03 | 1.3524E+00 | 2.8485E+02 |
| $\alpha_4$ | 5.80E-05 | 2.62E-03 | 1.59E-03 | 8.68E-03 | 2.01E-03 | 7.4939E-01 | 2.8545E+02 |
| $\alpha_5$ | 5.80E-10 | 6.89E-04 | 6.91E-05 | 3.57E-03 | 6.70E-04 | 1.9728E-01 | 2.8600E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9724730 | 0.9846920 | 0.9856170 | 0.9937420 | 0.9955280 | 3.3954E+02 | 5.2787E+00 |
| $\alpha_2$ | 1.41E-03 | 6.68E-03 | 5.75E-03 | 1.51E-02 | 2.80E-04 | 2.3017E+00 | 3.4252E+02 |
| $\alpha_3$ | 4.18E-04 | 4.04E-03 | 3.13E-03 | 1.08E-02 | 1.12E-03 | 1.3918E+00 | 3.4343E+02 |
| $\alpha_4$ | 1.33E-04 | 2.81E-03 | 1.92E-03 | 8.49E-03 | 1.68E-03 | 9.6722E-01 | 3.4385E+02 |
| $\alpha_5$ | 3.95E-06 | 1.37E-03 | 5.92E-04 | 5.37E-03 | 1.12E-03 | 4.7220E-01 | 3.4435E+02 |
| $\alpha_6$ | 2.16E-12 | 4.23E-04 | 1.58E-05 | 2.34E-03 | 2.80E-04 | 1.4574E-01 | 3.4467E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9725780 | 0.9834990 | 0.9842060 | 0.9919930 | 0.9961630 | 4.4375E+02 | 7.4452E+00 |
| $\alpha_2$ | 1.96E-03 | 6.91E-03 | 6.20E-03 | 1.43E-02 | 1.20E-04 | 3.1191E+00 | 4.4808E+02 |
| $\alpha_3$ | 6.08E-04 | 3.96E-03 | 3.26E-03 | 9.72E-03 | 6.00E-04 | 1.7875E+00 | 4.4941E+02 |
| $\alpha_4$ | 2.64E-04 | 2.88E-03 | 2.19E-03 | 7.87E-03 | 1.20E-03 | 1.3014E+00 | 4.4989E+02 |
| $\alpha_5$ | 5.77E-05 | 1.85E-03 | 1.19E-03 | 5.90E-03 | 1.20E-03 | 8.3427E-01 | 4.5036E+02 |
| $\alpha_6$ | 2.53E-07 | 7.59E-04 | 2.26E-04 | 3.32E-03 | 6.00E-04 | 3.4258E-01 | 4.5085E+02 |
| $\alpha_7$ | 3.68E-25 | 1.34E-04 | 1.35E-08 | 7.52E-04 | 1.20E-04 | 6.0371E-02 | 4.5113E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9738770 | 0.9838530 | 0.9844620 | 0.9917400 | 0.9966420 | 5.1553E+02 | 8.4611E+00 |
| $\alpha_2$ | 1.93E-03 | 6.41E-03 | 5.80E-03 | 1.30E-02 | 5.24E-05 | 3.3603E+00 | 5.2063E+02 |
| $\alpha_3$ | 5.55E-04 | 3.50E-03 | 2.89E-03 | 8.52E-03 | 3.15E-04 | 1.8322E+00 | 5.2216E+02 |
| $\alpha_4$ | 2.69E-04 | 2.64E-03 | 2.04E-03 | 7.05E-03 | 7.87E-04 | 1.3809E+00 | 5.2261E+02 |
| $\alpha_5$ | 1.05E-04 | 1.95E-03 | 1.36E-03 | 5.79E-03 | 1.05E-03 | 1.0208E+00 | 5.2297E+02 |
| $\alpha_6$ | 1.09E-05 | 1.15E-03 | 6.06E-04 | 4.12E-03 | 7.87E-04 | 6.0136E-01 | 5.2339E+02 |
| $\alpha_7$ | 1.26E-09 | 4.14E-04 | 5.27E-05 | 2.09E-03 | 3.15E-04 | 2.1677E-01 | 5.2377E+02 |
| $\alpha_8$ | 2.22E-30 | 9.30E-05 | 7.40E-10 | 4.90E-04 | 5.24E-05 | 4.8724E-02 | 5.2394E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9867020 | 0.9910950 | 0.9933070 | 0.9946380 | 0.9955280 | 0.9961630 | 0.9966420 |
| $\alpha_2$ | 1.33E-02 | 4.45E-03 | 1.67E-03 | 6.70E-04 | 2.80E-04 | 1.20E-04 | 5.24E-05 |
| $\alpha_3$ | | 4.45E-03 | 3.35E-03 | 2.01E-03 | 1.12E-03 | 6.00E-04 | 3.15E-04 |
| $\alpha_4$ | | | 1.67E-03 | 2.01E-03 | 1.68E-03 | 1.20E-03 | 7.87E-04 |
| $\alpha_5$ | | | | 6.70E-04 | 1.12E-03 | 1.20E-03 | 1.05E-03 |
| $\alpha_6$ | | | | | 2.80E-04 | 6.00E-04 | 7.87E-04 |
| $\alpha_7$ | | | | | | 1.20E-04 | 3.15E-04 |
| $\alpha_8$ | | | | | | | 5.24E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.87E-01 | 9.91E-01 | 9.93E-01 | 9.95E-01 | 9.96E-01 | 9.96E-01 | 9.97E-01 |
| Beta | 1.33E-02 | 8.90E-03 | 6.69E-03 | 5.36E-03 | 4.47E-03 | 3.84E-03 | 3.36E-03 |
| Gamma | | 5.00E-01 | 7.50E-01 | 8.75E-01 | 9.38E-01 | 9.69E-01 | 9.84E-01 |
| Delta | | | 3.33E-01 | 5.71E-01 | 7.33E-01 | 8.39E-01 | 9.05E-01 |
| Epsilon | | | | 2.50E-01 | 4.55E-01 | 6.15E-01 | 7.37E-01 |
| Mu | | | | | 2.00E-01 | 3.75E-01 | 5.24E-01 |
| Upsilon | | | | | | 1.67E-01 | 3.18E-01 |
| Sigma | | | | | | | 1.43E-01 |

BWR Residual Heat Removal Motor-Operated Valves

BWR RHR MOV FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 74.20 | 111.30 | 148.40 | 185.50 | 222.60 | 259.70 | 296.80 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.5000 | 0.2500 | 0.1250 | 0.0625 | 0.0313 | 0.0156 |
| $N_3$ | | 0.5000 | 0.5000 | 0.3750 | 0.2500 | 0.1563 | 0.0938 |
| $N_4$ | | | 0.2500 | 0.3750 | 0.3750 | 0.3125 | 0.2344 |
| $N_5$ | | | | 0.1250 | 0.2500 | 0.3125 | 0.3125 |
| $N_6$ | | | | | 0.0625 | 0.1563 | 0.2344 |
| $N_7$ | | | | | | 0.0313 | 0.0938 |
| $N_8$ | | | | | | | 0.0156 |

## 1.3.3.3 BWR RHR MOV FAIL TO CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 47.30
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9446310 | 0.9853090 | 0.9929860 | 0.9999270 | 0.9966090 | 3.4729E+01 | 5.1782E-01 |
| $\alpha_2$ | 7.08E-05 | 1.47E-02 | 7.02E-03 | 5.54E-02 | 3.39E-03 | 5.1782E-01 | 3.4729E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9464220 | 0.9799500 | 0.9844730 | 0.9980050 | 0.9931920 | 6.6025E+01 | 1.3509E+00 |
| $\alpha_2$ | 1.02E-03 | 1.61E-02 | 1.16E-02 | 4.65E-02 | 6.81E-03 | 1.0837E+00 | 6.6292E+01 |
| $\alpha_3$ | 1.38E-07 | 3.97E-03 | 7.96E-04 | 1.88E-02 | 0.00E+00 | 2.6722E-01 | 6.7109E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9457010 | 0.9756680 | 0.9788700 | 0.9946910 | 0.9897540 | 9.4436E+01 | 2.3551E+00 |
| $\alpha_2$ | 2.64E-03 | 1.79E-02 | 1.47E-02 | 4.40E-02 | 1.02E-02 | 1.7281E+00 | 9.5063E+01 |
| $\alpha_3$ | 4.69E-06 | 4.18E-03 | 1.54E-03 | 1.73E-02 | 0.00E+00 | 4.0431E-01 | 9.6387E+01 |
| $\alpha_4$ | 9.89E-09 | 2.30E-03 | 3.14E-04 | 1.15E-02 | 0.00E+00 | 2.2267E-01 | 9.6568E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9503380 | 0.9738070 | 0.9757540 | 0.9906320 | 0.9890430 | 1.5633E+02 | 4.2049E+00 |
| $\alpha_2$ | 4.19E-03 | 1.68E-02 | 1.48E-02 | 3.61E-02 | 9.59E-03 | 2.6975E+00 | 1.5784E+02 |
| $\alpha_3$ | 3.93E-04 | 6.61E-03 | 4.70E-03 | 1.93E-02 | 1.37E-03 | 1.0607E+00 | 1.5947E+02 |
| $\alpha_4$ | 1.53E-06 | 2.33E-03 | 7.84E-04 | 9.91E-03 | 0.00E+00 | 3.7439E-01 | 1.6016E+02 |
| $\alpha_5$ | 3.71E-21 | 4.50E-04 | 2.54E-07 | 2.60E-03 | 0.00E+00 | 7.2277E-02 | 1.6046E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9523810 | 0.9736200 | 0.9752340 | 0.9893540 | 0.9884620 | 1.8893E+02 | 5.1190E+00 |
| $\alpha_2$ | 3.98E-03 | 1.49E-02 | 1.33E-02 | 3.15E-02 | 9.06E-03 | 2.8989E+00 | 1.9115E+02 |
| $\alpha_3$ | 6.25E-04 | 6.74E-03 | 5.14E-03 | 1.83E-02 | 2.29E-03 | 1.3085E+00 | 1.9274E+02 |
| $\alpha_4$ | 3.08E-05 | 3.12E-03 | 1.66E-03 | 1.12E-02 | 1.91E-04 | 6.0612E-01 | 1.9344E+02 |
| $\alpha_5$ | 4.78E-09 | 1.15E-03 | 1.55E-04 | 5.74E-03 | 0.00E+00 | 2.2220E-01 | 1.9383E+02 |
| $\alpha_6$ | 7.26E-19 | 4.29E-04 | 7.49E-07 | 2.50E-03 | 0.00E+00 | 8.3237E-02 | 1.9397E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9551240 | 0.9729060 | 0.9740460 | 0.9868020 | 0.9880450 | 2.6784E+02 | 7.4589E+00 |
| $\alpha_2$ | 4.60E-03 | 1.38E-02 | 1.27E-02 | 2.71E-02 | 8.53E-03 | 3.8112E+00 | 2.7149E+02 |
| $\alpha_3$ | 1.13E-03 | 6.83E-03 | 5.68E-03 | 1.65E-02 | 2.93E-03 | 1.8800E+00 | 2.7342E+02 |
| $\alpha_4$ | 2.06E-04 | 3.74E-03 | 2.62E-03 | 1.11E-02 | 4.65E-04 | 1.0283E+00 | 2.7427E+02 |
| $\alpha_5$ | 9.56E-06 | 1.90E-03 | 9.04E-04 | 7.19E-03 | 2.71E-05 | 5.2407E-01 | 2.7477E+02 |
| $\alpha_6$ | 2.44E-10 | 6.77E-04 | 5.77E-05 | 3.55E-03 | 0.00E+00 | 1.8628E-01 | 2.7511E+02 |
| $\alpha_7$ | 0.00E+00 | 1.06E-04 | 9.24E-14 | 3.97E-04 | 0.00E+00 | 2.9071E-02 | 2.7527E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9570090 | 0.9732340 | 0.9742030 | 0.9861400 | 0.9877750 | 3.1429E+02 | 8.6437E+00 |
| $\alpha_2$ | 4.47E-03 | 1.27E-02 | 1.18E-02 | 2.44E-02 | 7.98E-03 | 4.1163E+00 | 3.1882E+02 |
| $\alpha_3$ | 1.19E-03 | 6.40E-03 | 5.41E-03 | 1.50E-02 | 3.39E-03 | 2.0663E+00 | 3.2087E+02 |
| $\alpha_4$ | 3.05E-04 | 3.78E-03 | 2.82E-03 | 1.05E-02 | 7.68E-04 | 1.2208E+00 | 3.2171E+02 |
| $\alpha_5$ | 4.21E-05 | 2.22E-03 | 1.31E-03 | 7.48E-03 | 8.79E-05 | 7.1683E-01 | 3.2222E+02 |
| $\alpha_6$ | 6.49E-07 | 1.14E-03 | 3.73E-04 | 4.86E-03 | 4.13E-06 | 3.6736E-01 | 3.2257E+02 |
| $\alpha_7$ | 5.04E-14 | 3.81E-04 | 6.84E-06 | 2.17E-03 | 0.00E+00 | 1.2297E-01 | 3.2281E+02 |
| $\alpha_8$ | 9.44E-43 | 1.03E-04 | 1.46E-12 | 4.33E-04 | 0.00E+00 | 3.3124E-02 | 3.2290E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9966090 | 0.9931920 | 0.9897540 | 0.9890430 | 0.9884620 | 0.9880450 | 0.9877750 |
| $\alpha_2$ | 3.39E-03 | 6.81E-03 | 1.02E-02 | 9.59E-03 | 9.06E-03 | 8.53E-03 | 7.98E-03 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 1.37E-03 | 2.29E-03 | 2.93E-03 | 3.39E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 1.91E-04 | 4.65E-04 | 7.68E-04 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 2.71E-05 | 8.79E-05 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 4.13E-06 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.97E-01 | 9.93E-01 | 9.90E-01 | 9.89E-01 | 9.88E-01 | 9.88E-01 | 9.88E-01 |
| Beta | 3.39E-03 | 6.81E-03 | 1.02E-02 | 1.10E-02 | 1.15E-02 | 1.20E-02 | 1.22E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 1.25E-01 | 2.15E-01 | 2.87E-01 | 3.48E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 7.70E-02 | 1.44E-01 | 2.02E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 5.52E-02 | 1.07E-01 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 4.49E-02 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

BWR Residual Heat Removal Motor-Operated Valves

BWR RHR MOV FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 23.65 | 35.47 | 47.30 | 59.13 | 70.95 | 82.78 | 94.60 |
| $N_1$ | 0.8333 | 1.0000 | 1.0000 | 1.0417 | 1.0417 | 1.0127 | 0.9645 |
| $N_2$ | 0.0833 | 0.2500 | 0.5000 | 0.5833 | 0.6597 | 0.7234 | 0.7716 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0833 | 0.1667 | 0.2488 | 0.3279 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0139 | 0.0394 | 0.0743 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0023 | 0.0085 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0004 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.3.4 BWR Isolation Condenser Motor-Operated Valves

## 1.3.4.1 ISO CONDENSER MOV FAIL TO OPEN/CLOSE

**System :** Isolation condenser
**Component :** Motor Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 8.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9069840 | 0.9767390 | 0.9904340 | 0.9999540 | 1.0000000 | 1.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.27E-05 | 2.33E-02 | 9.56E-03 | 9.30E-02 | 0.00E+00 | 4.3452E-01 | 1.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9187120 | 0.9715210 | 0.9791840 | 0.9981180 | 1.0000000 | 3.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.87E-04 | 2.16E-02 | 1.40E-02 | 6.82E-02 | 0.00E+00 | 8.3366E-01 | 3.7822E+01 |
| $\alpha_3$ | 2.43E-07 | 6.91E-03 | 1.40E-03 | 3.28E-02 | 0.00E+00 | 2.6722E-01 | 3.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9207150 | 0.9668680 | 0.9722640 | 0.9945410 | 1.0000000 | 5.4136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.82E-03 | 2.19E-02 | 1.65E-02 | 6.05E-02 | 0.00E+00 | 1.2281E+00 | 5.4763E+01 |
| $\alpha_3$ | 8.14E-06 | 7.22E-03 | 2.68E-03 | 2.98E-02 | 0.00E+00 | 4.0431E-01 | 5.5587E+01 |
| $\alpha_4$ | 1.72E-08 | 3.98E-03 | 5.45E-04 | 1.99E-02 | 0.00E+00 | 2.2267E-01 | 5.5768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9349600 | 0.9671470 | 0.9699980 | 0.9895730 | 1.0000000 | 1.0416E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.78E-03 | 1.96E-02 | 1.67E-02 | 4.54E-02 | 0.00E+00 | 2.1142E+00 | 1.0558E+02 |
| $\alpha_3$ | 4.43E-04 | 9.08E-03 | 6.27E-03 | 2.73E-02 | 0.00E+00 | 9.7738E-01 | 1.0672E+02 |
| $\alpha_4$ | 2.29E-06 | 3.48E-03 | 1.17E-03 | 1.48E-02 | 0.00E+00 | 3.7439E-01 | 1.0732E+02 |
| $\alpha_5$ | 5.54E-21 | 6.71E-04 | 3.80E-07 | 3.89E-03 | 0.00E+00 | 7.2277E-02 | 1.0763E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9376440 | 0.9668880 | 0.9692700 | 0.9879830 | 1.0000000 | 1.2494E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.56E-03 | 1.73E-02 | 1.49E-02 | 3.94E-02 | 0.00E+00 | 2.2392E+00 | 1.2698E+02 |
| $\alpha_3$ | 6.22E-04 | 8.84E-03 | 6.46E-03 | 2.52E-02 | 0.00E+00 | 1.1418E+00 | 1.2808E+02 |
| $\alpha_4$ | 4.10E-05 | 4.58E-03 | 2.40E-03 | 1.65E-02 | 0.00E+00 | 5.9222E-01 | 1.2863E+02 |
| $\alpha_5$ | 7.19E-09 | 1.72E-03 | 2.33E-04 | 8.62E-03 | 0.00E+00 | 2.2220E-01 | 1.2900E+02 |
| $\alpha_6$ | 1.09E-18 | 6.44E-04 | 1.13E-06 | 3.76E-03 | 0.00E+00 | 8.3237E-02 | 1.2914E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.3.4.2 ISO CONDENSER MOV FAIL TO OPEN

| | |
|---|---|
| **System :** | Isolation condenser |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8959650 | 0.9739500 | 0.9892430 | 0.9999480 | 1.0000000 | 1.6246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.81E-05 | 2.60E-02 | 1.08E-02 | 1.04E-01 | 0.00E+00 | 4.3452E-01 | 1.6246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9143470 | 0.9699670 | 0.9780280 | 0.9980130 | 1.0000000 | 3.5555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.25E-04 | 2.27E-02 | 1.48E-02 | 7.18E-02 | 0.00E+00 | 8.3366E-01 | 3.5822E+01 |
| $\alpha_3$ | 2.56E-07 | 7.29E-03 | 1.48E-03 | 3.46E-02 | 0.00E+00 | 2.6722E-01 | 3.6389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9178250 | 0.9656410 | 0.9712250 | 0.9943340 | 1.0000000 | 5.2136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.89E-03 | 2.27E-02 | 1.72E-02 | 6.27E-02 | 0.00E+00 | 1.2281E+00 | 5.2763E+01 |
| $\alpha_3$ | 8.45E-06 | 7.49E-03 | 2.78E-03 | 3.09E-02 | 0.00E+00 | 4.0431E-01 | 5.3587E+01 |
| $\alpha_4$ | 1.78E-08 | 4.12E-03 | 5.66E-04 | 2.07E-02 | 0.00E+00 | 2.2267E-01 | 5.3768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9337450 | 0.9665250 | 0.9694270 | 0.9893730 | 1.0000000 | 1.0216E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.85E-03 | 2.00E-02 | 1.71E-02 | 4.62E-02 | 0.00E+00 | 2.1142E+00 | 1.0358E+02 |
| $\alpha_3$ | 4.52E-04 | 9.25E-03 | 6.39E-03 | 2.78E-02 | 0.00E+00 | 9.7738E-01 | 1.0472E+02 |
| $\alpha_4$ | 2.33E-06 | 3.54E-03 | 1.19E-03 | 1.50E-02 | 0.00E+00 | 3.7439E-01 | 1.0532E+02 |
| $\alpha_5$ | 5.65E-21 | 6.84E-04 | 3.87E-07 | 3.96E-03 | 0.00E+00 | 7.2277E-02 | 1.0563E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366750 | 0.9663680 | 0.9687880 | 0.9877920 | 1.0000000 | 1.2294E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.62E-03 | 1.76E-02 | 1.51E-02 | 4.00E-02 | 0.00E+00 | 2.2392E+00 | 1.2498E+02 |
| $\alpha_3$ | 6.32E-04 | 8.98E-03 | 6.57E-03 | 2.55E-02 | 0.00E+00 | 1.1418E+00 | 1.2608E+02 |
| $\alpha_4$ | 4.16E-05 | 4.66E-03 | 2.44E-03 | 1.68E-02 | 0.00E+00 | 5.9222E-01 | 1.2663E+02 |
| $\alpha_5$ | 7.30E-09 | 1.75E-03 | 2.37E-04 | 8.75E-03 | 0.00E+00 | 2.2220E-01 | 1.2700E+02 |
| $\alpha_6$ | 1.11E-18 | 6.54E-04 | 1.14E-06 | 3.82E-03 | 0.00E+00 | 8.3237E-02 | 1.2714E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.3.4.3 ISO CONDENSER MOV FAIL TO CLOSE

| | |
|---|---|
| **System :** | Isolation condenser |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9311740 | 0.9652090 | 0.9682200 | 0.9889480 | 1.0000000 | 9.8161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.01E-03 | 2.08E-02 | 1.77E-02 | 4.80E-02 | 0.00E+00 | 2.1142E+00 | 9.9585E+01 |
| $\alpha_3$ | 4.70E-04 | 9.61E-03 | 6.64E-03 | 2.89E-02 | 0.00E+00 | 9.7738E-01 | 1.0072E+02 |
| $\alpha_4$ | 2.42E-06 | 3.68E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0132E+02 |
| $\alpha_5$ | 5.87E-21 | 7.11E-04 | 4.02E-07 | 4.12E-03 | 0.00E+00 | 7.2277E-02 | 1.0163E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9346440 | 0.9652760 | 0.9677640 | 0.9873890 | 1.0000000 | 1.1894E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.74E-03 | 1.82E-02 | 1.56E-02 | 4.13E-02 | 0.00E+00 | 2.2392E+00 | 1.2098E+02 |
| $\alpha_3$ | 6.53E-04 | 9.27E-03 | 6.78E-03 | 2.64E-02 | 0.00E+00 | 1.1418E+00 | 1.2208E+02 |
| $\alpha_4$ | 4.30E-05 | 4.81E-03 | 2.52E-03 | 1.73E-02 | 0.00E+00 | 5.9222E-01 | 1.2263E+02 |
| $\alpha_5$ | 7.54E-09 | 1.80E-03 | 2.45E-04 | 9.04E-03 | 0.00E+00 | 2.2220E-01 | 1.2300E+02 |
| $\alpha_6$ | 1.14E-18 | 6.76E-04 | 1.18E-06 | 3.94E-03 | 0.00E+00 | 8.3237E-02 | 1.2314E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.3.5 PWR Auxiliary Feedwater Motor-Operated Valves

## 1.3.5.1 AFW MOV FAIL TO OPEN/CLOSE SPAR: AFW-MOV-FO

**System :** Auxiliary feedwater
**Component :** Motor Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 56.80
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9211530 | 0.9746430 | 0.9831460 | 0.9990840 | 0.9815960 | 3.3356E+01 | 8.6782E-01 |
| $\alpha_2$ | 9.13E-04 | 2.54E-02 | 1.69E-02 | 7.88E-02 | 1.84E-02 | 8.6782E-01 | 3.3356E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9212760 | 0.9648050 | 0.9694410 | 0.9924600 | 0.9654380 | 6.3075E+01 | 2.3009E+00 |
| $\alpha_2$ | 5.45E-03 | 3.03E-02 | 2.57E-02 | 7.12E-02 | 3.31E-02 | 1.9837E+00 | 6.3392E+01 |
| $\alpha_3$ | 8.63E-07 | 4.85E-03 | 1.30E-03 | 2.18E-02 | 1.44E-03 | 3.1722E-01 | 6.5059E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9175380 | 0.9566550 | 0.9598800 | 0.9847510 | 0.9517160 | 8.9499E+01 | 4.0551E+00 |
| $\alpha_2$ | 1.02E-02 | 3.45E-02 | 3.12E-02 | 7.00E-02 | 4.39E-02 | 3.2281E+00 | 9.0326E+01 |
| $\alpha_3$ | 6.32E-05 | 6.46E-03 | 3.44E-03 | 2.31E-02 | 4.39E-03 | 6.0431E-01 | 9.2950E+01 |
| $\alpha_4$ | 1.02E-08 | 2.38E-03 | 3.25E-04 | 1.19E-02 | 0.00E+00 | 2.2267E-01 | 9.3331E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9316380 | 0.9602190 | 0.9621700 | 0.9821240 | 0.9526190 | 1.4977E+02 | 6.2049E+00 |
| $\alpha_2$ | 8.67E-03 | 2.53E-02 | 2.33E-02 | 4.88E-02 | 3.26E-02 | 3.9475E+00 | 1.5203E+02 |
| $\alpha_3$ | 1.82E-03 | 1.16E-02 | 9.60E-03 | 2.83E-02 | 1.48E-02 | 1.8107E+00 | 1.5416E+02 |
| $\alpha_4$ | 1.58E-06 | 2.40E-03 | 8.07E-04 | 1.02E-02 | 0.00E+00 | 3.7439E-01 | 1.5560E+02 |
| $\alpha_5$ | 3.82E-21 | 4.63E-04 | 2.62E-07 | 2.68E-03 | 0.00E+00 | 7.2277E-02 | 1.5590E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9358030 | 0.9613170 | 0.9629440 | 0.9812800 | 0.9551850 | 1.8088E+02 | 7.2786E+00 |
| $\alpha_2$ | 6.36E-03 | 1.96E-02 | 1.79E-02 | 3.85E-02 | 2.16E-02 | 3.6836E+00 | 1.8447E+02 |
| $\alpha_3$ | 3.29E-03 | 1.37E-02 | 1.21E-02 | 3.00E-02 | 2.16E-02 | 2.5862E+00 | 1.8557E+02 |
| $\alpha_4$ | 6.64E-05 | 3.74E-03 | 2.19E-03 | 1.27E-02 | 1.66E-03 | 7.0332E-01 | 1.8746E+02 |
| $\alpha_5$ | 4.93E-09 | 1.18E-03 | 1.60E-04 | 5.92E-03 | 0.00E+00 | 2.2220E-01 | 1.8794E+02 |
| $\alpha_6$ | 7.49E-19 | 4.42E-04 | 7.73E-07 | 2.58E-03 | 0.00E+00 | 8.3237E-02 | 1.8808E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9445200 | 0.9647700 | 0.9659230 | 0.9810880 | 0.9613410 | 2.5865E+02 | 9.4449E+00 |
| $\alpha_2$ | 5.54E-03 | 1.56E-02 | 1.44E-02 | 2.97E-02 | 1.41E-02 | 4.1841E+00 | 2.6391E+02 |
| $\alpha_3$ | 2.83E-03 | 1.07E-02 | 9.54E-03 | 2.27E-02 | 1.60E-02 | 2.8756E+00 | 2.6522E+02 |
| $\alpha_4$ | 7.93E-04 | 6.01E-03 | 4.83E-03 | 1.52E-02 | 8.02E-03 | 1.6111E+00 | 2.6648E+02 |
| $\alpha_5$ | 1.43E-05 | 2.08E-03 | 1.04E-03 | 7.69E-03 | 4.77E-04 | 5.5877E-01 | 2.6754E+02 |
| $\alpha_6$ | 2.51E-10 | 6.95E-04 | 5.93E-05 | 3.65E-03 | 0.00E+00 | 1.8628E-01 | 2.6791E+02 |
| $\alpha_7$ | 0.00E+00 | 1.08E-04 | 9.49E-14 | 4.08E-04 | 0.00E+00 | 2.9071E-02 | 2.6807E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9486030 | 0.9667310 | 0.9677140 | 0.9814950 | 0.9660060 | 3.0398E+02 | 1.0461E+01 |
| $\alpha_2$ | 4.71E-03 | 1.33E-02 | 1.23E-02 | 2.54E-02 | 9.49E-03 | 4.1822E+00 | 3.1026E+02 |
| $\alpha_3$ | 2.31E-03 | 8.95E-03 | 7.93E-03 | 1.91E-02 | 1.22E-02 | 2.8135E+00 | 3.1163E+02 |
| $\alpha_4$ | 1.09E-03 | 6.24E-03 | 5.23E-03 | 1.49E-02 | 9.25E-03 | 1.9628E+00 | 3.1248E+02 |
| $\alpha_5$ | 1.45E-04 | 3.08E-03 | 2.11E-03 | 9.31E-03 | 2.93E-03 | 9.6713E-01 | 3.1347E+02 |
| $\alpha_6$ | 8.67E-07 | 1.21E-03 | 4.11E-04 | 5.10E-03 | 1.39E-04 | 3.7926E-01 | 3.1406E+02 |
| $\alpha_7$ | 5.18E-14 | 3.91E-04 | 7.03E-06 | 2.23E-03 | 0.00E+00 | 1.2297E-01 | 3.1432E+02 |
| $\alpha_8$ | 9.70E-43 | 1.05E-04 | 1.50E-12 | 4.45E-04 | 0.00E+00 | 3.3124E-02 | 3.1441E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9815960 | 0.9654380 | 0.9517160 | 0.9526190 | 0.9551850 | 0.9613410 | 0.9660060 |
| $\alpha_2$ | 1.84E-02 | 3.31E-02 | 4.39E-02 | 3.26E-02 | 2.16E-02 | 1.41E-02 | 9.49E-03 |
| $\alpha_3$ | | 1.44E-03 | 4.39E-03 | 1.48E-02 | 2.16E-02 | 1.60E-02 | 1.22E-02 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 1.66E-03 | 8.02E-03 | 9.25E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 4.77E-04 | 2.93E-03 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 1.39E-04 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.82E-01 | 9.65E-01 | 9.52E-01 | 9.53E-01 | 9.55E-01 | 9.61E-01 | 9.66E-01 |
| Beta | 1.84E-02 | 3.46E-02 | 4.83E-02 | 4.74E-02 | 4.48E-02 | 3.87E-02 | 3.40E-02 |
| Gamma | | 4.17E-02 | 9.09E-02 | 3.12E-01 | 5.19E-01 | 6.35E-01 | 7.21E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 7.14E-02 | 3.46E-01 | 5.03E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 5.61E-02 | 2.49E-01 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 4.54E-02 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Motor-Operated Valves

AFW MOV FAIL TO OPEN/CLOSE SPAR: AFW-MOV-FO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 21.31 | 31.97 | 42.63 | 53.28 | 63.94 | 74.60 | 85.25 |
| $N_1$ | 1.8000 | 1.5500 | 0.7333 | 0.3333 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.4333 | 1.1500 | 2.0000 | 1.8333 | 1.4444 | 1.0963 | 0.8375 |
| $N_3$ | | 0.0500 | 0.2000 | 0.8333 | 1.4444 | 1.2444 | 1.0751 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.1111 | 0.6222 | 0.8163 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0370 | 0.2588 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0123 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.5.2 AFW MOV FAIL TO OPEN SPAR: AFW-MOV-CC

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 28.20
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8944810 | 0.9696120 | 0.9828540 | 0.9996220 | 0.9803920 | 2.0246E+01 | 6.3452E-01 |
| $\alpha_2$ | 3.76E-04 | 3.04E-02 | 1.71E-02 | 1.06E-01 | 1.96E-02 | 6.3452E-01 | 2.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9121850 | 0.9649730 | 0.9715230 | 0.9953160 | 0.9667770 | 4.4105E+01 | 1.6009E+00 |
| $\alpha_2$ | 2.55E-03 | 2.81E-02 | 2.15E-02 | 7.61E-02 | 2.99E-02 | 1.2837E+00 | 4.4422E+01 |
| $\alpha_3$ | 1.24E-06 | 6.94E-03 | 1.87E-03 | 3.11E-02 | 3.32E-03 | 3.1722E-01 | 4.5389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9161740 | 0.9608340 | 0.9652860 | 0.9902550 | 0.9595960 | 6.5136E+01 | 2.6551E+00 |
| $\alpha_2$ | 4.34E-03 | 2.70E-02 | 2.25E-02 | 6.50E-02 | 3.03E-02 | 1.8281E+00 | 6.5963E+01 |
| $\alpha_3$ | 8.75E-05 | 8.91E-03 | 4.76E-03 | 3.19E-02 | 1.01E-02 | 6.0431E-01 | 6.7187E+01 |
| $\alpha_4$ | 1.42E-08 | 3.28E-03 | 4.50E-04 | 1.65E-02 | 0.00E+00 | 2.2267E-01 | 6.7568E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9322830 | 0.9634590 | 0.9659250 | 0.9862100 | 0.9591840 | 1.1966E+02 | 4.5383E+00 |
| $\alpha_2$ | 5.11E-03 | 2.10E-02 | 1.85E-02 | 4.56E-02 | 2.04E-02 | 2.6142E+00 | 1.2158E+02 |
| $\alpha_3$ | 1.37E-03 | 1.19E-02 | 9.40E-03 | 3.10E-02 | 2.04E-02 | 1.4774E+00 | 1.2272E+02 |
| $\alpha_4$ | 1.98E-06 | 3.01E-03 | 1.01E-03 | 1.28E-02 | 0.00E+00 | 3.7439E-01 | 1.2382E+02 |
| $\alpha_5$ | 4.80E-21 | 5.82E-04 | 3.29E-07 | 3.37E-03 | 0.00E+00 | 7.2277E-02 | 1.2413E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9372950 | 0.9649070 | 0.9669470 | 0.9855370 | 0.9657530 | 1.4514E+02 | 5.2787E+00 |
| $\alpha_2$ | 3.06E-03 | 1.49E-02 | 1.28E-02 | 3.39E-02 | 0.00E+00 | 2.2392E+00 | 1.4818E+02 |
| $\alpha_3$ | 2.78E-03 | 1.42E-02 | 1.21E-02 | 3.29E-02 | 3.42E-02 | 2.1418E+00 | 1.4828E+02 |
| $\alpha_4$ | 3.52E-05 | 3.94E-03 | 2.06E-03 | 1.42E-02 | 0.00E+00 | 5.9222E-01 | 1.4983E+02 |
| $\alpha_5$ | 6.17E-09 | 1.48E-03 | 2.00E-04 | 7.40E-03 | 0.00E+00 | 2.2220E-01 | 1.5020E+02 |
| $\alpha_6$ | 9.37E-19 | 5.53E-04 | 9.68E-07 | 3.23E-03 | 0.00E+00 | 8.3237E-02 | 1.5034E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9451210 | 0.9668220 | 0.9682030 | 0.9838180 | 0.9705010 | 2.1695E+02 | 7.4450E+00 |
| $\alpha_2$ | 3.87E-03 | 1.38E-02 | 1.23E-02 | 2.85E-02 | 0.00E+00 | 3.0878E+00 | 2.2131E+02 |
| $\alpha_3$ | 2.03E-03 | 9.94E-03 | 8.53E-03 | 2.27E-02 | 1.77E-02 | 2.2312E+00 | 2.2216E+02 |
| $\alpha_4$ | 6.39E-04 | 6.19E-03 | 4.80E-03 | 1.65E-02 | 1.18E-02 | 1.3889E+00 | 2.2301E+02 |
| $\alpha_5$ | 1.14E-05 | 2.33E-03 | 1.10E-03 | 8.79E-03 | 0.00E+00 | 5.2177E-01 | 2.2387E+02 |
| $\alpha_6$ | 2.99E-10 | 8.30E-04 | 7.09E-05 | 4.36E-03 | 0.00E+00 | 1.8628E-01 | 2.2421E+02 |
| $\alpha_7$ | 0.00E+00 | 1.30E-04 | 1.13E-13 | 4.88E-04 | 0.00E+00 | 2.9071E-02 | 2.2437E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9485180 | 0.9680470 | 0.9692220 | 0.9835720 | 0.9740930 | 2.5633E+02 | 8.4610E+00 |
| $\alpha_2$ | 3.80E-03 | 1.26E-02 | 1.14E-02 | 2.56E-02 | 0.00E+00 | 3.3447E+00 | 2.6145E+02 |
| $\alpha_3$ | 1.50E-03 | 7.92E-03 | 6.72E-03 | 1.85E-02 | 9.33E-03 | 2.0984E+00 | 2.6269E+02 |
| $\alpha_4$ | 8.23E-04 | 6.14E-03 | 4.95E-03 | 1.55E-02 | 1.24E-02 | 1.6265E+00 | 2.6316E+02 |
| $\alpha_5$ | 1.15E-04 | 3.28E-03 | 2.14E-03 | 1.03E-02 | 4.15E-03 | 8.6833E-01 | 2.6392E+02 |
| $\alpha_6$ | 7.84E-07 | 1.39E-03 | 4.54E-04 | 5.93E-03 | 0.00E+00 | 3.6696E-01 | 2.6442E+02 |
| $\alpha_7$ | 6.15E-14 | 4.64E-04 | 8.35E-06 | 2.64E-03 | 0.00E+00 | 1.2297E-01 | 2.6467E+02 |
| $\alpha_8$ | 1.15E-42 | 1.25E-04 | 1.78E-12 | 5.29E-04 | 0.00E+00 | 3.3124E-02 | 2.6476E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9803920 | 0.9667770 | 0.9595960 | 0.9591840 | 0.9657530 | 0.9705010 | 0.9740930 |
| $\alpha_2$ | 1.96E-02 | 2.99E-02 | 3.03E-02 | 2.04E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 3.32E-03 | 1.01E-02 | 2.04E-02 | 3.42E-02 | 1.77E-02 | 9.33E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.18E-02 | 1.24E-02 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.15E-03 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.80E-01 | 9.67E-01 | 9.60E-01 | 9.59E-01 | 9.66E-01 | 9.71E-01 | 9.74E-01 |
| Beta | 1.96E-02 | 3.32E-02 | 4.04E-02 | 4.08E-02 | 3.42E-02 | 2.95E-02 | 2.59E-02 |
| Gamma | | 1.00E-01 | 2.50E-01 | 5.00E-01 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.00E-01 | 6.40E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.50E-01 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Motor-Operated Valves

AFW MOV FAIL TO OPEN SPAR: AFW-MOV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 9.40 | 14.10 | 18.80 | 23.50 | 28.20 | 32.90 | 37.60 |
| $N_1$ | 0.6000 | 0.4500 | 0.2000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.2000 | 0.4500 | 0.6000 | 0.5000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0500 | 0.2000 | 0.5000 | 1.0000 | 0.6000 | 0.3600 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.4000 | 0.4800 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.1600 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.5.3 AFW MOV FAIL TO CLOSE SPAR: AFW-MOV-OO

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 27.60
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9016080 | 0.9711570 | 0.9832270 | 0.9995620 | 0.9812960 | 2.2486E+01 | 6.6782E-01 |
| $\alpha_2$ | 4.36E-04 | 2.88E-02 | 1.68E-02 | 9.84E-02 | 1.87E-02 | 6.6782E-01 | 2.2486E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113900 | 0.9632580 | 0.9693770 | 0.9941640 | 0.9618740 | 4.7215E+01 | 1.8009E+00 |
| $\alpha_2$ | 3.90E-03 | 3.13E-02 | 2.52E-02 | 7.97E-02 | 3.81E-02 | 1.5337E+00 | 4.7482E+01 |
| $\alpha_3$ | 1.91E-07 | 5.45E-03 | 1.10E-03 | 2.59E-02 | 0.00E+00 | 2.6722E-01 | 4.8749E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9088840 | 0.9547930 | 0.9589530 | 0.9864770 | 0.9416990 | 6.8749E+01 | 3.2551E+00 |
| $\alpha_2$ | 8.98E-03 | 3.65E-02 | 3.23E-02 | 7.84E-02 | 5.83E-02 | 2.6281E+00 | 6.9376E+01 |
| $\alpha_3$ | 6.31E-06 | 5.62E-03 | 2.08E-03 | 2.32E-02 | 0.00E+00 | 4.0431E-01 | 7.1600E+01 |
| $\alpha_4$ | 1.33E-08 | 3.09E-03 | 4.23E-04 | 1.55E-02 | 0.00E+00 | 2.2267E-01 | 7.1781E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9279470 | 0.9597440 | 0.9620950 | 0.9834990 | 0.9436960 | 1.2409E+02 | 5.2049E+00 |
| $\alpha_2$ | 8.27E-03 | 2.67E-02 | 2.43E-02 | 5.33E-02 | 4.50E-02 | 3.4475E+00 | 1.2585E+02 |
| $\alpha_3$ | 9.45E-04 | 1.01E-02 | 7.75E-03 | 2.75E-02 | 1.13E-02 | 1.3107E+00 | 1.2798E+02 |
| $\alpha_4$ | 1.90E-06 | 2.90E-03 | 9.75E-04 | 1.23E-02 | 0.00E+00 | 3.7439E-01 | 1.2892E+02 |
| $\alpha_5$ | 4.61E-21 | 5.59E-04 | 3.16E-07 | 3.23E-03 | 0.00E+00 | 7.2277E-02 | 1.2922E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9311780 | 0.9598400 | 0.9617910 | 0.9818460 | 0.9430550 | 1.5006E+02 | 6.2786E+00 |
| $\alpha_2$ | 7.67E-03 | 2.36E-02 | 2.16E-02 | 4.63E-02 | 4.11E-02 | 3.6836E+00 | 1.5265E+02 |
| $\alpha_3$ | 1.31E-03 | 1.01E-02 | 8.15E-03 | 2.58E-02 | 1.27E-02 | 1.5862E+00 | 1.5475E+02 |
| $\alpha_4$ | 8.00E-05 | 4.50E-03 | 2.64E-03 | 1.53E-02 | 3.16E-03 | 7.0332E-01 | 1.5564E+02 |
| $\alpha_5$ | 5.94E-09 | 1.42E-03 | 1.93E-04 | 7.12E-03 | 0.00E+00 | 2.2220E-01 | 1.5612E+02 |
| $\alpha_6$ | 9.01E-19 | 5.32E-04 | 9.31E-07 | 3.11E-03 | 0.00E+00 | 8.3237E-02 | 1.5626E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9411850 | 0.9634630 | 0.9647910 | 0.9812030 | 0.9507900 | 2.2269E+02 | 8.4449E+00 |
| $\alpha_2$ | 6.43E-03 | 1.81E-02 | 1.67E-02 | 3.45E-02 | 2.70E-02 | 4.1841E+00 | 2.2695E+02 |
| $\alpha_3$ | 2.05E-03 | 9.85E-03 | 8.47E-03 | 2.23E-02 | 1.59E-02 | 2.2756E+00 | 2.2886E+02 |
| $\alpha_4$ | 4.16E-04 | 5.24E-03 | 3.90E-03 | 1.46E-02 | 5.47E-03 | 1.2111E+00 | 2.2992E+02 |
| $\alpha_5$ | 1.66E-05 | 2.42E-03 | 1.21E-03 | 8.91E-03 | 9.10E-04 | 5.5877E-01 | 2.3058E+02 |
| $\alpha_6$ | 2.91E-10 | 8.06E-04 | 6.88E-05 | 4.23E-03 | 0.00E+00 | 1.8628E-01 | 2.3095E+02 |
| $\alpha_7$ | 0.00E+00 | 1.26E-04 | 1.10E-13 | 4.73E-04 | 0.00E+00 | 2.9071E-02 | 2.3111E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9453060 | 0.9652620 | 0.9663990 | 0.9813480 | 0.9566720 | 2.6289E+02 | 9.4610E+00 |
| $\alpha_2$ | 5.44E-03 | 1.54E-02 | 1.42E-02 | 2.93E-02 | 1.81E-02 | 4.1822E+00 | 2.6817E+02 |
| $\alpha_3$ | 2.03E-03 | 9.01E-03 | 7.84E-03 | 2.00E-02 | 1.55E-02 | 2.4535E+00 | 2.6990E+02 |
| $\alpha_4$ | 6.29E-04 | 5.44E-03 | 4.29E-03 | 1.42E-02 | 7.29E-03 | 1.4828E+00 | 2.7087E+02 |
| $\alpha_5$ | 8.37E-05 | 2.96E-03 | 1.87E-03 | 9.57E-03 | 2.14E-03 | 8.0713E-01 | 2.7154E+02 |
| $\alpha_6$ | 1.00E-06 | 1.39E-03 | 4.75E-04 | 5.89E-03 | 2.66E-04 | 3.7926E-01 | 2.7197E+02 |
| $\alpha_7$ | 5.98E-14 | 4.52E-04 | 8.12E-06 | 2.57E-03 | 0.00E+00 | 1.2297E-01 | 2.7223E+02 |
| $\alpha_8$ | 1.12E-42 | 1.22E-04 | 1.73E-12 | 5.14E-04 | 0.00E+00 | 3.3124E-02 | 2.7232E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9812960 | 0.9618740 | 0.9416990 | 0.9436960 | 0.9430550 | 0.9507900 | 0.9566720 |
| $\alpha_2$ | 1.87E-02 | 3.81E-02 | 5.83E-02 | 4.50E-02 | 4.11E-02 | 2.70E-02 | 1.81E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 1.13E-02 | 1.27E-02 | 1.59E-02 | 1.55E-02 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 3.16E-03 | 5.47E-03 | 7.29E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 9.10E-04 | 2.14E-03 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 2.66E-04 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.81E-01 | 9.62E-01 | 9.42E-01 | 9.44E-01 | 9.43E-01 | 9.51E-01 | 9.57E-01 |
| Beta | 1.87E-02 | 3.81E-02 | 5.83E-02 | 5.63E-02 | 5.69E-02 | 4.92E-02 | 4.33E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 2.00E-01 | 2.78E-01 | 4.52E-01 | 5.81E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 2.00E-01 | 2.87E-01 | 3.85E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 1.43E-01 | 2.48E-01 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 1.11E-01 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Motor-Operated Valves

AFW MOV FAIL TO CLOSE SPAR: AFW-MOV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 11.04 | 16.56 | 22.08 | 27.60 | 33.12 | 38.64 | 44.16 |
| $N_1$ | 1.2000 | 1.1000 | 0.5333 | 0.3333 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.2333 | 0.7000 | 1.4000 | 1.3333 | 1.4444 | 1.0963 | 0.8375 |
| $N_3$ | | 0.0000 | 0.0000 | 0.3333 | 0.4444 | 0.6444 | 0.7151 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.1111 | 0.2222 | 0.3363 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0370 | 0.0988 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0123 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.3.6 PWR High Pressure Safety Injection Motor-Operated Valves

## 1.3.6.1 HIGH PRESSURE INJECTION MOV FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 60.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9754510 | 0.9939040 | 0.9975550 | 0.9999880 | 1.0000000 | 7.0846E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.09E-05 | 6.10E-03 | 2.44E-03 | 2.46E-02 | 0.00E+00 | 4.3452E-01 | 7.0846E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9652740 | 0.9879360 | 0.9912710 | 0.9992110 | 1.0000000 | 9.0155E+01 | 1.1009E+00 |
| $\alpha_2$ | 2.87E-04 | 9.14E-03 | 5.89E-03 | 2.91E-02 | 0.00E+00 | 8.3366E-01 | 9.0422E+01 |
| $\alpha_3$ | 1.02E-07 | 2.93E-03 | 5.87E-04 | 1.39E-02 | 0.00E+00 | 2.6722E-01 | 9.0989E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9588140 | 0.9829170 | 0.9857860 | 0.9972180 | 1.0000000 | 1.0674E+02 | 1.8551E+00 |
| $\alpha_2$ | 9.29E-04 | 1.13E-02 | 8.48E-03 | 3.14E-02 | 0.00E+00 | 1.2281E+00 | 1.0737E+02 |
| $\alpha_3$ | 4.17E-06 | 3.72E-03 | 1.38E-03 | 1.54E-02 | 0.00E+00 | 4.0431E-01 | 1.0819E+02 |
| $\alpha_4$ | 8.81E-09 | 2.05E-03 | 2.80E-04 | 1.03E-02 | 0.00E+00 | 2.2267E-01 | 1.0837E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9561320 | 0.9779270 | 0.9798830 | 0.9930350 | 1.0000000 | 1.5676E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.53E-03 | 1.32E-02 | 1.12E-02 | 3.06E-02 | 0.00E+00 | 2.1142E+00 | 1.5818E+02 |
| $\alpha_3$ | 2.97E-04 | 6.10E-03 | 4.20E-03 | 1.84E-02 | 0.00E+00 | 9.7738E-01 | 1.5932E+02 |
| $\alpha_4$ | 1.53E-06 | 2.34E-03 | 7.85E-04 | 9.92E-03 | 0.00E+00 | 3.7439E-01 | 1.5992E+02 |
| $\alpha_5$ | 3.72E-21 | 4.51E-04 | 2.55E-07 | 2.61E-03 | 0.00E+00 | 7.2277E-02 | 1.6023E+02 |

HIGH PRESSURE INJECTION MOV FAIL TO OPEN/CLOSE

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9555360 | 0.9764670 | 0.9781970 | 0.9915010 | 1.0000000 | 1.7754E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.52E-03 | 1.23E-02 | 1.06E-02 | 2.81E-02 | 0.00E+00 | 2.2392E+00 | 1.7958E+02 |
| $\alpha_3$ | 4.41E-04 | 6.28E-03 | 4.59E-03 | 1.79E-02 | 0.00E+00 | 1.1418E+00 | 1.8068E+02 |
| $\alpha_4$ | 2.91E-05 | 3.26E-03 | 1.70E-03 | 1.18E-02 | 0.00E+00 | 5.9222E-01 | 1.8123E+02 |
| $\alpha_5$ | 5.10E-09 | 1.22E-03 | 1.66E-04 | 6.12E-03 | 0.00E+00 | 2.2220E-01 | 1.8160E+02 |
| $\alpha_6$ | 7.75E-19 | 4.58E-04 | 8.00E-07 | 2.67E-03 | 0.00E+00 | 8.3237E-02 | 1.8174E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9560850 | 0.9743320 | 0.9755850 | 0.9883120 | 1.0000000 | 2.4465E+02 | 6.4450E+00 |
| $\alpha_2$ | 3.46E-03 | 1.23E-02 | 1.10E-02 | 2.55E-02 | 0.00E+00 | 3.0878E+00 | 2.4801E+02 |
| $\alpha_3$ | 8.75E-04 | 6.50E-03 | 5.24E-03 | 1.64E-02 | 0.00E+00 | 1.6312E+00 | 2.4946E+02 |
| $\alpha_4$ | 1.97E-04 | 3.94E-03 | 2.72E-03 | 1.18E-02 | 0.00E+00 | 9.8887E-01 | 2.5011E+02 |
| $\alpha_5$ | 1.02E-05 | 2.08E-03 | 9.83E-04 | 7.85E-03 | 0.00E+00 | 5.2177E-01 | 2.5057E+02 |
| $\alpha_6$ | 2.68E-10 | 7.42E-04 | 6.33E-05 | 3.89E-03 | 0.00E+00 | 1.8628E-01 | 2.5091E+02 |
| $\alpha_7$ | 0.00E+00 | 1.16E-04 | 1.01E-13 | 4.36E-04 | 0.00E+00 | 2.9071E-02 | 2.5107E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9569050 | 0.9739850 | 0.9750810 | 0.9873310 | 1.0000000 | 2.7933E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.50E-03 | 1.17E-02 | 1.05E-02 | 2.36E-02 | 0.00E+00 | 3.3447E+00 | 2.8345E+02 |
| $\alpha_3$ | 8.96E-04 | 6.06E-03 | 4.96E-03 | 1.50E-02 | 0.00E+00 | 1.7384E+00 | 2.8505E+02 |
| $\alpha_4$ | 2.83E-04 | 4.00E-03 | 2.92E-03 | 1.14E-02 | 0.00E+00 | 1.1465E+00 | 2.8564E+02 |
| $\alpha_5$ | 4.49E-05 | 2.47E-03 | 1.45E-03 | 8.36E-03 | 0.00E+00 | 7.0833E-01 | 2.8608E+02 |
| $\alpha_6$ | 7.24E-07 | 1.28E-03 | 4.19E-04 | 5.47E-03 | 0.00E+00 | 3.6696E-01 | 2.8642E+02 |
| $\alpha_7$ | 5.68E-14 | 4.29E-04 | 7.71E-06 | 2.44E-03 | 0.00E+00 | 1.2297E-01 | 2.8667E+02 |
| $\alpha_8$ | 1.06E-42 | 1.15E-04 | 1.65E-12 | 4.88E-04 | 0.00E+00 | 3.3124E-02 | 2.8676E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

HIGH PRESSURE INJECTION MOV FAIL TO OPEN/CLOSE

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 60.60 | 60.60 | 60.60 | 60.60 | 60.60 | 60.60 | 60.60 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.6.2 HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 29.60
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9566310 | 0.9892130 | 0.9956470 | 0.9999790 | 1.0000000 | 3.9846E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.94E-05 | 1.08E-02 | 4.35E-03 | 4.34E-02 | 0.00E+00 | 4.3452E-01 | 3.9846E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9475700 | 0.9817300 | 0.9867280 | 0.9988050 | 1.0000000 | 5.9155E+01 | 1.1009E+00 |
| $\alpha_2$ | 4.37E-04 | 1.38E-02 | 8.95E-03 | 4.39E-02 | 0.00E+00 | 8.3366E-01 | 5.9422E+01 |
| $\alpha_3$ | 1.55E-07 | 4.43E-03 | 8.92E-04 | 2.10E-02 | 0.00E+00 | 2.6722E-01 | 5.9989E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9425380 | 0.9760920 | 0.9800560 | 0.9960870 | 1.0000000 | 7.5736E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.31E-03 | 1.58E-02 | 1.19E-02 | 4.38E-02 | 0.00E+00 | 1.2281E+00 | 7.6363E+01 |
| $\alpha_3$ | 5.86E-06 | 5.21E-03 | 1.93E-03 | 2.15E-02 | 0.00E+00 | 4.0431E-01 | 7.7187E+01 |
| $\alpha_4$ | 1.24E-08 | 2.87E-03 | 3.92E-04 | 1.44E-02 | 0.00E+00 | 2.2267E-01 | 7.7368E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9457150 | 0.9726350 | 0.9750400 | 0.9913390 | 1.0000000 | 1.2576E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.14E-03 | 1.64E-02 | 1.39E-02 | 3.78E-02 | 0.00E+00 | 2.1142E+00 | 1.2718E+02 |
| $\alpha_3$ | 3.69E-04 | 7.56E-03 | 5.22E-03 | 2.27E-02 | 0.00E+00 | 9.7738E-01 | 1.2832E+02 |
| $\alpha_4$ | 1.90E-06 | 2.90E-03 | 9.75E-04 | 1.23E-02 | 0.00E+00 | 3.7439E-01 | 1.2892E+02 |
| $\alpha_5$ | 4.61E-21 | 5.59E-04 | 3.16E-07 | 3.23E-03 | 0.00E+00 | 7.2277E-02 | 1.2923E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9464910 | 0.9716300 | 0.9736940 | 0.9897260 | 1.0000000 | 1.4654E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.05E-03 | 1.48E-02 | 1.28E-02 | 3.38E-02 | 0.00E+00 | 2.2392E+00 | 1.4858E+02 |
| $\alpha_3$ | 5.33E-04 | 7.57E-03 | 5.53E-03 | 2.16E-02 | 0.00E+00 | 1.1418E+00 | 1.4968E+02 |
| $\alpha_4$ | 3.51E-05 | 3.93E-03 | 2.06E-03 | 1.42E-02 | 0.00E+00 | 5.9222E-01 | 1.5023E+02 |
| $\alpha_5$ | 6.16E-09 | 1.47E-03 | 2.00E-04 | 7.38E-03 | 0.00E+00 | 2.2220E-01 | 1.5060E+02 |
| $\alpha_6$ | 9.35E-19 | 5.52E-04 | 9.65E-07 | 3.22E-03 | 0.00E+00 | 8.3237E-02 | 1.5074E+02 |

HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO OPEN

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9499560 | 0.9707170 | 0.9721300 | 0.9866470 | 1.0000000 | 2.1365E+02 | 6.4450E+00 |
| $\alpha_2$ | 3.95E-03 | 1.40E-02 | 1.26E-02 | 2.90E-02 | 0.00E+00 | 3.0878E+00 | 2.1701E+02 |
| $\alpha_3$ | 9.98E-04 | 7.41E-03 | 5.98E-03 | 1.87E-02 | 0.00E+00 | 1.6312E+00 | 2.1846E+02 |
| $\alpha_4$ | 2.25E-04 | 4.49E-03 | 3.11E-03 | 1.35E-02 | 0.00E+00 | 9.8887E-01 | 2.1911E+02 |
| $\alpha_5$ | 1.17E-05 | 2.37E-03 | 1.12E-03 | 8.96E-03 | 0.00E+00 | 5.2177E-01 | 2.1957E+02 |
| $\alpha_6$ | 3.05E-10 | 8.46E-04 | 7.22E-05 | 4.44E-03 | 0.00E+00 | 1.8628E-01 | 2.1991E+02 |
| $\alpha_7$ | 0.00E+00 | 1.32E-04 | 1.16E-13 | 4.97E-04 | 0.00E+00 | 2.9071E-02 | 2.2007E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9517180 | 0.9708320 | 0.9720490 | 0.9857800 | 1.0000000 | 2.4833E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.93E-03 | 1.31E-02 | 1.18E-02 | 2.65E-02 | 0.00E+00 | 3.3447E+00 | 2.5245E+02 |
| $\alpha_3$ | 1.01E-03 | 6.80E-03 | 5.56E-03 | 1.68E-02 | 0.00E+00 | 1.7384E+00 | 2.5405E+02 |
| $\alpha_4$ | 3.17E-04 | 4.48E-03 | 3.28E-03 | 1.28E-02 | 0.00E+00 | 1.1465E+00 | 2.5464E+02 |
| $\alpha_5$ | 5.04E-05 | 2.77E-03 | 1.63E-03 | 9.37E-03 | 0.00E+00 | 7.0833E-01 | 2.5508E+02 |
| $\alpha_6$ | 8.12E-07 | 1.43E-03 | 4.70E-04 | 6.14E-03 | 0.00E+00 | 3.6696E-01 | 2.5542E+02 |
| $\alpha_7$ | 6.37E-14 | 4.81E-04 | 8.64E-06 | 2.74E-03 | 0.00E+00 | 1.2297E-01 | 2.5567E+02 |
| $\alpha_8$ | 1.19E-42 | 1.29E-04 | 1.84E-12 | 5.47E-04 | 0.00E+00 | 3.3124E-02 | 2.5576E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR High Pressure Safety Injection Motor-Operated Valves

HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 29.60 | 29.60 | 29.60 | 29.60 | 29.60 | 29.60 | 29.60 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.6.3 HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 27.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9536530 | 0.9884680 | 0.9953420 | 0.9999770 | 1.0000000 | 3.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.08E-05 | 1.15E-02 | 4.66E-03 | 4.63E-02 | 0.00E+00 | 4.3452E-01 | 3.7246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9452290 | 0.9809060 | 0.9861230 | 0.9987500 | 1.0000000 | 5.6555E+01 | 1.1009E+00 |
| $\alpha_2$ | 4.57E-04 | 1.45E-02 | 9.36E-03 | 4.59E-02 | 0.00E+00 | 8.3366E-01 | 5.6822E+01 |
| $\alpha_3$ | 1.62E-07 | 4.63E-03 | 9.32E-04 | 2.20E-02 | 0.00E+00 | 2.6722E-01 | 5.7389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9405680 | 0.9752630 | 0.9793590 | 0.9959440 | 1.0000000 | 7.3136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.35E-03 | 1.64E-02 | 1.23E-02 | 4.53E-02 | 0.00E+00 | 1.2281E+00 | 7.3763E+01 |
| $\alpha_3$ | 6.06E-06 | 5.39E-03 | 2.00E-03 | 2.23E-02 | 0.00E+00 | 4.0431E-01 | 7.4587E+01 |
| $\alpha_4$ | 1.28E-08 | 2.97E-03 | 4.06E-04 | 1.49E-02 | 0.00E+00 | 2.2267E-01 | 7.4768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9446120 | 0.9720730 | 0.9745250 | 0.9911590 | 1.0000000 | 1.2316E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.21E-03 | 1.67E-02 | 1.42E-02 | 3.86E-02 | 0.00E+00 | 2.1142E+00 | 1.2458E+02 |
| $\alpha_3$ | 3.76E-04 | 7.71E-03 | 5.33E-03 | 2.32E-02 | 0.00E+00 | 9.7738E-01 | 1.2572E+02 |
| $\alpha_4$ | 1.94E-06 | 2.95E-03 | 9.95E-04 | 1.25E-02 | 0.00E+00 | 3.7439E-01 | 1.2632E+02 |
| $\alpha_5$ | 4.71E-21 | 5.70E-04 | 3.22E-07 | 3.30E-03 | 0.00E+00 | 7.2277E-02 | 1.2663E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9455620 | 0.9711330 | 0.9732300 | 0.9895430 | 1.0000000 | 1.4394E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.10E-03 | 1.51E-02 | 1.30E-02 | 3.44E-02 | 0.00E+00 | 2.2392E+00 | 1.4598E+02 |
| $\alpha_3$ | 5.42E-04 | 7.70E-03 | 5.63E-03 | 2.19E-02 | 0.00E+00 | 1.1418E+00 | 1.4708E+02 |
| $\alpha_4$ | 3.57E-05 | 4.00E-03 | 2.09E-03 | 1.44E-02 | 0.00E+00 | 5.9222E-01 | 1.4763E+02 |
| $\alpha_5$ | 6.26E-09 | 1.50E-03 | 2.03E-04 | 7.51E-03 | 0.00E+00 | 2.2220E-01 | 1.4800E+02 |
| $\alpha_6$ | 9.51E-19 | 5.62E-04 | 9.82E-07 | 3.28E-03 | 0.00E+00 | 8.3237E-02 | 1.4814E+02 |

HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO CLOSE

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9493630 | 0.9703670 | 0.9717960 | 0.9864860 | 1.0000000 | 2.1105E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.00E-03 | 1.42E-02 | 1.27E-02 | 2.94E-02 | 0.00E+00 | 3.0878E+00 | 2.1441E+02 |
| $\alpha_3$ | 1.01E-03 | 7.50E-03 | 6.05E-03 | 1.89E-02 | 0.00E+00 | 1.6312E+00 | 2.1586E+02 |
| $\alpha_4$ | 2.28E-04 | 4.55E-03 | 3.15E-03 | 1.36E-02 | 0.00E+00 | 9.8887E-01 | 2.1651E+02 |
| $\alpha_5$ | 1.18E-05 | 2.40E-03 | 1.14E-03 | 9.07E-03 | 0.00E+00 | 5.2177E-01 | 2.1697E+02 |
| $\alpha_6$ | 3.09E-10 | 8.56E-04 | 7.31E-05 | 4.50E-03 | 0.00E+00 | 1.8628E-01 | 2.1731E+02 |
| $\alpha_7$ | 0.00E+00 | 1.34E-04 | 1.17E-13 | 5.03E-04 | 0.00E+00 | 2.9071E-02 | 2.1747E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9512310 | 0.9705320 | 0.9717610 | 0.9856330 | 1.0000000 | 2.4573E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.97E-03 | 1.32E-02 | 1.20E-02 | 2.68E-02 | 0.00E+00 | 3.3447E+00 | 2.4985E+02 |
| $\alpha_3$ | 1.02E-03 | 6.87E-03 | 5.62E-03 | 1.70E-02 | 0.00E+00 | 1.7384E+00 | 2.5145E+02 |
| $\alpha_4$ | 3.20E-04 | 4.53E-03 | 3.31E-03 | 1.29E-02 | 0.00E+00 | 1.1465E+00 | 2.5204E+02 |
| $\alpha_5$ | 5.09E-05 | 2.80E-03 | 1.64E-03 | 9.47E-03 | 0.00E+00 | 7.0833E-01 | 2.5248E+02 |
| $\alpha_6$ | 8.20E-07 | 1.45E-03 | 4.74E-04 | 6.20E-03 | 0.00E+00 | 3.6696E-01 | 2.5282E+02 |
| $\alpha_7$ | 6.43E-14 | 4.86E-04 | 8.73E-06 | 2.76E-03 | 0.00E+00 | 1.2297E-01 | 2.5307E+02 |
| $\alpha_8$ | 1.21E-42 | 1.31E-04 | 1.86E-12 | 5.53E-04 | 0.00E+00 | 3.3124E-02 | 2.5316E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR High Pressure Safety Injection Motor-Operated Valves

HIGH PRESSURE INJECTION MOTOR OPERATED VALVE FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 | 27.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.3.7 PWR Residual Heat Removal Motor-Operated Valves

## 1.3.7.1 PWR RHR MOV FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 81.80
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9167640 | 0.9790650 | 0.9912550 | 0.9999540 | 0.9992070 | 2.0709E+01 | 4.4282E-01 |
| $\alpha_2$ | 4.29E-05 | 2.09E-02 | 8.74E-03 | 8.32E-02 | 7.93E-04 | 4.4282E-01 | 2.0709E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9310450 | 0.9757070 | 0.9821540 | 0.9983190 | 0.9984070 | 4.5220E+01 | 1.1259E+00 |
| $\alpha_2$ | 6.42E-04 | 1.85E-02 | 1.22E-02 | 5.80E-02 | 1.59E-03 | 8.5866E-01 | 4.5487E+01 |
| $\alpha_3$ | 2.02E-07 | 5.77E-03 | 1.16E-03 | 2.73E-02 | 0.00E+00 | 2.6722E-01 | 4.6079E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9342130 | 0.9723460 | 0.9767860 | 0.9952940 | 0.9976080 | 6.6986E+01 | 1.9051E+00 |
| $\alpha_2$ | 1.66E-03 | 1.86E-02 | 1.41E-02 | 5.06E-02 | 2.39E-03 | 1.2781E+00 | 6.7613E+01 |
| $\alpha_3$ | 6.60E-06 | 5.87E-03 | 2.17E-03 | 2.42E-02 | 0.00E+00 | 4.0431E-01 | 6.8487E+01 |
| $\alpha_4$ | 1.39E-08 | 3.23E-03 | 4.42E-04 | 1.62E-02 | 0.00E+00 | 2.2267E-01 | 6.8668E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9432790 | 0.9712120 | 0.9736770 | 0.9907210 | 0.9968090 | 1.2218E+02 | 3.6215E+00 |
| $\alpha_2$ | 3.52E-03 | 1.75E-02 | 1.50E-02 | 3.99E-02 | 3.19E-03 | 2.1975E+00 | 1.2360E+02 |
| $\alpha_3$ | 3.79E-04 | 7.77E-03 | 5.36E-03 | 2.34E-02 | 0.00E+00 | 9.7738E-01 | 1.2482E+02 |
| $\alpha_4$ | 1.96E-06 | 2.98E-03 | 1.00E-03 | 1.26E-02 | 0.00E+00 | 3.7439E-01 | 1.2543E+02 |
| $\alpha_5$ | 4.74E-21 | 5.75E-04 | 3.25E-07 | 3.32E-03 | 0.00E+00 | 7.2277E-02 | 1.2573E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9459470 | 0.9711260 | 0.9731650 | 0.9893440 | 0.9960060 | 1.4811E+02 | 4.4037E+00 |
| $\alpha_2$ | 3.38E-03 | 1.55E-02 | 1.34E-02 | 3.47E-02 | 3.99E-03 | 2.3642E+00 | 1.5015E+02 |
| $\alpha_3$ | 5.27E-04 | 7.49E-03 | 5.47E-03 | 2.13E-02 | 0.00E+00 | 1.1418E+00 | 1.5137E+02 |
| $\alpha_4$ | 3.47E-05 | 3.88E-03 | 2.03E-03 | 1.40E-02 | 0.00E+00 | 5.9222E-01 | 1.5192E+02 |
| $\alpha_5$ | 6.09E-09 | 1.46E-03 | 1.97E-04 | 7.30E-03 | 0.00E+00 | 2.2220E-01 | 1.5229E+02 |
| $\alpha_6$ | 9.24E-19 | 5.46E-04 | 9.54E-07 | 3.18E-03 | 0.00E+00 | 8.3237E-02 | 1.5243E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9504540 | 0.9708360 | 0.9722060 | 0.9865310 | 0.9952040 | 2.2037E+02 | 6.6200E+00 |
| $\alpha_2$ | 4.24E-03 | 1.44E-02 | 1.30E-02 | 2.93E-02 | 4.80E-03 | 3.2628E+00 | 2.2373E+02 |
| $\alpha_3$ | 9.68E-04 | 7.19E-03 | 5.80E-03 | 1.81E-02 | 0.00E+00 | 1.6312E+00 | 2.2536E+02 |
| $\alpha_4$ | 2.18E-04 | 4.36E-03 | 3.01E-03 | 1.31E-02 | 0.00E+00 | 9.8887E-01 | 2.2600E+02 |
| $\alpha_5$ | 1.13E-05 | 2.30E-03 | 1.09E-03 | 8.69E-03 | 0.00E+00 | 5.2177E-01 | 2.2647E+02 |
| $\alpha_6$ | 2.96E-10 | 8.21E-04 | 7.00E-05 | 4.31E-03 | 0.00E+00 | 1.8628E-01 | 2.2680E+02 |
| $\alpha_7$ | 0.00E+00 | 1.28E-04 | 1.12E-13 | 4.82E-04 | 0.00E+00 | 2.9071E-02 | 2.2696E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9527560 | 0.9712740 | 0.9724380 | 0.9858120 | 0.9944010 | 2.6016E+02 | 7.6943E+00 |
| $\alpha_2$ | 4.23E-03 | 1.34E-02 | 1.22E-02 | 2.66E-02 | 5.60E-03 | 3.5780E+00 | 2.6428E+02 |
| $\alpha_3$ | 9.60E-04 | 6.49E-03 | 5.31E-03 | 1.61E-02 | 0.00E+00 | 1.7384E+00 | 2.6612E+02 |
| $\alpha_4$ | 3.03E-04 | 4.28E-03 | 3.13E-03 | 1.22E-02 | 0.00E+00 | 1.1465E+00 | 2.6671E+02 |
| $\alpha_5$ | 4.81E-05 | 2.64E-03 | 1.55E-03 | 8.95E-03 | 0.00E+00 | 7.0833E-01 | 2.6715E+02 |
| $\alpha_6$ | 7.75E-07 | 1.37E-03 | 4.48E-04 | 5.86E-03 | 0.00E+00 | 3.6696E-01 | 2.6749E+02 |
| $\alpha_7$ | 6.08E-14 | 4.59E-04 | 8.25E-06 | 2.61E-03 | 0.00E+00 | 1.2297E-01 | 2.6773E+02 |
| $\alpha_8$ | 1.14E-42 | 1.24E-04 | 1.76E-12 | 5.23E-04 | 0.00E+00 | 3.3124E-02 | 2.6782E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9992070 | 0.9984070 | 0.9976080 | 0.9968090 | 0.9960060 | 0.9952040 | 0.9944010 |
| $\alpha_2$ | 7.93E-04 | 1.59E-03 | 2.39E-03 | 3.19E-03 | 3.99E-03 | 4.80E-03 | 5.60E-03 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

PWR Residual Heat Removal Motor-Operated Valves

PWR RHR MOV FAIL TO OPEN/CLOSE

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.99E-01 | 9.98E-01 | 9.98E-01 | 9.97E-01 | 9.96E-01 | 9.95E-01 | 9.94E-01 |
| Beta | 7.93E-04 | 1.59E-03 | 2.39E-03 | 3.19E-03 | 3.99E-03 | 4.80E-03 | 5.60E-03 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 10.23 | 15.34 | 20.45 | 25.56 | 30.67 | 35.79 | 40.90 |
| $N_1$ | 0.2333 | 0.3250 | 0.4000 | 0.4583 | 0.5000 | 0.5250 | 0.5333 |
| $N_2$ | 0.0083 | 0.0250 | 0.0500 | 0.0833 | 0.1250 | 0.1750 | 0.2333 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.7.2 PWR RHR MOV FAIL TO OPEN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 54.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9006160 | 0.9749560 | 0.9894760 | 0.9999440 | 0.9988150 | 1.7239E+01 | 4.4282E-01 |
| $\alpha_2$ | 5.17E-05 | 2.50E-02 | 1.05E-02 | 9.94E-02 | 1.19E-03 | 4.4282E-01 | 1.7239E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9224590 | 0.9726370 | 0.9798620 | 0.9981020 | 0.9976170 | 4.0020E+01 | 1.1259E+00 |
| $\alpha_2$ | 7.25E-04 | 2.09E-02 | 1.38E-02 | 6.53E-02 | 2.38E-03 | 8.5866E-01 | 4.0287E+01 |
| $\alpha_3$ | 2.28E-07 | 6.49E-03 | 1.31E-03 | 3.08E-02 | 0.00E+00 | 2.6722E-01 | 4.0879E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9269650 | 0.9692590 | 0.9741650 | 0.9947630 | 0.9964230 | 6.0066E+01 | 1.9051E+00 |
| $\alpha_2$ | 1.85E-03 | 2.06E-02 | 1.57E-02 | 5.61E-02 | 3.58E-03 | 1.2781E+00 | 6.0693E+01 |
| $\alpha_3$ | 7.35E-06 | 6.52E-03 | 2.42E-03 | 2.69E-02 | 0.00E+00 | 4.0431E-01 | 6.1567E+01 |
| $\alpha_4$ | 1.55E-08 | 3.59E-03 | 4.92E-04 | 1.80E-02 | 0.00E+00 | 2.2267E-01 | 6.1748E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9391390 | 0.9690870 | 0.9717170 | 0.9900250 | 0.9952270 | 1.1353E+02 | 3.6215E+00 |
| $\alpha_2$ | 3.78E-03 | 1.88E-02 | 1.61E-02 | 4.29E-02 | 4.77E-03 | 2.1975E+00 | 1.1495E+02 |
| $\alpha_3$ | 4.07E-04 | 8.34E-03 | 5.76E-03 | 2.51E-02 | 0.00E+00 | 9.7738E-01 | 1.1617E+02 |
| $\alpha_4$ | 2.10E-06 | 3.20E-03 | 1.08E-03 | 1.36E-02 | 0.00E+00 | 3.7439E-01 | 1.1678E+02 |
| $\alpha_5$ | 5.09E-21 | 6.17E-04 | 3.49E-07 | 3.57E-03 | 0.00E+00 | 7.2277E-02 | 1.1708E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9420420 | 0.9690180 | 0.9711910 | 0.9885560 | 0.9940230 | 1.3773E+02 | 4.4037E+00 |
| $\alpha_2$ | 3.63E-03 | 1.66E-02 | 1.44E-02 | 3.72E-02 | 5.98E-03 | 2.3642E+00 | 1.3977E+02 |
| $\alpha_3$ | 5.65E-04 | 8.03E-03 | 5.87E-03 | 2.29E-02 | 0.00E+00 | 1.1418E+00 | 1.4099E+02 |
| $\alpha_4$ | 3.72E-05 | 4.17E-03 | 2.18E-03 | 1.50E-02 | 0.00E+00 | 5.9222E-01 | 1.4154E+02 |
| $\alpha_5$ | 6.53E-09 | 1.56E-03 | 2.12E-04 | 7.83E-03 | 0.00E+00 | 2.2220E-01 | 1.4191E+02 |
| $\alpha_6$ | 9.92E-19 | 5.86E-04 | 1.02E-06 | 3.42E-03 | 0.00E+00 | 8.3237E-02 | 1.4205E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9476820 | 0.9691890 | 0.9706330 | 0.9857620 | 0.9928190 | 2.0824E+02 | 6.6200E+00 |
| $\alpha_2$ | 4.48E-03 | 1.52E-02 | 1.37E-02 | 3.09E-02 | 7.18E-03 | 3.2628E+00 | 2.1160E+02 |
| $\alpha_3$ | 1.02E-03 | 7.59E-03 | 6.13E-03 | 1.92E-02 | 0.00E+00 | 1.6312E+00 | 2.1323E+02 |
| $\alpha_4$ | 2.31E-04 | 4.60E-03 | 3.19E-03 | 1.38E-02 | 0.00E+00 | 9.8887E-01 | 2.1387E+02 |
| $\alpha_5$ | 1.19E-05 | 2.43E-03 | 1.15E-03 | 9.18E-03 | 0.00E+00 | 5.2177E-01 | 2.1434E+02 |
| $\alpha_6$ | 3.13E-10 | 8.67E-04 | 7.40E-05 | 4.55E-03 | 0.00E+00 | 1.8628E-01 | 2.1467E+02 |
| $\alpha_7$ | 0.00E+00 | 1.35E-04 | 1.18E-13 | 5.09E-04 | 0.00E+00 | 2.9071E-02 | 2.1483E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9502050 | 0.9697080 | 0.9709320 | 0.9850290 | 0.9916130 | 2.4631E+02 | 7.6943E+00 |
| $\alpha_2$ | 4.47E-03 | 1.41E-02 | 1.28E-02 | 2.80E-02 | 8.39E-03 | 3.5780E+00 | 2.5043E+02 |
| $\alpha_3$ | 1.01E-03 | 6.84E-03 | 5.60E-03 | 1.69E-02 | 0.00E+00 | 1.7384E+00 | 2.5227E+02 |
| $\alpha_4$ | 3.19E-04 | 4.51E-03 | 3.30E-03 | 1.29E-02 | 0.00E+00 | 1.1465E+00 | 2.5286E+02 |
| $\alpha_5$ | 5.08E-05 | 2.79E-03 | 1.64E-03 | 9.44E-03 | 0.00E+00 | 7.0833E-01 | 2.5330E+02 |
| $\alpha_6$ | 8.17E-07 | 1.44E-03 | 4.73E-04 | 6.18E-03 | 0.00E+00 | 3.6696E-01 | 2.5364E+02 |
| $\alpha_7$ | 6.41E-14 | 4.84E-04 | 8.71E-06 | 2.76E-03 | 0.00E+00 | 1.2297E-01 | 2.5388E+02 |
| $\alpha_8$ | 1.20E-42 | 1.30E-04 | 1.86E-12 | 5.51E-04 | 0.00E+00 | 3.3124E-02 | 2.5397E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9988150 | 0.9976170 | 0.9964230 | 0.9952270 | 0.9940230 | 0.9928190 | 0.9916130 |
| $\alpha_2$ | 1.19E-03 | 2.38E-03 | 3.58E-03 | 4.77E-03 | 5.98E-03 | 7.18E-03 | 8.39E-03 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.99E-01 | 9.98E-01 | 9.96E-01 | 9.95E-01 | 9.94E-01 | 9.93E-01 | 9.92E-01 |
| Beta | 1.19E-03 | 2.38E-03 | 3.58E-03 | 4.77E-03 | 5.98E-03 | 7.18E-03 | 8.39E-03 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Residual Heat Removal Motor-Operated Valves

PWR RHR MOV FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 6.76 | 10.14 | 13.53 | 16.91 | 20.29 | 23.67 | 27.05 |
| $N_1$ | 0.2333 | 0.3250 | 0.4000 | 0.4583 | 0.5000 | 0.5250 | 0.5333 |
| $N_2$ | 0.0083 | 0.0250 | 0.0500 | 0.0833 | 0.1250 | 0.1750 | 0.2333 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.3.7.3 PWR RHR MOV FAIL TO CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 25.70
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9520050 | 0.9880560 | 0.9951740 | 0.9999760 | 1.0000000 | 3.5946E+01 | 4.3452E-01 |
| $\alpha_2$ | 2.15E-05 | 1.19E-02 | 4.83E-03 | 4.80E-02 | 0.00E+00 | 4.3452E-01 | 3.5946E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9439790 | 0.9804660 | 0.9857990 | 0.9987200 | 1.0000000 | 5.5255E+01 | 1.1009E+00 |
| $\alpha_2$ | 4.67E-04 | 1.48E-02 | 9.57E-03 | 4.69E-02 | 0.00E+00 | 8.3366E-01 | 5.5522E+01 |
| $\alpha_3$ | 1.66E-07 | 4.74E-03 | 9.54E-04 | 2.25E-02 | 0.00E+00 | 2.6722E-01 | 5.6089E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9395320 | 0.9748260 | 0.9789910 | 0.9958710 | 1.0000000 | 7.1836E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.38E-03 | 1.67E-02 | 1.25E-02 | 4.61E-02 | 0.00E+00 | 1.2281E+00 | 7.2463E+01 |
| $\alpha_3$ | 6.17E-06 | 5.49E-03 | 2.03E-03 | 2.27E-02 | 0.00E+00 | 4.0431E-01 | 7.3287E+01 |
| $\alpha_4$ | 1.30E-08 | 3.02E-03 | 4.13E-04 | 1.51E-02 | 0.00E+00 | 2.2267E-01 | 7.3468E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9440440 | 0.9717840 | 0.9742590 | 0.9910660 | 1.0000000 | 1.2186E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.24E-03 | 1.69E-02 | 1.44E-02 | 3.90E-02 | 0.00E+00 | 2.1142E+00 | 1.2328E+02 |
| $\alpha_3$ | 3.80E-04 | 7.79E-03 | 5.38E-03 | 2.34E-02 | 0.00E+00 | 9.7738E-01 | 1.2442E+02 |
| $\alpha_4$ | 1.96E-06 | 2.99E-03 | 1.00E-03 | 1.27E-02 | 0.00E+00 | 3.7439E-01 | 1.2502E+02 |
| $\alpha_5$ | 4.76E-21 | 5.76E-04 | 3.26E-07 | 3.34E-03 | 0.00E+00 | 7.2277E-02 | 1.2533E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9450850 | 0.9708770 | 0.9729920 | 0.9894500 | 1.0000000 | 1.4264E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.13E-03 | 1.52E-02 | 1.31E-02 | 3.47E-02 | 0.00E+00 | 2.2392E+00 | 1.4468E+02 |
| $\alpha_3$ | 5.47E-04 | 7.77E-03 | 5.68E-03 | 2.21E-02 | 0.00E+00 | 1.1418E+00 | 1.4578E+02 |
| $\alpha_4$ | 3.60E-05 | 4.03E-03 | 2.11E-03 | 1.45E-02 | 0.00E+00 | 5.9222E-01 | 1.4633E+02 |
| $\alpha_5$ | 6.32E-09 | 1.51E-03 | 2.05E-04 | 7.58E-03 | 0.00E+00 | 2.2220E-01 | 1.4670E+02 |
| $\alpha_6$ | 9.59E-19 | 5.67E-04 | 9.91E-07 | 3.31E-03 | 0.00E+00 | 8.3237E-02 | 1.4684E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9490610 | 0.9701890 | 0.9716260 | 0.9864030 | 1.0000000 | 2.0975E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.02E-03 | 1.43E-02 | 1.28E-02 | 2.96E-02 | 0.00E+00 | 3.0878E+00 | 2.1311E+02 |
| $\alpha_3$ | 1.02E-03 | 7.55E-03 | 6.09E-03 | 1.90E-02 | 0.00E+00 | 1.6312E+00 | 2.1456E+02 |
| $\alpha_4$ | 2.29E-04 | 4.57E-03 | 3.17E-03 | 1.37E-02 | 0.00E+00 | 9.8887E-01 | 2.1521E+02 |
| $\alpha_5$ | 1.19E-05 | 2.41E-03 | 1.14E-03 | 9.12E-03 | 0.00E+00 | 5.2177E-01 | 2.1567E+02 |
| $\alpha_6$ | 3.11E-10 | 8.62E-04 | 7.36E-05 | 4.52E-03 | 0.00E+00 | 1.8628E-01 | 2.1601E+02 |
| $\alpha_7$ | 0.00E+00 | 1.34E-04 | 1.18E-13 | 5.06E-04 | 0.00E+00 | 2.9071E-02 | 2.1617E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9509820 | 0.9703800 | 0.9716150 | 0.9855530 | 1.0000000 | 2.4443E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.99E-03 | 1.33E-02 | 1.20E-02 | 2.69E-02 | 0.00E+00 | 3.3447E+00 | 2.4855E+02 |
| $\alpha_3$ | 1.02E-03 | 6.90E-03 | 5.65E-03 | 1.71E-02 | 0.00E+00 | 1.7384E+00 | 2.5015E+02 |
| $\alpha_4$ | 3.22E-04 | 4.55E-03 | 3.33E-03 | 1.30E-02 | 0.00E+00 | 1.1465E+00 | 2.5074E+02 |
| $\alpha_5$ | 5.12E-05 | 2.81E-03 | 1.65E-03 | 9.52E-03 | 0.00E+00 | 7.0833E-01 | 2.5118E+02 |
| $\alpha_6$ | 8.24E-07 | 1.46E-03 | 4.77E-04 | 6.23E-03 | 0.00E+00 | 3.6696E-01 | 2.5152E+02 |
| $\alpha_7$ | 6.46E-14 | 4.88E-04 | 8.78E-06 | 2.78E-03 | 0.00E+00 | 1.2297E-01 | 2.5177E+02 |
| $\alpha_8$ | 1.21E-42 | 1.32E-04 | 1.87E-12 | 5.56E-04 | 0.00E+00 | 3.3124E-02 | 2.5186E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Residual Heat Removal Motor-Operated Valves

PWR RHR MOV FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 25.70 | 25.70 | 25.70 | 25.70 | 25.70 | 25.70 | 25.70 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.3.8 BWR High Pressure Coolant Injection and Reactor Core Isolation Cooling Motor-Operated Valves

## 1.3.8.1 COMBINED HPCI/RCIC MOTOR OPERATED VALVE FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 71.90
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9529140 | 0.9877530 | 0.9944270 | 0.9999520 | 0.9980650 | 3.9642E+01 | 4.9152E-01 |
| $\alpha_2$ | 4.48E-05 | 1.22E-02 | 5.58E-03 | 4.71E-02 | 1.94E-03 | 4.9152E-01 | 3.9642E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9538960 | 0.9831950 | 0.9872700 | 0.9985460 | 0.9964760 | 7.3501E+01 | 1.2563E+00 |
| $\alpha_2$ | 6.50E-04 | 1.31E-02 | 9.11E-03 | 3.93E-02 | 3.35E-03 | 9.8126E-01 | 7.3776E+01 |
| $\alpha_3$ | 1.72E-07 | 3.68E-03 | 7.78E-04 | 1.73E-02 | 1.77E-04 | 2.7502E-01 | 7.4482E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9538620 | 0.9799650 | 0.9828840 | 0.9960920 | 0.9951860 | 1.0456E+02 | 2.1377E+00 |
| $\alpha_2$ | 1.62E-03 | 1.39E-02 | 1.10E-02 | 3.61E-02 | 4.33E-03 | 1.4825E+00 | 1.0522E+02 |
| $\alpha_3$ | 6.89E-06 | 4.04E-03 | 1.60E-03 | 1.63E-02 | 4.63E-04 | 4.3151E-01 | 1.0627E+02 |
| $\alpha_4$ | 9.53E-09 | 2.10E-03 | 2.89E-04 | 1.05E-02 | 1.70E-05 | 2.2367E-01 | 1.0647E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9559310 | 0.9771560 | 0.9789690 | 0.9921840 | 0.9943590 | 1.6903E+02 | 3.9517E+00 |
| $\alpha_2$ | 3.23E-03 | 1.42E-02 | 1.24E-02 | 3.14E-02 | 4.69E-03 | 2.4579E+00 | 1.7052E+02 |
| $\alpha_3$ | 3.43E-04 | 6.02E-03 | 4.26E-03 | 1.77E-02 | 8.75E-04 | 1.0415E+00 | 1.7194E+02 |
| $\alpha_4$ | 1.60E-06 | 2.20E-03 | 7.51E-04 | 9.28E-03 | 7.37E-05 | 3.7979E-01 | 1.7260E+02 |
| $\alpha_5$ | 3.86E-21 | 4.19E-04 | 2.42E-07 | 2.42E-03 | 2.73E-06 | 7.2477E-02 | 1.7291E+02 |

COMBINED HPCI/RCIC MOTOR OPERATED VALVE FAIL TO OPEN/CLOSE

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9576620 | 0.9769000 | 0.9784080 | 0.9910010 | 0.9937330 | 2.0422E+02 | 4.8291E+00 |
| $\alpha_2$ | 3.14E-03 | 1.27E-02 | 1.12E-02 | 2.75E-02 | 4.84E-03 | 2.6645E+00 | 2.0638E+02 |
| $\alpha_3$ | 5.07E-04 | 5.98E-03 | 4.50E-03 | 1.65E-02 | 1.24E-03 | 1.2506E+00 | 2.0780E+02 |
| $\alpha_4$ | 2.89E-05 | 2.91E-03 | 1.55E-03 | 1.04E-02 | 1.73E-04 | 6.0742E-01 | 2.0844E+02 |
| $\alpha_5$ | 4.74E-09 | 1.07E-03 | 1.46E-04 | 5.34E-03 | 1.25E-05 | 2.2330E-01 | 2.0883E+02 |
| $\alpha_6$ | 6.74E-19 | 3.98E-04 | 6.96E-07 | 2.32E-03 | 0.00E+00 | 8.3237E-02 | 2.0897E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9980650 | 0.9964760 | 0.9951860 | 0.9943590 | 0.9937330 |
| $\alpha_2$ | 1.94E-03 | 3.35E-03 | 4.33E-03 | 4.69E-03 | 4.84E-03 |
| $\alpha_3$ | | 1.77E-04 | 4.63E-04 | 8.75E-04 | 1.24E-03 |
| $\alpha_4$ | | | 1.70E-05 | 7.37E-05 | 1.73E-04 |
| $\alpha_5$ | | | | 2.73E-06 | 1.25E-05 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.98E-01 | 9.96E-01 | 9.95E-01 | 9.94E-01 | 9.94E-01 |
| Beta | 1.94E-03 | 3.52E-03 | 4.81E-03 | 5.64E-03 | 6.27E-03 |
| Gamma | | 5.02E-02 | 9.98E-02 | 1.69E-01 | 2.27E-01 |
| Delta | | | 3.55E-02 | 8.03E-02 | 1.30E-01 |
| Epsilon | | | | 3.57E-02 | 6.75E-02 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 28.76 | 43.14 | 57.52 | 71.90 | 86.28 |
| $N_1$ | 0.6360 | 0.8064 | 0.9056 | 0.9685 | 0.9977 |
| $N_2$ | 0.0570 | 0.1476 | 0.2544 | 0.3437 | 0.4253 |
| $N_3$ | | 0.0078 | 0.0272 | 0.0641 | 0.1088 |
| $N_4$ | | | 0.0010 | 0.0054 | 0.0152 |
| $N_5$ | | | | 0.0002 | 0.0011 |
| $N_6$ | | | | | 0.0000 |

## 1.3.8.2 COMBINED HPCI AND RCIC MOTOR OPERATED VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 34.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9211970 | 0.9802910 | 0.9919000 | 0.9999600 | 0.9998260 | 2.1712E+01 | 4.3652E-01 |
| $\alpha_2$ | 3.70E-05 | 1.97E-02 | 8.10E-03 | 7.88E-02 | 1.74E-04 | 4.3652E-01 | 2.1712E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9339130 | 0.9768680 | 0.9831150 | 0.9984570 | 0.9996510 | 4.6743E+01 | 1.1069E+00 |
| $\alpha_2$ | 5.68E-04 | 1.75E-02 | 1.14E-02 | 5.54E-02 | 3.43E-04 | 8.3956E-01 | 4.7010E+01 |
| $\alpha_3$ | 1.96E-07 | 5.59E-03 | 1.13E-03 | 2.65E-02 | 5.82E-06 | 2.6732E-01 | 4.7583E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9369260 | 0.9736750 | 0.9779950 | 0.9956430 | 0.9994940 | 6.9043E+01 | 1.8667E+00 |
| $\alpha_2$ | 1.47E-03 | 1.75E-02 | 1.32E-02 | 4.82E-02 | 4.97E-04 | 1.2395E+00 | 6.9670E+01 |
| $\alpha_3$ | 6.44E-06 | 5.70E-03 | 2.11E-03 | 2.36E-02 | 8.73E-06 | 4.0451E-01 | 7.0505E+01 |
| $\alpha_4$ | 1.35E-08 | 3.14E-03 | 4.30E-04 | 1.57E-02 | 0.00E+00 | 2.2267E-01 | 7.0687E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9451060 | 0.9722840 | 0.9747050 | 0.9911900 | 0.9993370 | 1.2479E+02 | 3.5572E+00 |
| $\alpha_2$ | 3.23E-03 | 1.66E-02 | 1.42E-02 | 3.83E-02 | 6.46E-04 | 2.1327E+00 | 1.2621E+02 |
| $\alpha_3$ | 3.72E-04 | 7.62E-03 | 5.26E-03 | 2.29E-02 | 1.75E-05 | 9.7788E-01 | 1.2737E+02 |
| $\alpha_4$ | 1.92E-06 | 2.92E-03 | 9.82E-04 | 1.24E-02 | 0.00E+00 | 3.7439E-01 | 1.2797E+02 |
| $\alpha_5$ | 4.65E-21 | 5.63E-04 | 3.18E-07 | 3.26E-03 | 0.00E+00 | 7.2277E-02 | 1.2827E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9478660 | 0.9723200 | 0.9743230 | 0.9899360 | 0.9991850 | 1.5128E+02 | 4.3067E+00 |
| $\alpha_2$ | 3.03E-03 | 1.46E-02 | 1.25E-02 | 3.30E-02 | 7.86E-04 | 2.2662E+00 | 1.5332E+02 |
| $\alpha_3$ | 5.18E-04 | 7.35E-03 | 5.37E-03 | 2.09E-02 | 2.91E-05 | 1.1428E+00 | 1.5444E+02 |
| $\alpha_4$ | 3.40E-05 | 3.81E-03 | 1.99E-03 | 1.37E-02 | 0.00E+00 | 5.9222E-01 | 1.5499E+02 |
| $\alpha_5$ | 5.97E-09 | 1.43E-03 | 1.94E-04 | 7.15E-03 | 0.00E+00 | 2.2220E-01 | 1.5536E+02 |
| $\alpha_6$ | 9.06E-19 | 5.35E-04 | 9.35E-07 | 3.12E-03 | 0.00E+00 | 8.3237E-02 | 1.5550E+02 |

COMBINED HPCI AND RCIC MOTOR OPERATED VALVE FAIL TO OPEN

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9998260 | 0.9996510 | 0.9994940 | 0.9993370 | 0.9991850 |
| $\alpha_2$ | 1.74E-04 | 3.43E-04 | 4.97E-04 | 6.46E-04 | 7.86E-04 |
| $\alpha_3$ | | 5.82E-06 | 8.73E-06 | 1.75E-05 | 2.91E-05 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 9.99E-01 | 9.99E-01 | 9.99E-01 |
| Beta | 1.74E-04 | 3.49E-04 | 5.06E-04 | 6.63E-04 | 8.15E-04 |
| Gamma | | 1.67E-02 | 1.72E-02 | 2.63E-02 | 3.57E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 11.37 | 17.05 | 22.73 | 28.42 | 34.10 |
| $N_1$ | 0.0960 | 0.1382 | 0.1766 | 0.2115 | 0.2430 |
| $N_2$ | 0.0020 | 0.0059 | 0.0114 | 0.0185 | 0.0270 |
| $N_3$ | | 0.0001 | 0.0002 | 0.0005 | 0.0010 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.3.8.3 COMBINED HPCI AND RCIC MOTOR OPERATED VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 33.80
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9332640 | 0.9826260 | 0.9920650 | 0.9999340 | 0.9968560 | 2.7686E+01 | 4.8952E-01 |
| $\alpha_2$ | 6.27E-05 | 1.74E-02 | 7.93E-03 | 6.67E-02 | 3.14E-03 | 4.8952E-01 | 2.7686E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9396830 | 0.9779940 | 0.9833130 | 0.9981060 | 0.9942830 | 5.5573E+01 | 1.2505E+00 |
| $\alpha_2$ | 8.41E-04 | 1.72E-02 | 1.19E-02 | 5.14E-02 | 5.42E-03 | 9.7546E-01 | 5.5848E+01 |
| $\alpha_3$ | 2.27E-07 | 4.84E-03 | 1.03E-03 | 2.28E-02 | 2.98E-04 | 2.7502E-01 | 5.6548E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9409100 | 0.9743200 | 0.9780420 | 0.9950040 | 0.9922130 | 8.0665E+01 | 2.1261E+00 |
| $\alpha_2$ | 2.05E-03 | 1.78E-02 | 1.41E-02 | 4.62E-02 | 6.98E-03 | 1.4711E+00 | 8.1320E+01 |
| $\alpha_3$ | 8.86E-06 | 5.21E-03 | 2.07E-03 | 2.10E-02 | 7.76E-04 | 4.3131E-01 | 8.2360E+01 |
| $\alpha_4$ | 1.23E-08 | 2.70E-03 | 3.73E-04 | 1.35E-02 | 2.87E-05 | 2.2367E-01 | 8.2567E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9470050 | 0.9725190 | 0.9746940 | 0.9906040 | 0.9909130 | 1.3917E+02 | 3.9327E+00 |
| $\alpha_2$ | 3.85E-03 | 1.70E-02 | 1.49E-02 | 3.78E-02 | 7.49E-03 | 2.4394E+00 | 1.4066E+02 |
| $\alpha_3$ | 4.14E-04 | 7.27E-03 | 5.14E-03 | 2.14E-02 | 1.47E-03 | 1.0410E+00 | 1.4206E+02 |
| $\alpha_4$ | 1.93E-06 | 2.65E-03 | 9.09E-04 | 1.12E-02 | 1.24E-04 | 3.7979E-01 | 1.4272E+02 |
| $\alpha_5$ | 4.67E-21 | 5.06E-04 | 2.93E-07 | 2.93E-03 | 4.61E-06 | 7.2477E-02 | 1.4303E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9491920 | 0.9722790 | 0.9740810 | 0.9892130 | 0.9899490 | 1.6839E+02 | 4.8011E+00 |
| $\alpha_2$ | 3.71E-03 | 1.52E-02 | 1.34E-02 | 3.30E-02 | 7.66E-03 | 2.6375E+00 | 1.7055E+02 |
| $\alpha_3$ | 6.12E-04 | 7.22E-03 | 5.43E-03 | 1.99E-02 | 2.07E-03 | 1.2496E+00 | 1.7194E+02 |
| $\alpha_4$ | 3.49E-05 | 3.51E-03 | 1.87E-03 | 1.25E-02 | 2.92E-04 | 6.0742E-01 | 1.7258E+02 |
| $\alpha_5$ | 5.73E-09 | 1.29E-03 | 1.77E-04 | 6.45E-03 | 2.12E-05 | 2.2330E-01 | 1.7297E+02 |
| $\alpha_6$ | 8.13E-19 | 4.81E-04 | 8.40E-07 | 2.80E-03 | 0.00E+00 | 8.3237E-02 | 1.7311E+02 |

COMBINED HPCI AND RCIC MOTOR OPERATED VALVE FAIL TO CLOSE

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9968560 | 0.9942830 | 0.9922130 | 0.9909130 | 0.9899490 |
| $\alpha_2$ | 3.14E-03 | 5.42E-03 | 6.98E-03 | 7.49E-03 | 7.66E-03 |
| $\alpha_3$ | | 2.98E-04 | 7.76E-04 | 1.47E-03 | 2.07E-03 |
| $\alpha_4$ | | | 2.87E-05 | 1.24E-04 | 2.92E-04 |
| $\alpha_5$ | | | | 4.61E-06 | 2.12E-05 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.97E-01 | 9.94E-01 | 9.92E-01 | 9.91E-01 | 9.90E-01 |
| Beta | 3.14E-03 | 5.72E-03 | 7.79E-03 | 9.09E-03 | 1.01E-02 |
| Gamma | | 5.21E-02 | 1.03E-01 | 1.75E-01 | 2.38E-01 |
| Delta | | | 3.57E-02 | 8.09E-02 | 1.31E-01 |
| Epsilon | | | | 3.57E-02 | 6.75E-02 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 16.90 | 25.35 | 33.80 | 42.25 | 50.70 |
| $N_1$ | 0.5400 | 0.6683 | 0.7290 | 0.7570 | 0.7547 |
| $N_2$ | 0.0550 | 0.1418 | 0.2430 | 0.3252 | 0.3983 |
| $N_3$ | | 0.0078 | 0.0270 | 0.0636 | 0.1078 |
| $N_4$ | | | 0.0010 | 0.0054 | 0.0152 |
| $N_5$ | | | | 0.0002 | 0.0011 |
| $N_6$ | | | | | 0.0000 |

# 1.3.9 Pressurizer PORV Motor-Operated Block Valves

## 1.3.9.1 PRESSURIZER PORV BLOCK MOVS FAIL TO OPEN

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 4.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8819910 | 0.9704020 | 0.9877120 | 0.9999410 | 1.0000000 | 1.4246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.49E-05 | 2.96E-02 | 1.23E-02 | 1.18E-01 | 0.00E+00 | 4.3452E-01 | 1.4246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9094830 | 0.9682340 | 0.9767350 | 0.9978890 | 1.0000000 | 3.3555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.68E-04 | 2.41E-02 | 1.57E-02 | 7.59E-02 | 0.00E+00 | 8.3366E-01 | 3.3822E+01 |
| $\alpha_3$ | 2.71E-07 | 7.71E-03 | 1.56E-03 | 3.66E-02 | 0.00E+00 | 2.6722E-01 | 3.4389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9147120 | 0.9643190 | 0.9701040 | 0.9941100 | 1.0000000 | 5.0136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.96E-03 | 2.36E-02 | 1.78E-02 | 6.51E-02 | 0.00E+00 | 1.2281E+00 | 5.0763E+01 |
| $\alpha_3$ | 8.78E-06 | 7.78E-03 | 2.89E-03 | 3.21E-02 | 0.00E+00 | 4.0431E-01 | 5.1587E+01 |
| $\alpha_4$ | 1.85E-08 | 4.28E-03 | 5.88E-04 | 2.15E-02 | 0.00E+00 | 2.2267E-01 | 5.1768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

Pressurizer PORV Motor-Operated Block Valves

PRESSURIZER PORV BLOCK MOVS FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 4.00 | 4.00 | 4.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.3.9.2 PRESSURIZER PORV BLOCK MOVS FAIL TO CLOSE

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Motor Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 4.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8819910 | 0.9704020 | 0.9877120 | 0.9999410 | 1.0000000 | 1.4246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.49E-05 | 2.96E-02 | 1.23E-02 | 1.18E-01 | 0.00E+00 | 4.3452E-01 | 1.4246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9094830 | 0.9682340 | 0.9767350 | 0.9978890 | 1.0000000 | 3.3555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.68E-04 | 2.41E-02 | 1.57E-02 | 7.59E-02 | 0.00E+00 | 8.3366E-01 | 3.3822E+01 |
| $\alpha_3$ | 2.71E-07 | 7.71E-03 | 1.56E-03 | 3.66E-02 | 0.00E+00 | 2.6722E-01 | 3.4389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9147120 | 0.9643190 | 0.9701040 | 0.9941100 | 1.0000000 | 5.0136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.96E-03 | 2.36E-02 | 1.78E-02 | 6.51E-02 | 0.00E+00 | 1.2281E+00 | 5.0763E+01 |
| $\alpha_3$ | 8.78E-06 | 7.78E-03 | 2.89E-03 | 3.21E-02 | 0.00E+00 | 4.0431E-01 | 5.1587E+01 |
| $\alpha_4$ | 1.85E-08 | 4.28E-03 | 5.88E-04 | 2.15E-02 | 0.00E+00 | 2.2267E-01 | 5.1768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

Pressurizer PORV Motor-Operated Block Valves

PRESSURIZER PORV BLOCK MOVS FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 4.00 | 4.00 | 4.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

# 1.4 Air Operated Valves

## 1.4.1 Pooled Air Operated Valves

### 1.4.1.1 AOV FAIL TO OPEN/CLOSE ALL SYSTEMS SPAR: AOV-FO

**Component :** Air Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 213.10
Total Number of Common-Cause Failure Events: 11

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9331610 | 0.9644210 | 0.9669510 | 0.9870220 | 0.9649150 | 1.1670E+02 | 4.3052E+00 |
| $\alpha_2$ | 1.30E-02 | 3.56E-02 | 3.30E-02 | 6.68E-02 | 3.51E-02 | 4.3052E+00 | 1.1670E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9395680 | 0.9639620 | 0.9655560 | 0.9829220 | 0.9639370 | 1.8625E+02 | 6.9630E+00 |
| $\alpha_2$ | 8.13E-03 | 2.24E-02 | 2.07E-02 | 4.22E-02 | 2.15E-02 | 4.3208E+00 | 1.8889E+02 |
| $\alpha_3$ | 3.34E-03 | 1.37E-02 | 1.20E-02 | 2.96E-02 | 1.46E-02 | 2.6422E+00 | 1.9057E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9441460 | 0.9646650 | 0.9658430 | 0.9811630 | 0.9654090 | 2.5299E+02 | 9.2669E+00 |
| $\alpha_2$ | 6.80E-03 | 1.78E-02 | 1.66E-02 | 3.30E-02 | 1.61E-02 | 4.6774E+00 | 2.5758E+02 |
| $\alpha_3$ | 2.48E-03 | 1.01E-02 | 8.90E-03 | 2.19E-02 | 1.05E-02 | 2.6543E+00 | 2.5960E+02 |
| $\alpha_4$ | 1.26E-03 | 7.38E-03 | 6.17E-03 | 1.76E-02 | 7.99E-03 | 1.9352E+00 | 2.6032E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9503400 | 0.9670030 | 0.9678490 | 0.9807730 | 0.9679380 | 3.5335E+02 | 1.2057E+01 |
| $\alpha_2$ | 6.94E-03 | 1.60E-02 | 1.52E-02 | 2.81E-02 | 1.41E-02 | 5.8612E+00 | 3.5955E+02 |
| $\alpha_3$ | 1.70E-03 | 7.10E-03 | 6.23E-03 | 1.55E-02 | 6.09E-03 | 2.5952E+00 | 3.6281E+02 |
| $\alpha_4$ | 1.64E-03 | 6.98E-03 | 6.11E-03 | 1.53E-02 | 8.20E-03 | 2.5523E+00 | 3.6286E+02 |
| $\alpha_5$ | 1.66E-04 | 2.87E-03 | 2.03E-03 | 8.44E-03 | 3.67E-03 | 1.0486E+00 | 3.6436E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9543330 | 0.9690370 | 0.9697520 | 0.9813110 | 0.9706940 | 4.2465E+02 | 1.3568E+01 |
| $\alpha_2$ | 5.92E-03 | 1.36E-02 | 1.28E-02 | 2.37E-02 | 1.17E-02 | 5.9523E+00 | 4.3227E+02 |
| $\alpha_3$ | 1.56E-03 | 6.23E-03 | 5.49E-03 | 1.34E-02 | 5.01E-03 | 2.7294E+00 | 4.3549E+02 |
| $\alpha_4$ | 1.06E-03 | 5.16E-03 | 4.43E-03 | 1.18E-02 | 5.26E-03 | 2.2610E+00 | 4.3596E+02 |
| $\alpha_5$ | 7.75E-04 | 4.47E-03 | 3.74E-03 | 1.07E-02 | 5.48E-03 | 1.9584E+00 | 4.3626E+02 |
| $\alpha_6$ | 2.22E-05 | 1.52E-03 | 8.62E-04 | 5.27E-03 | 1.84E-03 | 6.6734E-01 | 4.3755E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9585020 | 0.9710430 | 0.9716070 | 0.9816660 | 0.9735660 | 5.4252E+02 | 1.6178E+01 |
| $\alpha_2$ | 5.23E-03 | 1.15E-02 | 1.10E-02 | 1.98E-02 | 9.12E-03 | 6.4461E+00 | 5.5225E+02 |
| $\alpha_3$ | 1.83E-03 | 6.05E-03 | 5.47E-03 | 1.23E-02 | 4.75E-03 | 3.3814E+00 | 5.5532E+02 |
| $\alpha_4$ | 8.93E-04 | 4.18E-03 | 3.61E-03 | 9.43E-03 | 3.66E-03 | 2.3358E+00 | 5.5636E+02 |
| $\alpha_5$ | 7.40E-04 | 3.83E-03 | 3.25E-03 | 8.88E-03 | 4.39E-03 | 2.1388E+00 | 5.5656E+02 |
| $\alpha_6$ | 3.03E-04 | 2.65E-03 | 2.08E-03 | 6.92E-03 | 3.51E-03 | 1.4781E+00 | 5.5722E+02 |
| $\alpha_7$ | 7.14E-07 | 7.12E-04 | 2.57E-04 | 2.96E-03 | 1.00E-03 | 3.9797E-01 | 5.5830E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9613450 | 0.9726590 | 0.9731440 | 0.9823110 | 0.9757040 | 6.2789E+02 | 1.7650E+01 |
| $\alpha_2$ | 4.62E-03 | 1.01E-02 | 9.63E-03 | 1.74E-02 | 7.62E-03 | 6.5394E+00 | 6.3900E+02 |
| $\alpha_3$ | 1.71E-03 | 5.47E-03 | 4.97E-03 | 1.10E-02 | 4.28E-03 | 3.5340E+00 | 6.4201E+02 |
| $\alpha_4$ | 8.15E-04 | 3.71E-03 | 3.21E-03 | 8.31E-03 | 2.98E-03 | 2.3957E+00 | 6.4314E+02 |
| $\alpha_5$ | 5.75E-04 | 3.16E-03 | 2.66E-03 | 7.43E-03 | 3.17E-03 | 2.0367E+00 | 6.4350E+02 |
| $\alpha_6$ | 4.32E-04 | 2.79E-03 | 2.30E-03 | 6.83E-03 | 3.42E-03 | 1.8007E+00 | 6.4374E+02 |
| $\alpha_7$ | 9.84E-05 | 1.65E-03 | 1.17E-03 | 4.83E-03 | 2.24E-03 | 1.0642E+00 | 6.4448E+02 |
| $\alpha_8$ | 2.32E-08 | 4.32E-04 | 9.32E-05 | 2.02E-03 | 5.86E-04 | 2.7902E-01 | 6.4526E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9649150 | 0.9639370 | 0.9654090 | 0.9679380 | 0.9706940 | 0.9735660 | 0.9757040 |
| $\alpha_2$ | 3.51E-02 | 2.15E-02 | 1.61E-02 | 1.41E-02 | 1.17E-02 | 9.12E-03 | 7.62E-03 |
| $\alpha_3$ | | 1.46E-02 | 1.05E-02 | 6.09E-03 | 5.01E-03 | 4.75E-03 | 4.28E-03 |
| $\alpha_4$ | | | 7.99E-03 | 8.20E-03 | 5.26E-03 | 3.66E-03 | 2.98E-03 |
| $\alpha_5$ | | | | 3.67E-03 | 5.48E-03 | 4.39E-03 | 3.17E-03 |
| $\alpha_6$ | | | | | 1.84E-03 | 3.51E-03 | 3.42E-03 |
| $\alpha_7$ | | | | | | 1.00E-03 | 2.24E-03 |
| $\alpha_8$ | | | | | | | 5.86E-04 |

Pooled Air Operated Valves

AOV FAIL TO OPEN/CLOSE ALL SYSTEMS SPAR: AOV-FO

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.65E-01 | 9.64E-01 | 9.65E-01 | 9.68E-01 | 9.71E-01 | 9.74E-01 | 9.76E-01 |
| Beta | 3.51E-02 | 3.61E-02 | 3.46E-02 | 3.21E-02 | 2.93E-02 | 2.64E-02 | 2.43E-02 |
| Gamma | | 4.05E-01 | 5.35E-01 | 5.60E-01 | 6.00E-01 | 6.55E-01 | 6.86E-01 |
| Delta | | | 4.32E-01 | 6.61E-01 | 7.15E-01 | 7.25E-01 | 7.43E-01 |
| Epsilon | | | | 3.10E-01 | 5.82E-01 | 7.09E-01 | 7.60E-01 |
| Mu | | | | | 2.52E-01 | 5.07E-01 | 6.64E-01 |
| Upsilon | | | | | | 2.22E-01 | 4.53E-01 |
| Sigma | | | | | | | 2.07E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 101.96 | 152.94 | 203.92 | 254.90 | 305.89 | 356.87 | 407.85 |
| $N_1$ | 4.4919 | 3.7507 | 2.9348 | 2.2845 | 1.8163 | 1.6020 | 1.3101 |
| $N_2$ | 3.8707 | 3.4871 | 3.4493 | 3.7470 | 3.7131 | 3.3583 | 3.1947 |
| $N_3$ | | 2.3750 | 2.2500 | 1.6178 | 1.5876 | 1.7502 | 1.7956 |
| $N_4$ | | | 1.7125 | 2.1779 | 1.6688 | 1.3469 | 1.2492 |
| $N_5$ | | | | 0.9763 | 1.7362 | 1.6170 | 1.3284 |
| $N_6$ | | | | | 0.5841 | 1.2918 | 1.4337 |
| $N_7$ | | | | | | 0.3689 | 0.9412 |
| $N_8$ | | | | | | | 0.2459 |

## 1.4.1.2 AOV FAIL TO OPEN ALL SYSTEMS SPAR: AOV-CC

| | |
|---|---|
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 126.20
Total Number of Common-Cause Failure Events: 5

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9375960 | 0.9739420 | 0.9782130 | 0.9956770 | 0.9764990 | 6.9901E+01 | 1.8702E+00 |
| $\alpha_2$ | 4.32E-03 | 2.61E-02 | 2.18E-02 | 6.24E-02 | 2.35E-02 | 1.8702E+00 | 6.9901E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9466770 | 0.9739610 | 0.9765260 | 0.9924820 | 0.9772990 | 1.1812E+02 | 3.1580E+00 |
| $\alpha_2$ | 3.90E-03 | 1.87E-02 | 1.61E-02 | 4.23E-02 | 1.58E-02 | 2.2658E+00 | 1.1901E+02 |
| $\alpha_3$ | 2.81E-04 | 7.36E-03 | 4.89E-03 | 2.29E-02 | 6.90E-03 | 8.9222E-01 | 1.2039E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9487750 | 0.9722600 | 0.9741180 | 0.9894030 | 0.9766300 | 1.6322E+02 | 4.6569E+00 |
| $\alpha_2$ | 4.82E-03 | 1.77E-02 | 1.58E-02 | 3.70E-02 | 1.45E-02 | 2.9674E+00 | 1.6491E+02 |
| $\alpha_3$ | 4.95E-04 | 6.88E-03 | 5.04E-03 | 1.95E-02 | 6.26E-03 | 1.1543E+00 | 1.6672E+02 |
| $\alpha_4$ | 1.78E-05 | 3.19E-03 | 1.54E-03 | 1.19E-02 | 2.61E-03 | 5.3517E-01 | 1.6734E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9525320 | 0.9716860 | 0.9729390 | 0.9865490 | 0.9764870 | 2.4164E+02 | 7.0413E+00 |
| $\alpha_2$ | 5.91E-03 | 1.67E-02 | 1.54E-02 | 3.19E-02 | 1.37E-02 | 4.1588E+00 | 2.4452E+02 |
| $\alpha_3$ | 1.05E-03 | 7.03E-03 | 5.76E-03 | 1.74E-02 | 5.17E-03 | 1.7482E+00 | 2.4693E+02 |
| $\alpha_4$ | 1.45E-04 | 3.64E-03 | 2.43E-03 | 1.13E-02 | 3.57E-03 | 9.0569E-01 | 2.4778E+02 |
| $\alpha_5$ | 5.45E-09 | 9.19E-04 | 1.33E-04 | 4.57E-03 | 1.05E-03 | 2.2858E-01 | 2.4845E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9540270 | 0.9714330 | 0.9724760 | 0.9852710 | 0.9760190 | 2.9059E+02 | 8.5453E+00 |
| $\alpha_2$ | 6.07E-03 | 1.58E-02 | 1.48E-02 | 2.92E-02 | 1.40E-02 | 4.7315E+00 | 2.9440E+02 |
| $\alpha_3$ | 1.02E-03 | 6.25E-03 | 5.19E-03 | 1.51E-02 | 4.10E-03 | 1.8710E+00 | 2.9726E+02 |
| $\alpha_4$ | 3.25E-04 | 4.06E-03 | 3.03E-03 | 1.13E-02 | 3.50E-03 | 1.2155E+00 | 2.9792E+02 |
| $\alpha_5$ | 1.38E-05 | 1.89E-03 | 9.56E-04 | 6.95E-03 | 1.93E-03 | 5.6600E-01 | 2.9857E+02 |
| $\alpha_6$ | 1.84E-11 | 5.39E-04 | 2.92E-05 | 2.93E-03 | 4.39E-04 | 1.6134E-01 | 2.9897E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9571200 | 0.9719440 | 0.9727350 | 0.9840790 | 0.9772650 | 3.8614E+02 | 1.1146E+01 |
| $\alpha_2$ | 5.88E-03 | 1.40E-02 | 1.32E-02 | 2.48E-02 | 1.19E-02 | 5.5565E+00 | 3.9173E+02 |
| $\alpha_3$ | 1.46E-03 | 6.32E-03 | 5.51E-03 | 1.39E-02 | 4.25E-03 | 2.5097E+00 | 3.9478E+02 |
| $\alpha_4$ | 5.37E-04 | 4.06E-03 | 3.27E-03 | 1.03E-02 | 3.02E-03 | 1.6142E+00 | 3.9567E+02 |
| $\alpha_5$ | 1.30E-04 | 2.52E-03 | 1.75E-03 | 7.53E-03 | 2.32E-03 | 1.0007E+00 | 3.9629E+02 |
| $\alpha_6$ | 9.90E-07 | 1.00E-03 | 3.60E-04 | 4.16E-03 | 1.02E-03 | 3.9718E-01 | 3.9689E+02 |
| $\alpha_7$ | 1.23E-22 | 1.72E-04 | 5.74E-08 | 9.84E-04 | 1.89E-04 | 6.8171E-02 | 3.9722E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9591840 | 0.9726970 | 0.9733780 | 0.9838890 | 0.9781510 | 4.4918E+02 | 1.2608E+01 |
| $\alpha_2$ | 5.52E-03 | 1.27E-02 | 1.20E-02 | 2.23E-02 | 1.08E-02 | 5.8813E+00 | 4.5591E+02 |
| $\alpha_3$ | 1.45E-03 | 5.84E-03 | 5.15E-03 | 1.26E-02 | 4.08E-03 | 2.6988E+00 | 4.5909E+02 |
| $\alpha_4$ | 5.79E-04 | 3.83E-03 | 3.14E-03 | 9.43E-03 | 2.64E-03 | 1.7686E+00 | 4.6002E+02 |
| $\alpha_5$ | 2.28E-04 | 2.70E-03 | 2.03E-03 | 7.48E-03 | 2.29E-03 | 1.2480E+00 | 4.6054E+02 |
| $\alpha_6$ | 2.84E-05 | 1.54E-03 | 9.06E-04 | 5.21E-03 | 1.46E-03 | 7.1106E-01 | 4.6108E+02 |
| $\alpha_7$ | 8.28E-09 | 5.37E-04 | 9.24E-05 | 2.61E-03 | 5.31E-04 | 2.4797E-01 | 4.6154E+02 |
| $\alpha_8$ | 2.40E-28 | 1.14E-04 | 2.42E-09 | 6.17E-04 | 8.28E-05 | 5.2624E-02 | 4.6174E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9764990 | 0.9772990 | 0.9766300 | 0.9764870 | 0.9760190 | 0.9772650 | 0.9781510 |
| $\alpha_2$ | 2.35E-02 | 1.58E-02 | 1.45E-02 | 1.37E-02 | 1.40E-02 | 1.19E-02 | 1.08E-02 |
| $\alpha_3$ | | 6.90E-03 | 6.26E-03 | 5.17E-03 | 4.10E-03 | 4.25E-03 | 4.08E-03 |
| $\alpha_4$ | | | 2.61E-03 | 3.57E-03 | 3.50E-03 | 3.02E-03 | 2.64E-03 |
| $\alpha_5$ | | | | 1.05E-03 | 1.93E-03 | 2.32E-03 | 2.29E-03 |
| $\alpha_6$ | | | | | 4.39E-04 | 1.02E-03 | 1.46E-03 |
| $\alpha_7$ | | | | | | 1.89E-04 | 5.31E-04 |
| $\alpha_8$ | | | | | | | 8.28E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.76E-01 | 9.77E-01 | 9.77E-01 | 9.76E-01 | 9.76E-01 | 9.77E-01 | 9.78E-01 |
| Beta | 2.35E-02 | 2.27E-02 | 2.34E-02 | 2.35E-02 | 2.40E-02 | 2.27E-02 | 2.18E-02 |
| Gamma | | 3.04E-01 | 3.79E-01 | 4.16E-01 | 4.16E-01 | 4.75E-01 | 5.07E-01 |
| Delta | | | 2.94E-01 | 4.71E-01 | 5.89E-01 | 6.07E-01 | 6.32E-01 |
| Epsilon | | | | 2.27E-01 | 4.04E-01 | 5.38E-01 | 6.23E-01 |
| Mu | | | | | 1.85E-01 | 3.43E-01 | 4.75E-01 |
| Upsilon | | | | | | 1.56E-01 | 2.96E-01 |
| Sigma | | | | | | | 1.35E-01 |

Pooled Air Operated Valves

AOV FAIL TO OPEN ALL SYSTEMS SPAR: AOV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 57.36 | 86.05 | 114.73 | 143.41 | 172.09 | 200.77 | 229.45 |
| $N_1$ | 2.2952 | 2.5107 | 2.3548 | 2.0670 | 1.5640 | 1.3174 | 0.9958 |
| $N_2$ | 1.4357 | 1.4321 | 1.7393 | 2.0446 | 2.4923 | 2.4687 | 2.5366 |
| $N_3$ | | 0.6250 | 0.7500 | 0.7708 | 0.7292 | 0.8785 | 0.9604 |
| $N_4$ | | | 0.3125 | 0.5313 | 0.6233 | 0.6253 | 0.6221 |
| $N_5$ | | | | 0.1563 | 0.3438 | 0.4789 | 0.5397 |
| $N_6$ | | | | | 0.0781 | 0.2109 | 0.3441 |
| $N_7$ | | | | | | 0.0391 | 0.1250 |
| $N_8$ | | | | | | | 0.0195 |

## 1.4.1.3 AOV FAIL TO CLOSE ALL SYSTEMS SPAR: AOV-OO

| | |
|---|---|
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 81.40
Total Number of Common-Cause Failure Events: 6

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8933080 | 0.9487700 | 0.9540420 | 0.9861950 | 0.9462850 | 5.3143E+01 | 2.8695E+00 |
| $\alpha_2$ | 1.38E-02 | 5.12E-02 | 4.60E-02 | 1.07E-01 | 5.37E-02 | 2.8695E+00 | 5.3143E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9082580 | 0.9492930 | 0.9523650 | 0.9798230 | 0.9424310 | 9.1845E+01 | 4.9059E+00 |
| $\alpha_2$ | 8.00E-03 | 2.99E-02 | 2.67E-02 | 6.26E-02 | 3.11E-02 | 2.8887E+00 | 9.3862E+01 |
| $\alpha_3$ | 3.80E-03 | 2.08E-02 | 1.76E-02 | 4.89E-02 | 2.65E-02 | 2.0172E+00 | 9.4734E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9184100 | 0.9519630 | 0.9541920 | 0.9779140 | 0.9467610 | 1.2812E+02 | 6.4651E+00 |
| $\alpha_2$ | 5.91E-03 | 2.18E-02 | 1.95E-02 | 4.57E-02 | 1.97E-02 | 2.9381E+00 | 1.3165E+02 |
| $\alpha_3$ | 2.38E-03 | 1.41E-02 | 1.18E-02 | 3.39E-02 | 1.73E-02 | 1.9043E+00 | 1.3268E+02 |
| $\alpha_4$ | 1.62E-03 | 1.21E-02 | 9.74E-03 | 3.04E-02 | 1.62E-02 | 1.6227E+00 | 1.3296E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9336340 | 0.9586120 | 0.9600870 | 0.9785620 | 0.9531140 | 1.9813E+02 | 8.5543E+00 |
| $\alpha_2$ | 6.15E-03 | 1.85E-02 | 1.69E-02 | 3.60E-02 | 1.59E-02 | 3.8165E+00 | 2.0287E+02 |
| $\alpha_3$ | 1.40E-03 | 8.83E-03 | 7.30E-03 | 2.15E-02 | 7.92E-03 | 1.8244E+00 | 2.0486E+02 |
| $\alpha_4$ | 1.77E-03 | 9.78E-03 | 8.25E-03 | 2.30E-02 | 1.54E-02 | 2.0211E+00 | 2.0466E+02 |
| $\alpha_5$ | 1.64E-04 | 4.32E-03 | 2.86E-03 | 1.34E-02 | 7.66E-03 | 8.9228E-01 | 2.0579E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9409330 | 0.9625820 | 0.9638190 | 0.9800120 | 0.9605640 | 2.3929E+02 | 9.3018E+00 |
| $\alpha_2$ | 4.30E-03 | 1.39E-02 | 1.26E-02 | 2.79E-02 | 9.58E-03 | 3.4600E+00 | 2.4513E+02 |
| $\alpha_3$ | 1.44E-03 | 8.05E-03 | 6.77E-03 | 1.90E-02 | 6.74E-03 | 2.0002E+00 | 2.4659E+02 |
| $\alpha_4$ | 8.92E-04 | 6.59E-03 | 5.32E-03 | 1.66E-02 | 8.21E-03 | 1.6378E+00 | 2.4695E+02 |
| $\alpha_5$ | 8.61E-04 | 6.49E-03 | 5.23E-03 | 1.65E-02 | 1.09E-02 | 1.6146E+00 | 2.4698E+02 |
| $\alpha_6$ | 2.07E-05 | 2.37E-03 | 1.23E-03 | 8.58E-03 | 3.97E-03 | 5.8924E-01 | 2.4800E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9484890 | 0.9660710 | 0.9669880 | 0.9805320 | 0.9659480 | 3.2678E+02 | 1.1477E+01 |
| $\alpha_2$ | 4.02E-03 | 1.18E-02 | 1.08E-02 | 2.27E-02 | 6.02E-03 | 3.9775E+00 | 3.3428E+02 |
| $\alpha_3$ | 1.70E-03 | 7.40E-03 | 6.45E-03 | 1.63E-02 | 5.90E-03 | 2.5028E+00 | 3.3575E+02 |
| $\alpha_4$ | 7.30E-04 | 5.06E-03 | 4.12E-03 | 1.26E-02 | 4.88E-03 | 1.7105E+00 | 3.3655E+02 |
| $\alpha_5$ | 6.77E-04 | 4.91E-03 | 3.97E-03 | 1.23E-02 | 7.70E-03 | 1.6599E+00 | 3.3660E+02 |
| $\alpha_6$ | 3.25E-04 | 3.75E-03 | 2.83E-03 | 1.03E-02 | 7.31E-03 | 1.2672E+00 | 3.3699E+02 |
| $\alpha_7$ | 5.08E-07 | 1.06E-03 | 3.37E-04 | 4.57E-03 | 2.23E-03 | 3.5887E-01 | 3.3790E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9525800 | 0.9682960 | 0.9690820 | 0.9813250 | 0.9700210 | 3.8184E+02 | 1.2502E+01 |
| $\alpha_2$ | 3.49E-03 | 1.02E-02 | 9.33E-03 | 1.96E-02 | 3.91E-03 | 4.0028E+00 | 3.9034E+02 |
| $\alpha_3$ | 1.55E-03 | 6.53E-03 | 5.71E-03 | 1.43E-02 | 4.97E-03 | 2.5736E+00 | 3.9177E+02 |
| $\alpha_4$ | 6.83E-04 | 4.50E-03 | 3.69E-03 | 1.11E-02 | 3.73E-03 | 1.7736E+00 | 3.9257E+02 |
| $\alpha_5$ | 4.45E-04 | 3.80E-03 | 3.00E-03 | 9.88E-03 | 4.69E-03 | 1.4970E+00 | 3.9285E+02 |
| $\alpha_6$ | 4.14E-04 | 3.69E-03 | 2.90E-03 | 9.70E-03 | 6.48E-03 | 1.4566E+00 | 3.9289E+02 |
| $\alpha_7$ | 1.04E-04 | 2.38E-03 | 1.61E-03 | 7.29E-03 | 4.85E-03 | 9.3917E-01 | 3.9340E+02 |
| $\alpha_8$ | 1.67E-08 | 6.58E-04 | 1.24E-04 | 3.15E-03 | 1.35E-03 | 2.5942E-01 | 3.9408E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9462850 | 0.9424310 | 0.9467610 | 0.9531140 | 0.9605640 | 0.9659480 | 0.9700210 |
| $\alpha_2$ | 5.37E-02 | 3.11E-02 | 1.97E-02 | 1.59E-02 | 9.58E-03 | 6.02E-03 | 3.91E-03 |
| $\alpha_3$ | | 2.65E-02 | 1.73E-02 | 7.92E-03 | 6.74E-03 | 5.90E-03 | 4.97E-03 |
| $\alpha_4$ | | | 1.62E-02 | 1.54E-02 | 8.21E-03 | 4.88E-03 | 3.73E-03 |
| $\alpha_5$ | | | | 7.66E-03 | 1.09E-02 | 7.70E-03 | 4.69E-03 |
| $\alpha_6$ | | | | | 3.97E-03 | 7.31E-03 | 6.48E-03 |
| $\alpha_7$ | | | | | | 2.23E-03 | 4.85E-03 |
| $\alpha_8$ | | | | | | | 1.35E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.46E-01 | 9.42E-01 | 9.47E-01 | 9.53E-01 | 9.61E-01 | 9.66E-01 | 9.70E-01 |
| Beta | 5.37E-02 | 5.76E-02 | 5.32E-02 | 4.69E-02 | 3.94E-02 | 3.41E-02 | 3.00E-02 |
| Gamma | | 4.60E-01 | 6.29E-01 | 6.61E-01 | 7.57E-01 | 8.23E-01 | 8.69E-01 |
| Delta | | | 4.83E-01 | 7.44E-01 | 7.74E-01 | 7.90E-01 | 8.09E-01 |
| Epsilon | | | | 3.32E-01 | 6.45E-01 | 7.79E-01 | 8.23E-01 |
| Mu | | | | | 2.67E-01 | 5.53E-01 | 7.30E-01 |
| Upsilon | | | | | | 2.34E-01 | 4.89E-01 |
| Sigma | | | | | | | 2.17E-01 |

Pooled Air Operated Valves

AOV FAIL TO CLOSE ALL SYSTEMS SPAR: AOV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 40.70 | 61.05 | 81.40 | 101.75 | 122.10 | 142.45 | 162.80 |
| $N_1$ | 2.1967 | 1.2400 | 0.5800 | 0.2175 | 0.2523 | 0.2845 | 0.3143 |
| $N_2$ | 2.4350 | 2.0550 | 1.7100 | 1.7023 | 1.2208 | 0.8897 | 0.6581 |
| $N_3$ | | 1.7500 | 1.5000 | 0.8470 | 0.8584 | 0.8716 | 0.8352 |
| $N_4$ | | | 1.4000 | 1.6467 | 1.0456 | 0.7216 | 0.6271 |
| $N_5$ | | | | 0.8200 | 1.3924 | 1.1381 | 0.7887 |
| $N_6$ | | | | | 0.5060 | 1.0809 | 1.0896 |
| $N_7$ | | | | | | 0.3298 | 0.8162 |
| $N_8$ | | | | | | | 0.2263 |

# 1.4.2 BWR Isolation Condenser Air-Operated Valves

## 1.4.2.1 ISO CONDENSER AOV FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | Isolation condenser |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.7072910 | 0.8822300 | 0.9029730 | 0.9858660 | 0.3333330 | 1.0746E+01 | 1.4345E+00 |
| $\alpha_2$ | 1.41E-02 | 1.18E-01 | 9.70E-02 | 2.93E-01 | 6.67E-01 | 1.4345E+00 | 1.0746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8529320 | 0.9351700 | 0.9439770 | 0.9872260 | 0.4285710 | 3.0305E+01 | 2.1009E+00 |
| $\alpha_2$ | 8.23E-04 | 2.57E-02 | 1.68E-02 | 8.11E-02 | 0.00E+00 | 8.3366E-01 | 3.1572E+01 |
| $\alpha_3$ | 3.50E-03 | 3.91E-02 | 3.00E-02 | 1.06E-01 | 5.71E-01 | 1.2672E+00 | 3.1139E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8811760 | 0.9428880 | 0.9487180 | 0.9846280 | 0.5000000 | 4.7136E+01 | 2.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 2.02E-03 | 2.45E-02 | 1.84E-02 | 6.75E-02 | 5.00E-01 | 1.2227E+00 | 4.8768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9177320 | 0.9554850 | 0.9584350 | 0.9831430 | 0.5555560 | 9.7411E+01 | 4.5382E+00 |
| $\alpha_2$ | 4.00E-03 | 2.07E-02 | 1.77E-02 | 4.79E-02 | 0.00E+00 | 2.1142E+00 | 9.9835E+01 |
| $\alpha_3$ | 4.69E-04 | 9.59E-03 | 6.63E-03 | 2.88E-02 | 0.00E+00 | 9.7738E-01 | 1.0097E+02 |
| $\alpha_4$ | 3.10E-04 | 8.58E-03 | 5.65E-03 | 2.68E-02 | 2.22E-01 | 8.7439E-01 | 1.0107E+02 |
| $\alpha_5$ | 4.31E-05 | 5.61E-03 | 2.87E-03 | 2.05E-02 | 2.22E-01 | 5.7228E-01 | 1.0138E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9239510 | 0.9573330 | 0.9597820 | 0.9823620 | 0.6000000 | 1.1844E+02 | 5.2787E+00 |
| $\alpha_2$ | 3.72E-03 | 1.81E-02 | 1.56E-02 | 4.11E-02 | 0.00E+00 | 2.2392E+00 | 1.2148E+02 |
| $\alpha_3$ | 6.50E-04 | 9.23E-03 | 6.75E-03 | 2.63E-02 | 0.00E+00 | 1.1418E+00 | 1.2258E+02 |
| $\alpha_4$ | 2.20E-04 | 6.81E-03 | 4.40E-03 | 2.16E-02 | 1.00E-01 | 8.4222E-01 | 1.2288E+02 |
| $\alpha_5$ | 1.14E-04 | 5.84E-03 | 3.48E-03 | 1.96E-02 | 2.00E-01 | 7.2220E-01 | 1.2300E+02 |
| $\alpha_6$ | 7.22E-07 | 2.69E-03 | 7.75E-04 | 1.19E-02 | 1.00E-01 | 3.3324E-01 | 1.2339E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.3333330 | 0.4285710 | 0.5000000 | 0.5555560 | 0.6000000 |
| $\alpha_2$ | 6.67E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 5.71E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 5.00E-01 | 2.22E-01 | 1.00E-01 |
| $\alpha_5$ | | | | 2.22E-01 | 2.00E-01 |
| $\alpha_6$ | | | | | 1.00E-01 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 3.33E-01 | 4.29E-01 | 5.00E-01 | 5.56E-01 | 6.00E-01 |
| Beta | 6.67E-01 | 5.71E-01 | 5.00E-01 | 4.44E-01 | 4.00E-01 |
| Gamma | | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Delta | | | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Epsilon | | | | 5.00E-01 | 7.50E-01 |
| Mu | | | | | 3.33E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 1.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 1.0000 | 0.5000 | 0.2500 |
| $N_5$ | | | | 0.5000 | 0.5000 |
| $N_6$ | | | | | 0.2500 |

## 1.4.2.2 ISO CONDENSER AOV FAIL TO OPEN

**System :** Isolation condenser
**Component :** Air Operated Valve
**Failure Mode :** Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8522320 | 0.9628000 | 0.9843830 | 0.9999320 | 1.0000000 | 1.1246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.00E-05 | 3.72E-02 | 1.56E-02 | 1.48E-01 | 0.00E+00 | 4.3452E-01 | 1.1246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9010680 | 0.9652240 | 0.9744830 | 0.9976820 | 1.0000000 | 3.0555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.43E-04 | 2.63E-02 | 1.72E-02 | 8.30E-02 | 0.00E+00 | 8.3366E-01 | 3.0822E+01 |
| $\alpha_3$ | 2.98E-07 | 8.44E-03 | 1.71E-03 | 4.00E-02 | 0.00E+00 | 2.6722E-01 | 3.1389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9095820 | 0.9621340 | 0.9682530 | 0.9937390 | 1.0000000 | 4.7136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.09E-03 | 2.51E-02 | 1.89E-02 | 6.90E-02 | 0.00E+00 | 1.2281E+00 | 4.7763E+01 |
| $\alpha_3$ | 9.32E-06 | 8.25E-03 | 3.07E-03 | 3.41E-02 | 0.00E+00 | 4.0431E-01 | 4.8587E+01 |
| $\alpha_4$ | 1.97E-08 | 4.55E-03 | 6.24E-04 | 2.28E-02 | 0.00E+00 | 2.2267E-01 | 4.8768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9304990 | 0.9648630 | 0.9678980 | 0.9888360 | 1.0000000 | 9.7161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.05E-03 | 2.10E-02 | 1.79E-02 | 4.85E-02 | 0.00E+00 | 2.1142E+00 | 9.8585E+01 |
| $\alpha_3$ | 4.74E-04 | 9.71E-03 | 6.71E-03 | 2.92E-02 | 0.00E+00 | 9.7738E-01 | 9.9722E+01 |
| $\alpha_4$ | 2.45E-06 | 3.72E-03 | 1.25E-03 | 1.58E-02 | 0.00E+00 | 3.7439E-01 | 1.0032E+02 |
| $\alpha_5$ | 5.93E-21 | 7.18E-04 | 4.06E-07 | 4.16E-03 | 0.00E+00 | 7.2277E-02 | 1.0063E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9341160 | 0.9649920 | 0.9674990 | 0.9872840 | 1.0000000 | 1.1794E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.77E-03 | 1.83E-02 | 1.58E-02 | 4.16E-02 | 0.00E+00 | 2.2392E+00 | 1.1998E+02 |
| $\alpha_3$ | 6.58E-04 | 9.34E-03 | 6.84E-03 | 2.66E-02 | 0.00E+00 | 1.1418E+00 | 1.2108E+02 |
| $\alpha_4$ | 4.33E-05 | 4.85E-03 | 2.54E-03 | 1.75E-02 | 0.00E+00 | 5.9222E-01 | 1.2163E+02 |
| $\alpha_5$ | 7.60E-09 | 1.82E-03 | 2.47E-04 | 9.11E-03 | 0.00E+00 | 2.2220E-01 | 1.2200E+02 |
| $\alpha_6$ | 1.15E-18 | 6.81E-04 | 1.19E-06 | 3.98E-03 | 0.00E+00 | 8.3237E-02 | 1.2214E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.4.2.3 ISO CONDENSER AOV FAIL TO CLOSE

| | |
|---|---|
| **System :** | Isolation condenser |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.6956560 | 0.8771890 | 0.8985750 | 0.9851950 | 0.0000000 | 1.0246E+01 | 1.4345E+00 |
| $\alpha_2$ | 1.48E-02 | 1.23E-01 | 1.01E-01 | 3.04E-01 | 1.00E+00 | 1.4345E+00 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8495560 | 0.9336340 | 0.9426210 | 0.9869090 | 0.0000000 | 2.9555E+01 | 2.1009E+00 |
| $\alpha_2$ | 8.43E-04 | 2.63E-02 | 1.72E-02 | 8.30E-02 | 0.00E+00 | 8.3366E-01 | 3.0822E+01 |
| $\alpha_3$ | 3.59E-03 | 4.00E-02 | 3.08E-02 | 1.08E-01 | 1.00E+00 | 1.2672E+00 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8788090 | 0.9417220 | 0.9476570 | 0.9843040 | 0.0000000 | 4.6136E+01 | 2.8551E+00 |
| $\alpha_2$ | 2.09E-03 | 2.51E-02 | 1.89E-02 | 6.90E-02 | 0.00E+00 | 1.2281E+00 | 4.7763E+01 |
| $\alpha_3$ | 9.32E-06 | 8.25E-03 | 3.07E-03 | 3.41E-02 | 0.00E+00 | 4.0431E-01 | 4.8587E+01 |
| $\alpha_4$ | 2.06E-03 | 2.50E-02 | 1.88E-02 | 6.88E-02 | 1.00E+00 | 1.2227E+00 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9167220 | 0.9549330 | 0.9579160 | 0.9829300 | 0.0000000 | 9.6161E+01 | 4.5382E+00 |
| $\alpha_2$ | 4.05E-03 | 2.10E-02 | 1.79E-02 | 4.85E-02 | 0.00E+00 | 2.1142E+00 | 9.8585E+01 |
| $\alpha_3$ | 4.74E-04 | 9.71E-03 | 6.71E-03 | 2.92E-02 | 0.00E+00 | 9.7738E-01 | 9.9722E+01 |
| $\alpha_4$ | 3.14E-04 | 8.68E-03 | 5.72E-03 | 2.72E-02 | 5.00E-01 | 8.7439E-01 | 9.9825E+01 |
| $\alpha_5$ | 4.37E-05 | 5.68E-03 | 2.91E-03 | 2.07E-02 | 5.00E-01 | 5.7228E-01 | 1.0013E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9230310 | 0.9568100 | 0.9592860 | 0.9821410 | 0.0000000 | 1.1694E+02 | 5.2787E+00 |
| $\alpha_2$ | 3.77E-03 | 1.83E-02 | 1.58E-02 | 4.16E-02 | 0.00E+00 | 2.2392E+00 | 1.1998E+02 |
| $\alpha_3$ | 6.58E-04 | 9.34E-03 | 6.84E-03 | 2.66E-02 | 0.00E+00 | 1.1418E+00 | 1.2108E+02 |
| $\alpha_4$ | 2.23E-04 | 6.89E-03 | 4.45E-03 | 2.19E-02 | 2.50E-01 | 8.4222E-01 | 1.2138E+02 |
| $\alpha_5$ | 1.16E-04 | 5.91E-03 | 3.52E-03 | 1.98E-02 | 5.00E-01 | 7.2220E-01 | 1.2150E+02 |
| $\alpha_6$ | 7.30E-07 | 2.73E-03 | 7.85E-04 | 1.20E-02 | 2.50E-01 | 3.3324E-01 | 1.2189E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| $\alpha_2$ | 1.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 1.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 1.00E+00 | 5.00E-01 | 2.50E-01 |
| $\alpha_5$ | | | | 5.00E-01 | 5.00E-01 |
| $\alpha_6$ | | | | | 2.50E-01 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Gamma | | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Delta | | | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Epsilon | | | | 5.00E-01 | 7.50E-01 |
| Mu | | | | | 3.33E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 1.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 1.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 1.0000 | 0.5000 | 0.2500 |
| $N_5$ | | | | 0.5000 | 0.5000 |
| $N_6$ | | | | | 0.2500 |

# 1.4.3 PWR Auxiliary Feedwater Air-Operated Valves

## 1.4.3.1 AFW AOV FAIL TO OPEN/CLOSE SPAR: AOV-FO

**Component :** Air Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 213.10
Total Number of Common-Cause Failure Events: 11

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9331610 | 0.9644210 | 0.9669510 | 0.9870220 | 0.9649150 | 1.1670E+02 | 4.3052E+00 |
| $\alpha_2$ | 1.30E-02 | 3.56E-02 | 3.30E-02 | 6.68E-02 | 3.51E-02 | 4.3052E+00 | 1.1670E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9395680 | 0.9639620 | 0.9655560 | 0.9829220 | 0.9639370 | 1.8625E+02 | 6.9630E+00 |
| $\alpha_2$ | 8.13E-03 | 2.24E-02 | 2.07E-02 | 4.22E-02 | 2.15E-02 | 4.3208E+00 | 1.8889E+02 |
| $\alpha_3$ | 3.34E-03 | 1.37E-02 | 1.20E-02 | 2.96E-02 | 1.46E-02 | 2.6422E+00 | 1.9057E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9441460 | 0.9646650 | 0.9658430 | 0.9811630 | 0.9654090 | 2.5299E+02 | 9.2669E+00 |
| $\alpha_2$ | 6.80E-03 | 1.78E-02 | 1.66E-02 | 3.30E-02 | 1.61E-02 | 4.6774E+00 | 2.5758E+02 |
| $\alpha_3$ | 2.48E-03 | 1.01E-02 | 8.90E-03 | 2.19E-02 | 1.05E-02 | 2.6543E+00 | 2.5960E+02 |
| $\alpha_4$ | 1.26E-03 | 7.38E-03 | 6.17E-03 | 1.76E-02 | 7.99E-03 | 1.9352E+00 | 2.6032E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9503400 | 0.9670030 | 0.9678490 | 0.9807730 | 0.9679380 | 3.5335E+02 | 1.2057E+01 |
| $\alpha_2$ | 6.94E-03 | 1.60E-02 | 1.52E-02 | 2.81E-02 | 1.41E-02 | 5.8612E+00 | 3.5955E+02 |
| $\alpha_3$ | 1.70E-03 | 7.10E-03 | 6.23E-03 | 1.55E-02 | 6.09E-03 | 2.5952E+00 | 3.6281E+02 |
| $\alpha_4$ | 1.64E-03 | 6.98E-03 | 6.11E-03 | 1.53E-02 | 8.20E-03 | 2.5523E+00 | 3.6286E+02 |
| $\alpha_5$ | 1.66E-04 | 2.87E-03 | 2.03E-03 | 8.44E-03 | 3.67E-03 | 1.0486E+00 | 3.6436E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9543330 | 0.9690370 | 0.9697520 | 0.9813110 | 0.9706940 | 4.2465E+02 | 1.3568E+01 |
| $\alpha_2$ | 5.92E-03 | 1.36E-02 | 1.28E-02 | 2.37E-02 | 1.17E-02 | 5.9523E+00 | 4.3227E+02 |
| $\alpha_3$ | 1.56E-03 | 6.23E-03 | 5.49E-03 | 1.34E-02 | 5.01E-03 | 2.7294E+00 | 4.3549E+02 |
| $\alpha_4$ | 1.06E-03 | 5.16E-03 | 4.43E-03 | 1.18E-02 | 5.26E-03 | 2.2610E+00 | 4.3596E+02 |
| $\alpha_5$ | 7.75E-04 | 4.47E-03 | 3.74E-03 | 1.07E-02 | 5.48E-03 | 1.9584E+00 | 4.3626E+02 |
| $\alpha_6$ | 2.22E-05 | 1.52E-03 | 8.62E-04 | 5.27E-03 | 1.84E-03 | 6.6734E-01 | 4.3755E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9585020 | 0.9710430 | 0.9716070 | 0.9816660 | 0.9735660 | 5.4252E+02 | 1.6178E+01 |
| $\alpha_2$ | 5.23E-03 | 1.15E-02 | 1.10E-02 | 1.98E-02 | 9.12E-03 | 6.4461E+00 | 5.5225E+02 |
| $\alpha_3$ | 1.83E-03 | 6.05E-03 | 5.47E-03 | 1.23E-02 | 4.75E-03 | 3.3814E+00 | 5.5532E+02 |
| $\alpha_4$ | 8.93E-04 | 4.18E-03 | 3.61E-03 | 9.43E-03 | 3.66E-03 | 2.3358E+00 | 5.5636E+02 |
| $\alpha_5$ | 7.40E-04 | 3.83E-03 | 3.25E-03 | 8.88E-03 | 4.39E-03 | 2.1388E+00 | 5.5656E+02 |
| $\alpha_6$ | 3.03E-04 | 2.65E-03 | 2.08E-03 | 6.92E-03 | 3.51E-03 | 1.4781E+00 | 5.5722E+02 |
| $\alpha_7$ | 7.14E-07 | 7.12E-04 | 2.57E-04 | 2.96E-03 | 1.00E-03 | 3.9797E-01 | 5.5830E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9613450 | 0.9726590 | 0.9731440 | 0.9823110 | 0.9757040 | 6.2789E+02 | 1.7650E+01 |
| $\alpha_2$ | 4.62E-03 | 1.01E-02 | 9.63E-03 | 1.74E-02 | 7.62E-03 | 6.5394E+00 | 6.3900E+02 |
| $\alpha_3$ | 1.71E-03 | 5.47E-03 | 4.97E-03 | 1.10E-02 | 4.28E-03 | 3.5340E+00 | 6.4201E+02 |
| $\alpha_4$ | 8.15E-04 | 3.71E-03 | 3.21E-03 | 8.31E-03 | 2.98E-03 | 2.3957E+00 | 6.4314E+02 |
| $\alpha_5$ | 5.75E-04 | 3.16E-03 | 2.66E-03 | 7.43E-03 | 3.17E-03 | 2.0367E+00 | 6.4350E+02 |
| $\alpha_6$ | 4.32E-04 | 2.79E-03 | 2.30E-03 | 6.83E-03 | 3.42E-03 | 1.8007E+00 | 6.4374E+02 |
| $\alpha_7$ | 9.84E-05 | 1.65E-03 | 1.17E-03 | 4.83E-03 | 2.24E-03 | 1.0642E+00 | 6.4448E+02 |
| $\alpha_8$ | 2.32E-08 | 4.32E-04 | 9.32E-05 | 2.02E-03 | 5.86E-04 | 2.7902E-01 | 6.4526E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9649150 | 0.9639370 | 0.9654090 | 0.9679380 | 0.9706940 | 0.9735660 | 0.9757040 |
| $\alpha_2$ | 3.51E-02 | 2.15E-02 | 1.61E-02 | 1.41E-02 | 1.17E-02 | 9.12E-03 | 7.62E-03 |
| $\alpha_3$ | | 1.46E-02 | 1.05E-02 | 6.09E-03 | 5.01E-03 | 4.75E-03 | 4.28E-03 |
| $\alpha_4$ | | | 7.99E-03 | 8.20E-03 | 5.26E-03 | 3.66E-03 | 2.98E-03 |
| $\alpha_5$ | | | | 3.67E-03 | 5.48E-03 | 4.39E-03 | 3.17E-03 |
| $\alpha_6$ | | | | | 1.84E-03 | 3.51E-03 | 3.42E-03 |
| $\alpha_7$ | | | | | | 1.00E-03 | 2.24E-03 |
| $\alpha_8$ | | | | | | | 5.86E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.65E-01 | 9.64E-01 | 9.65E-01 | 9.68E-01 | 9.71E-01 | 9.74E-01 | 9.76E-01 |
| Beta | 3.51E-02 | 3.61E-02 | 3.46E-02 | 3.21E-02 | 2.93E-02 | 2.64E-02 | 2.43E-02 |
| Gamma | | 4.05E-01 | 5.35E-01 | 5.60E-01 | 6.00E-01 | 6.55E-01 | 6.86E-01 |
| Delta | | | 4.32E-01 | 6.61E-01 | 7.15E-01 | 7.25E-01 | 7.43E-01 |
| Epsilon | | | | 3.10E-01 | 5.82E-01 | 7.09E-01 | 7.60E-01 |
| Mu | | | | | 2.52E-01 | 5.07E-01 | 6.64E-01 |
| Upsilon | | | | | | 2.22E-01 | 4.53E-01 |
| Sigma | | | | | | | 2.07E-01 |

PWR Auxiliary Feedwater Air-Operated Valves

AFW AOV FAIL TO OPEN/CLOSE SPAR: AOV-FO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 101.96 | 152.94 | 203.92 | 254.90 | 305.89 | 356.87 | 407.85 |
| $N_1$ | 4.4919 | 3.7507 | 2.9348 | 2.2845 | 1.8163 | 1.6020 | 1.3101 |
| $N_2$ | 3.8707 | 3.4871 | 3.4493 | 3.7470 | 3.7131 | 3.3583 | 3.1947 |
| $N_3$ | | 2.3750 | 2.2500 | 1.6178 | 1.5876 | 1.7502 | 1.7956 |
| $N_4$ | | | 1.7125 | 2.1779 | 1.6688 | 1.3469 | 1.2492 |
| $N_5$ | | | | 0.9763 | 1.7362 | 1.6170 | 1.3284 |
| $N_6$ | | | | | 0.5841 | 1.2918 | 1.4337 |
| $N_7$ | | | | | | 0.3689 | 0.9412 |
| $N_8$ | | | | | | | 0.2459 |

## 1.4.3.2 AFW AOV FAIL TO OPEN SPAR: AFW-AOV-CC

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 29.10
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8922460 | 0.9663920 | 0.9785260 | 0.9990900 | 0.9723270 | 2.2628E+01 | 7.8692E-01 |
| $\alpha_2$ | 9.07E-04 | 3.36E-02 | 2.15E-02 | 1.08E-01 | 2.77E-02 | 7.8692E-01 | 2.2628E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9085350 | 0.9613400 | 0.9674070 | 0.9933620 | 0.9568340 | 4.7446E+01 | 1.9080E+00 |
| $\alpha_2$ | 3.75E-03 | 3.07E-02 | 2.46E-02 | 7.86E-02 | 3.65E-02 | 1.5158E+00 | 4.7838E+01 |
| $\alpha_3$ | 7.31E-06 | 7.95E-03 | 2.85E-03 | 3.32E-02 | 6.69E-03 | 3.9222E-01 | 4.8962E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9114200 | 0.9564500 | 0.9605930 | 0.9873070 | 0.9468580 | 6.9331E+01 | 3.1569E+00 |
| $\alpha_2$ | 6.27E-03 | 3.06E-02 | 2.64E-02 | 6.93E-02 | 4.04E-02 | 2.2174E+00 | 7.0270E+01 |
| $\alpha_3$ | 1.23E-04 | 9.03E-03 | 5.08E-03 | 3.13E-02 | 1.02E-02 | 6.5431E-01 | 7.1834E+01 |
| $\alpha_4$ | 2.63E-07 | 3.93E-03 | 8.88E-04 | 1.83E-02 | 2.55E-03 | 2.8517E-01 | 7.2203E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9265130 | 0.9586130 | 0.9609470 | 0.9827290 | 0.9391150 | 1.2449E+02 | 5.3747E+00 |
| $\alpha_2$ | 8.24E-03 | 2.66E-02 | 2.42E-02 | 5.31E-02 | 4.43E-02 | 3.4505E+00 | 1.2641E+02 |
| $\alpha_3$ | 8.98E-04 | 9.93E-03 | 7.55E-03 | 2.71E-02 | 1.04E-02 | 1.2899E+00 | 1.2857E+02 |
| $\alpha_4$ | 2.19E-05 | 4.09E-03 | 1.97E-03 | 1.53E-02 | 5.18E-03 | 5.3069E-01 | 1.2933E+02 |
| $\alpha_5$ | 1.30E-15 | 7.98E-04 | 5.85E-06 | 4.63E-03 | 1.04E-03 | 1.0358E-01 | 1.2976E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9278940 | 0.9572720 | 0.9592060 | 0.9800480 | 0.9320500 | 1.5022E+02 | 6.7051E+00 |
| $\alpha_2$ | 8.84E-03 | 2.55E-02 | 2.36E-02 | 4.91E-02 | 4.96E-02 | 4.0093E+00 | 1.5292E+02 |
| $\alpha_3$ | 1.04E-03 | 9.27E-03 | 7.28E-03 | 2.43E-02 | 8.75E-03 | 1.4543E+00 | 1.5547E+02 |
| $\alpha_4$ | 1.61E-04 | 5.27E-03 | 3.37E-03 | 1.68E-02 | 6.56E-03 | 8.2662E-01 | 1.5610E+02 |
| $\alpha_5$ | 3.44E-07 | 2.01E-03 | 5.35E-04 | 9.05E-03 | 2.63E-03 | 3.1600E-01 | 1.5661E+02 |
| $\alpha_6$ | 2.66E-16 | 6.30E-04 | 3.49E-06 | 3.66E-03 | 4.37E-04 | 9.8837E-02 | 1.5683E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9375820 | 0.9605850 | 0.9619010 | 0.9790820 | 0.9347890 | 2.2257E+02 | 9.1325E+00 |
| $\alpha_2$ | 8.04E-03 | 2.07E-02 | 1.94E-02 | 3.81E-02 | 4.16E-02 | 4.8019E+00 | 2.2690E+02 |
| $\alpha_3$ | 1.73E-03 | 9.08E-03 | 7.71E-03 | 2.11E-02 | 1.15E-02 | 2.1046E+00 | 2.2960E+02 |
| $\alpha_4$ | 4.70E-04 | 5.45E-03 | 4.11E-03 | 1.50E-02 | 6.63E-03 | 1.2623E+00 | 2.3044E+02 |
| $\alpha_5$ | 4.79E-05 | 2.96E-03 | 1.71E-03 | 1.01E-02 | 3.98E-03 | 6.8587E-01 | 2.3102E+02 |
| $\alpha_6$ | 1.16E-08 | 1.04E-03 | 1.69E-04 | 5.09E-03 | 1.33E-03 | 2.4098E-01 | 2.3146E+02 |
| $\alpha_7$ | 1.30E-38 | 1.59E-04 | 1.71E-11 | 7.27E-04 | 1.89E-04 | 3.6871E-02 | 2.3167E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9410070 | 0.9617910 | 0.9629120 | 0.9787410 | 0.9364770 | 2.6244E+02 | 1.0426E+01 |
| $\alpha_2$ | 7.49E-03 | 1.87E-02 | 1.75E-02 | 3.38E-02 | 3.75E-02 | 5.0941E+00 | 2.6777E+02 |
| $\alpha_3$ | 1.74E-03 | 8.35E-03 | 7.18E-03 | 1.89E-02 | 1.15E-02 | 2.2772E+00 | 2.7059E+02 |
| $\alpha_4$ | 6.02E-04 | 5.35E-03 | 4.20E-03 | 1.40E-02 | 6.71E-03 | 1.4599E+00 | 2.7141E+02 |
| $\alpha_5$ | 1.44E-04 | 3.40E-03 | 2.29E-03 | 1.04E-02 | 4.69E-03 | 9.2713E-01 | 2.7194E+02 |
| $\alpha_6$ | 5.29E-06 | 1.75E-03 | 7.62E-04 | 6.82E-03 | 2.34E-03 | 4.7636E-01 | 2.7239E+02 |
| $\alpha_7$ | 8.55E-12 | 5.65E-04 | 2.61E-05 | 3.10E-03 | 6.71E-04 | 1.5427E-01 | 2.7271E+02 |
| $\alpha_8$ | 1.54E-38 | 1.36E-04 | 1.57E-11 | 6.22E-04 | 8.36E-05 | 3.7024E-02 | 2.7283E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9723270 | 0.9568340 | 0.9468580 | 0.9391150 | 0.9320500 | 0.9347890 | 0.9364770 |
| $\alpha_2$ | 2.77E-02 | 3.65E-02 | 4.04E-02 | 4.43E-02 | 4.96E-02 | 4.16E-02 | 3.75E-02 |
| $\alpha_3$ | | 6.69E-03 | 1.02E-02 | 1.04E-02 | 8.75E-03 | 1.15E-02 | 1.15E-02 |
| $\alpha_4$ | | | 2.55E-03 | 5.18E-03 | 6.56E-03 | 6.63E-03 | 6.71E-03 |
| $\alpha_5$ | | | | 1.04E-03 | 2.63E-03 | 3.98E-03 | 4.69E-03 |
| $\alpha_6$ | | | | | 4.37E-04 | 1.33E-03 | 2.34E-03 |
| $\alpha_7$ | | | | | | 1.89E-04 | 6.71E-04 |
| $\alpha_8$ | | | | | | | 8.36E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.72E-01 | 9.57E-01 | 9.47E-01 | 9.39E-01 | 9.32E-01 | 9.35E-01 | 9.36E-01 |
| Beta | 2.77E-02 | 4.32E-02 | 5.31E-02 | 6.09E-02 | 6.79E-02 | 6.52E-02 | 6.35E-02 |
| Gamma | | 1.55E-01 | 2.40E-01 | 2.72E-01 | 2.70E-01 | 3.62E-01 | 4.10E-01 |
| Delta | | | 2.00E-01 | 3.75E-01 | 5.24E-01 | 5.14E-01 | 5.57E-01 |
| Epsilon | | | | 1.67E-01 | 3.18E-01 | 4.53E-01 | 5.37E-01 |
| Mu | | | | | 1.43E-01 | 2.76E-01 | 3.98E-01 |
| Upsilon | | | | | | 1.25E-01 | 2.43E-01 |
| Sigma | | | | | | | 1.11E-01 |

PWR Auxiliary Feedwater Air-Operated Valves

AFW AOV FAIL TO OPEN SPAR: AFW-AOV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 10.92 | 16.38 | 21.84 | 27.30 | 32.76 | 38.22 | 43.68 |
| $N_1$ | 1.4619 | 1.5107 | 1.3548 | 1.0253 | 0.5223 | 0.3047 | 0.0313 |
| $N_2$ | 0.3524 | 0.6821 | 0.9893 | 1.3363 | 1.7701 | 1.7141 | 1.7494 |
| $N_3$ | | 0.1250 | 0.2500 | 0.3125 | 0.3125 | 0.4734 | 0.5388 |
| $N_4$ | | | 0.0625 | 0.1563 | 0.2344 | 0.2734 | 0.3134 |
| $N_5$ | | | | 0.0313 | 0.0938 | 0.1641 | 0.2188 |
| $N_6$ | | | | | 0.0156 | 0.0547 | 0.1094 |
| $N_7$ | | | | | | 0.0078 | 0.0313 |
| $N_8$ | | | | | | | 0.0039 |

## 1.4.3.3 AFW AOV FAIL TO CLOSE SPAR: AFW-AOV-OO

**System :** Auxiliary feedwater
**Component :** Air Operated Valve
**Failure Mode :** Fail to close (reseat) on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 20.50
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9022980 | 0.9724260 | 0.9850050 | 0.9997270 | 0.9849480 | 2.1259E+01 | 6.0282E-01 |
| $\alpha_2$ | 2.75E-04 | 2.76E-02 | 1.50E-02 | 9.77E-02 | 1.51E-02 | 6.0282E-01 | 2.1259E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9147100 | 0.9659630 | 0.9723190 | 0.9954300 | 0.9694400 | 4.5575E+01 | 1.6059E+00 |
| $\alpha_2$ | 2.79E-03 | 2.84E-02 | 2.20E-02 | 7.57E-02 | 3.06E-02 | 1.3387E+00 | 4.5842E+01 |
| $\alpha_3$ | 1.98E-07 | 5.66E-03 | 1.14E-03 | 2.69E-02 | 0.00E+00 | 2.6722E-01 | 4.6914E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9139780 | 0.9588830 | 0.9632070 | 0.9889980 | 0.9534350 | 6.6816E+01 | 2.8651E+00 |
| $\alpha_2$ | 6.66E-03 | 3.21E-02 | 2.77E-02 | 7.25E-02 | 4.66E-02 | 2.2381E+00 | 6.7443E+01 |
| $\alpha_3$ | 6.53E-06 | 5.80E-03 | 2.15E-03 | 2.40E-02 | 0.00E+00 | 4.0431E-01 | 6.9277E+01 |
| $\alpha_4$ | 1.38E-08 | 3.20E-03 | 4.37E-04 | 1.60E-02 | 0.00E+00 | 2.2267E-01 | 6.9458E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9333610 | 0.9640160 | 0.9664390 | 0.9863940 | 0.9621790 | 1.2201E+02 | 4.5543E+00 |
| $\alpha_2$ | 5.72E-03 | 2.21E-02 | 1.96E-02 | 4.69E-02 | 2.54E-02 | 2.7965E+00 | 1.2377E+02 |
| $\alpha_3$ | 9.66E-04 | 1.04E-02 | 7.92E-03 | 2.81E-02 | 1.24E-02 | 1.3111E+00 | 1.2525E+02 |
| $\alpha_4$ | 1.94E-06 | 2.96E-03 | 9.96E-04 | 1.26E-02 | 0.00E+00 | 3.7439E-01 | 1.2619E+02 |
| $\alpha_5$ | 4.71E-21 | 5.71E-04 | 3.23E-07 | 3.30E-03 | 0.00E+00 | 7.2277E-02 | 1.2649E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9382390 | 0.9654020 | 0.9674080 | 0.9857100 | 0.9680500 | 1.4794E+02 | 5.3019E+00 |
| $\alpha_2$ | 4.42E-03 | 1.77E-02 | 1.56E-02 | 3.79E-02 | 1.46E-02 | 2.7060E+00 | 1.5054E+02 |
| $\alpha_3$ | 1.34E-03 | 1.04E-02 | 8.32E-03 | 2.63E-02 | 1.39E-02 | 1.5871E+00 | 1.5165E+02 |
| $\alpha_4$ | 8.16E-05 | 4.59E-03 | 2.69E-03 | 1.56E-02 | 3.47E-03 | 7.0332E-01 | 1.5254E+02 |
| $\alpha_5$ | 6.06E-09 | 1.45E-03 | 1.96E-04 | 7.26E-03 | 0.00E+00 | 2.2220E-01 | 1.5302E+02 |
| $\alpha_6$ | 9.20E-19 | 5.43E-04 | 9.50E-07 | 3.17E-03 | 0.00E+00 | 8.3237E-02 | 1.5316E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9457280 | 0.9671620 | 0.9685250 | 0.9839570 | 0.9722630 | 2.2021E+02 | 7.4767E+00 |
| $\alpha_2$ | 4.59E-03 | 1.50E-02 | 1.36E-02 | 3.02E-02 | 8.78E-03 | 3.4142E+00 | 2.2427E+02 |
| $\alpha_3$ | 1.71E-03 | 9.12E-03 | 7.73E-03 | 2.13E-02 | 1.20E-02 | 2.0772E+00 | 2.2561E+02 |
| $\alpha_4$ | 4.23E-04 | 5.32E-03 | 3.96E-03 | 1.49E-02 | 5.98E-03 | 1.2112E+00 | 2.2648E+02 |
| $\alpha_5$ | 1.68E-05 | 2.45E-03 | 1.23E-03 | 9.05E-03 | 9.95E-04 | 5.5877E-01 | 2.2713E+02 |
| $\alpha_6$ | 2.95E-10 | 8.18E-04 | 6.98E-05 | 4.29E-03 | 0.00E+00 | 1.8628E-01 | 2.2750E+02 |
| $\alpha_7$ | 0.00E+00 | 1.28E-04 | 1.12E-13 | 4.81E-04 | 0.00E+00 | 2.9071E-02 | 2.2766E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9490360 | 0.9683400 | 0.9694990 | 0.9836930 | 0.9754180 | 2.6004E+02 | 8.5022E+00 |
| $\alpha_2$ | 4.23E-03 | 1.33E-02 | 1.21E-02 | 2.65E-02 | 5.57E-03 | 3.5808E+00 | 2.6496E+02 |
| $\alpha_3$ | 1.54E-03 | 7.95E-03 | 6.77E-03 | 1.84E-02 | 9.39E-03 | 2.1360E+00 | 2.6641E+02 |
| $\alpha_4$ | 5.93E-04 | 5.37E-03 | 4.21E-03 | 1.41E-02 | 7.00E-03 | 1.4429E+00 | 2.6710E+02 |
| $\alpha_5$ | 8.49E-05 | 3.01E-03 | 1.90E-03 | 9.70E-03 | 2.33E-03 | 8.0713E-01 | 2.6774E+02 |
| $\alpha_6$ | 1.02E-06 | 1.41E-03 | 4.82E-04 | 5.97E-03 | 2.90E-04 | 3.7926E-01 | 2.6816E+02 |
| $\alpha_7$ | 6.06E-14 | 4.58E-04 | 8.23E-06 | 2.61E-03 | 0.00E+00 | 1.2297E-01 | 2.6842E+02 |
| $\alpha_8$ | 1.14E-42 | 1.23E-04 | 1.76E-12 | 5.21E-04 | 0.00E+00 | 3.3124E-02 | 2.6851E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9849480 | 0.9694400 | 0.9534350 | 0.9621790 | 0.9680500 | 0.9722630 | 0.9754180 |
| $\alpha_2$ | 1.51E-02 | 3.06E-02 | 4.66E-02 | 2.54E-02 | 1.46E-02 | 8.78E-03 | 5.57E-03 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 1.24E-02 | 1.39E-02 | 1.20E-02 | 9.39E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 3.47E-03 | 5.98E-03 | 7.00E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 9.95E-04 | 2.33E-03 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 2.90E-04 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.85E-01 | 9.69E-01 | 9.53E-01 | 9.62E-01 | 9.68E-01 | 9.72E-01 | 9.75E-01 |
| Beta | 1.51E-02 | 3.06E-02 | 4.66E-02 | 3.78E-02 | 3.19E-02 | 2.77E-02 | 2.46E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 3.28E-01 | 5.44E-01 | 6.84E-01 | 7.73E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 2.00E-01 | 3.68E-01 | 5.06E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 1.43E-01 | 2.73E-01 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 1.11E-01 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Air-Operated Valves

AFW AOV FAIL TO CLOSE SPAR: AFW-AOV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 10.25 | 15.38 | 20.50 | 25.63 | 30.75 | 35.88 | 41.00 |
| $N_1$ | 0.7633 | 0.6400 | 0.1800 | 0.2175 | 0.2523 | 0.2845 | 0.3143 |
| $N_2$ | 0.1683 | 0.5050 | 1.0100 | 0.6823 | 0.4668 | 0.3264 | 0.2361 |
| $N_3$ | | 0.0000 | 0.0000 | 0.3337 | 0.4453 | 0.4460 | 0.3976 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.1111 | 0.2223 | 0.2964 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0370 | 0.0988 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0123 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.4.4 High Pressure Coolant Injection and Reactor Core Isolation Cooling Air Operated Valves

## 1.4.4.1 COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO OPEN/CLOSE

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand<br>Fail to Open/Close Mode Unspecified (demand based)<br>Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 3.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8734960 | 0.9682380 | 0.9867710 | 0.9999360 | 1.0000000 | 1.3246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.92E-05 | 3.18E-02 | 1.32E-02 | 1.27E-01 | 0.00E+00 | 4.3452E-01 | 1.3246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9068390 | 0.9672900 | 0.9760300 | 0.9978250 | 1.0000000 | 3.2555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.91E-04 | 2.48E-02 | 1.62E-02 | 7.82E-02 | 0.00E+00 | 8.3366E-01 | 3.2822E+01 |
| $\alpha_3$ | 2.80E-07 | 7.94E-03 | 1.61E-03 | 3.77E-02 | 0.00E+00 | 2.6722E-01 | 3.3389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9130680 | 0.9636200 | 0.9695110 | 0.9939910 | 1.0000000 | 4.9136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.00E-03 | 2.41E-02 | 1.82E-02 | 6.63E-02 | 0.00E+00 | 1.2281E+00 | 4.9763E+01 |
| $\alpha_3$ | 8.95E-06 | 7.93E-03 | 2.95E-03 | 3.27E-02 | 0.00E+00 | 4.0431E-01 | 5.0587E+01 |
| $\alpha_4$ | 1.89E-08 | 4.37E-03 | 5.99E-04 | 2.19E-02 | 0.00E+00 | 2.2267E-01 | 5.0768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9318350 | 0.9655480 | 0.9685320 | 0.9890570 | 1.0000000 | 9.9161E+01 | 3.5382E+00 |
| $\alpha_2$ | 3.97E-03 | 2.06E-02 | 1.76E-02 | 4.76E-02 | 0.00E+00 | 2.1142E+00 | 1.0059E+02 |
| $\alpha_3$ | 4.65E-04 | 9.52E-03 | 6.58E-03 | 2.86E-02 | 0.00E+00 | 9.7738E-01 | 1.0172E+02 |
| $\alpha_4$ | 2.40E-06 | 3.65E-03 | 1.23E-03 | 1.55E-02 | 0.00E+00 | 3.7439E-01 | 1.0232E+02 |
| $\alpha_5$ | 5.81E-21 | 7.04E-04 | 3.98E-07 | 4.08E-03 | 0.00E+00 | 7.2277E-02 | 1.0263E+02 |

COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO OPEN/CLOSE

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9351640 | 0.9655550 | 0.9680290 | 0.9874920 | 1.0000000 | 1.1994E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.71E-03 | 1.80E-02 | 1.55E-02 | 4.10E-02 | 0.00E+00 | 2.2392E+00 | 1.2198E+02 |
| $\alpha_3$ | 6.48E-04 | 9.19E-03 | 6.73E-03 | 2.62E-02 | 0.00E+00 | 1.1418E+00 | 1.2308E+02 |
| $\alpha_4$ | 4.26E-05 | 4.77E-03 | 2.50E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2363E+02 |
| $\alpha_5$ | 7.48E-09 | 1.79E-03 | 2.43E-04 | 8.96E-03 | 0.00E+00 | 2.2220E-01 | 1.2400E+02 |
| $\alpha_6$ | 1.14E-18 | 6.70E-04 | 1.17E-06 | 3.91E-03 | 0.00E+00 | 8.3237E-02 | 1.2414E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.4.4.2 COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 3.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8734960 | 0.9682380 | 0.9867710 | 0.9999360 | 1.0000000 | 1.3246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.92E-05 | 3.18E-02 | 1.32E-02 | 1.27E-01 | 0.00E+00 | 4.3452E-01 | 1.3246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9068390 | 0.9672900 | 0.9760300 | 0.9978250 | 1.0000000 | 3.2555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.91E-04 | 2.48E-02 | 1.62E-02 | 7.82E-02 | 0.00E+00 | 8.3366E-01 | 3.2822E+01 |
| $\alpha_3$ | 2.80E-07 | 7.94E-03 | 1.61E-03 | 3.77E-02 | 0.00E+00 | 2.6722E-01 | 3.3389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9130680 | 0.9636200 | 0.9695110 | 0.9939910 | 1.0000000 | 4.9136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.00E-03 | 2.41E-02 | 1.82E-02 | 6.63E-02 | 0.00E+00 | 1.2281E+00 | 4.9763E+01 |
| $\alpha_3$ | 8.95E-06 | 7.93E-03 | 2.95E-03 | 3.27E-02 | 0.00E+00 | 4.0431E-01 | 5.0587E+01 |
| $\alpha_4$ | 1.89E-08 | 4.37E-03 | 5.99E-04 | 2.19E-02 | 0.00E+00 | 2.2267E-01 | 5.0768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9318350 | 0.9655480 | 0.9685320 | 0.9890570 | 1.0000000 | 9.9161E+01 | 3.5382E+00 |
| $\alpha_2$ | 3.97E-03 | 2.06E-02 | 1.76E-02 | 4.76E-02 | 0.00E+00 | 2.1142E+00 | 1.0059E+02 |
| $\alpha_3$ | 4.65E-04 | 9.52E-03 | 6.58E-03 | 2.86E-02 | 0.00E+00 | 9.7738E-01 | 1.0172E+02 |
| $\alpha_4$ | 2.40E-06 | 3.65E-03 | 1.23E-03 | 1.55E-02 | 0.00E+00 | 3.7439E-01 | 1.0232E+02 |
| $\alpha_5$ | 5.81E-21 | 7.04E-04 | 3.98E-07 | 4.08E-03 | 0.00E+00 | 7.2277E-02 | 1.0263E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9351640 | 0.9655550 | 0.9680290 | 0.9874920 | 1.0000000 | 1.1994E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.71E-03 | 1.80E-02 | 1.55E-02 | 4.10E-02 | 0.00E+00 | 2.2392E+00 | 1.2198E+02 |
| $\alpha_3$ | 6.48E-04 | 9.19E-03 | 6.73E-03 | 2.62E-02 | 0.00E+00 | 1.1418E+00 | 1.2308E+02 |
| $\alpha_4$ | 4.26E-05 | 4.77E-03 | 2.50E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2363E+02 |
| $\alpha_5$ | 7.48E-09 | 1.79E-03 | 2.43E-04 | 8.96E-03 | 0.00E+00 | 2.2220E-01 | 1.2400E+02 |
| $\alpha_6$ | 1.14E-18 | 6.70E-04 | 1.17E-06 | 3.91E-03 | 0.00E+00 | 8.3237E-02 | 1.2414E+02 |

COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO OPEN

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.4.4.3 COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Air Operated Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 1.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 1.0000000 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 1.0000000 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 1.0000000 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 1.0000000 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

COMBINED HPCI AND RCIC AIR OPERATED VALVE FAIL TO CLOSE

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.5 Check Valves

## 1.5.1 Pooled Check Valves

### 1.5.1.1 CHECK VALVE FAIL TO OPEN ALL SYSTEMS SPAR: CKV-CC

**Component :** Check Valve
**Failure Mode :** Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 8.00
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9069840 | 0.9767390 | 0.9904340 | 0.9999540 | 1.0000000 | 1.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.27E-05 | 2.33E-02 | 9.56E-03 | 9.30E-02 | 0.00E+00 | 4.3452E-01 | 1.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9187120 | 0.9715210 | 0.9791840 | 0.9981180 | 1.0000000 | 3.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.87E-04 | 2.16E-02 | 1.40E-02 | 6.82E-02 | 0.00E+00 | 8.3366E-01 | 3.7822E+01 |
| $\alpha_3$ | 2.43E-07 | 6.91E-03 | 1.40E-03 | 3.28E-02 | 0.00E+00 | 2.6722E-01 | 3.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9207150 | 0.9668680 | 0.9722640 | 0.9945410 | 1.0000000 | 5.4136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.82E-03 | 2.19E-02 | 1.65E-02 | 6.05E-02 | 0.00E+00 | 1.2281E+00 | 5.4763E+01 |
| $\alpha_3$ | 8.14E-06 | 7.22E-03 | 2.68E-03 | 2.98E-02 | 0.00E+00 | 4.0431E-01 | 5.5587E+01 |
| $\alpha_4$ | 1.72E-08 | 3.98E-03 | 5.45E-04 | 1.99E-02 | 0.00E+00 | 2.2267E-01 | 5.5768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9349600 | 0.9671470 | 0.9699980 | 0.9895730 | 1.0000000 | 1.0416E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.78E-03 | 1.96E-02 | 1.67E-02 | 4.54E-02 | 0.00E+00 | 2.1142E+00 | 1.0558E+02 |
| $\alpha_3$ | 4.43E-04 | 9.08E-03 | 6.27E-03 | 2.73E-02 | 0.00E+00 | 9.7738E-01 | 1.0672E+02 |
| $\alpha_4$ | 2.29E-06 | 3.48E-03 | 1.17E-03 | 1.48E-02 | 0.00E+00 | 3.7439E-01 | 1.0732E+02 |
| $\alpha_5$ | 5.54E-21 | 6.71E-04 | 3.80E-07 | 3.89E-03 | 0.00E+00 | 7.2277E-02 | 1.0763E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9376440 | 0.9668880 | 0.9692700 | 0.9879830 | 1.0000000 | 1.2494E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.56E-03 | 1.73E-02 | 1.49E-02 | 3.94E-02 | 0.00E+00 | 2.2392E+00 | 1.2698E+02 |
| $\alpha_3$ | 6.22E-04 | 8.84E-03 | 6.46E-03 | 2.52E-02 | 0.00E+00 | 1.1418E+00 | 1.2808E+02 |
| $\alpha_4$ | 4.10E-05 | 4.58E-03 | 2.40E-03 | 1.65E-02 | 0.00E+00 | 5.9222E-01 | 1.2863E+02 |
| $\alpha_5$ | 7.19E-09 | 1.72E-03 | 2.33E-04 | 8.62E-03 | 0.00E+00 | 2.2220E-01 | 1.2900E+02 |
| $\alpha_6$ | 1.09E-18 | 6.44E-04 | 1.13E-06 | 3.76E-03 | 0.00E+00 | 8.3237E-02 | 1.2914E+02 |

CHECK VALVE FAIL TO OPEN ALL SYSTEMS SPAR: CKV-CC

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9445570 | 0.9675310 | 0.9690930 | 0.9851770 | 1.0000000 | 1.9205E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.38E-03 | 1.56E-02 | 1.40E-02 | 3.22E-02 | 0.00E+00 | 3.0878E+00 | 1.9541E+02 |
| $\alpha_3$ | 1.11E-03 | 8.22E-03 | 6.64E-03 | 2.07E-02 | 0.00E+00 | 1.6312E+00 | 1.9686E+02 |
| $\alpha_4$ | 2.50E-04 | 4.98E-03 | 3.45E-03 | 1.49E-02 | 0.00E+00 | 9.8887E-01 | 1.9751E+02 |
| $\alpha_5$ | 1.29E-05 | 2.63E-03 | 1.24E-03 | 9.93E-03 | 0.00E+00 | 5.2177E-01 | 1.9797E+02 |
| $\alpha_6$ | 3.39E-10 | 9.38E-04 | 8.01E-05 | 4.93E-03 | 0.00E+00 | 1.8628E-01 | 1.9831E+02 |
| $\alpha_7$ | 0.00E+00 | 1.46E-04 | 1.28E-13 | 5.51E-04 | 0.00E+00 | 2.9071E-02 | 1.9847E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9473090 | 0.9681410 | 0.9694650 | 0.9844540 | 1.0000000 | 2.2673E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.30E-03 | 1.43E-02 | 1.29E-02 | 2.89E-02 | 0.00E+00 | 3.3447E+00 | 2.3085E+02 |
| $\alpha_3$ | 1.10E-03 | 7.42E-03 | 6.08E-03 | 1.84E-02 | 0.00E+00 | 1.7384E+00 | 2.3245E+02 |
| $\alpha_4$ | 3.47E-04 | 4.90E-03 | 3.58E-03 | 1.39E-02 | 0.00E+00 | 1.1465E+00 | 2.3304E+02 |
| $\alpha_5$ | 5.51E-05 | 3.02E-03 | 1.78E-03 | 1.02E-02 | 0.00E+00 | 7.0833E-01 | 2.3348E+02 |
| $\alpha_6$ | 8.87E-07 | 1.57E-03 | 5.13E-04 | 6.70E-03 | 0.00E+00 | 3.6696E-01 | 2.3382E+02 |
| $\alpha_7$ | 6.95E-14 | 5.25E-04 | 9.44E-06 | 2.99E-03 | 0.00E+00 | 1.2297E-01 | 2.3407E+02 |
| $\alpha_8$ | 1.30E-42 | 1.41E-04 | 2.02E-12 | 5.98E-04 | 0.00E+00 | 3.3124E-02 | 2.3416E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

Pooled Check Valves

CHECK VALVE FAIL TO OPEN ALL SYSTEMS SPAR: CKV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.5.1.2 CHECK VALVE FAIL TO CLOSE ALL SYSTEMS SPAR:CKV-OO

**Component :** Check Valve
**Failure Mode :** Fail to close (reseat) on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 37.00
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8693950 | 0.9492330 | 0.9594150 | 0.9941760 | 0.9431720 | 2.7009E+01 | 1.4445E+00 |
| $\alpha_2$ | 5.82E-03 | 5.08E-02 | 4.06E-02 | 1.31E-01 | 5.68E-02 | 1.4445E+00 | 2.7009E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9142230 | 0.9625010 | 0.9678000 | 0.9926280 | 0.9606420 | 5.4680E+01 | 2.1303E+00 |
| $\alpha_2$ | 2.43E-03 | 2.40E-02 | 1.87E-02 | 6.38E-02 | 2.02E-02 | 1.3628E+00 | 5.5448E+01 |
| $\alpha_3$ | 3.28E-04 | 1.35E-02 | 8.38E-03 | 4.42E-02 | 1.91E-02 | 7.6752E-01 | 5.6043E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9263150 | 0.9646970 | 0.9683930 | 0.9904440 | 0.9693570 | 7.9595E+01 | 2.9128E+00 |
| $\alpha_2$ | 2.30E-03 | 1.86E-02 | 1.49E-02 | 4.77E-02 | 8.88E-03 | 1.5347E+00 | 8.0973E+01 |
| $\alpha_3$ | 4.38E-04 | 1.10E-02 | 7.35E-03 | 3.39E-02 | 1.45E-02 | 9.0541E-01 | 8.1602E+01 |
| $\alpha_4$ | 1.67E-05 | 5.73E-03 | 2.49E-03 | 2.24E-02 | 7.24E-03 | 4.7267E-01 | 8.2035E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9400120 | 0.9675070 | 0.9696700 | 0.9876020 | 0.9744740 | 1.3794E+02 | 4.6326E+00 |
| $\alpha_2$ | 3.51E-03 | 1.63E-02 | 1.41E-02 | 3.67E-02 | 5.05E-03 | 2.3306E+00 | 1.4024E+02 |
| $\alpha_3$ | 9.42E-04 | 9.51E-03 | 7.33E-03 | 2.55E-02 | 8.82E-03 | 1.3553E+00 | 1.4122E+02 |
| $\alpha_4$ | 1.17E-04 | 5.26E-03 | 3.20E-03 | 1.74E-02 | 8.75E-03 | 7.4939E-01 | 1.4182E+02 |
| $\alpha_5$ | 1.17E-09 | 1.38E-03 | 1.39E-04 | 7.16E-03 | 2.92E-03 | 1.9728E-01 | 1.4238E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9441460 | 0.9685840 | 0.9703780 | 0.9868810 | 0.9777680 | 1.6702E+02 | 5.4173E+00 |
| $\alpha_2$ | 3.17E-03 | 1.41E-02 | 1.23E-02 | 3.13E-02 | 3.82E-03 | 2.4346E+00 | 1.7000E+02 |
| $\alpha_3$ | 8.48E-04 | 8.10E-03 | 6.30E-03 | 2.15E-02 | 4.99E-03 | 1.3975E+00 | 1.7104E+02 |
| $\alpha_4$ | 2.66E-04 | 5.61E-03 | 3.85E-03 | 1.70E-02 | 7.32E-03 | 9.6722E-01 | 1.7147E+02 |
| $\alpha_5$ | 7.92E-06 | 2.74E-03 | 1.19E-03 | 1.07E-02 | 4.88E-03 | 4.7220E-01 | 1.7197E+02 |
| $\alpha_6$ | 4.32E-12 | 8.45E-04 | 3.16E-05 | 4.68E-03 | 1.22E-03 | 1.4574E-01 | 1.7229E+02 |

CHECK VALVE FAIL TO CLOSE ALL SYSTEMS SPAR:CKV-OO

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9497250 | 0.9694660 | 0.9707080 | 0.9849580 | 0.9800170 | 2.4242E+02 | 7.6352E+00 |
| $\alpha_2$ | 3.92E-03 | 1.32E-02 | 1.19E-02 | 2.68E-02 | 3.55E-03 | 3.2991E+00 | 2.4676E+02 |
| $\alpha_3$ | 1.11E-03 | 7.19E-03 | 5.92E-03 | 1.76E-02 | 2.79E-03 | 1.7975E+00 | 2.4826E+02 |
| $\alpha_4$ | 4.77E-04 | 5.20E-03 | 3.96E-03 | 1.42E-02 | 5.25E-03 | 1.3014E+00 | 2.4875E+02 |
| $\alpha_5$ | 1.04E-04 | 3.34E-03 | 2.14E-03 | 1.06E-02 | 5.25E-03 | 8.3427E-01 | 2.4922E+02 |
| $\alpha_6$ | 4.58E-07 | 1.37E-03 | 4.09E-04 | 6.00E-03 | 2.62E-03 | 3.4258E-01 | 2.4971E+02 |
| $\alpha_7$ | 6.65E-25 | 2.41E-04 | 2.44E-08 | 1.36E-03 | 5.26E-04 | 6.0371E-02 | 2.4999E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9525820 | 0.9704220 | 0.9714810 | 0.9846380 | 0.9817730 | 2.8538E+02 | 8.6984E+00 |
| $\alpha_2$ | 3.85E-03 | 1.22E-02 | 1.11E-02 | 2.42E-02 | 3.42E-03 | 3.5771E+00 | 2.9050E+02 |
| $\alpha_3$ | 1.02E-03 | 6.30E-03 | 5.22E-03 | 1.53E-02 | 1.67E-03 | 1.8521E+00 | 2.9223E+02 |
| $\alpha_4$ | 4.80E-04 | 4.70E-03 | 3.63E-03 | 1.26E-02 | 3.46E-03 | 1.3815E+00 | 2.9270E+02 |
| $\alpha_5$ | 1.88E-04 | 3.47E-03 | 2.43E-03 | 1.03E-02 | 4.60E-03 | 1.0208E+00 | 2.9306E+02 |
| $\alpha_6$ | 1.95E-05 | 2.04E-03 | 1.08E-03 | 7.35E-03 | 3.45E-03 | 6.0136E-01 | 2.9348E+02 |
| $\alpha_7$ | 2.24E-09 | 7.37E-04 | 9.40E-05 | 3.72E-03 | 1.38E-03 | 2.1677E-01 | 2.9386E+02 |
| $\alpha_8$ | 3.95E-30 | 1.66E-04 | 1.32E-09 | 8.74E-04 | 2.30E-04 | 4.8724E-02 | 2.9403E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9431720 | 0.9606420 | 0.9693570 | 0.9744740 | 0.9777680 | 0.9800170 | 0.9817730 |
| $\alpha_2$ | 5.68E-02 | 2.02E-02 | 8.88E-03 | 5.05E-03 | 3.82E-03 | 3.55E-03 | 3.42E-03 |
| $\alpha_3$ | | 1.91E-02 | 1.45E-02 | 8.82E-03 | 4.99E-03 | 2.79E-03 | 1.67E-03 |
| $\alpha_4$ | | | 7.24E-03 | 8.75E-03 | 7.32E-03 | 5.25E-03 | 3.46E-03 |
| $\alpha_5$ | | | | 2.92E-03 | 4.88E-03 | 5.25E-03 | 4.60E-03 |
| $\alpha_6$ | | | | | 1.22E-03 | 2.62E-03 | 3.45E-03 |
| $\alpha_7$ | | | | | | 5.26E-04 | 1.38E-03 |
| $\alpha_8$ | | | | | | | 2.30E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.43E-01 | 9.61E-01 | 9.69E-01 | 9.74E-01 | 9.78E-01 | 9.80E-01 | 9.82E-01 |
| Beta | 5.68E-02 | 3.94E-02 | 3.06E-02 | 2.55E-02 | 2.22E-02 | 2.00E-02 | 1.82E-02 |
| Gamma | | 4.86E-01 | 7.10E-01 | 8.02E-01 | 8.28E-01 | 8.22E-01 | 8.12E-01 |
| Delta | | | 3.33E-01 | 5.70E-01 | 7.29E-01 | 8.30E-01 | 8.87E-01 |
| Epsilon | | | | 2.50E-01 | 4.55E-01 | 6.15E-01 | 7.36E-01 |
| Mu | | | | | 2.00E-01 | 3.75E-01 | 5.24E-01 |
| Upsilon | | | | | | 1.67E-01 | 3.18E-01 |
| Sigma | | | | | | | 1.43E-01 |

Pooled Check Valves

CHECK VALVE FAIL TO CLOSE ALL SYSTEMS SPAR:CKV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 16.44 | 24.67 | 32.89 | 41.11 | 49.33 | 57.56 | 65.78 |
| $N_1$ | 0.3229 | 0.4551 | 0.5691 | 0.6657 | 0.7457 | 0.8100 | 0.8717 |
| $N_2$ | 1.0100 | 0.5291 | 0.3066 | 0.2164 | 0.1954 | 0.2113 | 0.2324 |
| $N_3$ | | 0.5003 | 0.5011 | 0.3779 | 0.2557 | 0.1663 | 0.1137 |
| $N_4$ | | | 0.2500 | 0.3750 | 0.3750 | 0.3125 | 0.2350 |
| $N_5$ | | | | 0.1250 | 0.2500 | 0.3125 | 0.3125 |
| $N_6$ | | | | | 0.0625 | 0.1563 | 0.2344 |
| $N_7$ | | | | | | 0.0313 | 0.0938 |
| $N_8$ | | | | | | | 0.0156 |

## 1.5.1.3 CHECK VALVE FAIL TO REMAIN CLOSED ALL SYSTEMS SPAR:CKV-CO

| | |
|---|---|
| **Component :** | Check Valve |
| **Failure Mode :** | Spurious operation open or close |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 1.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 1.0000000 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 1.0000000 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 1.0000000 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 1.0000000 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

CHECK VALVE FAIL TO REMAIN CLOSED ALL SYSTEMS SPAR:CKV-CO

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9422570 | 0.9661670 | 0.9677850 | 0.9845420 | 1.0000000 | 1.8405E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.57E-03 | 1.62E-02 | 1.45E-02 | 3.35E-02 | 0.00E+00 | 3.0878E+00 | 1.8741E+02 |
| $\alpha_3$ | 1.15E-03 | 8.56E-03 | 6.91E-03 | 2.16E-02 | 0.00E+00 | 1.6312E+00 | 1.8886E+02 |
| $\alpha_4$ | 2.60E-04 | 5.19E-03 | 3.59E-03 | 1.56E-02 | 0.00E+00 | 9.8887E-01 | 1.8951E+02 |
| $\alpha_5$ | 1.35E-05 | 2.74E-03 | 1.30E-03 | 1.04E-02 | 0.00E+00 | 5.2177E-01 | 1.8997E+02 |
| $\alpha_6$ | 3.53E-10 | 9.78E-04 | 8.35E-05 | 5.13E-03 | 0.00E+00 | 1.8628E-01 | 1.9031E+02 |
| $\alpha_7$ | 0.00E+00 | 1.53E-04 | 1.34E-13 | 5.75E-04 | 0.00E+00 | 2.9071E-02 | 1.9047E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9454620 | 0.9670150 | 0.9683850 | 0.9838980 | 1.0000000 | 2.1873E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.45E-03 | 1.48E-02 | 1.34E-02 | 2.99E-02 | 0.00E+00 | 3.3447E+00 | 2.2285E+02 |
| $\alpha_3$ | 1.14E-03 | 7.69E-03 | 6.29E-03 | 1.90E-02 | 0.00E+00 | 1.7384E+00 | 2.2445E+02 |
| $\alpha_4$ | 3.59E-04 | 5.07E-03 | 3.71E-03 | 1.44E-02 | 0.00E+00 | 1.1465E+00 | 2.2504E+02 |
| $\alpha_5$ | 5.70E-05 | 3.13E-03 | 1.84E-03 | 1.06E-02 | 0.00E+00 | 7.0833E-01 | 2.2548E+02 |
| $\alpha_6$ | 9.18E-07 | 1.62E-03 | 5.31E-04 | 6.94E-03 | 0.00E+00 | 3.6696E-01 | 2.2582E+02 |
| $\alpha_7$ | 7.20E-14 | 5.44E-04 | 9.78E-06 | 3.10E-03 | 0.00E+00 | 1.2297E-01 | 2.2607E+02 |
| $\alpha_8$ | 1.35E-42 | 1.46E-04 | 2.09E-12 | 6.19E-04 | 0.00E+00 | 3.3124E-02 | 2.2616E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

Pooled Check Valves
CHECK VALVE FAIL TO REMAIN CLOSED ALL SYSTEMS SPAR:CKV-CO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

### 1.5.1.4 CKV FAIL TO REMAIN CLOSED (LEAKAGE) ALL SYSTEMS SPAR:CKV-CO

**Component :** Check Valve
**Failure Mode :** Fail to remain closed(detectable leakage)
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 44.50
Total Number of Common-Cause Failure Events: 7

## *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.7881420 | 0.8849500 | 0.8920470 | 0.9574400 | 0.8537550 | 3.1985E+01 | 4.1583E+00 |
| $\alpha_2$ | 4.26E-02 | 1.15E-01 | 1.08E-01 | 2.12E-01 | 1.46E-01 | 4.1583E+00 | 3.1985E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8497360 | 0.9125510 | 0.9166750 | 0.9612580 | 0.8684710 | 6.0683E+01 | 5.8152E+00 |
| $\alpha_2$ | 1.52E-02 | 4.99E-02 | 4.55E-02 | 9.99E-02 | 6.94E-02 | 3.3194E+00 | 6.3179E+01 |
| $\alpha_3$ | 8.78E-03 | 3.75E-02 | 3.30E-02 | 8.19E-02 | 6.22E-02 | 2.4958E+00 | 6.4002E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8686360 | 0.9192150 | 0.9221830 | 0.9596440 | 0.8751490 | 8.6291E+01 | 7.5837E+00 |
| $\alpha_2$ | 1.33E-02 | 4.00E-02 | 3.68E-02 | 7.78E-02 | 5.51E-02 | 3.7567E+00 | 9.0118E+01 |
| $\alpha_3$ | 6.36E-03 | 2.70E-02 | 2.37E-02 | 5.88E-02 | 4.64E-02 | 2.5329E+00 | 9.1342E+01 |
| $\alpha_4$ | 1.26E-03 | 1.38E-02 | 1.05E-02 | 3.75E-02 | 2.34E-02 | 1.2941E+00 | 9.2581E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8988560 | 0.9343250 | 0.9361810 | 0.9634390 | 0.8802890 | 1.4518E+02 | 1.0205E+01 |
| $\alpha_2$ | 1.17E-02 | 3.03E-02 | 2.83E-02 | 5.58E-02 | 4.66E-02 | 4.7094E+00 | 1.5068E+02 |
| $\alpha_3$ | 5.36E-03 | 1.94E-02 | 1.74E-02 | 4.03E-02 | 3.66E-02 | 3.0131E+00 | 1.5237E+02 |
| $\alpha_4$ | 2.03E-03 | 1.22E-02 | 1.02E-02 | 2.92E-02 | 2.73E-02 | 1.8923E+00 | 1.5349E+02 |
| $\alpha_5$ | 3.34E-05 | 3.80E-03 | 1.98E-03 | 1.37E-02 | 9.30E-03 | 5.9018E-01 | 1.5479E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9085170 | 0.9395700 | 0.9411390 | 0.9652700 | 0.8930000 | 1.7536E+02 | 1.1279E+01 |
| $\alpha_2$ | 7.75E-03 | 2.20E-02 | 2.04E-02 | 4.21E-02 | 2.87E-02 | 4.1142E+00 | 1.8252E+02 |
| $\alpha_3$ | 5.49E-03 | 1.81E-02 | 1.64E-02 | 3.65E-02 | 3.41E-02 | 3.3739E+00 | 1.8326E+02 |
| $\alpha_4$ | 2.49E-03 | 1.21E-02 | 1.04E-02 | 2.74E-02 | 2.54E-02 | 2.2529E+00 | 1.8439E+02 |
| $\alpha_5$ | 5.07E-04 | 6.45E-03 | 4.80E-03 | 1.81E-02 | 1.50E-02 | 1.2043E+00 | 1.8543E+02 |
| $\alpha_6$ | 4.77E-07 | 1.79E-03 | 5.13E-04 | 7.89E-03 | 3.82E-03 | 3.3324E-01 | 1.8631E+02 |

CKV FAIL TO REMAIN CLOSED (LEAKAGE) ALL SYSTEMS SPAR:CKV-CO

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9255470 | 0.9493890 | 0.9505160 | 0.9693910 | 0.9068650 | 2.5221E+02 | 1.3445E+01 |
| $\alpha_2$ | 6.33E-03 | 1.70E-02 | 1.58E-02 | 3.17E-02 | 1.90E-02 | 4.5128E+00 | 2.6114E+02 |
| $\alpha_3$ | 3.45E-03 | 1.20E-02 | 1.08E-02 | 2.46E-02 | 2.06E-02 | 3.1812E+00 | 2.6247E+02 |
| $\alpha_4$ | 3.00E-03 | 1.11E-02 | 9.91E-03 | 2.33E-02 | 2.61E-02 | 2.9514E+00 | 2.6270E+02 |
| $\alpha_5$ | 1.19E-03 | 7.14E-03 | 5.95E-03 | 1.72E-02 | 1.83E-02 | 1.8968E+00 | 2.6376E+02 |
| $\alpha_6$ | 6.23E-05 | 2.82E-03 | 1.71E-03 | 9.35E-03 | 7.48E-03 | 7.4878E-01 | 2.6491E+02 |
| $\alpha_7$ | 8.57E-12 | 5.80E-04 | 2.67E-05 | 3.18E-03 | 1.66E-03 | 1.5407E-01 | 2.6550E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9323950 | 0.9535150 | 0.9544860 | 0.9713300 | 0.9175500 | 2.9663E+02 | 1.4461E+01 |
| $\alpha_2$ | 5.26E-03 | 1.43E-02 | 1.32E-02 | 2.68E-02 | 1.29E-02 | 4.4378E+00 | 3.0665E+02 |
| $\alpha_3$ | 2.74E-03 | 9.83E-03 | 8.80E-03 | 2.04E-02 | 1.56E-02 | 3.0590E+00 | 3.0803E+02 |
| $\alpha_4$ | 1.75E-03 | 7.82E-03 | 6.79E-03 | 1.74E-02 | 1.51E-02 | 2.4321E+00 | 3.0866E+02 |
| $\alpha_5$ | 2.35E-03 | 9.07E-03 | 8.04E-03 | 1.93E-02 | 2.49E-02 | 2.8214E+00 | 3.0827E+02 |
| $\alpha_6$ | 2.62E-04 | 3.69E-03 | 2.70E-03 | 1.05E-02 | 9.20E-03 | 1.1483E+00 | 3.0994E+02 |
| $\alpha_7$ | 4.06E-06 | 1.50E-03 | 6.42E-04 | 5.90E-03 | 4.05E-03 | 4.6677E-01 | 3.1062E+02 |
| $\alpha_8$ | 4.83E-17 | 3.07E-04 | 1.39E-06 | 1.79E-03 | 7.36E-04 | 9.5624E-02 | 3.1100E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8537550 | 0.8684710 | 0.8751490 | 0.8802890 | 0.8930000 | 0.9068650 | 0.9175500 |
| $\alpha_2$ | 1.46E-01 | 6.94E-02 | 5.51E-02 | 4.66E-02 | 2.87E-02 | 1.90E-02 | 1.29E-02 |
| $\alpha_3$ | | 6.22E-02 | 4.64E-02 | 3.66E-02 | 3.41E-02 | 2.06E-02 | 1.56E-02 |
| $\alpha_4$ | | | 2.34E-02 | 2.73E-02 | 2.54E-02 | 2.61E-02 | 1.51E-02 |
| $\alpha_5$ | | | | 9.30E-03 | 1.50E-02 | 1.83E-02 | 2.49E-02 |
| $\alpha_6$ | | | | | 3.82E-03 | 7.48E-03 | 9.20E-03 |
| $\alpha_7$ | | | | | | 1.66E-03 | 4.05E-03 |
| $\alpha_8$ | | | | | | | 7.36E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 8.54E-01 | 8.68E-01 | 8.75E-01 | 8.80E-01 | 8.93E-01 | 9.07E-01 | 9.18E-01 |
| Beta | 1.46E-01 | 1.32E-01 | 1.25E-01 | 1.20E-01 | 1.07E-01 | 9.31E-02 | 8.24E-02 |
| Gamma | | 4.73E-01 | 5.59E-01 | 6.11E-01 | 7.32E-01 | 7.96E-01 | 8.44E-01 |
| Delta | | | 3.35E-01 | 5.00E-01 | 5.64E-01 | 7.22E-01 | 7.76E-01 |
| Epsilon | | | | 2.54E-01 | 4.26E-01 | 5.12E-01 | 7.20E-01 |
| Mu | | | | | 2.03E-01 | 3.33E-01 | 3.60E-01 |
| Upsilon | | | | | | 1.82E-01 | 3.42E-01 |
| Sigma | | | | | | | 1.54E-01 |

Pooled Check Valves

CKV FAIL TO REMAIN CLOSED (LEAKAGE) ALL SYSTEMS SPAR:CKV-CO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 19.47 | 29.21 | 38.95 | 48.69 | 58.42 | 68.16 | 77.90 |
| $N_1$ | 2.2690 | 1.9179 | 1.2048 | 0.3333 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 3.7238 | 2.4857 | 2.5286 | 2.5952 | 1.8750 | 1.4250 | 1.0931 |
| $N_3$ | | 2.2286 | 2.1286 | 2.0357 | 2.2321 | 1.5500 | 1.3206 |
| $N_4$ | | | 1.0714 | 1.5179 | 1.6607 | 1.9625 | 1.2856 |
| $N_5$ | | | | 0.5179 | 0.9821 | 1.3750 | 2.1131 |
| $N_6$ | | | | | 0.2500 | 0.5625 | 0.7813 |
| $N_7$ | | | | | | 0.1250 | 0.3438 |
| $N_8$ | | | | | | | 0.0625 |

## 1.5.2 BWR Residual Heat Removal Check Valves

### 1.5.2.1 BWR RHR CHECK VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9311740 | 0.9652090 | 0.9682200 | 0.9889480 | 1.0000000 | 9.8161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.01E-03 | 2.08E-02 | 1.77E-02 | 4.80E-02 | 0.00E+00 | 2.1142E+00 | 9.9585E+01 |
| $\alpha_3$ | 4.70E-04 | 9.61E-03 | 6.64E-03 | 2.89E-02 | 0.00E+00 | 9.7738E-01 | 1.0072E+02 |
| $\alpha_4$ | 2.42E-06 | 3.68E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0132E+02 |
| $\alpha_5$ | 5.87E-21 | 7.11E-04 | 4.02E-07 | 4.12E-03 | 0.00E+00 | 7.2277E-02 | 1.0163E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9346440 | 0.9652760 | 0.9677640 | 0.9873890 | 1.0000000 | 1.1894E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.74E-03 | 1.82E-02 | 1.56E-02 | 4.13E-02 | 0.00E+00 | 2.2392E+00 | 1.2098E+02 |
| $\alpha_3$ | 6.53E-04 | 9.27E-03 | 6.78E-03 | 2.64E-02 | 0.00E+00 | 1.1418E+00 | 1.2208E+02 |
| $\alpha_4$ | 4.30E-05 | 4.81E-03 | 2.52E-03 | 1.73E-02 | 0.00E+00 | 5.9222E-01 | 1.2263E+02 |
| $\alpha_5$ | 7.54E-09 | 1.80E-03 | 2.45E-04 | 9.04E-03 | 0.00E+00 | 2.2220E-01 | 1.2300E+02 |
| $\alpha_6$ | 1.14E-18 | 6.76E-04 | 1.18E-06 | 3.94E-03 | 0.00E+00 | 8.3237E-02 | 1.2314E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9428470 | 0.9665190 | 0.9681250 | 0.9847050 | 1.0000000 | 1.8605E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.52E-03 | 1.60E-02 | 1.44E-02 | 3.32E-02 | 0.00E+00 | 3.0878E+00 | 1.8941E+02 |
| $\alpha_3$ | 1.14E-03 | 8.47E-03 | 6.84E-03 | 2.14E-02 | 0.00E+00 | 1.6312E+00 | 1.9086E+02 |
| $\alpha_4$ | 2.57E-04 | 5.14E-03 | 3.56E-03 | 1.54E-02 | 0.00E+00 | 9.8887E-01 | 1.9151E+02 |
| $\alpha_5$ | 1.33E-05 | 2.71E-03 | 1.28E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9197E+02 |
| $\alpha_6$ | 3.49E-10 | 9.68E-04 | 8.26E-05 | 5.08E-03 | 0.00E+00 | 1.8628E-01 | 1.9231E+02 |
| $\alpha_7$ | 0.00E+00 | 1.51E-04 | 1.32E-13 | 5.69E-04 | 0.00E+00 | 2.9071E-02 | 1.9247E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9459360 | 0.9673040 | 0.9686640 | 0.9840410 | 1.0000000 | 2.2073E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.41E-03 | 1.47E-02 | 1.33E-02 | 2.97E-02 | 0.00E+00 | 3.3447E+00 | 2.2485E+02 |
| $\alpha_3$ | 1.13E-03 | 7.62E-03 | 6.24E-03 | 1.88E-02 | 0.00E+00 | 1.7384E+00 | 2.2645E+02 |
| $\alpha_4$ | 3.56E-04 | 5.02E-03 | 3.67E-03 | 1.43E-02 | 0.00E+00 | 1.1465E+00 | 2.2704E+02 |
| $\alpha_5$ | 5.65E-05 | 3.10E-03 | 1.82E-03 | 1.05E-02 | 0.00E+00 | 7.0833E-01 | 2.2748E+02 |
| $\alpha_6$ | 9.10E-07 | 1.61E-03 | 5.27E-04 | 6.88E-03 | 0.00E+00 | 3.6696E-01 | 2.2782E+02 |
| $\alpha_7$ | 7.14E-14 | 5.39E-04 | 9.69E-06 | 3.07E-03 | 0.00E+00 | 1.2297E-01 | 2.2807E+02 |
| $\alpha_8$ | 1.34E-42 | 1.45E-04 | 2.07E-12 | 6.14E-04 | 0.00E+00 | 3.3124E-02 | 2.2816E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

BWR Residual Heat Removal Check Valves

BWR RHR CHECK VALVE FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.5.2.2 BWR RHR CHECK VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8959650 | 0.9739500 | 0.9892430 | 0.9999480 | 1.0000000 | 1.6246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.81E-05 | 2.60E-02 | 1.08E-02 | 1.04E-01 | 0.00E+00 | 4.3452E-01 | 1.6246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9143470 | 0.9699670 | 0.9780280 | 0.9980130 | 1.0000000 | 3.5555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.25E-04 | 2.27E-02 | 1.48E-02 | 7.18E-02 | 0.00E+00 | 8.3366E-01 | 3.5822E+01 |
| $\alpha_3$ | 2.56E-07 | 7.29E-03 | 1.48E-03 | 3.46E-02 | 0.00E+00 | 2.6722E-01 | 3.6389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9178250 | 0.9656410 | 0.9712250 | 0.9943340 | 1.0000000 | 5.2136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.89E-03 | 2.27E-02 | 1.72E-02 | 6.27E-02 | 0.00E+00 | 1.2281E+00 | 5.2763E+01 |
| $\alpha_3$ | 8.45E-06 | 7.49E-03 | 2.78E-03 | 3.09E-02 | 0.00E+00 | 4.0431E-01 | 5.3587E+01 |
| $\alpha_4$ | 1.78E-08 | 4.12E-03 | 5.66E-04 | 2.07E-02 | 0.00E+00 | 2.2267E-01 | 5.3768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9337450 | 0.9665250 | 0.9694270 | 0.9893730 | 1.0000000 | 1.0216E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.85E-03 | 2.00E-02 | 1.71E-02 | 4.62E-02 | 0.00E+00 | 2.1142E+00 | 1.0358E+02 |
| $\alpha_3$ | 4.52E-04 | 9.25E-03 | 6.39E-03 | 2.78E-02 | 0.00E+00 | 9.7738E-01 | 1.0472E+02 |
| $\alpha_4$ | 2.33E-06 | 3.54E-03 | 1.19E-03 | 1.50E-02 | 0.00E+00 | 3.7439E-01 | 1.0532E+02 |
| $\alpha_5$ | 5.65E-21 | 6.84E-04 | 3.87E-07 | 3.96E-03 | 0.00E+00 | 7.2277E-02 | 1.0563E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366750 | 0.9663680 | 0.9687880 | 0.9877920 | 1.0000000 | 1.2294E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.62E-03 | 1.76E-02 | 1.51E-02 | 4.00E-02 | 0.00E+00 | 2.2392E+00 | 1.2498E+02 |
| $\alpha_3$ | 6.32E-04 | 8.98E-03 | 6.57E-03 | 2.55E-02 | 0.00E+00 | 1.1418E+00 | 1.2608E+02 |
| $\alpha_4$ | 4.16E-05 | 4.66E-03 | 2.44E-03 | 1.68E-02 | 0.00E+00 | 5.9222E-01 | 1.2663E+02 |
| $\alpha_5$ | 7.30E-09 | 1.75E-03 | 2.37E-04 | 8.75E-03 | 0.00E+00 | 2.2220E-01 | 1.2700E+02 |
| $\alpha_6$ | 1.11E-18 | 6.54E-04 | 1.14E-06 | 3.82E-03 | 0.00E+00 | 8.3237E-02 | 1.2714E+02 |

BWR Residual Heat Removal Check Valves

BWR RHR CHECK VALVE FAIL TO CLOSE

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9439980 | 0.9672000 | 0.9687770 | 0.9850250 | 1.0000000 | 1.9005E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.43E-03 | 1.57E-02 | 1.41E-02 | 3.25E-02 | 0.00E+00 | 3.0878E+00 | 1.9341E+02 |
| $\alpha_3$ | 1.12E-03 | 8.30E-03 | 6.70E-03 | 2.10E-02 | 0.00E+00 | 1.6312E+00 | 1.9486E+02 |
| $\alpha_4$ | 2.52E-04 | 5.03E-03 | 3.48E-03 | 1.51E-02 | 0.00E+00 | 9.8887E-01 | 1.9551E+02 |
| $\alpha_5$ | 1.31E-05 | 2.66E-03 | 1.26E-03 | 1.00E-02 | 0.00E+00 | 5.2177E-01 | 1.9597E+02 |
| $\alpha_6$ | 3.42E-10 | 9.48E-04 | 8.09E-05 | 4.98E-03 | 0.00E+00 | 1.8628E-01 | 1.9631E+02 |
| $\alpha_7$ | 0.00E+00 | 1.48E-04 | 1.30E-13 | 5.57E-04 | 0.00E+00 | 2.9071E-02 | 1.9647E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9468590 | 0.9678670 | 0.9692050 | 0.9843190 | 1.0000000 | 2.2473E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.33E-03 | 1.44E-02 | 1.30E-02 | 2.92E-02 | 0.00E+00 | 3.3447E+00 | 2.2885E+02 |
| $\alpha_3$ | 1.11E-03 | 7.49E-03 | 6.13E-03 | 1.85E-02 | 0.00E+00 | 1.7384E+00 | 2.3045E+02 |
| $\alpha_4$ | 3.50E-04 | 4.94E-03 | 3.61E-03 | 1.41E-02 | 0.00E+00 | 1.1465E+00 | 2.3104E+02 |
| $\alpha_5$ | 5.55E-05 | 3.05E-03 | 1.79E-03 | 1.03E-02 | 0.00E+00 | 7.0833E-01 | 2.3148E+02 |
| $\alpha_6$ | 8.95E-07 | 1.58E-03 | 5.17E-04 | 6.76E-03 | 0.00E+00 | 3.6696E-01 | 2.3182E+02 |
| $\alpha_7$ | 7.01E-14 | 5.30E-04 | 9.53E-06 | 3.02E-03 | 0.00E+00 | 1.2297E-01 | 2.3207E+02 |
| $\alpha_8$ | 1.31E-42 | 1.43E-04 | 2.03E-12 | 6.03E-04 | 0.00E+00 | 3.3124E-02 | 2.3216E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

BWR Residual Heat Removal Check Valves

BWR RHR CHECK VALVE FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.5.3 PWR Auxiliary Feedwater Check Valves

## 1.5.3.1 CHECK VALVE FAIL TO OPEN SPAR: AFW-CKV-CC

| | |
|---|---|
| **System :** | Auxiliary feedwater |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9311740 | 0.9652090 | 0.9682200 | 0.9889480 | 1.0000000 | 9.8161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.01E-03 | 2.08E-02 | 1.77E-02 | 4.80E-02 | 0.00E+00 | 2.1142E+00 | 9.9585E+01 |
| $\alpha_3$ | 4.70E-04 | 9.61E-03 | 6.64E-03 | 2.89E-02 | 0.00E+00 | 9.7738E-01 | 1.0072E+02 |
| $\alpha_4$ | 2.42E-06 | 3.68E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0132E+02 |
| $\alpha_5$ | 5.87E-21 | 7.11E-04 | 4.02E-07 | 4.12E-03 | 0.00E+00 | 7.2277E-02 | 1.0163E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9346440 | 0.9652760 | 0.9677640 | 0.9873890 | 1.0000000 | 1.1894E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.74E-03 | 1.82E-02 | 1.56E-02 | 4.13E-02 | 0.00E+00 | 2.2392E+00 | 1.2098E+02 |
| $\alpha_3$ | 6.53E-04 | 9.27E-03 | 6.78E-03 | 2.64E-02 | 0.00E+00 | 1.1418E+00 | 1.2208E+02 |
| $\alpha_4$ | 4.30E-05 | 4.81E-03 | 2.52E-03 | 1.73E-02 | 0.00E+00 | 5.9222E-01 | 1.2263E+02 |
| $\alpha_5$ | 7.54E-09 | 1.80E-03 | 2.45E-04 | 9.04E-03 | 0.00E+00 | 2.2220E-01 | 1.2300E+02 |
| $\alpha_6$ | 1.14E-18 | 6.76E-04 | 1.18E-06 | 3.94E-03 | 0.00E+00 | 8.3237E-02 | 1.2314E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9428470 | 0.9665190 | 0.9681250 | 0.9847050 | 1.0000000 | 1.8605E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.52E-03 | 1.60E-02 | 1.44E-02 | 3.32E-02 | 0.00E+00 | 3.0878E+00 | 1.8941E+02 |
| $\alpha_3$ | 1.14E-03 | 8.47E-03 | 6.84E-03 | 2.14E-02 | 0.00E+00 | 1.6312E+00 | 1.9086E+02 |
| $\alpha_4$ | 2.57E-04 | 5.14E-03 | 3.56E-03 | 1.54E-02 | 0.00E+00 | 9.8887E-01 | 1.9151E+02 |
| $\alpha_5$ | 1.33E-05 | 2.71E-03 | 1.28E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9197E+02 |
| $\alpha_6$ | 3.49E-10 | 9.68E-04 | 8.26E-05 | 5.08E-03 | 0.00E+00 | 1.8628E-01 | 1.9231E+02 |
| $\alpha_7$ | 0.00E+00 | 1.51E-04 | 1.32E-13 | 5.69E-04 | 0.00E+00 | 2.9071E-02 | 1.9247E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9459360 | 0.9673040 | 0.9686640 | 0.9840410 | 1.0000000 | 2.2073E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.41E-03 | 1.47E-02 | 1.33E-02 | 2.97E-02 | 0.00E+00 | 3.3447E+00 | 2.2485E+02 |
| $\alpha_3$ | 1.13E-03 | 7.62E-03 | 6.24E-03 | 1.88E-02 | 0.00E+00 | 1.7384E+00 | 2.2645E+02 |
| $\alpha_4$ | 3.56E-04 | 5.02E-03 | 3.67E-03 | 1.43E-02 | 0.00E+00 | 1.1465E+00 | 2.2704E+02 |
| $\alpha_5$ | 5.65E-05 | 3.10E-03 | 1.82E-03 | 1.05E-02 | 0.00E+00 | 7.0833E-01 | 2.2748E+02 |
| $\alpha_6$ | 9.10E-07 | 1.61E-03 | 5.27E-04 | 6.88E-03 | 0.00E+00 | 3.6696E-01 | 2.2782E+02 |
| $\alpha_7$ | 7.14E-14 | 5.39E-04 | 9.69E-06 | 3.07E-03 | 0.00E+00 | 1.2297E-01 | 2.2807E+02 |
| $\alpha_8$ | 1.34E-42 | 1.45E-04 | 2.07E-12 | 6.14E-04 | 0.00E+00 | 3.3124E-02 | 2.2816E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Check Valves

CHECK VALVE FAIL TO OPEN SPAR: AFW-CKV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.5.3.2 CHECK VALVE FAIL TO CLOSE SPAR: AFW-CKV-OO

**System :** Auxiliary feedwater
**Component :** Check Valve
**Failure Mode :** Fail to close (reseat) on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 5.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8591660 | 0.9642770 | 0.9846980 | 0.9999250 | 0.9943280 | 1.1999E+01 | 4.4452E-01 |
| $\alpha_2$ | 7.69E-05 | 3.57E-02 | 1.53E-02 | 1.41E-01 | 5.67E-03 | 4.4452E-01 | 1.1999E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9042200 | 0.9660380 | 0.9748750 | 0.9976030 | 0.9887980 | 3.2150E+01 | 1.1303E+00 |
| $\alpha_2$ | 9.18E-04 | 2.59E-02 | 1.72E-02 | 8.08E-02 | 1.11E-02 | 8.6276E-01 | 3.2418E+01 |
| $\alpha_3$ | 2.87E-07 | 8.04E-03 | 1.63E-03 | 3.81E-02 | 1.14E-04 | 2.6752E-01 | 3.3013E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9120970 | 0.9628430 | 0.9686800 | 0.9936070 | 0.9834520 | 4.9565E+01 | 1.9128E+00 |
| $\alpha_2$ | 2.27E-03 | 2.50E-02 | 1.91E-02 | 6.77E-02 | 1.62E-02 | 1.2847E+00 | 5.0193E+01 |
| $\alpha_3$ | 9.05E-06 | 7.88E-03 | 2.94E-03 | 3.25E-02 | 3.15E-04 | 4.0541E-01 | 5.1072E+01 |
| $\alpha_4$ | 1.87E-08 | 4.33E-03 | 5.94E-04 | 2.17E-02 | 0.00E+00 | 2.2267E-01 | 5.1255E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9314140 | 0.9650830 | 0.9680270 | 0.9886850 | 0.9782220 | 1.0040E+02 | 3.6325E+00 |
| $\alpha_2$ | 4.29E-03 | 2.12E-02 | 1.82E-02 | 4.83E-02 | 2.11E-02 | 2.2056E+00 | 1.0183E+02 |
| $\alpha_3$ | 4.64E-04 | 9.42E-03 | 6.52E-03 | 2.83E-02 | 6.70E-04 | 9.8028E-01 | 1.0305E+02 |
| $\alpha_4$ | 2.37E-06 | 3.60E-03 | 1.21E-03 | 1.53E-02 | 0.00E+00 | 3.7439E-01 | 1.0366E+02 |
| $\alpha_5$ | 5.74E-21 | 6.95E-04 | 3.93E-07 | 4.02E-03 | 0.00E+00 | 7.2277E-02 | 1.0396E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9347590 | 0.9650530 | 0.9674780 | 0.9870430 | 0.9732140 | 1.2198E+02 | 4.4173E+00 |
| $\alpha_2$ | 4.11E-03 | 1.88E-02 | 1.63E-02 | 4.19E-02 | 2.57E-02 | 2.3721E+00 | 1.2403E+02 |
| $\alpha_3$ | 6.46E-04 | 9.08E-03 | 6.65E-03 | 2.58E-02 | 1.10E-03 | 1.1475E+00 | 1.2525E+02 |
| $\alpha_4$ | 4.19E-05 | 4.69E-03 | 2.45E-03 | 1.69E-02 | 0.00E+00 | 5.9222E-01 | 1.2581E+02 |
| $\alpha_5$ | 7.35E-09 | 1.76E-03 | 2.38E-04 | 8.81E-03 | 0.00E+00 | 2.2220E-01 | 1.2618E+02 |
| $\alpha_6$ | 1.12E-18 | 6.59E-04 | 1.15E-06 | 3.84E-03 | 0.00E+00 | 8.3237E-02 | 1.2631E+02 |

CHECK VALVE FAIL TO CLOSE SPAR: AFW-CKV-OO

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9427360 | 0.9662330 | 0.9678020 | 0.9843570 | 0.9683330 | 1.8986E+02 | 6.6350E+00 |
| $\alpha_2$ | 4.92E-03 | 1.66E-02 | 1.50E-02 | 3.39E-02 | 3.00E-02 | 3.2678E+00 | 1.9323E+02 |
| $\alpha_3$ | 1.14E-03 | 8.35E-03 | 6.75E-03 | 2.10E-02 | 1.67E-03 | 1.6412E+00 | 1.9485E+02 |
| $\alpha_4$ | 2.52E-04 | 5.03E-03 | 3.48E-03 | 1.51E-02 | 0.00E+00 | 9.8887E-01 | 1.9551E+02 |
| $\alpha_5$ | 1.31E-05 | 2.66E-03 | 1.26E-03 | 1.00E-02 | 0.00E+00 | 5.2177E-01 | 1.9597E+02 |
| $\alpha_6$ | 3.42E-10 | 9.48E-04 | 8.09E-05 | 4.98E-03 | 0.00E+00 | 1.8628E-01 | 1.9631E+02 |
| $\alpha_7$ | 0.00E+00 | 1.48E-04 | 1.30E-13 | 5.57E-04 | 0.00E+00 | 2.9071E-02 | 1.9647E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9457360 | 0.9669610 | 0.9682920 | 0.9836540 | 0.9652000 | 2.2531E+02 | 7.6983E+00 |
| $\alpha_2$ | 4.83E-03 | 1.53E-02 | 1.39E-02 | 3.04E-02 | 3.18E-02 | 3.5615E+00 | 2.2945E+02 |
| $\alpha_3$ | 1.13E-03 | 7.55E-03 | 6.19E-03 | 1.86E-02 | 2.92E-03 | 1.7583E+00 | 2.3125E+02 |
| $\alpha_4$ | 3.49E-04 | 4.92E-03 | 3.60E-03 | 1.40E-02 | 8.80E-05 | 1.1471E+00 | 2.3186E+02 |
| $\alpha_5$ | 5.53E-05 | 3.04E-03 | 1.79E-03 | 1.03E-02 | 0.00E+00 | 7.0833E-01 | 2.3230E+02 |
| $\alpha_6$ | 8.91E-07 | 1.57E-03 | 5.16E-04 | 6.74E-03 | 0.00E+00 | 3.6696E-01 | 2.3264E+02 |
| $\alpha_7$ | 6.99E-14 | 5.28E-04 | 9.49E-06 | 3.00E-03 | 0.00E+00 | 1.2297E-01 | 2.3289E+02 |
| $\alpha_8$ | 1.31E-42 | 1.42E-04 | 2.03E-12 | 6.01E-04 | 0.00E+00 | 3.3124E-02 | 2.3298E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9943280 | 0.9887980 | 0.9834520 | 0.9782220 | 0.9732140 | 0.9683330 | 0.9652000 |
| $\alpha_2$ | 5.67E-03 | 1.11E-02 | 1.62E-02 | 2.11E-02 | 2.57E-02 | 3.00E-02 | 3.18E-02 |
| $\alpha_3$ | | 1.14E-04 | 3.15E-04 | 6.70E-04 | 1.10E-03 | 1.67E-03 | 2.92E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.80E-05 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.94E-01 | 9.89E-01 | 9.83E-01 | 9.78E-01 | 9.73E-01 | 9.68E-01 | 9.65E-01 |
| Beta | 5.67E-03 | 1.12E-02 | 1.65E-02 | 2.18E-02 | 2.68E-02 | 3.17E-02 | 3.48E-02 |
| Gamma | | 1.02E-02 | 1.91E-02 | 3.08E-02 | 4.11E-02 | 5.26E-02 | 8.64E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.93E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Auxiliary Feedwater Check Valves

CHECK VALVE FAIL TO CLOSE SPAR: AFW-CKV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 1.43 | 2.14 | 2.86 | 3.57 | 4.29 | 5.00 | 5.71 |
| $N_1$ | 0.3229 | 0.4551 | 0.5691 | 0.6657 | 0.7457 | 0.8100 | 0.8717 |
| $N_2$ | 0.0100 | 0.0291 | 0.0566 | 0.0914 | 0.1329 | 0.1800 | 0.2168 |
| $N_3$ | | 0.0003 | 0.0011 | 0.0029 | 0.0057 | 0.0100 | 0.0199 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0006 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.5.4 PWR High Pressure Safety Injection Check Valves

## 1.5.4.1 HIGH PRESSURE INJECTION CHECK VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 3.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8734960 | 0.9682380 | 0.9867710 | 0.9999360 | 1.0000000 | 1.3246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.92E-05 | 3.18E-02 | 1.32E-02 | 1.27E-01 | 0.00E+00 | 4.3452E-01 | 1.3246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9068390 | 0.9672900 | 0.9760300 | 0.9978250 | 1.0000000 | 3.2555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.91E-04 | 2.48E-02 | 1.62E-02 | 7.82E-02 | 0.00E+00 | 8.3366E-01 | 3.2822E+01 |
| $\alpha_3$ | 2.80E-07 | 7.94E-03 | 1.61E-03 | 3.77E-02 | 0.00E+00 | 2.6722E-01 | 3.3389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9130680 | 0.9636200 | 0.9695110 | 0.9939910 | 1.0000000 | 4.9136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.00E-03 | 2.41E-02 | 1.82E-02 | 6.63E-02 | 0.00E+00 | 1.2281E+00 | 4.9763E+01 |
| $\alpha_3$ | 8.95E-06 | 7.93E-03 | 2.95E-03 | 3.27E-02 | 0.00E+00 | 4.0431E-01 | 5.0587E+01 |
| $\alpha_4$ | 1.89E-08 | 4.37E-03 | 5.99E-04 | 2.19E-02 | 0.00E+00 | 2.2267E-01 | 5.0768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9318350 | 0.9655480 | 0.9685320 | 0.9890570 | 1.0000000 | 9.9161E+01 | 3.5382E+00 |
| $\alpha_2$ | 3.97E-03 | 2.06E-02 | 1.76E-02 | 4.76E-02 | 0.00E+00 | 2.1142E+00 | 1.0059E+02 |
| $\alpha_3$ | 4.65E-04 | 9.52E-03 | 6.58E-03 | 2.86E-02 | 0.00E+00 | 9.7738E-01 | 1.0172E+02 |
| $\alpha_4$ | 2.40E-06 | 3.65E-03 | 1.23E-03 | 1.55E-02 | 0.00E+00 | 3.7439E-01 | 1.0232E+02 |
| $\alpha_5$ | 5.81E-21 | 7.04E-04 | 3.98E-07 | 4.08E-03 | 0.00E+00 | 7.2277E-02 | 1.0263E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9351640 | 0.9655550 | 0.9680290 | 0.9874920 | 1.0000000 | 1.1994E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.71E-03 | 1.80E-02 | 1.55E-02 | 4.10E-02 | 0.00E+00 | 2.2392E+00 | 1.2198E+02 |
| $\alpha_3$ | 6.48E-04 | 9.19E-03 | 6.73E-03 | 2.62E-02 | 0.00E+00 | 1.1418E+00 | 1.2308E+02 |
| $\alpha_4$ | 4.26E-05 | 4.77E-03 | 2.50E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2363E+02 |
| $\alpha_5$ | 7.48E-09 | 1.79E-03 | 2.43E-04 | 8.96E-03 | 0.00E+00 | 2.2220E-01 | 1.2400E+02 |
| $\alpha_6$ | 1.14E-18 | 6.70E-04 | 1.17E-06 | 3.91E-03 | 0.00E+00 | 8.3237E-02 | 1.2414E+02 |

PWR High Pressure Safety Injection Check Valves

HIGH PRESSURE INJECTION CHECK VALVE FAIL TO OPEN

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 3.00 | 3.00 | 3.00 | 3.00 | 3.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.5.4.2 HIGH PRESSURE INJECTION CHECK VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | Chemical and volume control<br>High pressure injection |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 8.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9093850 | 0.9773460 | 0.9906920 | 0.9999550 | 1.0000000 | 1.8746E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.16E-05 | 2.27E-02 | 9.31E-03 | 9.06E-02 | 0.00E+00 | 4.3452E-01 | 1.8746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9197350 | 0.9718850 | 0.9794540 | 0.9981430 | 1.0000000 | 3.8055E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.78E-04 | 2.13E-02 | 1.39E-02 | 6.73E-02 | 0.00E+00 | 8.3366E-01 | 3.8322E+01 |
| $\alpha_3$ | 2.40E-07 | 6.82E-03 | 1.38E-03 | 3.24E-02 | 0.00E+00 | 2.6722E-01 | 3.8889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9214020 | 0.9671620 | 0.9725130 | 0.9945900 | 1.0000000 | 5.4636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.80E-03 | 2.17E-02 | 1.64E-02 | 6.00E-02 | 0.00E+00 | 1.2281E+00 | 5.5263E+01 |
| $\alpha_3$ | 8.07E-06 | 7.16E-03 | 2.66E-03 | 2.96E-02 | 0.00E+00 | 4.0431E-01 | 5.6087E+01 |
| $\alpha_4$ | 1.70E-08 | 3.94E-03 | 5.40E-04 | 1.97E-02 | 0.00E+00 | 2.2267E-01 | 5.6268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9352570 | 0.9672990 | 0.9701370 | 0.9896220 | 1.0000000 | 1.0466E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.76E-03 | 1.95E-02 | 1.67E-02 | 4.52E-02 | 0.00E+00 | 2.1142E+00 | 1.0608E+02 |
| $\alpha_3$ | 4.41E-04 | 9.03E-03 | 6.24E-03 | 2.72E-02 | 0.00E+00 | 9.7738E-01 | 1.0722E+02 |
| $\alpha_4$ | 2.28E-06 | 3.46E-03 | 1.17E-03 | 1.47E-02 | 0.00E+00 | 3.7439E-01 | 1.0782E+02 |
| $\alpha_5$ | 5.52E-21 | 6.68E-04 | 3.78E-07 | 3.87E-03 | 0.00E+00 | 7.2277E-02 | 1.0813E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9378820 | 0.9670160 | 0.9693880 | 0.9880300 | 1.0000000 | 1.2544E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.55E-03 | 1.73E-02 | 1.48E-02 | 3.92E-02 | 0.00E+00 | 2.2392E+00 | 1.2748E+02 |
| $\alpha_3$ | 6.20E-04 | 8.80E-03 | 6.44E-03 | 2.51E-02 | 0.00E+00 | 1.1418E+00 | 1.2858E+02 |
| $\alpha_4$ | 4.08E-05 | 4.57E-03 | 2.39E-03 | 1.65E-02 | 0.00E+00 | 5.9222E-01 | 1.2913E+02 |
| $\alpha_5$ | 7.16E-09 | 1.71E-03 | 2.32E-04 | 8.58E-03 | 0.00E+00 | 2.2220E-01 | 1.2950E+02 |
| $\alpha_6$ | 1.09E-18 | 6.42E-04 | 1.12E-06 | 3.75E-03 | 0.00E+00 | 8.3237E-02 | 1.2964E+02 |

PWR High Pressure Safety Injection Check Valves

HIGH PRESSURE INJECTION CHECK VALVE FAIL TO CLOSE

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 8.50 | 8.50 | 8.50 | 8.50 | 8.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.5.5 PWR Residual Heat Removal Check Valves

## 1.5.5.1 PWR RHR CHECK VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 1.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 1.0000000 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 1.0000000 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 1.0000000 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 1.0000000 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9422570 | 0.9661670 | 0.9677850 | 0.9845420 | 1.0000000 | 1.8405E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.57E-03 | 1.62E-02 | 1.45E-02 | 3.35E-02 | 0.00E+00 | 3.0878E+00 | 1.8741E+02 |
| $\alpha_3$ | 1.15E-03 | 8.56E-03 | 6.91E-03 | 2.16E-02 | 0.00E+00 | 1.6312E+00 | 1.8886E+02 |
| $\alpha_4$ | 2.60E-04 | 5.19E-03 | 3.59E-03 | 1.56E-02 | 0.00E+00 | 9.8887E-01 | 1.8951E+02 |
| $\alpha_5$ | 1.35E-05 | 2.74E-03 | 1.30E-03 | 1.04E-02 | 0.00E+00 | 5.2177E-01 | 1.8997E+02 |
| $\alpha_6$ | 3.53E-10 | 9.78E-04 | 8.35E-05 | 5.13E-03 | 0.00E+00 | 1.8628E-01 | 1.9031E+02 |
| $\alpha_7$ | 0.00E+00 | 1.53E-04 | 1.34E-13 | 5.75E-04 | 0.00E+00 | 2.9071E-02 | 1.9047E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9454620 | 0.9670150 | 0.9683850 | 0.9838980 | 1.0000000 | 2.1873E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.45E-03 | 1.48E-02 | 1.34E-02 | 2.99E-02 | 0.00E+00 | 3.3447E+00 | 2.2285E+02 |
| $\alpha_3$ | 1.14E-03 | 7.69E-03 | 6.29E-03 | 1.90E-02 | 0.00E+00 | 1.7384E+00 | 2.2445E+02 |
| $\alpha_4$ | 3.59E-04 | 5.07E-03 | 3.71E-03 | 1.44E-02 | 0.00E+00 | 1.1465E+00 | 2.2504E+02 |
| $\alpha_5$ | 5.70E-05 | 3.13E-03 | 1.84E-03 | 1.06E-02 | 0.00E+00 | 7.0833E-01 | 2.2548E+02 |
| $\alpha_6$ | 9.18E-07 | 1.62E-03 | 5.31E-04 | 6.94E-03 | 0.00E+00 | 3.6696E-01 | 2.2582E+02 |
| $\alpha_7$ | 7.20E-14 | 5.44E-04 | 9.78E-06 | 3.10E-03 | 0.00E+00 | 1.2297E-01 | 2.2607E+02 |
| $\alpha_8$ | 1.35E-42 | 1.46E-04 | 2.09E-12 | 6.19E-04 | 0.00E+00 | 3.3124E-02 | 2.2616E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Residual Heat Removal Check Valves

PWR RHR CHECK VALVE FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.5.5.2 PWR RHR CHECK VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8989610 | 0.9747090 | 0.9895680 | 0.9999500 | 1.0000000 | 1.6746E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.66E-05 | 2.53E-02 | 1.04E-02 | 1.01E-01 | 0.00E+00 | 4.3452E-01 | 1.6746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9154810 | 0.9703710 | 0.9783290 | 0.9980400 | 1.0000000 | 3.6055E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.15E-04 | 2.24E-02 | 1.46E-02 | 7.09E-02 | 0.00E+00 | 8.3366E-01 | 3.6322E+01 |
| $\alpha_3$ | 2.53E-07 | 7.19E-03 | 1.45E-03 | 3.41E-02 | 0.00E+00 | 2.6722E-01 | 3.6889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9185670 | 0.9659560 | 0.9714920 | 0.9943870 | 1.0000000 | 5.2636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.87E-03 | 2.25E-02 | 1.70E-02 | 6.21E-02 | 0.00E+00 | 1.2281E+00 | 5.3263E+01 |
| $\alpha_3$ | 8.37E-06 | 7.42E-03 | 2.76E-03 | 3.06E-02 | 0.00E+00 | 4.0431E-01 | 5.4087E+01 |
| $\alpha_4$ | 1.77E-08 | 4.09E-03 | 5.60E-04 | 2.05E-02 | 0.00E+00 | 2.2267E-01 | 5.4268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9340530 | 0.9666830 | 0.9695720 | 0.9894240 | 1.0000000 | 1.0266E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.84E-03 | 1.99E-02 | 1.70E-02 | 4.60E-02 | 0.00E+00 | 2.1142E+00 | 1.0408E+02 |
| $\alpha_3$ | 4.50E-04 | 9.20E-03 | 6.36E-03 | 2.77E-02 | 0.00E+00 | 9.7738E-01 | 1.0522E+02 |
| $\alpha_4$ | 2.32E-06 | 3.53E-03 | 1.19E-03 | 1.50E-02 | 0.00E+00 | 3.7439E-01 | 1.0582E+02 |
| $\alpha_5$ | 5.62E-21 | 6.81E-04 | 3.85E-07 | 3.94E-03 | 0.00E+00 | 7.2277E-02 | 1.0613E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9369200 | 0.9664990 | 0.9689110 | 0.9878400 | 1.0000000 | 1.2344E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.60E-03 | 1.75E-02 | 1.51E-02 | 3.98E-02 | 0.00E+00 | 2.2392E+00 | 1.2548E+02 |
| $\alpha_3$ | 6.30E-04 | 8.94E-03 | 6.54E-03 | 2.55E-02 | 0.00E+00 | 1.1418E+00 | 1.2658E+02 |
| $\alpha_4$ | 4.15E-05 | 4.64E-03 | 2.43E-03 | 1.67E-02 | 0.00E+00 | 5.9222E-01 | 1.2713E+02 |
| $\alpha_5$ | 7.27E-09 | 1.74E-03 | 2.36E-04 | 8.72E-03 | 0.00E+00 | 2.2220E-01 | 1.2750E+02 |
| $\alpha_6$ | 1.10E-18 | 6.52E-04 | 1.14E-06 | 3.80E-03 | 0.00E+00 | 8.3237E-02 | 1.2764E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9441390 | 0.9672830 | 0.9688570 | 0.9850630 | 1.0000000 | 1.9055E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.42E-03 | 1.57E-02 | 1.41E-02 | 3.24E-02 | 0.00E+00 | 3.0878E+00 | 1.9391E+02 |
| $\alpha_3$ | 1.12E-03 | 8.28E-03 | 6.69E-03 | 2.09E-02 | 0.00E+00 | 1.6312E+00 | 1.9536E+02 |
| $\alpha_4$ | 2.52E-04 | 5.02E-03 | 3.48E-03 | 1.51E-02 | 0.00E+00 | 9.8887E-01 | 1.9601E+02 |
| $\alpha_5$ | 1.30E-05 | 2.65E-03 | 1.25E-03 | 1.00E-02 | 0.00E+00 | 5.2177E-01 | 1.9647E+02 |
| $\alpha_6$ | 3.41E-10 | 9.46E-04 | 8.07E-05 | 4.96E-03 | 0.00E+00 | 1.8628E-01 | 1.9681E+02 |
| $\alpha_7$ | 0.00E+00 | 1.48E-04 | 1.29E-13 | 5.56E-04 | 0.00E+00 | 2.9071E-02 | 1.9697E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9469720 | 0.9679360 | 0.9692720 | 0.9843530 | 1.0000000 | 2.2523E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.32E-03 | 1.44E-02 | 1.30E-02 | 2.91E-02 | 0.00E+00 | 3.3447E+00 | 2.2935E+02 |
| $\alpha_3$ | 1.11E-03 | 7.47E-03 | 6.11E-03 | 1.85E-02 | 0.00E+00 | 1.7384E+00 | 2.3095E+02 |
| $\alpha_4$ | 3.49E-04 | 4.93E-03 | 3.60E-03 | 1.40E-02 | 0.00E+00 | 1.1465E+00 | 2.3154E+02 |
| $\alpha_5$ | 5.54E-05 | 3.04E-03 | 1.79E-03 | 1.03E-02 | 0.00E+00 | 7.0833E-01 | 2.3198E+02 |
| $\alpha_6$ | 8.93E-07 | 1.58E-03 | 5.16E-04 | 6.75E-03 | 0.00E+00 | 3.6696E-01 | 2.3232E+02 |
| $\alpha_7$ | 7.00E-14 | 5.28E-04 | 9.50E-06 | 3.01E-03 | 0.00E+00 | 1.2297E-01 | 2.3257E+02 |
| $\alpha_8$ | 1.31E-42 | 1.42E-04 | 2.03E-12 | 6.02E-04 | 0.00E+00 | 3.3124E-02 | 2.3266E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Residual Heat Removal Check Valves

PWR RHR CHECK VALVE FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 6.50 | 6.50 | 6.50 | 6.50 | 6.50 | 6.50 | 6.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.5.6 BWR High Pressure Coolant Injection/Reactor Core Isolation Cooling Check Valves

## 1.5.6.1 COMBINED HPCI AND RCIC CHECK VALVE FAIL TO OPEN

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8522320 | 0.9628000 | 0.9843830 | 0.9999320 | 1.0000000 | 1.1246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.00E-05 | 3.72E-02 | 1.56E-02 | 1.48E-01 | 0.00E+00 | 4.3452E-01 | 1.1246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9010680 | 0.9652240 | 0.9744830 | 0.9976820 | 1.0000000 | 3.0555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.43E-04 | 2.63E-02 | 1.72E-02 | 8.30E-02 | 0.00E+00 | 8.3366E-01 | 3.0822E+01 |
| $\alpha_3$ | 2.98E-07 | 8.44E-03 | 1.71E-03 | 4.00E-02 | 0.00E+00 | 2.6722E-01 | 3.1389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9095820 | 0.9621340 | 0.9682530 | 0.9937390 | 1.0000000 | 4.7136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.09E-03 | 2.51E-02 | 1.89E-02 | 6.90E-02 | 0.00E+00 | 1.2281E+00 | 4.7763E+01 |
| $\alpha_3$ | 9.32E-06 | 8.25E-03 | 3.07E-03 | 3.41E-02 | 0.00E+00 | 4.0431E-01 | 4.8587E+01 |
| $\alpha_4$ | 1.97E-08 | 4.55E-03 | 6.24E-04 | 2.28E-02 | 0.00E+00 | 2.2267E-01 | 4.8768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9304990 | 0.9648630 | 0.9678980 | 0.9888360 | 1.0000000 | 9.7161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.05E-03 | 2.10E-02 | 1.79E-02 | 4.85E-02 | 0.00E+00 | 2.1142E+00 | 9.8585E+01 |
| $\alpha_3$ | 4.74E-04 | 9.71E-03 | 6.71E-03 | 2.92E-02 | 0.00E+00 | 9.7738E-01 | 9.9722E+01 |
| $\alpha_4$ | 2.45E-06 | 3.72E-03 | 1.25E-03 | 1.58E-02 | 0.00E+00 | 3.7439E-01 | 1.0032E+02 |
| $\alpha_5$ | 5.93E-21 | 7.18E-04 | 4.06E-07 | 4.16E-03 | 0.00E+00 | 7.2277E-02 | 1.0063E+02 |

BWR High Pressure Coolant Injection/Reactor Core Isolation Cooling Check Valves

COMBINED HPCI AND RCIC CHECK VALVE FAIL TO OPEN

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9341160 | 0.9649920 | 0.9674990 | 0.9872840 | 1.0000000 | 1.1794E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.77E-03 | 1.83E-02 | 1.58E-02 | 4.16E-02 | 0.00E+00 | 2.2392E+00 | 1.1998E+02 |
| $\alpha_3$ | 6.58E-04 | 9.34E-03 | 6.84E-03 | 2.66E-02 | 0.00E+00 | 1.1418E+00 | 1.2108E+02 |
| $\alpha_4$ | 4.33E-05 | 4.85E-03 | 2.54E-03 | 1.75E-02 | 0.00E+00 | 5.9222E-01 | 1.2163E+02 |
| $\alpha_5$ | 7.60E-09 | 1.82E-03 | 2.47E-04 | 9.11E-03 | 0.00E+00 | 2.2220E-01 | 1.2200E+02 |
| $\alpha_6$ | 1.15E-18 | 6.81E-04 | 1.19E-06 | 3.98E-03 | 0.00E+00 | 8.3237E-02 | 1.2214E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.5.6.2 COMBINED HPCI AND RCIC CHECK VALVE FAIL TO CLOSE

| | |
|---|---|
| **System :** | High pressure coolant injection<br>Reactor core isolation |
| **Component :** | Check Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 4.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8819910 | 0.9704020 | 0.9877120 | 0.9999410 | 1.0000000 | 1.4246E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.49E-05 | 2.96E-02 | 1.23E-02 | 1.18E-01 | 0.00E+00 | 4.3452E-01 | 1.4246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9094830 | 0.9682340 | 0.9767350 | 0.9978890 | 1.0000000 | 3.3555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.68E-04 | 2.41E-02 | 1.57E-02 | 7.59E-02 | 0.00E+00 | 8.3366E-01 | 3.3822E+01 |
| $\alpha_3$ | 2.71E-07 | 7.71E-03 | 1.56E-03 | 3.66E-02 | 0.00E+00 | 2.6722E-01 | 3.4389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9147120 | 0.9643190 | 0.9701040 | 0.9941100 | 1.0000000 | 5.0136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.96E-03 | 2.36E-02 | 1.78E-02 | 6.51E-02 | 0.00E+00 | 1.2281E+00 | 5.0763E+01 |
| $\alpha_3$ | 8.78E-06 | 7.78E-03 | 2.89E-03 | 3.21E-02 | 0.00E+00 | 4.0431E-01 | 5.1587E+01 |
| $\alpha_4$ | 1.85E-08 | 4.28E-03 | 5.88E-04 | 2.15E-02 | 0.00E+00 | 2.2267E-01 | 5.1768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9324830 | 0.9658790 | 0.9688380 | 0.9891640 | 1.0000000 | 1.0016E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.93E-03 | 2.04E-02 | 1.74E-02 | 4.71E-02 | 0.00E+00 | 2.1142E+00 | 1.0158E+02 |
| $\alpha_3$ | 4.61E-04 | 9.43E-03 | 6.51E-03 | 2.83E-02 | 0.00E+00 | 9.7738E-01 | 1.0272E+02 |
| $\alpha_4$ | 2.37E-06 | 3.61E-03 | 1.22E-03 | 1.53E-02 | 0.00E+00 | 3.7439E-01 | 1.0332E+02 |
| $\alpha_5$ | 5.76E-21 | 6.97E-04 | 3.94E-07 | 4.04E-03 | 0.00E+00 | 7.2277E-02 | 1.0363E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9356760 | 0.9658310 | 0.9682860 | 0.9875940 | 1.0000000 | 1.2094E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.68E-03 | 1.79E-02 | 1.54E-02 | 4.06E-02 | 0.00E+00 | 2.2392E+00 | 1.2298E+02 |
| $\alpha_3$ | 6.42E-04 | 9.12E-03 | 6.67E-03 | 2.60E-02 | 0.00E+00 | 1.1418E+00 | 1.2408E+02 |
| $\alpha_4$ | 4.23E-05 | 4.73E-03 | 2.48E-03 | 1.71E-02 | 0.00E+00 | 5.9222E-01 | 1.2463E+02 |
| $\alpha_5$ | 7.42E-09 | 1.77E-03 | 2.41E-04 | 8.89E-03 | 0.00E+00 | 2.2220E-01 | 1.2500E+02 |
| $\alpha_6$ | 1.13E-18 | 6.65E-04 | 1.16E-06 | 3.88E-03 | 0.00E+00 | 8.3237E-02 | 1.2514E+02 |

BWR High Pressure Coolant Injection/Reactor Core Isolation Cooling Check Valves

COMBINED HPCI AND RCIC CHECK VALVE FAIL TO CLOSE

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 4.00 | 4.00 | 4.00 | 4.00 | 4.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.6 Strainers, Trash Racks, and Filters

## 1.6.1 Pooled Strainers (Non-ESW)

### 1.6.1.1 GENERIC CLEAN DISCHARGE STRAINER PLUGS

**System :** Chemical and volume control
Component cooling water
Control rod drive
High pressure injection
Standby liquid control
**Component :** Strainer
**Failure Mode :** No flow/plugged
**Component Group :** Passive filter/strainer
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 0.9888200 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 0.9888200 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 0.9888200 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 0.9888200 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

GENERIC CLEAN DISCHARGE STRAINER PLUGS
**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 0.9888200 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9888200 | 0.9888200 | 0.9888200 | 0.9888200 | 0.9888200 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.6.2 Emergency Service Water Strainers

### 1.6.2.1 SERVICE WATER TSA FTO NON ENVIRONMENTAL SPAR:TSA-FO

| | |
|---|---|
| **System :** | Normally operating service water |
| | Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | Fail to Operate (General operation failure, rate based) |
| **Component Group :** | Traveling Screen |
| **Prox. Cause :** | State of other component |
| | Design error or inadequacy |
| | Manufacturing error or inadequacy |
| | Construction/installation error or inadequacy |
| | Setpoint drift |
| | Ambient environmental stress |
| | Inadequate procedure |
| | Inadequate maintenance |
| | Age/Wear |
| | Accidental human action |
| | Human action procedure |
| | Other |
| | Internal environment |
| | Internal to component, piece-part |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 28.00
Total Number of Common-Cause Failure Events: 2

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9206260 | 0.9793800 | 0.9906270 | 0.9999260 | 0.9960990 | 2.3013E+01 | 4.8452E-01 |
| $\alpha_2$ | 7.07E-05 | 2.06E-02 | 9.37E-03 | 7.94E-02 | 3.90E-03 | 4.8452E-01 | 2.3013E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9312830 | 0.9748850 | 0.9809220 | 0.9978300 | 0.9921670 | 4.8555E+01 | 1.2509E+00 |
| $\alpha_2$ | 9.91E-04 | 1.97E-02 | 1.38E-02 | 5.89E-02 | 7.83E-03 | 9.8366E-01 | 4.8822E+01 |
| $\alpha_3$ | 1.88E-07 | 5.37E-03 | 1.08E-03 | 2.54E-02 | 0.00E+00 | 2.6722E-01 | 4.9539E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9328590 | 0.9706490 | 0.9748180 | 0.9941830 | 0.9882040 | 7.1269E+01 | 2.1551E+00 |
| $\alpha_2$ | 2.56E-03 | 2.08E-02 | 1.66E-02 | 5.33E-02 | 1.18E-02 | 1.5281E+00 | 7.1896E+01 |
| $\alpha_3$ | 6.19E-06 | 5.51E-03 | 2.04E-03 | 2.28E-02 | 0.00E+00 | 4.0431E-01 | 7.3020E+01 |
| $\alpha_4$ | 1.31E-08 | 3.03E-03 | 4.15E-04 | 1.52E-02 | 0.00E+00 | 2.2267E-01 | 7.3201E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9412660 | 0.9693120 | 0.9716620 | 0.9893090 | 0.9844230 | 1.2734E+02 | 4.0315E+00 |
| $\alpha_2$ | 4.79E-03 | 1.98E-02 | 1.74E-02 | 4.30E-02 | 1.55E-02 | 2.6042E+00 | 1.2877E+02 |
| $\alpha_3$ | 3.67E-04 | 7.46E-03 | 5.16E-03 | 2.24E-02 | 1.04E-04 | 9.8068E-01 | 1.3039E+02 |
| $\alpha_4$ | 1.87E-06 | 2.85E-03 | 9.59E-04 | 1.21E-02 | 0.00E+00 | 3.7439E-01 | 1.3100E+02 |
| $\alpha_5$ | 4.54E-21 | 5.50E-04 | 3.11E-07 | 3.18E-03 | 0.00E+00 | 7.2277E-02 | 1.3130E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9429390 | 0.9684980 | 0.9704410 | 0.9874090 | 0.9806530 | 1.5406E+02 | 5.0111E+00 |
| $\alpha_2$ | 5.07E-03 | 1.86E-02 | 1.66E-02 | 3.89E-02 | 1.91E-02 | 2.9631E+00 | 1.5611E+02 |
| $\alpha_3$ | 5.17E-04 | 7.23E-03 | 5.30E-03 | 2.05E-02 | 2.22E-04 | 1.1502E+00 | 1.5792E+02 |
| $\alpha_4$ | 3.33E-05 | 3.72E-03 | 1.95E-03 | 1.34E-02 | 2.64E-06 | 5.9232E-01 | 1.5848E+02 |
| $\alpha_5$ | 5.84E-09 | 1.40E-03 | 1.89E-04 | 7.00E-03 | 0.00E+00 | 2.2220E-01 | 1.5885E+02 |
| $\alpha_6$ | 8.86E-19 | 5.23E-04 | 9.15E-07 | 3.05E-03 | 0.00E+00 | 8.3237E-02 | 1.5899E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9960990 | 0.9921670 | 0.9882040 | 0.9844230 | 0.9806530 |
| $\alpha_2$ | 3.90E-03 | 7.83E-03 | 1.18E-02 | 1.55E-02 | 1.91E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 1.04E-04 | 2.22E-04 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 2.64E-06 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.96E-01 | 9.92E-01 | 9.88E-01 | 9.84E-01 | 9.81E-01 |
| Beta | 3.90E-03 | 7.83E-03 | 1.18E-02 | 1.56E-02 | 1.93E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 6.69E-03 | 1.16E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 1.18E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 11.20 | 16.80 | 22.40 | 28.00 | 33.60 |
| $N_1$ | 1.5667 | 2.2000 | 2.7333 | 3.1750 | 3.5230 |
| $N_2$ | 0.0500 | 0.1500 | 0.3000 | 0.4900 | 0.7239 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0033 | 0.0084 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0001 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.6.2.2 SERVICE WATER TSA PLUG NON ENVIRONMENTAL SPAR:TSA-PG

| | |
|---|---|
| **System :** | Normally operating service water |
| | Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | No flow/plugged |
| **Component Group :** | Traveling Screen |
| **Prox. Cause :** | State of other component |
| | Design error or inadequacy |
| | Manufacturing error or inadequacy |
| | Construction/installation error or inadequacy |
| | Setpoint drift |
| | Ambient environmental stress |
| | Inadequate procedure |
| | Inadequate maintenance |
| | Age/Wear |
| | Accidental human action |
| | Human action procedure |
| | Other |
| | Internal environment |
| | Internal to component, piece-part |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8522320 | 0.9628000 | 0.9843830 | 0.9999320 | 1.0000000 | 1.1246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.00E-05 | 3.72E-02 | 1.56E-02 | 1.48E-01 | 0.00E+00 | 4.3452E-01 | 1.1246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9010680 | 0.9652240 | 0.9744830 | 0.9976820 | 1.0000000 | 3.0555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.43E-04 | 2.63E-02 | 1.72E-02 | 8.30E-02 | 0.00E+00 | 8.3366E-01 | 3.0822E+01 |
| $\alpha_3$ | 2.98E-07 | 8.44E-03 | 1.71E-03 | 4.00E-02 | 0.00E+00 | 2.6722E-01 | 3.1389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9095820 | 0.9621340 | 0.9682530 | 0.9937390 | 1.0000000 | 4.7136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.09E-03 | 2.51E-02 | 1.89E-02 | 6.90E-02 | 0.00E+00 | 1.2281E+00 | 4.7763E+01 |
| $\alpha_3$ | 9.32E-06 | 8.25E-03 | 3.07E-03 | 3.41E-02 | 0.00E+00 | 4.0431E-01 | 4.8587E+01 |
| $\alpha_4$ | 1.97E-08 | 4.55E-03 | 6.24E-04 | 2.28E-02 | 0.00E+00 | 2.2267E-01 | 4.8768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9304990 | 0.9648630 | 0.9678980 | 0.9888360 | 1.0000000 | 9.7161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.05E-03 | 2.10E-02 | 1.79E-02 | 4.85E-02 | 0.00E+00 | 2.1142E+00 | 9.8585E+01 |
| $\alpha_3$ | 4.74E-04 | 9.71E-03 | 6.71E-03 | 2.92E-02 | 0.00E+00 | 9.7738E-01 | 9.9722E+01 |
| $\alpha_4$ | 2.45E-06 | 3.72E-03 | 1.25E-03 | 1.58E-02 | 0.00E+00 | 3.7439E-01 | 1.0032E+02 |
| $\alpha_5$ | 5.93E-21 | 7.18E-04 | 4.06E-07 | 4.16E-03 | 0.00E+00 | 7.2277E-02 | 1.0063E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9341160 | 0.9649920 | 0.9674990 | 0.9872840 | 1.0000000 | 1.1794E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.77E-03 | 1.83E-02 | 1.58E-02 | 4.16E-02 | 0.00E+00 | 2.2392E+00 | 1.1998E+02 |
| $\alpha_3$ | 6.58E-04 | 9.34E-03 | 6.84E-03 | 2.66E-02 | 0.00E+00 | 1.1418E+00 | 1.2108E+02 |
| $\alpha_4$ | 4.33E-05 | 4.85E-03 | 2.54E-03 | 1.75E-02 | 0.00E+00 | 5.9222E-01 | 1.2163E+02 |
| $\alpha_5$ | 7.60E-09 | 1.82E-03 | 2.47E-04 | 9.11E-03 | 0.00E+00 | 2.2220E-01 | 1.2200E+02 |
| $\alpha_6$ | 1.15E-18 | 6.81E-04 | 1.19E-06 | 3.98E-03 | 0.00E+00 | 8.3237E-02 | 1.2214E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.6.2.3 SERVICE WATER STRAINER PLUG NON ENVIRONMENTAL SPAR:STR-PG

| | |
|---|---|
| **System :** | Normally operating service water |
| | Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter |
| | No flow/plugged |
| **Component Group :** | Self-Cleaning filter/strainer |
| **Prox. Cause :** | State of other component |
| | Design error or inadequacy |
| | Manufacturing error or inadequacy |
| | Construction/installation error or inadequacy |
| | Setpoint drift |
| | Ambient environmental stress |
| | Inadequate procedure |
| | Inadequate maintenance |
| | Age/Wear |
| | Accidental human action |
| | Human action procedure |
| | Other |
| | Internal environment |
| | Internal to component, piece-part |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 37.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9633370 | 0.9908870 | 0.9963330 | 0.9999820 | 1.0000000 | 4.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.63E-05 | 9.11E-03 | 3.67E-03 | 3.67E-02 | 0.00E+00 | 4.3452E-01 | 4.7246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9532560 | 0.9837280 | 0.9881890 | 0.9989340 | 1.0000000 | 6.6555E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.88E-04 | 1.23E-02 | 7.96E-03 | 3.91E-02 | 0.00E+00 | 8.3366E-01 | 6.6822E+01 |
| $\alpha_3$ | 1.38E-07 | 3.95E-03 | 7.93E-04 | 1.87E-02 | 0.00E+00 | 2.6722E-01 | 6.7389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9474900 | 0.9781730 | 0.9818070 | 0.9964330 | 1.0000000 | 8.3136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.19E-03 | 1.44E-02 | 1.09E-02 | 4.00E-02 | 0.00E+00 | 1.2281E+00 | 8.3763E+01 |
| $\alpha_3$ | 5.34E-06 | 4.76E-03 | 1.76E-03 | 1.97E-02 | 0.00E+00 | 4.0431E-01 | 8.4587E+01 |
| $\alpha_4$ | 1.13E-08 | 2.62E-03 | 3.58E-04 | 1.31E-02 | 0.00E+00 | 2.2267E-01 | 8.4768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9486250 | 0.9741160 | 0.9763980 | 0.9918180 | 1.0000000 | 1.3316E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.97E-03 | 1.55E-02 | 1.32E-02 | 3.58E-02 | 0.00E+00 | 2.1142E+00 | 1.3458E+02 |
| $\alpha_3$ | 3.49E-04 | 7.15E-03 | 4.93E-03 | 2.15E-02 | 0.00E+00 | 9.7738E-01 | 1.3572E+02 |
| $\alpha_4$ | 1.80E-06 | 2.74E-03 | 9.22E-04 | 1.16E-02 | 0.00E+00 | 3.7439E-01 | 1.3632E+02 |
| $\alpha_5$ | 4.36E-21 | 5.29E-04 | 2.99E-07 | 3.06E-03 | 0.00E+00 | 7.2277E-02 | 1.3663E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9489700 | 0.9729570 | 0.9749300 | 0.9902120 | 1.0000000 | 1.5394E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.90E-03 | 1.42E-02 | 1.22E-02 | 3.22E-02 | 0.00E+00 | 2.2392E+00 | 1.5598E+02 |
| $\alpha_3$ | 5.07E-04 | 7.22E-03 | 5.27E-03 | 2.06E-02 | 0.00E+00 | 1.1418E+00 | 1.5708E+02 |
| $\alpha_4$ | 3.34E-05 | 3.74E-03 | 1.96E-03 | 1.35E-02 | 0.00E+00 | 5.9222E-01 | 1.5763E+02 |
| $\alpha_5$ | 5.87E-09 | 1.40E-03 | 1.90E-04 | 7.04E-03 | 0.00E+00 | 2.2220E-01 | 1.5800E+02 |
| $\alpha_6$ | 8.91E-19 | 5.26E-04 | 9.20E-07 | 3.07E-03 | 0.00E+00 | 8.3237E-02 | 1.5814E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 37.00 | 37.00 | 37.00 | 37.00 | 37.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.6.2.4 ESW STRAINER PLUG POOLED CAUSES SPAR:ESW-STR-POOL-PG

| | |
|---|---|
| **System :** | Normally operating service water |
| | Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter |
| | No flow/plugged |
| **Component Group :** | Self-Cleaning filter/strainer |
| **Prox. Cause :** | State of other component |
| | Design error or inadequacy |
| | Manufacturing error or inadequacy |
| | Construction/installation error or inadequacy |
| | Setpoint drift |
| | Ambient environmental stress |
| | Inadequate procedure |
| | Inadequate maintenance |
| | Age/Wear |
| | Accidental human action |
| | Human action procedure |
| | Other |
| | Internal environment |
| | Internal to component, piece-part |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 37.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9633370 | 0.9908870 | 0.9963330 | 0.9999820 | 1.0000000 | 4.7246E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.63E-05 | 9.11E-03 | 3.67E-03 | 3.67E-02 | 0.00E+00 | 4.3452E-01 | 4.7246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9532560 | 0.9837280 | 0.9881890 | 0.9989340 | 1.0000000 | 6.6555E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.88E-04 | 1.23E-02 | 7.96E-03 | 3.91E-02 | 0.00E+00 | 8.3366E-01 | 6.6822E+01 |
| $\alpha_3$ | 1.38E-07 | 3.95E-03 | 7.93E-04 | 1.87E-02 | 0.00E+00 | 2.6722E-01 | 6.7389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9474900 | 0.9781730 | 0.9818070 | 0.9964330 | 1.0000000 | 8.3136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.19E-03 | 1.44E-02 | 1.09E-02 | 4.00E-02 | 0.00E+00 | 1.2281E+00 | 8.3763E+01 |
| $\alpha_3$ | 5.34E-06 | 4.76E-03 | 1.76E-03 | 1.97E-02 | 0.00E+00 | 4.0431E-01 | 8.4587E+01 |
| $\alpha_4$ | 1.13E-08 | 2.62E-03 | 3.58E-04 | 1.31E-02 | 0.00E+00 | 2.2267E-01 | 8.4768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9486250 | 0.9741160 | 0.9763980 | 0.9918180 | 1.0000000 | 1.3316E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.97E-03 | 1.55E-02 | 1.32E-02 | 3.58E-02 | 0.00E+00 | 2.1142E+00 | 1.3458E+02 |
| $\alpha_3$ | 3.49E-04 | 7.15E-03 | 4.93E-03 | 2.15E-02 | 0.00E+00 | 9.7738E-01 | 1.3572E+02 |
| $\alpha_4$ | 1.80E-06 | 2.74E-03 | 9.22E-04 | 1.16E-02 | 0.00E+00 | 3.7439E-01 | 1.3632E+02 |
| $\alpha_5$ | 4.36E-21 | 5.29E-04 | 2.99E-07 | 3.06E-03 | 0.00E+00 | 7.2277E-02 | 1.3663E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9489700 | 0.9729570 | 0.9749300 | 0.9902120 | 1.0000000 | 1.5394E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.90E-03 | 1.42E-02 | 1.22E-02 | 3.22E-02 | 0.00E+00 | 2.2392E+00 | 1.5598E+02 |
| $\alpha_3$ | 5.07E-04 | 7.22E-03 | 5.27E-03 | 2.06E-02 | 0.00E+00 | 1.1418E+00 | 1.5708E+02 |
| $\alpha_4$ | 3.34E-05 | 3.74E-03 | 1.96E-03 | 1.35E-02 | 0.00E+00 | 5.9222E-01 | 1.5763E+02 |
| $\alpha_5$ | 5.87E-09 | 1.40E-03 | 1.90E-04 | 7.04E-03 | 0.00E+00 | 2.2220E-01 | 1.5800E+02 |
| $\alpha_6$ | 8.91E-19 | 5.26E-04 | 9.20E-07 | 3.07E-03 | 0.00E+00 | 8.3237E-02 | 1.5814E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 37.00 | 37.00 | 37.00 | 37.00 | 37.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.6.3 Pooled Sump Strainers

## 1.6.3.1 SUMP SUCTION PLUGGED

| | |
|---|---|
| **System :** | Containment spray recirculation<br>High pressure core spray<br>High pressure coolant injection<br>Low pressure core spray<br>Reactor core isolation<br>Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter<br>No flow/plugged |
| **Component Group :** | Sump Strainer Filter |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8581890 | 0.9643270 | 0.9850590 | 0.9999350 | 1.0000000 | 1.1746E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.69E-05 | 3.57E-02 | 1.49E-02 | 1.42E-01 | 0.00E+00 | 4.3452E-01 | 1.1746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9025780 | 0.9657640 | 0.9748880 | 0.9977200 | 1.0000000 | 3.1055E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.29E-04 | 2.59E-02 | 1.69E-02 | 8.18E-02 | 0.00E+00 | 8.3366E-01 | 3.1322E+01 |
| $\alpha_3$ | 2.93E-07 | 8.31E-03 | 1.69E-03 | 3.94E-02 | 0.00E+00 | 2.6722E-01 | 3.1889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9104790 | 0.9625170 | 0.9685780 | 0.9938040 | 1.0000000 | 4.7636E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.06E-03 | 2.48E-02 | 1.87E-02 | 6.83E-02 | 0.00E+00 | 1.2281E+00 | 4.8263E+01 |
| $\alpha_3$ | 9.23E-06 | 8.17E-03 | 3.04E-03 | 3.37E-02 | 0.00E+00 | 4.0431E-01 | 4.9087E+01 |
| $\alpha_4$ | 1.95E-08 | 4.50E-03 | 6.18E-04 | 2.25E-02 | 0.00E+00 | 2.2267E-01 | 4.9268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9308380 | 0.9650370 | 0.9680620 | 0.9888920 | 1.0000000 | 9.7661E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.03E-03 | 2.09E-02 | 1.78E-02 | 4.83E-02 | 0.00E+00 | 2.1142E+00 | 9.9085E+01 |
| $\alpha_3$ | 4.72E-04 | 9.66E-03 | 6.68E-03 | 2.90E-02 | 0.00E+00 | 9.7738E-01 | 1.0022E+02 |
| $\alpha_4$ | 2.43E-06 | 3.70E-03 | 1.25E-03 | 1.57E-02 | 0.00E+00 | 3.7439E-01 | 1.0082E+02 |
| $\alpha_5$ | 5.90E-21 | 7.14E-04 | 4.04E-07 | 4.14E-03 | 0.00E+00 | 7.2277E-02 | 1.0113E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9343810 | 0.9651340 | 0.9676320 | 0.9873370 | 1.0000000 | 1.1844E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.75E-03 | 1.82E-02 | 1.57E-02 | 4.15E-02 | 0.00E+00 | 2.2392E+00 | 1.2048E+02 |
| $\alpha_3$ | 6.56E-04 | 9.30E-03 | 6.81E-03 | 2.65E-02 | 0.00E+00 | 1.1418E+00 | 1.2158E+02 |
| $\alpha_4$ | 4.32E-05 | 4.83E-03 | 2.53E-03 | 1.74E-02 | 0.00E+00 | 5.9222E-01 | 1.2213E+02 |
| $\alpha_5$ | 7.57E-09 | 1.81E-03 | 2.46E-04 | 9.07E-03 | 0.00E+00 | 2.2220E-01 | 1.2250E+02 |
| $\alpha_6$ | 1.15E-18 | 6.78E-04 | 1.19E-06 | 3.96E-03 | 0.00E+00 | 8.3237E-02 | 1.2264E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.6.4 PWR Containment Sump Strainers

## 1.6.4.1 CONTAINMENT SPRAY SUMP STRAINER PLUG STR-PG

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter<br>No flow/plugged |
| **Component Group :** | Sump Strainer Filter |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 1.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 0.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 0.00 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

# 1.6.5 BWR Suppression Pool Strainers

## 1.6.5.1 BWR RHR SUMP STRAINER PLUG

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter<br>No flow/plugged |
| **Component Group :** | Sump Strainer Filter |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 0.9877750 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 0.9877750 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 0.9877750 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 0.9877750 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 0.9877750 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9877750 | 0.9877750 | 0.9877750 | 0.9877750 | 0.9877750 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.6.6 Extreme Environmental Event CCF Distributions

## 1.6.6.1 CIRCULATING WATER TSA EXTREME ENVIRONMENTAL PLUG

| | |
|---|---|
| **System :** | Circulating water system |
| **Component :** | Strainer |
| **Failure Mode :** | No flow/plugged |
| **Component Group :** | Traveling Screen |
| **Prox. Cause :** | Extreme environmental stress |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 20.00
Total Number of Common-Cause Failure Events: 16

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.5679640 | 0.7008240 | 0.7047340 | 0.8202940 | 0.5852780 | 2.4231E+01 | 1.0344E+01 |
| $\alpha_2$ | 1.80E-01 | 2.99E-01 | 2.95E-01 | 4.32E-01 | 4.15E-01 | 1.0344E+01 | 2.4231E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.6819680 | 0.7747750 | 0.7778270 | 0.8571340 | 0.5787480 | 4.6689E+01 | 1.3572E+01 |
| $\alpha_2$ | 4.71E-02 | 1.02E-01 | 9.81E-02 | 1.73E-01 | 1.80E-01 | 6.1766E+00 | 5.4085E+01 |
| $\alpha_3$ | 6.16E-02 | 1.23E-01 | 1.19E-01 | 1.98E-01 | 2.41E-01 | 7.3958E+00 | 5.2866E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.7215890 | 0.7978290 | 0.8002440 | 0.8658210 | 0.5705780 | 6.5839E+01 | 1.6684E+01 |
| $\alpha_2$ | 3.84E-02 | 8.11E-02 | 7.77E-02 | 1.35E-01 | 1.58E-01 | 6.6924E+00 | 7.5830E+01 |
| $\alpha_3$ | 3.16E-02 | 7.13E-02 | 6.79E-02 | 1.23E-01 | 1.59E-01 | 5.8853E+00 | 7.6637E+01 |
| $\alpha_4$ | 1.77E-02 | 4.98E-02 | 4.62E-02 | 9.41E-02 | 1.12E-01 | 4.1060E+00 | 7.8417E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8093550 | 0.8603590 | 0.8620920 | 0.9054540 | 0.5954810 | 1.1950E+02 | 1.9396E+01 |
| $\alpha_2$ | 1.78E-02 | 4.12E-02 | 3.90E-02 | 7.21E-02 | 9.22E-02 | 5.7273E+00 | 1.3317E+02 |
| $\alpha_3$ | 2.43E-02 | 5.08E-02 | 4.86E-02 | 8.46E-02 | 1.55E-01 | 7.0548E+00 | 1.3184E+02 |
| $\alpha_4$ | 1.29E-02 | 3.36E-02 | 3.14E-02 | 6.19E-02 | 1.09E-01 | 4.6661E+00 | 1.3423E+02 |
| $\alpha_5$ | 2.43E-03 | 1.40E-02 | 1.18E-02 | 3.33E-02 | 4.78E-02 | 1.9473E+00 | 1.3695E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8327830 | 0.8771430 | 0.8786640 | 0.9163030 | 0.6350360 | 1.4478E+02 | 2.0279E+01 |
| $\alpha_2$ | 5.97E-03 | 2.00E-02 | 1.81E-02 | 4.05E-02 | 2.42E-02 | 3.2997E+00 | 1.6176E+02 |
| $\alpha_3$ | 2.19E-02 | 4.49E-02 | 4.31E-02 | 7.41E-02 | 1.43E-01 | 7.4077E+00 | 1.5765E+02 |
| $\alpha_4$ | 1.43E-02 | 3.38E-02 | 3.19E-02 | 5.96E-02 | 1.14E-01 | 5.5783E+00 | 1.5948E+02 |
| $\alpha_5$ | 4.92E-03 | 1.80E-02 | 1.61E-02 | 3.76E-02 | 6.27E-02 | 2.9722E+00 | 1.6209E+02 |
| $\alpha_6$ | 3.36E-04 | 6.18E-03 | 4.34E-03 | 1.83E-02 | 2.14E-02 | 1.0207E+00 | 1.6404E+02 |

CIRCULATING WATER TSA EXTREME ENVIRONMENTAL PLUG
*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.5852780 | 0.5787480 | 0.5705780 | 0.5954810 | 0.6350360 |
| $\alpha_2$ | 4.15E-01 | 1.80E-01 | 1.58E-01 | 9.22E-02 | 2.42E-02 |
| $\alpha_3$ | | 2.41E-01 | 1.59E-01 | 1.55E-01 | 1.43E-01 |
| $\alpha_4$ | | | 1.12E-01 | 1.09E-01 | 1.14E-01 |
| $\alpha_5$ | | | | 4.78E-02 | 6.27E-02 |
| $\alpha_6$ | | | | | 2.14E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 5.85E-01 | 5.79E-01 | 5.71E-01 | 5.95E-01 | 6.35E-01 |
| Beta | 4.15E-01 | 4.21E-01 | 4.29E-01 | 4.05E-01 | 3.65E-01 |
| Gamma | | 5.72E-01 | 6.32E-01 | 7.72E-01 | 9.34E-01 |
| Delta | | | 4.15E-01 | 5.04E-01 | 5.81E-01 |
| Epsilon | | | | 3.04E-01 | 4.25E-01 |
| Mu | | | | | 2.54E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 9.28 | 13.92 | 18.56 | 23.20 | 27.84 |
| $N_1$ | 4.7048 | 3.2143 | 1.1429 | 0.1429 | 0.0000 |
| $N_2$ | 9.9095 | 5.3429 | 5.4643 | 3.6131 | 1.0605 |
| $N_3$ | | 7.1286 | 5.4810 | 6.0774 | 6.2659 |
| $N_4$ | | | 3.8833 | 4.2917 | 4.9861 |
| $N_5$ | | | | 1.8750 | 2.7500 |
| $N_6$ | | | | | 0.9375 |

## 1.6.6.2 CIRCULATING WATER TSA NON ENVIRONMENTAL PLUG SPAR:CWS-PG

| | |
|---|---|
| **System :** | Circulating water system |
| **Component :** | Strainer |
| **Failure Mode :** | No flow/plugged |
| **Component Group :** | Traveling Screen |
| **Prox. Cause :** | State of other component<br>Design error or inadequacy<br>Manufacturing error or inadequacy<br>Construction/installation error or inadequacy<br>Setpoint drift<br>Ambient environmental stress<br>Inadequate procedure<br>Inadequate maintenance<br>Age/Wear<br>Accidental human action<br>Human action procedure<br>Other<br>Internal environment<br>Internal to component, piece-part<br>Unknown |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 8.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9069840 | 0.9767390 | 0.9904340 | 0.9999540 | 1.0000000 | 1.8246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.27E-05 | 2.33E-02 | 9.56E-03 | 9.30E-02 | 0.00E+00 | 4.3452E-01 | 1.8246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9187120 | 0.9715210 | 0.9791840 | 0.9981180 | 1.0000000 | 3.7555E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.87E-04 | 2.16E-02 | 1.40E-02 | 6.82E-02 | 0.00E+00 | 8.3366E-01 | 3.7822E+01 |
| $\alpha_3$ | 2.43E-07 | 6.91E-03 | 1.40E-03 | 3.28E-02 | 0.00E+00 | 2.6722E-01 | 3.8389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9207150 | 0.9668680 | 0.9722640 | 0.9945410 | 1.0000000 | 5.4136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.82E-03 | 2.19E-02 | 1.65E-02 | 6.05E-02 | 0.00E+00 | 1.2281E+00 | 5.4763E+01 |
| $\alpha_3$ | 8.14E-06 | 7.22E-03 | 2.68E-03 | 2.98E-02 | 0.00E+00 | 4.0431E-01 | 5.5587E+01 |
| $\alpha_4$ | 1.72E-08 | 3.98E-03 | 5.45E-04 | 1.99E-02 | 0.00E+00 | 2.2267E-01 | 5.5768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9349600 | 0.9671470 | 0.9699980 | 0.9895730 | 1.0000000 | 1.0416E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.78E-03 | 1.96E-02 | 1.67E-02 | 4.54E-02 | 0.00E+00 | 2.1142E+00 | 1.0558E+02 |
| $\alpha_3$ | 4.43E-04 | 9.08E-03 | 6.27E-03 | 2.73E-02 | 0.00E+00 | 9.7738E-01 | 1.0672E+02 |
| $\alpha_4$ | 2.29E-06 | 3.48E-03 | 1.17E-03 | 1.48E-02 | 0.00E+00 | 3.7439E-01 | 1.0732E+02 |
| $\alpha_5$ | 5.54E-21 | 6.71E-04 | 3.80E-07 | 3.89E-03 | 0.00E+00 | 7.2277E-02 | 1.0763E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9376440 | 0.9668880 | 0.9692700 | 0.9879830 | 1.0000000 | 1.2494E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.56E-03 | 1.73E-02 | 1.49E-02 | 3.94E-02 | 0.00E+00 | 2.2392E+00 | 1.2698E+02 |
| $\alpha_3$ | 6.22E-04 | 8.84E-03 | 6.46E-03 | 2.52E-02 | 0.00E+00 | 1.1418E+00 | 1.2808E+02 |
| $\alpha_4$ | 4.10E-05 | 4.58E-03 | 2.40E-03 | 1.65E-02 | 0.00E+00 | 5.9222E-01 | 1.2863E+02 |
| $\alpha_5$ | 7.19E-09 | 1.72E-03 | 2.33E-04 | 8.62E-03 | 0.00E+00 | 2.2220E-01 | 1.2900E+02 |
| $\alpha_6$ | 1.09E-18 | 6.44E-04 | 1.13E-06 | 3.76E-03 | 0.00E+00 | 8.3237E-02 | 1.2914E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 8.00 | 8.00 | 8.00 | 8.00 | 8.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

### 1.6.6.3 SERVICE WATER STRAINER PLUG ENVIRONMENTAL SPAR:STR-EE-PG

| | |
|---|---|
| **System :** | Normally operating service water<br>Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | High dP across filter<br>No flow/plugged |
| **Component Group :** | Self-Cleaning filter/strainer |
| **Prox. Cause :** | Extreme environmental stress |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 21.50
Total Number of Common-Cause Failure Events: 4

#### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8630170 | 0.9448060 | 0.9547470 | 0.9925020 | 0.9363500 | 2.7409E+01 | 1.6012E+00 |
| $\alpha_2$ | 7.50E-03 | 5.52E-02 | 4.53E-02 | 1.37E-01 | 6.36E-02 | 1.6012E+00 | 2.7409E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8683090 | 0.9306610 | 0.9356900 | 0.9758180 | 0.8913750 | 5.2805E+01 | 3.9342E+00 |
| $\alpha_2$ | 1.80E-02 | 5.88E-02 | 5.36E-02 | 1.17E-01 | 9.58E-02 | 3.3337E+00 | 5.3406E+01 |
| $\alpha_3$ | 1.01E-04 | 1.06E-02 | 5.64E-03 | 3.79E-02 | 1.28E-02 | 6.0052E-01 | 5.6139E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8801540 | 0.9312460 | 0.9347590 | 0.9703330 | 0.8881660 | 7.5917E+01 | 5.6050E+00 |
| $\alpha_2$ | 1.49E-02 | 4.52E-02 | 4.15E-02 | 8.81E-02 | 7.33E-02 | 3.6864E+00 | 7.7836E+01 |
| $\alpha_3$ | 2.09E-03 | 1.81E-02 | 1.43E-02 | 4.70E-02 | 3.19E-02 | 1.4737E+00 | 8.0048E+01 |
| $\alpha_4$ | 1.12E-05 | 5.46E-03 | 2.24E-03 | 2.18E-02 | 6.63E-03 | 4.4487E-01 | 8.1077E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113660 | 0.9458520 | 0.9479600 | 0.9731450 | 0.9003610 | 1.3297E+02 | 7.6123E+00 |
| $\alpha_2$ | 9.57E-03 | 2.80E-02 | 2.58E-02 | 5.40E-02 | 4.45E-02 | 3.9348E+00 | 1.3665E+02 |
| $\alpha_3$ | 3.89E-03 | 1.73E-02 | 1.51E-02 | 3.83E-02 | 3.56E-02 | 2.4311E+00 | 1.3815E+02 |
| $\alpha_4$ | 4.02E-04 | 7.30E-03 | 5.13E-03 | 2.16E-02 | 1.59E-02 | 1.0260E+00 | 1.3956E+02 |
| $\alpha_5$ | 5.90E-09 | 1.57E-03 | 2.08E-04 | 7.87E-03 | 3.62E-03 | 2.2038E-01 | 1.4036E+02 |

SERVICE WATER STRAINER PLUG ENVIRONMENTAL SPAR:STR-EE-PG
**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9187530 | 0.9491320 | 0.9508900 | 0.9734970 | 0.9099760 | 1.6080E+02 | 8.6179E+00 |
| $\alpha_2$ | 7.04E-03 | 2.17E-02 | 1.98E-02 | 4.27E-02 | 2.98E-02 | 3.6747E+00 | 1.6574E+02 |
| $\alpha_3$ | 3.62E-03 | 1.52E-02 | 1.33E-02 | 3.32E-02 | 2.97E-02 | 2.5753E+00 | 1.6684E+02 |
| $\alpha_4$ | 1.11E-03 | 9.06E-03 | 7.21E-03 | 2.33E-02 | 1.96E-02 | 1.5346E+00 | 1.6788E+02 |
| $\alpha_5$ | 5.10E-05 | 3.84E-03 | 2.15E-03 | 1.34E-02 | 8.90E-03 | 6.5130E-01 | 1.6877E+02 |
| $\alpha_6$ | 2.72E-10 | 1.07E-03 | 8.58E-05 | 5.67E-03 | 2.05E-03 | 1.8204E-01 | 1.6924E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9363500 | 0.8913750 | 0.8881660 | 0.9003610 | 0.9099760 |
| $\alpha_2$ | 6.36E-02 | 9.58E-02 | 7.33E-02 | 4.45E-02 | 2.98E-02 |
| $\alpha_3$ | | 1.28E-02 | 3.19E-02 | 3.56E-02 | 2.97E-02 |
| $\alpha_4$ | | | 6.63E-03 | 1.59E-02 | 1.96E-02 |
| $\alpha_5$ | | | | 3.62E-03 | 8.90E-03 |
| $\alpha_6$ | | | | | 2.05E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.36E-01 | 8.91E-01 | 8.88E-01 | 9.00E-01 | 9.10E-01 |
| Beta | 6.36E-02 | 1.09E-01 | 1.12E-01 | 9.96E-02 | 9.00E-02 |
| Gamma | | 1.18E-01 | 3.44E-01 | 5.53E-01 | 6.69E-01 |
| Delta | | | 1.72E-01 | 3.55E-01 | 5.06E-01 |
| Epsilon | | | | 1.85E-01 | 3.59E-01 |
| Mu | | | | | 1.87E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 14.33 | 21.50 | 28.67 | 35.83 | 43.00 |
| $N_1$ | 2.8333 | 1.7500 | 1.1111 | 0.9838 | 0.8623 |
| $N_2$ | 1.1667 | 2.5000 | 2.4583 | 1.8206 | 1.4355 |
| $N_3$ | | 0.3333 | 1.0694 | 1.4537 | 1.4335 |
| $N_4$ | | | 0.2222 | 0.6516 | 0.9424 |
| $N_5$ | | | | 0.1481 | 0.4291 |
| $N_6$ | | | | | 0.0988 |

## 1.6.6.4 SERVICE WATER TSA PLUG ENVIRONMENTAL SPAR:TSA-EE-PG

| | |
|---|---|
| **System :** | Circulating water system<br>Normally operating service water<br>Standby service water |
| **Component :** | Strainer |
| **Failure Mode :** | No flow/plugged |
| **Component Group :** | Traveling Screen |
| **Prox. Cause :** | Extreme environmental stress |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 25.00
Total Number of Common-Cause Failure Events: 17

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.5912630 | 0.7166530 | 0.7205040 | 0.8288590 | 0.6211870 | 2.7111E+01 | 1.0719E+01 |
| $\alpha_2$ | 1.71E-01 | 2.83E-01 | 2.79E-01 | 4.09E-01 | 3.79E-01 | 1.0719E+01 | 2.7111E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.6911370 | 0.7799070 | 0.7827980 | 0.8587870 | 0.6144970 | 5.0530E+01 | 1.4260E+01 |
| $\alpha_2$ | 4.87E-02 | 1.03E-01 | 9.85E-02 | 1.70E-01 | 1.70E-01 | 6.6453E+00 | 5.8145E+01 |
| $\alpha_3$ | 5.96E-02 | 1.18E-01 | 1.14E-01 | 1.89E-01 | 2.15E-01 | 7.6145E+00 | 5.7175E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.7278580 | 0.8010860 | 0.8033680 | 0.8665220 | 0.6101540 | 7.0714E+01 | 1.7559E+01 |
| $\alpha_2$ | 3.88E-02 | 8.01E-02 | 7.69E-02 | 1.32E-01 | 1.45E-01 | 7.0674E+00 | 8.1205E+01 |
| $\alpha_3$ | 3.24E-02 | 7.09E-02 | 6.77E-02 | 1.20E-01 | 1.45E-01 | 6.2603E+00 | 8.2012E+01 |
| $\alpha_4$ | 1.74E-02 | 4.79E-02 | 4.45E-02 | 9.01E-02 | 9.95E-02 | 4.2310E+00 | 8.4042E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8108090 | 0.8605090 | 0.8621610 | 0.9045780 | 0.6358340 | 1.2551E+02 | 2.0346E+01 |
| $\alpha_2$ | 1.80E-02 | 4.08E-02 | 3.87E-02 | 7.08E-02 | 8.32E-02 | 5.9523E+00 | 1.3990E+02 |
| $\alpha_3$ | 2.50E-02 | 5.09E-02 | 4.89E-02 | 8.39E-02 | 1.40E-01 | 7.4298E+00 | 1.3843E+02 |
| $\alpha_4$ | 1.34E-02 | 3.39E-02 | 3.18E-02 | 6.15E-02 | 9.89E-02 | 4.9411E+00 | 1.4091E+02 |
| $\alpha_5$ | 2.52E-03 | 1.39E-02 | 1.17E-02 | 3.26E-02 | 4.23E-02 | 2.0223E+00 | 1.4383E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8339720 | 0.8772210 | 0.8786710 | 0.9155100 | 0.6732390 | 1.5194E+02 | 2.1266E+01 |
| $\alpha_2$ | 6.09E-03 | 1.98E-02 | 1.80E-02 | 3.97E-02 | 2.29E-02 | 3.4272E+00 | 1.6978E+02 |
| $\alpha_3$ | 2.21E-02 | 4.44E-02 | 4.27E-02 | 7.27E-02 | 1.26E-01 | 7.6927E+00 | 1.6551E+02 |
| $\alpha_4$ | 1.49E-02 | 3.41E-02 | 3.24E-02 | 5.94E-02 | 1.02E-01 | 5.9133E+00 | 1.6729E+02 |
| $\alpha_5$ | 5.27E-03 | 1.83E-02 | 1.65E-02 | 3.75E-02 | 5.66E-02 | 3.1672E+00 | 1.7004E+02 |
| $\alpha_6$ | 3.70E-04 | 6.15E-03 | 4.39E-03 | 1.80E-02 | 1.89E-02 | 1.0657E+00 | 1.7214E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.6211870 | 0.6144970 | 0.6101540 | 0.6358340 | 0.6732390 |
| $\alpha_2$ | 3.79E-01 | 1.70E-01 | 1.45E-01 | 8.32E-02 | 2.29E-02 |
| $\alpha_3$ | | 2.15E-01 | 1.45E-01 | 1.40E-01 | 1.26E-01 |
| $\alpha_4$ | | | 9.95E-02 | 9.89E-02 | 1.02E-01 |
| $\alpha_5$ | | | | 4.23E-02 | 5.66E-02 |
| $\alpha_6$ | | | | | 1.89E-02 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 6.21E-01 | 6.14E-01 | 6.10E-01 | 6.36E-01 | 6.73E-01 |
| Beta | 3.79E-01 | 3.86E-01 | 3.90E-01 | 3.64E-01 | 3.27E-01 |
| Gamma | | 5.58E-01 | 6.28E-01 | 7.72E-01 | 9.30E-01 |
| Delta | | | 4.06E-01 | 5.02E-01 | 5.85E-01 |
| Epsilon | | | | 2.99E-01 | 4.25E-01 |
| Mu | | | | | 2.50E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 11.66 | 17.48 | 23.31 | 29.14 | 34.97 |
| $N_1$ | 5.2048 | 3.4955 | 1.2679 | 0.2054 | 0.0300 |
| $N_2$ | 10.2845 | 5.8116 | 5.8393 | 3.8381 | 1.1880 |
| $N_3$ | | 7.3473 | 5.8560 | 6.4524 | 6.5509 |
| $N_4$ | | | 4.0083 | 4.5667 | 5.3211 |
| $N_5$ | | | | 1.9500 | 2.9450 |
| $N_6$ | | | | | 0.9825 |

# 1.7 Heat Exchangers

## 1.7.1 PWR HEAT EXCHANGER LOSS OF HEAT TRANSFER

### 1.7.1.1 PWR RHR HEAT EXCHANGER PLUG/LOSS OF HEAT TRANSFER

**System :** Residual Heat Removal (LCI in BWRs, LPI in PWRs)
**Component :** Heat Exchanger
**Failure Mode :** High dP across filter
Loss of heat transfer capabilities in heat exchangers
No flow/plugged
**Plant Type :** PWR
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

PWR HEAT EXCHANGER LOSS OF HEAT TRANSFER

PWR RHR HEAT EXCHANGER PLUG/LOSS OF HEAT TRANSFER

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.7.2 Pooled Heat Exchanger Plugged or Failure to Transfer Heat

### 1.7.2.1 HEAT EXCHANGER PLUGGED ALL SYSTEMS NON ENVIRO SPAR:HTX-PG

| | |
|---|---|
| **Component :** | Heat Exchanger |
| **Failure Mode :** | Loss of heat transfer capabilities in heat exchangers |
| **Prox. Cause :** | State of other component<br>Design error or inadequacy<br>Manufacturing error or inadequacy<br>Construction/installation error or inadequacy<br>Setpoint drift<br>Ambient environmental stress<br>Inadequate procedure<br>Inadequate maintenance<br>Age/Wear<br>Accidental human action<br>Human action procedure<br>Other<br>Internal environment<br>Internal to component, piece-part<br>Unknown |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 19.60
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8999170 | 0.9748730 | 0.9895490 | 0.9999470 | 0.9994530 | 1.7002E+01 | 4.3822E-01 |
| $\alpha_2$ | 4.87E-05 | 2.51E-02 | 1.04E-02 | 1.00E-01 | 5.47E-04 | 4.3822E-01 | 1.7002E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9224360 | 0.9727520 | 0.9800330 | 0.9981620 | 0.9989450 | 3.9683E+01 | 1.1116E+00 |
| $\alpha_2$ | 6.84E-04 | 2.07E-02 | 1.35E-02 | 6.52E-02 | 1.05E-03 | 8.4426E-01 | 3.9950E+01 |
| $\alpha_3$ | 2.31E-07 | 6.55E-03 | 1.32E-03 | 3.11E-02 | 9.86E-06 | 2.6732E-01 | 4.0527E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9271730 | 0.9694980 | 0.9744410 | 0.9949080 | 0.9984460 | 5.9630E+01 | 1.8761E+00 |
| $\alpha_2$ | 1.74E-03 | 2.03E-02 | 1.54E-02 | 5.57E-02 | 1.52E-03 | 1.2486E+00 | 6.0257E+01 |
| $\alpha_3$ | 7.48E-06 | 6.58E-03 | 2.45E-03 | 2.72E-02 | 3.70E-05 | 4.0481E-01 | 6.1101E+01 |
| $\alpha_4$ | 1.56E-08 | 3.62E-03 | 4.96E-04 | 1.81E-02 | 0.00E+00 | 2.2267E-01 | 6.1283E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9994530 | 0.9989450 | 0.9984460 |
| $\alpha_2$ | 5.47E-04 | 1.05E-03 | 1.52E-03 |
| $\alpha_3$ | | 9.86E-06 | 3.70E-05 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.99E-01 | 9.99E-01 | 9.98E-01 |
| Beta | 5.47E-04 | 1.06E-03 | 1.55E-03 |
| Gamma | | 9.35E-03 | 2.38E-02 |
| Delta | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 6.53 | 9.80 | 13.07 |
| $N_1$ | 0.2260 | 0.3284 | 0.4242 |
| $N_2$ | 0.0037 | 0.0106 | 0.0205 |
| $N_3$ | | 0.0001 | 0.0005 |
| $N_4$ | | | 0.0000 |

# 1.7.3 Containment Spray Heat Exchanger

## 1.7.3.1 CONTAINMENT SPRAY HTX LOSS OF HEAT TRANSFER

| | |
|---|---|
| **System :** | Containment spray recirculation |
| **Component :** | Heat Exchanger |
| **Failure Mode :** | Fail to Operate (General operation failure, rate based)<br>Loss of heat transfer capabilities in heat exchangers<br>No flow/plugged |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8687700 | 0.9670330 | 0.9862440 | 0.9999400 | 1.0000000 | 1.2746E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.16E-05 | 3.30E-02 | 1.38E-02 | 1.31E-01 | 0.00E+00 | 4.3452E-01 | 1.2746E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 |
|---|---|
| $\alpha_1$ | 1.0000000 |
| $\alpha_2$ | 0.00E+00 |

| MGL Parameter | CCCG=2 |
|---|---|
| 1-Beta | 1.00E+00 |
| Beta | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 |
|---|---|
| Adj. Ind. Events | 2.50 |
| $N_1$ | 0.0000 |
| $N_2$ | 0.0000 |

# 1.7.4 BWR Residual Heat Removal Heat Exchanger

## 1.7.4.1 BWR RHR HEAT EXCHANGER LOSS OF HEAT TRANSFER CAPABILITIES

| | |
|---|---|
| **System :** | Residual Heat Removal (LCI in BWRs, LPI in PWRs) |
| **Component :** | Heat Exchanger |
| **Failure Mode :** | High dP across filter<br>Loss of heat transfer capabilities in heat exchangers<br>No flow/plugged |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

BWR Residual Heat Removal Heat Exchanger

BWR RHR HEAT EXCHANGER LOSS OF HEAT TRANSFER CAPABILITIES

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

# 1.7.5 BWR Isolation Condenser Heat Exchanger

## 1.7.5.1 ISO CONDENSER HEAT EXCHANGER PLUG/LOSS OF HEAT TRANSFER

| | |
|---|---|
| **System :** | Isolation condenser |
| **Component :** | Heat Exchanger |
| **Failure Mode :** | High dP across filter<br>Loss of heat transfer capabilities in heat exchangers<br>No flow/plugged |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 0.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 0.0000000 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 0.0000000 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.0000000 | 0.0000000 | 0.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

BWR Isolation Condenser Heat Exchanger

ISO CONDENSER HEAT EXCHANGER PLUG/LOSS OF HEAT TRANSFER

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

## 1.7.6 Component Cooling Heat Exchanger

### 1.7.6.1 CCW HEAT EXCHANGER LOSS OF HEAT TRANSFER SPAR: CCW-HTX-PG

| | |
|---|---|
| **System :** | Component cooling water |
| **Component :** | Heat Exchanger |
| **Failure Mode :** | Fail to Operate (General operation failure, rate based)<br>Loss of heat transfer capabilities in heat exchangers<br>No flow/plugged |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 20.60
Total Number of Common-Cause Failure Events: 2

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8930490 | 0.9697340 | 0.9834560 | 0.9996960 | 0.9816940 | 1.9379E+01 | 6.0482E-01 |
| $\alpha_2$ | 3.07E-04 | 3.03E-02 | 1.65E-02 | 1.07E-01 | 1.83E-02 | 6.0482E-01 | 1.9379E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9091620 | 0.9636650 | 0.9704010 | 0.9950860 | 0.9627200 | 4.2743E+01 | 1.6116E+00 |
| $\alpha_2$ | 3.01E-03 | 3.03E-02 | 2.36E-02 | 8.07E-02 | 3.73E-02 | 1.3443E+00 | 4.3010E+01 |
| $\alpha_3$ | 2.12E-07 | 6.03E-03 | 1.22E-03 | 2.86E-02 | 7.30E-06 | 2.6732E-01 | 4.4087E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9089030 | 0.9563680 | 0.9609160 | 0.9882680 | 0.9430410 | 6.3040E+01 | 2.8761E+00 |
| $\alpha_2$ | 7.12E-03 | 3.41E-02 | 2.95E-02 | 7.69E-02 | 5.69E-02 | 2.2486E+00 | 6.3667E+01 |
| $\alpha_3$ | 6.97E-06 | 6.14E-03 | 2.28E-03 | 2.54E-02 | 2.79E-05 | 4.0481E-01 | 6.5511E+01 |
| $\alpha_4$ | 1.46E-08 | 3.38E-03 | 4.62E-04 | 1.69E-02 | 0.00E+00 | 2.2267E-01 | 6.5693E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9816940 | 0.9627200 | 0.9430410 |
| $\alpha_2$ | 1.83E-02 | 3.73E-02 | 5.69E-02 |
| $\alpha_3$ | | 7.30E-06 | 2.79E-05 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.82E-01 | 9.63E-01 | 9.43E-01 |
| Beta | 1.83E-02 | 3.73E-02 | 5.70E-02 |
| Gamma | | 1.96E-04 | 4.90E-04 |
| Delta | | | 0.00E+00 |

CCW HEAT EXCHANGER LOSS OF HEAT TRANSFER SPAR: CCW-HTX-PG

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 8.24 | 12.36 | 16.48 |
| $N_1$ | 0.8927 | 0.8284 | 0.4242 |
| $N_2$ | 0.1703 | 0.5106 | 1.0205 |
| $N_3$ | | 0.0001 | 0.0005 |
| $N_4$ | | | 0.0000 |

# 1.8 Safety and Relief Valves

## 1.8.1 Pooled Safety Valves

### 1.8.1.1 SAFETY VALVES (DIRECT ACTING) FAIL TO OPEN ALL SYS

**Component :** Safety Valve (Single Acting)
**Failure Mode :** Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 3.00
Total Number of Common-Cause Failure Events: 3

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8416100 | 0.9581450 | 0.9801360 | 0.9998350 | 0.9467440 | 1.1284E+01 | 4.9292E-01 |
| $\alpha_2$ | 1.63E-04 | 4.19E-02 | 1.99E-02 | 1.58E-01 | 5.33E-02 | 4.9292E-01 | 1.1284E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8939080 | 0.9608260 | 0.9699400 | 0.9965220 | 0.8964810 | 3.0948E+01 | 1.2618E+00 |
| $\alpha_2$ | 1.57E-03 | 3.07E-02 | 2.16E-02 | 9.08E-02 | 9.90E-02 | 9.8746E-01 | 3.1222E+01 |
| $\alpha_3$ | 3.93E-07 | 8.52E-03 | 1.81E-03 | 4.01E-02 | 4.57E-03 | 2.7432E-01 | 3.1935E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9020960 | 0.9569720 | 0.9629390 | 0.9914180 | 0.8508220 | 4.7819E+01 | 2.1501E+00 |
| $\alpha_2$ | 3.58E-03 | 2.99E-02 | 2.39E-02 | 7.69E-02 | 1.36E-01 | 1.4962E+00 | 4.8473E+01 |
| $\alpha_3$ | 1.46E-05 | 8.62E-03 | 3.44E-03 | 3.48E-02 | 1.34E-02 | 4.3071E-01 | 4.9538E+01 |
| $\alpha_4$ | 1.99E-08 | 4.47E-03 | 6.16E-04 | 2.24E-02 | 2.53E-04 | 2.2317E-01 | 4.9746E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9252350 | 0.9609280 | 0.9639040 | 0.9864380 | 0.8096950 | 9.8074E+01 | 3.9878E+00 |
| $\alpha_2$ | 5.70E-03 | 2.45E-02 | 2.15E-02 | 5.37E-02 | 1.64E-01 | 2.5006E+00 | 9.9561E+01 |
| $\alpha_3$ | 5.77E-04 | 1.02E-02 | 7.20E-03 | 2.99E-02 | 2.56E-02 | 1.0378E+00 | 1.0102E+02 |
| $\alpha_4$ | 2.56E-06 | 3.69E-03 | 1.26E-03 | 1.56E-02 | 1.14E-03 | 3.7709E-01 | 1.0168E+02 |
| $\alpha_5$ | 5.85E-21 | 7.08E-04 | 4.01E-07 | 4.10E-03 | 0.00E+00 | 7.2277E-02 | 1.0199E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9282440 | 0.9605120 | 0.9629670 | 0.9843880 | 0.7732650 | 1.1904E+02 | 4.8939E+00 |
| $\alpha_2$ | 5.60E-03 | 2.21E-02 | 1.96E-02 | 4.72E-02 | 1.83E-01 | 2.7363E+00 | 1.2120E+02 |
| $\alpha_3$ | 8.61E-04 | 1.01E-02 | 7.61E-03 | 2.78E-02 | 4.05E-02 | 1.2517E+00 | 1.2268E+02 |
| $\alpha_4$ | 4.60E-05 | 4.84E-03 | 2.56E-03 | 1.74E-02 | 3.02E-03 | 6.0042E-01 | 1.2333E+02 |
| $\alpha_5$ | 7.50E-09 | 1.79E-03 | 2.43E-04 | 8.98E-03 | 0.00E+00 | 2.2220E-01 | 1.2371E+02 |
| $\alpha_6$ | 1.14E-18 | 6.72E-04 | 1.18E-06 | 3.92E-03 | 0.00E+00 | 8.3237E-02 | 1.2385E+02 |

SAFETY VALVES (DIRECT ACTING) FAIL TO OPEN ALL SYS

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9378850 | 0.9626420 | 0.9642250 | 0.9819880 | 0.7408230 | 1.8629E+02 | 7.2294E+00 |
| $\alpha_2$ | 6.17E-03 | 1.90E-02 | 1.74E-02 | 3.74E-02 | 1.96E-01 | 3.6799E+00 | 1.8984E+02 |
| $\alpha_3$ | 1.46E-03 | 9.32E-03 | 7.70E-03 | 2.28E-02 | 5.72E-02 | 1.8043E+00 | 1.9172E+02 |
| $\alpha_4$ | 2.74E-04 | 5.21E-03 | 3.63E-03 | 1.55E-02 | 6.34E-03 | 1.0081E+00 | 1.9251E+02 |
| $\alpha_5$ | 1.33E-05 | 2.70E-03 | 1.28E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9300E+02 |
| $\alpha_6$ | 3.47E-10 | 9.63E-04 | 8.22E-05 | 5.05E-03 | 0.00E+00 | 1.8628E-01 | 1.9333E+02 |
| $\alpha_7$ | 0.00E+00 | 1.50E-04 | 1.32E-13 | 5.66E-04 | 0.00E+00 | 2.9071E-02 | 1.9349E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9409490 | 0.9633480 | 0.9646850 | 0.9811730 | 0.7140320 | 2.2110E+02 | 8.4121E+00 |
| $\alpha_2$ | 6.03E-03 | 1.75E-02 | 1.61E-02 | 3.36E-02 | 2.00E-01 | 4.0111E+00 | 2.2550E+02 |
| $\alpha_3$ | 1.53E-03 | 8.65E-03 | 7.27E-03 | 2.05E-02 | 7.40E-02 | 1.9846E+00 | 2.2753E+02 |
| $\alpha_4$ | 3.92E-04 | 5.16E-03 | 3.82E-03 | 1.45E-02 | 1.16E-02 | 1.1850E+00 | 2.2833E+02 |
| $\alpha_5$ | 5.62E-05 | 3.09E-03 | 1.81E-03 | 1.04E-02 | 0.00E+00 | 7.0833E-01 | 2.2880E+02 |
| $\alpha_6$ | 9.05E-07 | 1.60E-03 | 5.24E-04 | 6.84E-03 | 0.00E+00 | 3.6696E-01 | 2.2915E+02 |
| $\alpha_7$ | 7.10E-14 | 5.36E-04 | 9.64E-06 | 3.05E-03 | 0.00E+00 | 1.2297E-01 | 2.2939E+02 |
| $\alpha_8$ | 1.33E-42 | 1.44E-04 | 2.06E-12 | 6.10E-04 | 0.00E+00 | 3.3124E-02 | 2.2948E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9467440 | 0.8964810 | 0.8508220 | 0.8096950 | 0.7732650 | 0.7408230 | 0.7140320 |
| $\alpha_2$ | 5.33E-02 | 9.90E-02 | 1.36E-01 | 1.64E-01 | 1.83E-01 | 1.96E-01 | 2.00E-01 |
| $\alpha_3$ | | 4.57E-03 | 1.34E-02 | 2.56E-02 | 4.05E-02 | 5.72E-02 | 7.40E-02 |
| $\alpha_4$ | | | 2.53E-04 | 1.14E-03 | 3.02E-03 | 6.34E-03 | 1.16E-02 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.47E-01 | 8.96E-01 | 8.51E-01 | 8.10E-01 | 7.73E-01 | 7.41E-01 | 7.14E-01 |
| Beta | 5.33E-02 | 1.04E-01 | 1.49E-01 | 1.90E-01 | 2.27E-01 | 2.59E-01 | 2.86E-01 |
| Gamma | | 4.41E-02 | 9.12E-02 | 1.40E-01 | 1.92E-01 | 2.45E-01 | 2.99E-01 |
| Delta | | | 1.86E-02 | 4.28E-02 | 6.94E-02 | 9.98E-02 | 1.35E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

SAFETY VALVES (DIRECT ACTING) FAIL TO OPEN ALL SYS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.38 | 0.56 | 0.75 | 0.94 | 1.13 | 1.31 | 1.50 |
| $N_1$ | 0.6582 | 0.8334 | 0.9325 | 0.9725 | 0.9681 | 0.9321 | 0.8748 |
| $N_2$ | 0.0584 | 0.1538 | 0.2681 | 0.3864 | 0.4971 | 0.5921 | 0.6664 |
| $N_3$ | | 0.0071 | 0.0264 | 0.0604 | 0.1099 | 0.1731 | 0.2462 |
| $N_4$ | | | 0.0005 | 0.0027 | 0.0082 | 0.0192 | 0.0385 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.8.1.2 SAFETY VALVES (DIRECT ACTING) FAIL TO CLOSE ALL SYS

| | |
|---|---|
| **Component :** | Safety Valve (Single Acting) |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8520040 | 0.9624790 | 0.9839450 | 0.9999230 | 0.9926000 | 1.1359E+01 | 4.4282E-01 |
| $\alpha_2$ | 7.92E-05 | 3.75E-02 | 1.61E-02 | 1.48E-01 | 7.40E-03 | 4.4282E-01 | 1.1359E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9016600 | 0.9651600 | 0.9742450 | 0.9975600 | 0.9849400 | 3.1190E+01 | 1.1259E+00 |
| $\alpha_2$ | 9.29E-04 | 2.66E-02 | 1.76E-02 | 8.29E-02 | 1.51E-02 | 8.5866E-01 | 3.1457E+01 |
| $\alpha_3$ | 2.91E-07 | 8.27E-03 | 1.68E-03 | 3.92E-02 | 0.00E+00 | 2.6722E-01 | 3.2049E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9101260 | 0.9620430 | 0.9680200 | 0.9935000 | 0.9772730 | 4.8286E+01 | 1.9051E+00 |
| $\alpha_2$ | 2.29E-03 | 2.55E-02 | 1.95E-02 | 6.92E-02 | 2.27E-02 | 1.2781E+00 | 4.8913E+01 |
| $\alpha_3$ | 9.10E-06 | 8.06E-03 | 3.00E-03 | 3.33E-02 | 0.00E+00 | 4.0431E-01 | 4.9787E+01 |
| $\alpha_4$ | 1.92E-08 | 4.44E-03 | 6.09E-04 | 2.22E-02 | 0.00E+00 | 2.2267E-01 | 4.9968E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9305070 | 0.9646440 | 0.9676270 | 0.9885670 | 0.9695050 | 9.8809E+01 | 3.6215E+00 |
| $\alpha_2$ | 4.33E-03 | 2.15E-02 | 1.84E-02 | 4.90E-02 | 3.05E-02 | 2.1975E+00 | 1.0023E+02 |
| $\alpha_3$ | 4.66E-04 | 9.54E-03 | 6.60E-03 | 2.87E-02 | 0.00E+00 | 9.7738E-01 | 1.0145E+02 |
| $\alpha_4$ | 2.40E-06 | 3.66E-03 | 1.23E-03 | 1.55E-02 | 0.00E+00 | 3.7439E-01 | 1.0206E+02 |
| $\alpha_5$ | 5.83E-21 | 7.06E-04 | 3.99E-07 | 4.09E-03 | 0.00E+00 | 7.2277E-02 | 1.0236E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9339130 | 0.9646220 | 0.9670870 | 0.9869070 | 0.9615980 | 1.2007E+02 | 4.4037E+00 |
| $\alpha_2$ | 4.15E-03 | 1.90E-02 | 1.65E-02 | 4.24E-02 | 3.84E-02 | 2.3642E+00 | 1.2211E+02 |
| $\alpha_3$ | 6.46E-04 | 9.17E-03 | 6.71E-03 | 2.61E-02 | 0.00E+00 | 1.1418E+00 | 1.2333E+02 |
| $\alpha_4$ | 4.26E-05 | 4.76E-03 | 2.49E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2388E+02 |
| $\alpha_5$ | 7.47E-09 | 1.79E-03 | 2.42E-04 | 8.94E-03 | 0.00E+00 | 2.2220E-01 | 1.2425E+02 |
| $\alpha_6$ | 1.13E-18 | 6.69E-04 | 1.17E-06 | 3.90E-03 | 0.00E+00 | 8.3237E-02 | 1.2439E+02 |

SAFETY VALVES (DIRECT ACTING) FAIL TO CLOSE ALL SYS

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9421820 | 0.9659200 | 0.9675070 | 0.9842320 | 0.9534570 | 1.8763E+02 | 6.6200E+00 |
| $\alpha_2$ | 4.96E-03 | 1.68E-02 | 1.52E-02 | 3.42E-02 | 4.65E-02 | 3.2628E+00 | 1.9099E+02 |
| $\alpha_3$ | 1.13E-03 | 8.40E-03 | 6.78E-03 | 2.12E-02 | 0.00E+00 | 1.6312E+00 | 1.9262E+02 |
| $\alpha_4$ | 2.55E-04 | 5.09E-03 | 3.52E-03 | 1.53E-02 | 0.00E+00 | 9.8887E-01 | 1.9326E+02 |
| $\alpha_5$ | 1.32E-05 | 2.69E-03 | 1.27E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9373E+02 |
| $\alpha_6$ | 3.46E-10 | 9.59E-04 | 8.19E-05 | 5.03E-03 | 0.00E+00 | 1.8628E-01 | 1.9406E+02 |
| $\alpha_7$ | 0.00E+00 | 1.50E-04 | 1.31E-13 | 5.63E-04 | 0.00E+00 | 2.9071E-02 | 1.9422E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9451620 | 0.9666130 | 0.9679560 | 0.9834840 | 0.9453190 | 2.2276E+02 | 7.6943E+00 |
| $\alpha_2$ | 4.93E-03 | 1.55E-02 | 1.41E-02 | 3.08E-02 | 5.47E-02 | 3.5780E+00 | 2.2688E+02 |
| $\alpha_3$ | 1.12E-03 | 7.54E-03 | 6.17E-03 | 1.87E-02 | 0.00E+00 | 1.7384E+00 | 2.2872E+02 |
| $\alpha_4$ | 3.52E-04 | 4.97E-03 | 3.64E-03 | 1.42E-02 | 0.00E+00 | 1.1465E+00 | 2.2931E+02 |
| $\alpha_5$ | 5.60E-05 | 3.07E-03 | 1.81E-03 | 1.04E-02 | 0.00E+00 | 7.0833E-01 | 2.2975E+02 |
| $\alpha_6$ | 9.01E-07 | 1.59E-03 | 5.21E-04 | 6.81E-03 | 0.00E+00 | 3.6696E-01 | 2.3009E+02 |
| $\alpha_7$ | 7.07E-14 | 5.34E-04 | 9.60E-06 | 3.04E-03 | 0.00E+00 | 1.2297E-01 | 2.3033E+02 |
| $\alpha_8$ | 1.32E-42 | 1.44E-04 | 2.05E-12 | 6.07E-04 | 0.00E+00 | 3.3124E-02 | 2.3042E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9926000 | 0.9849400 | 0.9772730 | 0.9695050 | 0.9615980 | 0.9534570 | 0.9453190 |
| $\alpha_2$ | 7.40E-03 | 1.51E-02 | 2.27E-02 | 3.05E-02 | 3.84E-02 | 4.65E-02 | 5.47E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.93E-01 | 9.85E-01 | 9.77E-01 | 9.70E-01 | 9.62E-01 | 9.53E-01 | 9.45E-01 |
| Beta | 7.40E-03 | 1.51E-02 | 2.27E-02 | 3.05E-02 | 3.84E-02 | 4.65E-02 | 5.47E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

SAFETY VALVES (DIRECT ACTING) FAIL TO CLOSE ALL SYS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.88 | 1.31 | 1.75 | 2.19 | 2.63 | 3.06 | 3.50 |
| $N_1$ | 0.2333 | 0.3250 | 0.4000 | 0.4583 | 0.5000 | 0.5250 | 0.5333 |
| $N_2$ | 0.0083 | 0.0250 | 0.0500 | 0.0833 | 0.1250 | 0.1750 | 0.2333 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.8.2 PWR Steam Generator Safety Valves

### 1.8.2.1 PWR MAIN STEAM CODE SAFETIES FAIL TO OPEN

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Safety Valve (Single Acting) |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 3

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8382550 | 0.9572370 | 0.9796800 | 0.9998310 | 0.9310180 | 1.1034E+01 | 4.9292E-01 |
| $\alpha_2$ | 1.67E-04 | 4.28E-02 | 2.03E-02 | 1.62E-01 | 6.90E-02 | 4.9292E-01 | 1.1034E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8927010 | 0.9603710 | 0.9695830 | 0.9964800 | 0.8641390 | 3.0578E+01 | 1.2618E+00 |
| $\alpha_2$ | 1.59E-03 | 3.10E-02 | 2.18E-02 | 9.18E-02 | 1.30E-01 | 9.8746E-01 | 3.0852E+01 |
| $\alpha_3$ | 3.97E-07 | 8.62E-03 | 1.83E-03 | 4.05E-02 | 6.00E-03 | 2.7432E-01 | 3.1565E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9011290 | 0.9565370 | 0.9625600 | 0.9913290 | 0.8003380 | 4.7319E+01 | 2.1501E+00 |
| $\alpha_2$ | 3.62E-03 | 3.02E-02 | 2.42E-02 | 7.77E-02 | 1.81E-01 | 1.4962E+00 | 4.7973E+01 |
| $\alpha_3$ | 1.48E-05 | 8.71E-03 | 3.47E-03 | 3.51E-02 | 1.79E-02 | 4.3071E-01 | 4.9038E+01 |
| $\alpha_4$ | 2.01E-08 | 4.51E-03 | 6.23E-04 | 2.26E-02 | 3.38E-04 | 2.2317E-01 | 4.9246E+01 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9310180 | 0.8641390 | 0.8003380 |
| $\alpha_2$ | 6.90E-02 | 1.30E-01 | 1.81E-01 |
| $\alpha_3$ | | 6.00E-03 | 1.79E-02 |
| $\alpha_4$ | | | 3.38E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.31E-01 | 8.64E-01 | 8.00E-01 |
| Beta | 6.90E-02 | 1.36E-01 | 2.00E-01 |
| Gamma | | 4.41E-02 | 9.12E-02 |
| Delta | | | 1.86E-02 |

PWR MAIN STEAM CODE SAFETIES FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 0.13 | 0.19 | 0.25 |
| $N_1$ | 0.6582 | 0.8334 | 0.9325 |
| $N_2$ | 0.0584 | 0.1538 | 0.2681 |
| $N_3$ | | 0.0071 | 0.0264 |
| $N_4$ | | | 0.0005 |

## 1.8.2.2 PWR MAIN STEAM CODE SAFETIES FAIL TO CLOSE

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Safety Valve (Single Acting) |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8503880 | 0.9620610 | 0.9837560 | 0.9999220 | 0.9916300 | 1.1229E+01 | 4.4282E-01 |
| $\alpha_2$ | 8.01E-05 | 3.79E-02 | 1.62E-02 | 1.50E-01 | 8.37E-03 | 4.4282E-01 | 1.1229E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9011190 | 0.9649650 | 0.9740980 | 0.9975450 | 0.9831080 | 3.1010E+01 | 1.1259E+00 |
| $\alpha_2$ | 9.34E-04 | 2.67E-02 | 1.77E-02 | 8.33E-02 | 1.69E-02 | 8.5866E-01 | 3.1277E+01 |
| $\alpha_3$ | 2.93E-07 | 8.32E-03 | 1.69E-03 | 3.94E-02 | 0.00E+00 | 2.6722E-01 | 3.1869E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9096840 | 0.9618530 | 0.9678530 | 0.9934660 | 0.9743590 | 4.8036E+01 | 1.9051E+00 |
| $\alpha_2$ | 2.30E-03 | 2.56E-02 | 1.96E-02 | 6.95E-02 | 2.56E-02 | 1.2781E+00 | 4.8663E+01 |
| $\alpha_3$ | 9.14E-06 | 8.10E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9537E+01 |
| $\alpha_4$ | 1.93E-08 | 4.46E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9718E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9302990 | 0.9645370 | 0.9675290 | 0.9885310 | 0.9656010 | 9.8499E+01 | 3.6215E+00 |
| $\alpha_2$ | 4.34E-03 | 2.15E-02 | 1.85E-02 | 4.91E-02 | 3.44E-02 | 2.1975E+00 | 9.9923E+01 |
| $\alpha_3$ | 4.68E-04 | 9.57E-03 | 6.62E-03 | 2.88E-02 | 0.00E+00 | 9.7738E-01 | 1.0114E+02 |
| $\alpha_4$ | 2.41E-06 | 3.67E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0175E+02 |
| $\alpha_5$ | 5.85E-21 | 7.08E-04 | 4.00E-07 | 4.10E-03 | 0.00E+00 | 7.2277E-02 | 1.0205E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9337130 | 0.9645130 | 0.9669850 | 0.9868660 | 0.9565220 | 1.1969E+02 | 4.4037E+00 |
| $\alpha_2$ | 4.16E-03 | 1.91E-02 | 1.65E-02 | 4.26E-02 | 4.35E-02 | 2.3642E+00 | 1.2173E+02 |
| $\alpha_3$ | 6.48E-04 | 9.20E-03 | 6.73E-03 | 2.62E-02 | 0.00E+00 | 1.1418E+00 | 1.2295E+02 |
| $\alpha_4$ | 4.27E-05 | 4.77E-03 | 2.50E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2350E+02 |
| $\alpha_5$ | 7.49E-09 | 1.79E-03 | 2.43E-04 | 8.97E-03 | 0.00E+00 | 2.2220E-01 | 1.2387E+02 |
| $\alpha_6$ | 1.14E-18 | 6.71E-04 | 1.17E-06 | 3.92E-03 | 0.00E+00 | 8.3237E-02 | 1.2401E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9420580 | 0.9658460 | 0.9674360 | 0.9841980 | 0.9474470 | 1.8721E+02 | 6.6200E+00 |
| $\alpha_2$ | 4.97E-03 | 1.68E-02 | 1.52E-02 | 3.43E-02 | 5.26E-02 | 3.2628E+00 | 1.9057E+02 |
| $\alpha_3$ | 1.13E-03 | 8.42E-03 | 6.80E-03 | 2.12E-02 | 0.00E+00 | 1.6312E+00 | 1.9220E+02 |
| $\alpha_4$ | 2.56E-04 | 5.10E-03 | 3.53E-03 | 1.53E-02 | 0.00E+00 | 9.8887E-01 | 1.9284E+02 |
| $\alpha_5$ | 1.32E-05 | 2.69E-03 | 1.27E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9331E+02 |
| $\alpha_6$ | 3.47E-10 | 9.61E-04 | 8.21E-05 | 5.04E-03 | 0.00E+00 | 1.8628E-01 | 1.9364E+02 |
| $\alpha_7$ | 0.00E+00 | 1.50E-04 | 1.31E-13 | 5.65E-04 | 0.00E+00 | 2.9071E-02 | 1.9380E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9450440 | 0.9665400 | 0.9678870 | 0.9834470 | 0.9380610 | 2.2226E+02 | 7.6943E+00 |
| $\alpha_2$ | 4.94E-03 | 1.56E-02 | 1.42E-02 | 3.09E-02 | 6.19E-02 | 3.5780E+00 | 2.2638E+02 |
| $\alpha_3$ | 1.12E-03 | 7.56E-03 | 6.19E-03 | 1.87E-02 | 0.00E+00 | 1.7384E+00 | 2.2822E+02 |
| $\alpha_4$ | 3.53E-04 | 4.99E-03 | 3.64E-03 | 1.42E-02 | 0.00E+00 | 1.1465E+00 | 2.2881E+02 |
| $\alpha_5$ | 5.61E-05 | 3.08E-03 | 1.81E-03 | 1.04E-02 | 0.00E+00 | 7.0833E-01 | 2.2925E+02 |
| $\alpha_6$ | 9.03E-07 | 1.60E-03 | 5.22E-04 | 6.83E-03 | 0.00E+00 | 3.6696E-01 | 2.2959E+02 |
| $\alpha_7$ | 7.08E-14 | 5.35E-04 | 9.62E-06 | 3.04E-03 | 0.00E+00 | 1.2297E-01 | 2.2983E+02 |
| $\alpha_8$ | 1.33E-42 | 1.44E-04 | 2.05E-12 | 6.09E-04 | 0.00E+00 | 3.3124E-02 | 2.2992E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9916300 | 0.9831080 | 0.9743590 | 0.9656010 | 0.9565220 | 0.9474470 | 0.9380610 |
| $\alpha_2$ | 8.37E-03 | 1.69E-02 | 2.56E-02 | 3.44E-02 | 4.35E-02 | 5.26E-02 | 6.19E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.92E-01 | 9.83E-01 | 9.74E-01 | 9.66E-01 | 9.57E-01 | 9.47E-01 | 9.38E-01 |
| Beta | 8.37E-03 | 1.69E-02 | 2.56E-02 | 3.44E-02 | 4.35E-02 | 5.26E-02 | 6.19E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR MAIN STEAM CODE SAFETIES FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.75 | 1.13 | 1.50 | 1.88 | 2.25 | 2.63 | 3.00 |
| $N_1$ | 0.2333 | 0.3250 | 0.4000 | 0.4583 | 0.5000 | 0.5250 | 0.5333 |
| $N_2$ | 0.0083 | 0.0250 | 0.0500 | 0.0833 | 0.1250 | 0.1750 | 0.2333 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.8.3 BWR Safety Relief Valves

## 1.8.3.1 SAFETY RELIEF VALVE FAIL TO OPEN SPAR: SRV-CC

**Component :** Safety Relief Valve (Dual Actuation)
**Failure Mode :** Fail to open on demand
**Plant Type :** BWR
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 21.00
Total Number of Common-Cause Failure Events: 5

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8791940 | 0.9662980 | 0.9820640 | 0.9997190 | 0.9777850 | 1.6593E+01 | 5.7872E-01 |
| $\alpha_2$ | 2.83E-04 | 3.37E-02 | 1.79E-02 | 1.21E-01 | 2.22E-02 | 5.7872E-01 | 1.6593E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040050 | 0.9623710 | 0.9697670 | 0.9953930 | 0.9568450 | 3.8670E+01 | 1.5120E+00 |
| $\alpha_2$ | 2.59E-03 | 3.07E-02 | 2.33E-02 | 8.42E-02 | 4.20E-02 | 1.2341E+00 | 3.8948E+01 |
| $\alpha_3$ | 3.62E-07 | 6.92E-03 | 1.50E-03 | 3.24E-02 | 1.12E-03 | 2.7792E-01 | 3.9904E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9066350 | 0.9563910 | 0.9613440 | 0.9891940 | 0.9372740 | 5.7794E+01 | 2.6353E+00 |
| $\alpha_2$ | 5.78E-03 | 3.25E-02 | 2.75E-02 | 7.65E-02 | 5.93E-02 | 1.9663E+00 | 5.8463E+01 |
| $\alpha_3$ | 1.55E-05 | 7.38E-03 | 3.04E-03 | 2.94E-02 | 3.35E-03 | 4.4601E-01 | 5.9983E+01 |
| $\alpha_4$ | 1.62E-08 | 3.69E-03 | 5.07E-04 | 1.85E-02 | 2.41E-05 | 2.2297E-01 | 6.0206E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9251620 | 0.9592340 | 0.9618760 | 0.9842800 | 0.9247780 | 1.1028E+02 | 4.6868E+00 |
| $\alpha_2$ | 7.75E-03 | 2.71E-02 | 2.44E-02 | 5.57E-02 | 6.58E-02 | 3.1182E+00 | 1.1185E+02 |
| $\alpha_3$ | 6.59E-04 | 9.75E-03 | 7.09E-03 | 2.79E-02 | 9.37E-03 | 1.1204E+00 | 1.1385E+02 |
| $\alpha_4$ | 2.21E-06 | 3.27E-03 | 1.11E-03 | 1.39E-02 | 9.82E-05 | 3.7589E-01 | 1.1459E+02 |
| $\alpha_5$ | 5.19E-21 | 6.29E-04 | 3.55E-07 | 3.64E-03 | 0.00E+00 | 7.2277E-02 | 1.1489E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9271430 | 0.9581910 | 0.9603680 | 0.9817880 | 0.9143510 | 1.3341E+02 | 5.8212E+00 |
| $\alpha_2$ | 7.84E-03 | 2.51E-02 | 2.28E-02 | 5.00E-02 | 6.95E-02 | 3.4903E+00 | 1.3574E+02 |
| $\alpha_3$ | 1.10E-03 | 1.02E-02 | 7.98E-03 | 2.69E-02 | 1.55E-02 | 1.4216E+00 | 1.3781E+02 |
| $\alpha_4$ | 4.22E-05 | 4.34E-03 | 2.30E-03 | 1.55E-02 | 6.44E-04 | 6.0382E-01 | 1.3863E+02 |
| $\alpha_5$ | 6.67E-09 | 1.60E-03 | 2.16E-04 | 8.00E-03 | 0.00E+00 | 2.2220E-01 | 1.3901E+02 |
| $\alpha_6$ | 1.01E-18 | 5.98E-04 | 1.05E-06 | 3.49E-03 | 0.00E+00 | 8.3237E-02 | 1.3915E+02 |

SAFETY RELIEF VALVE FAIL TO OPEN SPAR: SRV-CC

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9360390 | 0.9602910 | 0.9617340 | 0.9796090 | 0.9061800 | 2.0279E+02 | 8.3856E+00 |
| $\alpha_2$ | 8.06E-03 | 2.15E-02 | 2.00E-02 | 4.00E-02 | 7.02E-02 | 4.5393E+00 | 2.0664E+02 |
| $\alpha_3$ | 1.87E-03 | 9.89E-03 | 8.39E-03 | 2.30E-02 | 2.21E-02 | 2.0887E+00 | 2.0909E+02 |
| $\alpha_4$ | 2.61E-04 | 4.83E-03 | 3.38E-03 | 1.43E-02 | 1.47E-03 | 1.0193E+00 | 2.1016E+02 |
| $\alpha_5$ | 1.23E-05 | 2.48E-03 | 1.17E-03 | 9.35E-03 | 5.80E-05 | 5.2297E-01 | 2.1065E+02 |
| $\alpha_6$ | 3.18E-10 | 8.82E-04 | 7.53E-05 | 4.63E-03 | 0.00E+00 | 1.8628E-01 | 2.1099E+02 |
| $\alpha_7$ | 0.00E+00 | 1.38E-04 | 1.20E-13 | 5.18E-04 | 0.00E+00 | 2.9071E-02 | 2.1115E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9387250 | 0.9607840 | 0.9620120 | 0.9786510 | 0.9003310 | 2.3972E+02 | 9.7847E+00 |
| $\alpha_2$ | 7.77E-03 | 1.97E-02 | 1.85E-02 | 3.60E-02 | 6.78E-02 | 4.9258E+00 | 2.4458E+02 |
| $\alpha_3$ | 2.16E-03 | 9.69E-03 | 8.42E-03 | 2.16E-02 | 2.91E-02 | 2.4180E+00 | 2.4709E+02 |
| $\alpha_4$ | 3.80E-04 | 4.83E-03 | 3.59E-03 | 1.35E-02 | 2.51E-03 | 1.2051E+00 | 2.4830E+02 |
| $\alpha_5$ | 5.31E-05 | 2.86E-03 | 1.68E-03 | 9.64E-03 | 1.80E-04 | 7.1253E-01 | 2.4879E+02 |
| $\alpha_6$ | 8.36E-07 | 1.47E-03 | 4.82E-04 | 6.29E-03 | 8.58E-06 | 3.6716E-01 | 2.4914E+02 |
| $\alpha_7$ | 6.53E-14 | 4.93E-04 | 8.86E-06 | 2.81E-03 | 0.00E+00 | 1.2297E-01 | 2.4938E+02 |
| $\alpha_8$ | 1.22E-42 | 1.33E-04 | 1.89E-12 | 5.61E-04 | 0.00E+00 | 3.3124E-02 | 2.4947E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9777850 | 0.9568450 | 0.9372740 | 0.9247780 | 0.9143510 | 0.9061800 | 0.9003310 |
| $\alpha_2$ | 2.22E-02 | 4.20E-02 | 5.93E-02 | 6.58E-02 | 6.95E-02 | 7.02E-02 | 6.78E-02 |
| $\alpha_3$ | | 1.12E-03 | 3.35E-03 | 9.37E-03 | 1.55E-02 | 2.21E-02 | 2.91E-02 |
| $\alpha_4$ | | | 2.41E-05 | 9.82E-05 | 6.44E-04 | 1.47E-03 | 2.51E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 5.80E-05 | 1.80E-04 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 8.58E-06 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.78E-01 | 9.57E-01 | 9.37E-01 | 9.25E-01 | 9.14E-01 | 9.06E-01 | 9.00E-01 |
| Beta | 2.22E-02 | 4.32E-02 | 6.27E-02 | 7.52E-02 | 8.56E-02 | 9.38E-02 | 9.97E-02 |
| Gamma | | 2.60E-02 | 5.38E-02 | 1.26E-01 | 1.89E-01 | 2.52E-01 | 3.20E-01 |
| Delta | | | 7.14E-03 | 1.04E-02 | 3.98E-02 | 6.46E-02 | 8.48E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 3.80E-02 | 6.98E-02 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 4.55E-02 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

SAFETY RELIEF VALVE FAIL TO OPEN SPAR: SRV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 4.67 | 7.00 | 9.33 | 11.67 | 14.00 | 16.33 | 18.67 |
| $N_1$ | 1.6770 | 2.1151 | 2.3281 | 2.4497 | 2.4670 | 2.4137 | 2.3205 |
| $N_2$ | 0.1442 | 0.4004 | 0.7382 | 1.0040 | 1.2511 | 1.4515 | 1.5811 |
| $N_3$ | | 0.0107 | 0.0417 | 0.1430 | 0.2798 | 0.4575 | 0.6796 |
| $N_4$ | | | 0.0003 | 0.0015 | 0.0116 | 0.0304 | 0.0586 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0012 | 0.0042 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0002 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.8.3.2 SAFETY RELIEF VALVE FAIL TO CLOSE SPAR: SRV-OO

| | |
|---|---|
| **Component :** | Safety Relief Valve (Dual Actuation) |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 6.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8959650 | 0.9739500 | 0.9892430 | 0.9999480 | 1.0000000 | 1.6246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.81E-05 | 2.60E-02 | 1.08E-02 | 1.04E-01 | 0.00E+00 | 4.3452E-01 | 1.6246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9143470 | 0.9699670 | 0.9780280 | 0.9980130 | 1.0000000 | 3.5555E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.25E-04 | 2.27E-02 | 1.48E-02 | 7.18E-02 | 0.00E+00 | 8.3366E-01 | 3.5822E+01 |
| $\alpha_3$ | 2.56E-07 | 7.29E-03 | 1.48E-03 | 3.46E-02 | 0.00E+00 | 2.6722E-01 | 3.6389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9178250 | 0.9656410 | 0.9712250 | 0.9943340 | 1.0000000 | 5.2136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.89E-03 | 2.27E-02 | 1.72E-02 | 6.27E-02 | 0.00E+00 | 1.2281E+00 | 5.2763E+01 |
| $\alpha_3$ | 8.45E-06 | 7.49E-03 | 2.78E-03 | 3.09E-02 | 0.00E+00 | 4.0431E-01 | 5.3587E+01 |
| $\alpha_4$ | 1.78E-08 | 4.12E-03 | 5.66E-04 | 2.07E-02 | 0.00E+00 | 2.2267E-01 | 5.3768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9337450 | 0.9665250 | 0.9694270 | 0.9893730 | 1.0000000 | 1.0216E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.85E-03 | 2.00E-02 | 1.71E-02 | 4.62E-02 | 0.00E+00 | 2.1142E+00 | 1.0358E+02 |
| $\alpha_3$ | 4.52E-04 | 9.25E-03 | 6.39E-03 | 2.78E-02 | 0.00E+00 | 9.7738E-01 | 1.0472E+02 |
| $\alpha_4$ | 2.33E-06 | 3.54E-03 | 1.19E-03 | 1.50E-02 | 0.00E+00 | 3.7439E-01 | 1.0532E+02 |
| $\alpha_5$ | 5.65E-21 | 6.84E-04 | 3.87E-07 | 3.96E-03 | 0.00E+00 | 7.2277E-02 | 1.0563E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366750 | 0.9663680 | 0.9687880 | 0.9877920 | 1.0000000 | 1.2294E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.62E-03 | 1.76E-02 | 1.51E-02 | 4.00E-02 | 0.00E+00 | 2.2392E+00 | 1.2498E+02 |
| $\alpha_3$ | 6.32E-04 | 8.98E-03 | 6.57E-03 | 2.55E-02 | 0.00E+00 | 1.1418E+00 | 1.2608E+02 |
| $\alpha_4$ | 4.16E-05 | 4.66E-03 | 2.44E-03 | 1.68E-02 | 0.00E+00 | 5.9222E-01 | 1.2663E+02 |
| $\alpha_5$ | 7.30E-09 | 1.75E-03 | 2.37E-04 | 8.75E-03 | 0.00E+00 | 2.2220E-01 | 1.2700E+02 |
| $\alpha_6$ | 1.11E-18 | 6.54E-04 | 1.14E-06 | 3.82E-03 | 0.00E+00 | 8.3237E-02 | 1.2714E+02 |

SAFETY RELIEF VALVE FAIL TO CLOSE SPAR: SRV-OO

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9439980 | 0.9672000 | 0.9687770 | 0.9850250 | 1.0000000 | 1.9005E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.43E-03 | 1.57E-02 | 1.41E-02 | 3.25E-02 | 0.00E+00 | 3.0878E+00 | 1.9341E+02 |
| $\alpha_3$ | 1.12E-03 | 8.30E-03 | 6.70E-03 | 2.10E-02 | 0.00E+00 | 1.6312E+00 | 1.9486E+02 |
| $\alpha_4$ | 2.52E-04 | 5.03E-03 | 3.48E-03 | 1.51E-02 | 0.00E+00 | 9.8887E-01 | 1.9551E+02 |
| $\alpha_5$ | 1.31E-05 | 2.66E-03 | 1.26E-03 | 1.00E-02 | 0.00E+00 | 5.2177E-01 | 1.9597E+02 |
| $\alpha_6$ | 3.42E-10 | 9.48E-04 | 8.09E-05 | 4.98E-03 | 0.00E+00 | 1.8628E-01 | 1.9631E+02 |
| $\alpha_7$ | 0.00E+00 | 1.48E-04 | 1.30E-13 | 5.57E-04 | 0.00E+00 | 2.9071E-02 | 1.9647E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9468590 | 0.9678670 | 0.9692050 | 0.9843190 | 1.0000000 | 2.2473E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.33E-03 | 1.44E-02 | 1.30E-02 | 2.92E-02 | 0.00E+00 | 3.3447E+00 | 2.2885E+02 |
| $\alpha_3$ | 1.11E-03 | 7.49E-03 | 6.13E-03 | 1.85E-02 | 0.00E+00 | 1.7384E+00 | 2.3045E+02 |
| $\alpha_4$ | 3.50E-04 | 4.94E-03 | 3.61E-03 | 1.41E-02 | 0.00E+00 | 1.1465E+00 | 2.3104E+02 |
| $\alpha_5$ | 5.55E-05 | 3.05E-03 | 1.79E-03 | 1.03E-02 | 0.00E+00 | 7.0833E-01 | 2.3148E+02 |
| $\alpha_6$ | 8.95E-07 | 1.58E-03 | 5.17E-04 | 6.76E-03 | 0.00E+00 | 3.6696E-01 | 2.3182E+02 |
| $\alpha_7$ | 7.01E-14 | 5.30E-04 | 9.53E-06 | 3.02E-03 | 0.00E+00 | 1.2297E-01 | 2.3207E+02 |
| $\alpha_8$ | 1.31E-42 | 1.43E-04 | 2.03E-12 | 6.03E-04 | 0.00E+00 | 3.3124E-02 | 2.3216E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

SAFETY RELIEF VALVE FAIL TO CLOSE SPAR: SRV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 | 6.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.8.4 PWR Pressurizer Safety Valve

## 1.8.4.1 PWR PRESSURIZER CODE SAFETIES FAIL TO OPEN

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Safety Valve (Single Acting) |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 2.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8636860 | 0.9657330 | 0.9856730 | 0.9999380 | 1.0000000 | 1.2246E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.41E-05 | 3.43E-02 | 1.43E-02 | 1.36E-01 | 0.00E+00 | 4.3452E-01 | 1.2246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9040420 | 0.9662880 | 0.9752810 | 0.9977560 | 1.0000000 | 3.1555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.16E-04 | 2.55E-02 | 1.67E-02 | 8.05E-02 | 0.00E+00 | 8.3366E-01 | 3.1822E+01 |
| $\alpha_3$ | 2.88E-07 | 8.18E-03 | 1.66E-03 | 3.88E-02 | 0.00E+00 | 2.6722E-01 | 3.2389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9628920 | 0.9688970 | 0.9938680 | 1.0000000 | 4.8136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.04E-03 | 2.46E-02 | 1.86E-02 | 6.77E-02 | 0.00E+00 | 1.2281E+00 | 4.8763E+01 |
| $\alpha_3$ | 9.14E-06 | 8.09E-03 | 3.01E-03 | 3.34E-02 | 0.00E+00 | 4.0431E-01 | 4.9587E+01 |
| $\alpha_4$ | 1.93E-08 | 4.45E-03 | 6.12E-04 | 2.23E-02 | 0.00E+00 | 2.2267E-01 | 4.9768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9311740 | 0.9652090 | 0.9682200 | 0.9889480 | 1.0000000 | 9.8161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.01E-03 | 2.08E-02 | 1.77E-02 | 4.80E-02 | 0.00E+00 | 2.1142E+00 | 9.9585E+01 |
| $\alpha_3$ | 4.70E-04 | 9.61E-03 | 6.64E-03 | 2.89E-02 | 0.00E+00 | 9.7738E-01 | 1.0072E+02 |
| $\alpha_4$ | 2.42E-06 | 3.68E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0132E+02 |
| $\alpha_5$ | 5.87E-21 | 7.11E-04 | 4.02E-07 | 4.12E-03 | 0.00E+00 | 7.2277E-02 | 1.0163E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9346440 | 0.9652760 | 0.9677640 | 0.9873890 | 1.0000000 | 1.1894E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.74E-03 | 1.82E-02 | 1.56E-02 | 4.13E-02 | 0.00E+00 | 2.2392E+00 | 1.2098E+02 |
| $\alpha_3$ | 6.53E-04 | 9.27E-03 | 6.78E-03 | 2.64E-02 | 0.00E+00 | 1.1418E+00 | 1.2208E+02 |
| $\alpha_4$ | 4.30E-05 | 4.81E-03 | 2.52E-03 | 1.73E-02 | 0.00E+00 | 5.9222E-01 | 1.2263E+02 |
| $\alpha_5$ | 7.54E-09 | 1.80E-03 | 2.45E-04 | 9.04E-03 | 0.00E+00 | 2.2220E-01 | 1.2300E+02 |
| $\alpha_6$ | 1.14E-18 | 6.76E-04 | 1.18E-06 | 3.94E-03 | 0.00E+00 | 8.3237E-02 | 1.2314E+02 |

PWR PRESSURIZER CODE SAFETIES FAIL TO OPEN

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9428470 | 0.9665190 | 0.9681250 | 0.9847050 | 1.0000000 | 1.8605E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.52E-03 | 1.60E-02 | 1.44E-02 | 3.32E-02 | 0.00E+00 | 3.0878E+00 | 1.8941E+02 |
| $\alpha_3$ | 1.14E-03 | 8.47E-03 | 6.84E-03 | 2.14E-02 | 0.00E+00 | 1.6312E+00 | 1.9086E+02 |
| $\alpha_4$ | 2.57E-04 | 5.14E-03 | 3.56E-03 | 1.54E-02 | 0.00E+00 | 9.8887E-01 | 1.9151E+02 |
| $\alpha_5$ | 1.33E-05 | 2.71E-03 | 1.28E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9197E+02 |
| $\alpha_6$ | 3.49E-10 | 9.68E-04 | 8.26E-05 | 5.08E-03 | 0.00E+00 | 1.8628E-01 | 1.9231E+02 |
| $\alpha_7$ | 0.00E+00 | 1.51E-04 | 1.32E-13 | 5.69E-04 | 0.00E+00 | 2.9071E-02 | 1.9247E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9459360 | 0.9673040 | 0.9686640 | 0.9840410 | 1.0000000 | 2.2073E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.41E-03 | 1.47E-02 | 1.33E-02 | 2.97E-02 | 0.00E+00 | 3.3447E+00 | 2.2485E+02 |
| $\alpha_3$ | 1.13E-03 | 7.62E-03 | 6.24E-03 | 1.88E-02 | 0.00E+00 | 1.7384E+00 | 2.2645E+02 |
| $\alpha_4$ | 3.56E-04 | 5.02E-03 | 3.67E-03 | 1.43E-02 | 0.00E+00 | 1.1465E+00 | 2.2704E+02 |
| $\alpha_5$ | 5.65E-05 | 3.10E-03 | 1.82E-03 | 1.05E-02 | 0.00E+00 | 7.0833E-01 | 2.2748E+02 |
| $\alpha_6$ | 9.10E-07 | 1.61E-03 | 5.27E-04 | 6.88E-03 | 0.00E+00 | 3.6696E-01 | 2.2782E+02 |
| $\alpha_7$ | 7.14E-14 | 5.39E-04 | 9.69E-06 | 3.07E-03 | 0.00E+00 | 1.2297E-01 | 2.2807E+02 |
| $\alpha_8$ | 1.34E-42 | 1.45E-04 | 2.07E-12 | 6.14E-04 | 0.00E+00 | 3.3124E-02 | 2.2816E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Pressurizer Safety Valve

PWR PRESSURIZER CODE SAFETIES FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 | 2.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.8.4.2 PWR PRESSURIZER CODE SAFETIES FAIL TO CLOSE

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Safety Valve (Single Acting) |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 1.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8522320 | 0.9628000 | 0.9843830 | 0.9999320 | 1.0000000 | 1.1246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.00E-05 | 3.72E-02 | 1.56E-02 | 1.48E-01 | 0.00E+00 | 4.3452E-01 | 1.1246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9010680 | 0.9652240 | 0.9744830 | 0.9976820 | 1.0000000 | 3.0555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.43E-04 | 2.63E-02 | 1.72E-02 | 8.30E-02 | 0.00E+00 | 8.3366E-01 | 3.0822E+01 |
| $\alpha_3$ | 2.98E-07 | 8.44E-03 | 1.71E-03 | 4.00E-02 | 0.00E+00 | 2.6722E-01 | 3.1389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9095820 | 0.9621340 | 0.9682530 | 0.9937390 | 1.0000000 | 4.7136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.09E-03 | 2.51E-02 | 1.89E-02 | 6.90E-02 | 0.00E+00 | 1.2281E+00 | 4.7763E+01 |
| $\alpha_3$ | 9.32E-06 | 8.25E-03 | 3.07E-03 | 3.41E-02 | 0.00E+00 | 4.0431E-01 | 4.8587E+01 |
| $\alpha_4$ | 1.97E-08 | 4.55E-03 | 6.24E-04 | 2.28E-02 | 0.00E+00 | 2.2267E-01 | 4.8768E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

PWR Pressurizer Safety Valve

PWR PRESSURIZER CODE SAFETIES FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 1.00 | 1.00 | 1.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

# 1.9 PORVs

## 1.9.1 Pooled PORVs

### 1.9.1.1 POWER OPERATED RELIEF VALVES FAIL TO OPEN ALL SYSTEMS

**Component :** Power Operated Relief Valve
**Failure Mode :** Fail to open on demand
**Op. Mode :** CCF Event Can Only Happen During Power Operation
CCF Event May Occur During Both Power Operation & Shutdown
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 99.80
Total Number of Common-Cause Failure Events: 8

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9312520 | 0.9745140 | 0.9804040 | 0.9976200 | 0.9785230 | 4.9849E+01 | 1.3037E+00 |
| $\alpha_2$ | 2.38E-03 | 2.55E-02 | 1.96E-02 | 6.87E-02 | 2.15E-02 | 1.3037E+00 | 4.9849E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9293350 | 0.9655040 | 0.9688890 | 0.9901000 | 0.9662310 | 8.7244E+01 | 3.1171E+00 |
| $\alpha_2$ | 6.73E-03 | 2.83E-02 | 2.49E-02 | 6.15E-02 | 2.88E-02 | 2.5542E+00 | 8.7807E+01 |
| $\alpha_3$ | 4.44E-05 | 6.23E-03 | 3.15E-03 | 2.29E-02 | 4.95E-03 | 5.6292E-01 | 8.9798E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9369540 | 0.9666090 | 0.9690390 | 0.9879640 | 0.9698160 | 1.2256E+02 | 4.2338E+00 |
| $\alpha_2$ | 4.40E-03 | 1.93E-02 | 1.69E-02 | 4.27E-02 | 1.55E-02 | 2.4533E+00 | 1.2434E+02 |
| $\alpha_3$ | 1.12E-03 | 1.09E-02 | 8.45E-03 | 2.90E-02 | 1.24E-02 | 1.3814E+00 | 1.2541E+02 |
| $\alpha_4$ | 3.23E-06 | 3.15E-03 | 1.14E-03 | 1.31E-02 | 2.24E-03 | 3.9907E-01 | 1.2639E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9458650 | 0.9685690 | 0.9701370 | 0.9859100 | 0.9727030 | 1.9134E+02 | 6.2092E+00 |
| $\alpha_2$ | 4.50E-03 | 1.58E-02 | 1.42E-02 | 3.26E-02 | 1.03E-02 | 3.1228E+00 | 1.9443E+02 |
| $\alpha_3$ | 1.61E-03 | 9.61E-03 | 8.02E-03 | 2.31E-02 | 9.42E-03 | 1.8993E+00 | 1.9565E+02 |
| $\alpha_4$ | 2.77E-04 | 5.15E-03 | 3.60E-03 | 1.53E-02 | 6.57E-03 | 1.0169E+00 | 1.9653E+02 |
| $\alpha_5$ | 7.35E-11 | 8.61E-04 | 5.58E-05 | 4.62E-03 | 1.00E-03 | 1.7018E-01 | 1.9738E+02 |

POWER OPERATED RELIEF VALVES FAIL TO OPEN ALL SYSTEMS

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9492920 | 0.9695440 | 0.9708490 | 0.9853270 | 0.9745680 | 2.3078E+02 | 7.2494E+00 |
| $\alpha_2$ | 4.10E-03 | 1.38E-02 | 1.25E-02 | 2.81E-02 | 8.99E-03 | 3.2896E+00 | 2.3474E+02 |
| $\alpha_3$ | 1.14E-03 | 7.46E-03 | 6.13E-03 | 1.83E-02 | 5.42E-03 | 1.7754E+00 | 2.3625E+02 |
| $\alpha_4$ | 6.30E-04 | 5.93E-03 | 4.61E-03 | 1.57E-02 | 7.01E-03 | 1.4112E+00 | 2.3662E+02 |
| $\alpha_5$ | 3.35E-05 | 2.69E-03 | 1.49E-03 | 9.45E-03 | 3.59E-03 | 6.4100E-01 | 2.3739E+02 |
| $\alpha_6$ | 3.80E-13 | 5.56E-04 | 1.39E-05 | 3.13E-03 | 4.19E-04 | 1.3224E-01 | 2.3790E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9531740 | 0.9701180 | 0.9710770 | 0.9837970 | 0.9756610 | 3.1649E+02 | 9.7488E+00 |
| $\alpha_2$ | 4.83E-03 | 1.33E-02 | 1.23E-02 | 2.51E-02 | 9.23E-03 | 4.3403E+00 | 3.2190E+02 |
| $\alpha_3$ | 1.14E-03 | 6.24E-03 | 5.26E-03 | 1.47E-02 | 2.97E-03 | 2.0350E+00 | 3.2420E+02 |
| $\alpha_4$ | 7.09E-04 | 5.11E-03 | 4.14E-03 | 1.28E-02 | 4.99E-03 | 1.6660E+00 | 3.2457E+02 |
| $\alpha_5$ | 2.96E-04 | 3.72E-03 | 2.77E-03 | 1.04E-02 | 5.09E-03 | 1.2128E+00 | 3.2503E+02 |
| $\alpha_6$ | 2.77E-06 | 1.36E-03 | 5.55E-04 | 5.45E-03 | 1.90E-03 | 4.4458E-01 | 3.2579E+02 |
| $\alpha_7$ | 1.86E-29 | 1.53E-04 | 1.75E-09 | 8.18E-04 | 1.55E-04 | 5.0071E-02 | 3.2619E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9553170 | 0.9707620 | 0.9715850 | 0.9834100 | 0.9762440 | 3.6966E+02 | 1.1134E+01 |
| $\alpha_2$ | 5.00E-03 | 1.28E-02 | 1.20E-02 | 2.35E-02 | 9.90E-03 | 4.8748E+00 | 3.7592E+02 |
| $\alpha_3$ | 9.91E-04 | 5.39E-03 | 4.55E-03 | 1.26E-02 | 2.02E-03 | 2.0512E+00 | 3.7874E+02 |
| $\alpha_4$ | 5.25E-04 | 4.13E-03 | 3.30E-03 | 1.06E-02 | 2.76E-03 | 1.5731E+00 | 3.7922E+02 |
| $\alpha_5$ | 3.95E-04 | 3.71E-03 | 2.89E-03 | 9.85E-03 | 4.56E-03 | 1.4135E+00 | 3.7938E+02 |
| $\alpha_6$ | 9.79E-05 | 2.40E-03 | 1.61E-03 | 7.42E-03 | 3.54E-03 | 9.1486E-01 | 3.7988E+02 |
| $\alpha_7$ | 2.31E-08 | 6.99E-04 | 1.38E-04 | 3.32E-03 | 9.26E-04 | 2.6607E-01 | 3.8053E+02 |
| $\alpha_8$ | 5.73E-36 | 1.05E-04 | 4.80E-11 | 5.07E-04 | 4.53E-05 | 4.0124E-02 | 3.8075E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9785230 | 0.9662310 | 0.9698160 | 0.9727030 | 0.9745680 | 0.9756610 | 0.9762440 |
| $\alpha_2$ | 2.15E-02 | 2.88E-02 | 1.55E-02 | 1.03E-02 | 8.99E-03 | 9.23E-03 | 9.90E-03 |
| $\alpha_3$ | | 4.95E-03 | 1.24E-02 | 9.42E-03 | 5.42E-03 | 2.97E-03 | 2.02E-03 |
| $\alpha_4$ | | | 2.24E-03 | 6.57E-03 | 7.01E-03 | 4.99E-03 | 2.76E-03 |
| $\alpha_5$ | | | | 1.00E-03 | 3.59E-03 | 5.09E-03 | 4.56E-03 |
| $\alpha_6$ | | | | | 4.19E-04 | 1.90E-03 | 3.54E-03 |
| $\alpha_7$ | | | | | | 1.55E-04 | 9.26E-04 |
| $\alpha_8$ | | | | | | | 4.53E-05 |

Pooled PORVs

POWER OPERATED RELIEF VALVES FAIL TO OPEN ALL SYSTEMS

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.79E-01 | 9.66E-01 | 9.70E-01 | 9.73E-01 | 9.75E-01 | 9.76E-01 | 9.76E-01 |
| Beta | 2.15E-02 | 3.38E-02 | 3.02E-02 | 2.73E-02 | 2.54E-02 | 2.43E-02 | 2.38E-02 |
| Gamma | | 1.47E-01 | 4.85E-01 | 6.22E-01 | 6.46E-01 | 6.21E-01 | 5.83E-01 |
| Delta | | | 1.53E-01 | 4.45E-01 | 6.70E-01 | 8.03E-01 | 8.54E-01 |
| Epsilon | | | | 1.32E-01 | 3.64E-01 | 5.89E-01 | 7.67E-01 |
| Mu | | | | | 1.05E-01 | 2.88E-01 | 4.97E-01 |
| Upsilon | | | | | | 7.52E-02 | 2.15E-01 |
| Sigma | | | | | | | 4.66E-02 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 36.29 | 54.44 | 72.58 | 90.73 | 108.87 | 127.02 | 145.16 |
| $N_1$ | 3.3129 | 3.2489 | 3.8484 | 4.4453 | 4.9747 | 5.4152 | 5.7670 |
| $N_2$ | 0.8692 | 1.7205 | 1.2252 | 1.0086 | 1.0504 | 1.2525 | 1.5301 |
| $N_3$ | | 0.2957 | 0.9771 | 0.9219 | 0.6336 | 0.4038 | 0.3128 |
| $N_4$ | | | 0.1764 | 0.6425 | 0.8190 | 0.6771 | 0.4266 |
| $N_5$ | | | | 0.0979 | 0.4188 | 0.6910 | 0.7052 |
| $N_6$ | | | | | 0.0490 | 0.2583 | 0.5479 |
| $N_7$ | | | | | | 0.0210 | 0.1431 |
| $N_8$ | | | | | | | 0.0070 |

## 1.9.1.2 POWER OPERATED RELIEF VALVES FAIL TO CLOSE ALL SYSTEMS

**Component :** Power Operated Relief Valve
**Failure Mode :** Fail to close (reseat) on demand
**Op. Mode :** CCF Event Can Only Happen During Power Operation
CCF Event May Occur During Both Power Operation & Shutdown
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 31.10
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9336460 | 0.9834320 | 0.9932310 | 0.9999660 | 0.9998910 | 2.5893E+01 | 4.3622E-01 |
| $\alpha_2$ | 3.08E-05 | 1.66E-02 | 6.77E-03 | 6.64E-02 | 1.09E-04 | 4.3622E-01 | 2.5893E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9415350 | 0.9795700 | 0.9851170 | 0.9986480 | 0.9997870 | 5.3025E+01 | 1.1059E+00 |
| $\alpha_2$ | 4.99E-04 | 1.55E-02 | 1.01E-02 | 4.90E-02 | 2.13E-04 | 8.3866E-01 | 5.3292E+01 |
| $\alpha_3$ | 1.73E-07 | 4.94E-03 | 9.94E-04 | 2.34E-02 | 0.00E+00 | 2.6722E-01 | 5.3864E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9435460 | 0.9764750 | 0.9803590 | 0.9961230 | 0.9996800 | 7.7416E+01 | 1.8651E+00 |
| $\alpha_2$ | 1.31E-03 | 1.56E-02 | 1.18E-02 | 4.31E-02 | 3.20E-04 | 1.2381E+00 | 7.8043E+01 |
| $\alpha_3$ | 5.73E-06 | 5.10E-03 | 1.89E-03 | 2.11E-02 | 0.00E+00 | 4.0431E-01 | 7.8877E+01 |
| $\alpha_4$ | 1.21E-08 | 2.81E-03 | 3.84E-04 | 1.41E-02 | 0.00E+00 | 2.2267E-01 | 7.9058E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9492370 | 0.9743960 | 0.9766440 | 0.9918800 | 0.9995910 | 1.3526E+02 | 3.5542E+00 |
| $\alpha_2$ | 2.97E-03 | 1.53E-02 | 1.31E-02 | 3.54E-02 | 4.01E-04 | 2.1299E+00 | 1.3668E+02 |
| $\alpha_3$ | 3.44E-04 | 7.04E-03 | 4.86E-03 | 2.12E-02 | 7.67E-06 | 9.7768E-01 | 1.3784E+02 |
| $\alpha_4$ | 1.77E-06 | 2.70E-03 | 9.07E-04 | 1.15E-02 | 0.00E+00 | 3.7439E-01 | 1.3844E+02 |
| $\alpha_5$ | 4.29E-21 | 5.21E-04 | 2.94E-07 | 3.01E-03 | 0.00E+00 | 7.2277E-02 | 1.3874E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9517600 | 0.9744150 | 0.9762770 | 0.9907130 | 0.9995060 | 1.6384E+02 | 4.3019E+00 |
| $\alpha_2$ | 2.79E-03 | 1.35E-02 | 1.16E-02 | 3.05E-02 | 4.77E-04 | 2.2616E+00 | 1.6588E+02 |
| $\alpha_3$ | 4.78E-04 | 6.80E-03 | 4.97E-03 | 1.94E-02 | 1.70E-05 | 1.1426E+00 | 1.6700E+02 |
| $\alpha_4$ | 3.15E-05 | 3.52E-03 | 1.84E-03 | 1.27E-02 | 0.00E+00 | 5.9222E-01 | 1.6755E+02 |
| $\alpha_5$ | 5.52E-09 | 1.32E-03 | 1.79E-04 | 6.62E-03 | 0.00E+00 | 2.2220E-01 | 1.6792E+02 |
| $\alpha_6$ | 8.38E-19 | 4.95E-04 | 8.65E-07 | 2.89E-03 | 0.00E+00 | 8.3237E-02 | 1.6806E+02 |

POWER OPERATED RELIEF VALVES FAIL TO CLOSE ALL SYSTEMS

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9548720 | 0.9735890 | 0.9748690 | 0.9879420 | 0.9994210 | 2.3875E+02 | 6.4767E+00 |
| $\alpha_2$ | 3.61E-03 | 1.27E-02 | 1.14E-02 | 2.63E-02 | 5.50E-04 | 3.1179E+00 | 2.4211E+02 |
| $\alpha_3$ | 8.98E-04 | 6.66E-03 | 5.37E-03 | 1.68E-02 | 2.92E-05 | 1.6328E+00 | 2.4359E+02 |
| $\alpha_4$ | 2.02E-04 | 4.03E-03 | 2.79E-03 | 1.21E-02 | 0.00E+00 | 9.8887E-01 | 2.4424E+02 |
| $\alpha_5$ | 1.05E-05 | 2.13E-03 | 1.01E-03 | 8.04E-03 | 0.00E+00 | 5.2177E-01 | 2.4470E+02 |
| $\alpha_6$ | 2.74E-10 | 7.60E-04 | 6.48E-05 | 3.99E-03 | 0.00E+00 | 1.8628E-01 | 2.4504E+02 |
| $\alpha_7$ | 0.00E+00 | 1.19E-04 | 1.04E-13 | 4.46E-04 | 0.00E+00 | 2.9071E-02 | 2.4520E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9570100 | 0.9740180 | 0.9751080 | 0.9873170 | 0.9993430 | 2.8124E+02 | 7.5021E+00 |
| $\alpha_2$ | 3.55E-03 | 1.17E-02 | 1.06E-02 | 2.37E-02 | 6.15E-04 | 3.3832E+00 | 2.8536E+02 |
| $\alpha_3$ | 8.93E-04 | 6.03E-03 | 4.93E-03 | 1.49E-02 | 4.00E-05 | 1.7409E+00 | 2.8700E+02 |
| $\alpha_4$ | 2.81E-04 | 3.97E-03 | 2.90E-03 | 1.13E-02 | 1.60E-06 | 1.1466E+00 | 2.8760E+02 |
| $\alpha_5$ | 4.46E-05 | 2.45E-03 | 1.44E-03 | 8.30E-03 | 0.00E+00 | 7.0833E-01 | 2.8803E+02 |
| $\alpha_6$ | 7.19E-07 | 1.27E-03 | 4.16E-04 | 5.44E-03 | 0.00E+00 | 3.6696E-01 | 2.8838E+02 |
| $\alpha_7$ | 5.64E-14 | 4.26E-04 | 7.66E-06 | 2.42E-03 | 0.00E+00 | 1.2297E-01 | 2.8862E+02 |
| $\alpha_8$ | 1.06E-42 | 1.15E-04 | 1.63E-12 | 4.85E-04 | 0.00E+00 | 3.3124E-02 | 2.8871E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9998910 | 0.9997870 | 0.9996800 | 0.9995910 | 0.9995060 | 0.9994210 | 0.9993430 |
| $\alpha_2$ | 1.09E-04 | 2.13E-04 | 3.20E-04 | 4.01E-04 | 4.77E-04 | 5.50E-04 | 6.15E-04 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 7.67E-06 | 1.70E-05 | 2.92E-05 | 4.00E-05 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.60E-06 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 9.99E-01 | 9.99E-01 |
| Beta | 1.09E-04 | 2.13E-04 | 3.20E-04 | 4.09E-04 | 4.94E-04 | 5.79E-04 | 6.57E-04 |
| Gamma | | 0.00E+00 | 0.00E+00 | 1.88E-02 | 3.45E-02 | 5.05E-02 | 6.33E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.85E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

Pooled PORVs

POWER OPERATED RELIEF VALVES FAIL TO CLOSE ALL SYSTEMS

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 15.55 | 23.33 | 31.10 | 38.88 | 46.65 | 54.42 | 62.20 |
| $N_1$ | 0.0967 | 0.1400 | 0.1800 | 0.2175 | 0.2523 | 0.2845 | 0.3143 |
| $N_2$ | 0.0017 | 0.0050 | 0.0100 | 0.0157 | 0.0224 | 0.0301 | 0.0385 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0003 | 0.0008 | 0.0016 | 0.0025 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.9.2 PWR Steam Generator PORV

### 1.9.2.1 PWR MAIN STEAM PORV FAIL TO OPEN SPAR: ADV-CC

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Power Operated Relief Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 78.70
Total Number of Common-Cause Failure Events: 6

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9089810 | 0.9662920 | 0.9740850 | 0.9969210 | 0.9690100 | 3.6799E+01 | 1.2837E+00 |
| $\alpha_2$ | 3.08E-03 | 3.37E-02 | 2.59E-02 | 9.10E-02 | 3.10E-02 | 1.2837E+00 | 3.6799E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9112620 | 0.9567510 | 0.9609950 | 0.9877200 | 0.9511450 | 6.7718E+01 | 3.0611E+00 |
| $\alpha_2$ | 8.26E-03 | 3.53E-02 | 3.10E-02 | 7.71E-02 | 4.15E-02 | 2.5002E+00 | 6.8279E+01 |
| $\alpha_3$ | 5.57E-05 | 7.92E-03 | 4.00E-03 | 2.91E-02 | 7.32E-03 | 5.6092E-01 | 7.0218E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9223160 | 0.9590080 | 0.9620120 | 0.9854180 | 0.9568800 | 9.6601E+01 | 4.1292E+00 |
| $\alpha_2$ | 5.11E-03 | 2.34E-02 | 2.03E-02 | 5.22E-02 | 2.14E-02 | 2.3561E+00 | 9.8374E+01 |
| $\alpha_3$ | 1.39E-03 | 1.36E-02 | 1.06E-02 | 3.64E-02 | 1.84E-02 | 1.3742E+00 | 9.9356E+01 |
| $\alpha_4$ | 4.06E-06 | 3.96E-03 | 1.44E-03 | 1.64E-02 | 3.34E-03 | 3.9887E-01 | 1.0033E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366010 | 0.9633550 | 0.9652170 | 0.9837580 | 0.9615910 | 1.5895E+02 | 6.0463E+00 |
| $\alpha_2$ | 4.93E-03 | 1.80E-02 | 1.61E-02 | 3.77E-02 | 1.32E-02 | 2.9770E+00 | 1.6202E+02 |
| $\alpha_3$ | 1.89E-03 | 1.14E-02 | 9.51E-03 | 2.75E-02 | 1.39E-02 | 1.8831E+00 | 1.6311E+02 |
| $\alpha_4$ | 3.30E-04 | 6.16E-03 | 4.31E-03 | 1.83E-02 | 9.83E-03 | 1.0160E+00 | 1.6398E+02 |
| $\alpha_5$ | 8.80E-11 | 1.03E-03 | 6.68E-05 | 5.53E-03 | 1.50E-03 | 1.7018E-01 | 1.6483E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9409440 | 0.9647240 | 0.9662690 | 0.9832240 | 0.9647540 | 1.9200E+02 | 7.0207E+00 |
| $\alpha_2$ | 4.38E-03 | 1.55E-02 | 1.39E-02 | 3.21E-02 | 1.10E-02 | 3.0927E+00 | 1.9593E+02 |
| $\alpha_3$ | 1.31E-03 | 8.77E-03 | 7.19E-03 | 2.17E-02 | 7.77E-03 | 1.7462E+00 | 1.9727E+02 |
| $\alpha_4$ | 7.50E-04 | 7.08E-03 | 5.51E-03 | 1.88E-02 | 1.05E-02 | 1.4087E+00 | 1.9761E+02 |
| $\alpha_5$ | 4.01E-05 | 3.22E-03 | 1.78E-03 | 1.13E-02 | 5.38E-03 | 6.4090E-01 | 1.9838E+02 |
| $\alpha_6$ | 4.55E-13 | 6.64E-04 | 1.66E-05 | 3.74E-03 | 6.30E-04 | 1.3224E-01 | 1.9889E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9469870 | 0.9663440 | 0.9674440 | 0.9819420 | 0.9667170 | 2.7131E+02 | 9.4494E+00 |
| $\alpha_2$ | 5.09E-03 | 1.46E-02 | 1.34E-02 | 2.79E-02 | 1.11E-02 | 4.0923E+00 | 2.7667E+02 |
| $\alpha_3$ | 1.26E-03 | 7.08E-03 | 5.95E-03 | 1.68E-02 | 3.96E-03 | 1.9891E+00 | 2.7877E+02 |
| $\alpha_4$ | 8.18E-04 | 5.92E-03 | 4.79E-03 | 1.49E-02 | 7.44E-03 | 1.6609E+00 | 2.7910E+02 |
| $\alpha_5$ | 3.44E-04 | 4.32E-03 | 3.21E-03 | 1.21E-02 | 7.65E-03 | 1.2124E+00 | 2.7955E+02 |
| $\alpha_6$ | 3.22E-06 | 1.58E-03 | 6.46E-04 | 6.34E-03 | 2.86E-03 | 4.4458E-01 | 2.8031E+02 |
| $\alpha_7$ | 2.17E-29 | 1.78E-04 | 2.03E-09 | 9.50E-04 | 2.33E-04 | 5.0071E-02 | 2.8071E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9497200 | 0.9672830 | 0.9682280 | 0.9816250 | 0.9678740 | 3.1812E+02 | 1.0760E+01 |
| $\alpha_2$ | 5.23E-03 | 1.39E-02 | 1.29E-02 | 2.59E-02 | 1.20E-02 | 4.5772E+00 | 3.2430E+02 |
| $\alpha_3$ | 1.07E-03 | 6.04E-03 | 5.07E-03 | 1.43E-02 | 2.40E-03 | 1.9850E+00 | 3.2689E+02 |
| $\alpha_4$ | 5.99E-04 | 4.76E-03 | 3.80E-03 | 1.22E-02 | 4.07E-03 | 1.5640E+00 | 3.2732E+02 |
| $\alpha_5$ | 4.56E-04 | 4.30E-03 | 3.34E-03 | 1.14E-02 | 6.86E-03 | 1.4127E+00 | 3.2747E+02 |
| $\alpha_6$ | 1.13E-04 | 2.78E-03 | 1.86E-03 | 8.59E-03 | 5.34E-03 | 9.1486E-01 | 3.2797E+02 |
| $\alpha_7$ | 2.68E-08 | 8.09E-04 | 1.60E-04 | 3.84E-03 | 1.39E-03 | 2.6607E-01 | 3.2861E+02 |
| $\alpha_8$ | 6.63E-36 | 1.22E-04 | 5.55E-11 | 5.87E-04 | 6.82E-05 | 4.0124E-02 | 3.2884E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9690100 | 0.9511450 | 0.9568800 | 0.9615910 | 0.9647540 | 0.9667170 | 0.9678740 |
| $\alpha_2$ | 3.10E-02 | 4.15E-02 | 2.14E-02 | 1.32E-02 | 1.10E-02 | 1.11E-02 | 1.20E-02 |
| $\alpha_3$ | | 7.32E-03 | 1.84E-02 | 1.39E-02 | 7.77E-03 | 3.96E-03 | 2.40E-03 |
| $\alpha_4$ | | | 3.34E-03 | 9.83E-03 | 1.05E-02 | 7.44E-03 | 4.07E-03 |
| $\alpha_5$ | | | | 1.50E-03 | 5.38E-03 | 7.65E-03 | 6.86E-03 |
| $\alpha_6$ | | | | | 6.30E-04 | 2.86E-03 | 5.34E-03 |
| $\alpha_7$ | | | | | | 2.33E-04 | 1.39E-03 |
| $\alpha_8$ | | | | | | | 6.82E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.69E-01 | 9.51E-01 | 9.57E-01 | 9.62E-01 | 9.65E-01 | 9.67E-01 | 9.68E-01 |
| Beta | 3.10E-02 | 4.89E-02 | 4.31E-02 | 3.84E-02 | 3.52E-02 | 3.33E-02 | 3.21E-02 |
| Gamma | | 1.50E-01 | 5.04E-01 | 6.56E-01 | 6.89E-01 | 6.66E-01 | 6.26E-01 |
| Delta | | | 1.54E-01 | 4.49E-01 | 6.80E-01 | 8.21E-01 | 8.81E-01 |
| Epsilon | | | | 1.32E-01 | 3.64E-01 | 5.91E-01 | 7.71E-01 |
| Mu | | | | | 1.05E-01 | 2.88E-01 | 4.98E-01 |
| Upsilon | | | | | | 7.52E-02 | 2.15E-01 |
| Sigma | | | | | | | 4.66E-02 |

PWR Steam Generator PORV

PWR MAIN STEAM PORV FAIL TO OPEN SPAR: ADV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 23.60 | 35.40 | 47.20 | 59.00 | 70.79 | 82.59 | 94.39 |
| $N_1$ | 2.9529 | 2.7629 | 3.2652 | 3.7892 | 4.2661 | 4.6712 | 5.0018 |
| $N_2$ | 0.8492 | 1.6665 | 1.1280 | 0.8628 | 0.8535 | 1.0045 | 1.2325 |
| $N_3$ | | 0.2937 | 0.9699 | 0.9057 | 0.6044 | 0.3579 | 0.2466 |
| $N_4$ | | | 0.1762 | 0.6416 | 0.8165 | 0.6720 | 0.4175 |
| $N_5$ | | | | 0.0979 | 0.4187 | 0.6906 | 0.7044 |
| $N_6$ | | | | | 0.0490 | 0.2583 | 0.5479 |
| $N_7$ | | | | | | 0.0210 | 0.1431 |
| $N_8$ | | | | | | | 0.0070 |

## 1.9.2.2 PWR MAIN STEAM PORV FAIL TO CLOSE SPAR: ADV-OO

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Power Operated Relief Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 25.00
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9250270 | 0.9812610 | 0.9923200 | 0.9999620 | 0.9998650 | 2.2843E+01 | 4.3622E-01 |
| $\alpha_2$ | 3.50E-05 | 1.87E-02 | 7.68E-03 | 7.50E-02 | 1.35E-04 | 4.3622E-01 | 2.2843E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9361880 | 0.9776820 | 0.9837230 | 0.9985190 | 0.9997350 | 4.8445E+01 | 1.1059E+00 |
| $\alpha_2$ | 5.46E-04 | 1.69E-02 | 1.10E-02 | 5.35E-02 | 2.65E-04 | 8.3866E-01 | 4.8712E+01 |
| $\alpha_3$ | 1.89E-07 | 5.39E-03 | 1.09E-03 | 2.56E-02 | 0.00E+00 | 2.6722E-01 | 4.9284E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9388960 | 0.9745140 | 0.9787070 | 0.9957890 | 0.9996030 | 7.1316E+01 | 1.8651E+00 |
| $\alpha_2$ | 1.42E-03 | 1.69E-02 | 1.28E-02 | 4.66E-02 | 3.97E-04 | 1.2381E+00 | 7.1943E+01 |
| $\alpha_3$ | 6.21E-06 | 5.52E-03 | 2.05E-03 | 2.28E-02 | 0.00E+00 | 4.0431E-01 | 7.2777E+01 |
| $\alpha_4$ | 1.31E-08 | 3.04E-03 | 4.16E-04 | 1.52E-02 | 0.00E+00 | 2.2267E-01 | 7.2958E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9463140 | 0.9729060 | 0.9752780 | 0.9913960 | 0.9994920 | 1.2763E+02 | 3.5542E+00 |
| $\alpha_2$ | 3.15E-03 | 1.62E-02 | 1.38E-02 | 3.75E-02 | 4.99E-04 | 2.1299E+00 | 1.2905E+02 |
| $\alpha_3$ | 3.64E-04 | 7.45E-03 | 5.14E-03 | 2.24E-02 | 9.53E-06 | 9.7768E-01 | 1.3021E+02 |
| $\alpha_4$ | 1.87E-06 | 2.85E-03 | 9.60E-04 | 1.21E-02 | 0.00E+00 | 3.7439E-01 | 1.3081E+02 |
| $\alpha_5$ | 4.55E-21 | 5.51E-04 | 3.11E-07 | 3.19E-03 | 0.00E+00 | 7.2277E-02 | 1.3111E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9490140 | 0.9729430 | 0.9749060 | 0.9901720 | 0.9993860 | 1.5469E+02 | 4.3019E+00 |
| $\alpha_2$ | 2.95E-03 | 1.42E-02 | 1.22E-02 | 3.23E-02 | 5.93E-04 | 2.2616E+00 | 1.5673E+02 |
| $\alpha_3$ | 5.06E-04 | 7.19E-03 | 5.25E-03 | 2.05E-02 | 2.12E-05 | 1.1426E+00 | 1.5785E+02 |
| $\alpha_4$ | 3.33E-05 | 3.72E-03 | 1.95E-03 | 1.34E-02 | 0.00E+00 | 5.9222E-01 | 1.5840E+02 |
| $\alpha_5$ | 5.84E-09 | 1.40E-03 | 1.89E-04 | 7.00E-03 | 0.00E+00 | 2.2220E-01 | 1.5877E+02 |
| $\alpha_6$ | 8.86E-19 | 5.24E-04 | 9.15E-07 | 3.05E-03 | 0.00E+00 | 8.3237E-02 | 1.5891E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9528350 | 0.9723880 | 0.9737220 | 0.9873880 | 0.9992810 | 2.2808E+02 | 6.4767E+00 |
| $\alpha_2$ | 3.77E-03 | 1.33E-02 | 1.19E-02 | 2.75E-02 | 6.83E-04 | 3.1179E+00 | 2.3144E+02 |
| $\alpha_3$ | 9.39E-04 | 6.96E-03 | 5.62E-03 | 1.76E-02 | 3.63E-05 | 1.6328E+00 | 2.3292E+02 |
| $\alpha_4$ | 2.11E-04 | 4.22E-03 | 2.92E-03 | 1.27E-02 | 0.00E+00 | 9.8887E-01 | 2.3357E+02 |
| $\alpha_5$ | 1.09E-05 | 2.22E-03 | 1.05E-03 | 8.41E-03 | 0.00E+00 | 5.2177E-01 | 2.3403E+02 |
| $\alpha_6$ | 2.86E-10 | 7.94E-04 | 6.78E-05 | 4.17E-03 | 0.00E+00 | 1.8628E-01 | 2.3437E+02 |
| $\alpha_7$ | 0.00E+00 | 1.24E-04 | 1.08E-13 | 4.66E-04 | 0.00E+00 | 2.9071E-02 | 2.3453E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9551270 | 0.9728720 | 0.9740060 | 0.9867510 | 0.9991840 | 2.6904E+02 | 7.5021E+00 |
| $\alpha_2$ | 3.71E-03 | 1.22E-02 | 1.11E-02 | 2.47E-02 | 7.65E-04 | 3.3832E+00 | 2.7316E+02 |
| $\alpha_3$ | 9.33E-04 | 6.30E-03 | 5.15E-03 | 1.56E-02 | 4.96E-05 | 1.7409E+00 | 2.7480E+02 |
| $\alpha_4$ | 2.93E-04 | 4.15E-03 | 3.03E-03 | 1.18E-02 | 1.99E-06 | 1.1466E+00 | 2.7540E+02 |
| $\alpha_5$ | 4.66E-05 | 2.56E-03 | 1.50E-03 | 8.67E-03 | 0.00E+00 | 7.0833E-01 | 2.7583E+02 |
| $\alpha_6$ | 7.51E-07 | 1.33E-03 | 4.34E-04 | 5.68E-03 | 0.00E+00 | 3.6696E-01 | 2.7618E+02 |
| $\alpha_7$ | 5.89E-14 | 4.45E-04 | 7.99E-06 | 2.53E-03 | 0.00E+00 | 1.2297E-01 | 2.7642E+02 |
| $\alpha_8$ | 1.10E-42 | 1.20E-04 | 1.71E-12 | 5.06E-04 | 0.00E+00 | 3.3124E-02 | 2.7651E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9998650 | 0.9997350 | 0.9996030 | 0.9994920 | 0.9993860 | 0.9992810 | 0.9991840 |
| $\alpha_2$ | 1.35E-04 | 2.65E-04 | 3.97E-04 | 4.99E-04 | 5.93E-04 | 6.83E-04 | 7.65E-04 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 9.53E-06 | 2.12E-05 | 3.63E-05 | 4.96E-05 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.99E-06 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 9.99E-01 | 9.99E-01 | 9.99E-01 | 9.99E-01 |
| Beta | 1.35E-04 | 2.65E-04 | 3.97E-04 | 5.08E-04 | 6.14E-04 | 7.19E-04 | 8.16E-04 |
| Gamma | | 0.00E+00 | 0.00E+00 | 1.88E-02 | 3.45E-02 | 5.05E-02 | 6.33E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.85E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

PWR Steam Generator PORV

PWR MAIN STEAM PORV FAIL TO CLOSE SPAR: ADV-OO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 12.50 | 18.75 | 25.00 | 31.25 | 37.50 | 43.75 | 50.00 |
| $N_1$ | 0.0967 | 0.1400 | 0.1800 | 0.2175 | 0.2523 | 0.2845 | 0.3143 |
| $N_2$ | 0.0017 | 0.0050 | 0.0100 | 0.0157 | 0.0224 | 0.0301 | 0.0385 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0003 | 0.0008 | 0.0016 | 0.0025 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0001 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.9.3 PWR Pressurizer Power Operated Relief Valves

## 1.9.3.1 PRESSURIZER PORVS FAIL TO OPEN SPAR: PPR-SRV-CC

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Power Operated Relief Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 19.10
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9404860 | 0.9849300 | 0.9936000 | 0.9999610 | 0.9989730 | 2.9706E+01 | 4.5452E-01 |
| $\alpha_2$ | 3.57E-05 | 1.51E-02 | 6.40E-03 | 5.95E-02 | 1.03E-03 | 4.5452E-01 | 2.9706E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9455050 | 0.9806700 | 0.9857140 | 0.9985830 | 0.9980820 | 5.8691E+01 | 1.1569E+00 |
| $\alpha_2$ | 5.63E-04 | 1.48E-02 | 9.88E-03 | 4.60E-02 | 1.85E-03 | 8.8766E-01 | 5.8960E+01 |
| $\alpha_3$ | 1.70E-07 | 4.50E-03 | 9.17E-04 | 2.13E-02 | 6.85E-05 | 2.6922E-01 | 5.9579E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9466870 | 0.9774440 | 0.9810010 | 0.9960380 | 0.9973100 | 8.4919E+01 | 1.9597E+00 |
| $\alpha_2$ | 1.46E-03 | 1.53E-02 | 1.17E-02 | 4.11E-02 | 2.50E-03 | 1.3253E+00 | 8.5553E+01 |
| $\alpha_3$ | 5.97E-06 | 4.74E-03 | 1.79E-03 | 1.95E-02 | 1.85E-04 | 4.1151E-01 | 8.6467E+01 |
| $\alpha_4$ | 1.12E-08 | 2.57E-03 | 3.51E-04 | 1.28E-02 | 5.14E-06 | 2.2287E-01 | 8.6656E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 0.9989730 | 0.9980820 | 0.9973100 |
| $\alpha_2$ | 1.03E-03 | 1.85E-03 | 2.50E-03 |
| $\alpha_3$ | | 6.85E-05 | 1.85E-04 |
| $\alpha_4$ | | | 5.14E-06 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 9.99E-01 | 9.98E-01 | 9.97E-01 |
| Beta | 1.03E-03 | 1.92E-03 | 2.69E-03 |
| Gamma | | 3.57E-02 | 7.07E-02 |
| Delta | | | 2.70E-02 |

PWR Pressurizer Power Operated Relief Valves

PRESSURIZER PORVS FAIL TO OPEN SPAR: PPR-SRV-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 19.10 | 28.65 | 38.20 |
| $N_1$ | 0.3600 | 0.4860 | 0.5832 |
| $N_2$ | 0.0200 | 0.0540 | 0.0972 |
| $N_3$ | | 0.0020 | 0.0072 |
| $N_4$ | | | 0.0002 |

## 1.9.3.2 PWR PRESSURIZER PORVS FAIL TO CLOSE

| | |
|---|---|
| **System :** | Reactor coolant |
| **Component :** | Power Operated Relief Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 5.10
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8901120 | 0.9724650 | 0.9886040 | 0.9999450 | 1.0000000 | 1.5346E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.09E-05 | 2.75E-02 | 1.14E-02 | 1.10E-01 | 0.00E+00 | 4.3452E-01 | 1.5346E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9122210 | 0.9692110 | 0.9774640 | 0.9979560 | 1.0000000 | 3.4655E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.44E-04 | 2.33E-02 | 1.52E-02 | 7.36E-02 | 0.00E+00 | 8.3366E-01 | 3.4922E+01 |
| $\alpha_3$ | 2.63E-07 | 7.47E-03 | 1.51E-03 | 3.54E-02 | 0.00E+00 | 2.6722E-01 | 3.5489E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9164510 | 0.9650590 | 0.9707310 | 0.9942350 | 1.0000000 | 5.1236E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.92E-03 | 2.31E-02 | 1.75E-02 | 6.38E-02 | 0.00E+00 | 1.2281E+00 | 5.1863E+01 |
| $\alpha_3$ | 8.59E-06 | 7.62E-03 | 2.83E-03 | 3.14E-02 | 0.00E+00 | 4.0431E-01 | 5.2687E+01 |
| $\alpha_4$ | 1.81E-08 | 4.19E-03 | 5.75E-04 | 2.10E-02 | 0.00E+00 | 2.2267E-01 | 5.2868E+01 |

### *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 |

PWR Pressurizer Power Operated Relief Valves

PWR PRESSURIZER PORVS FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 |
|---|---|---|---|
| Adj. Ind. Events | 5.10 | 5.10 | 5.10 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 |

# 1.10 Main Steam Isolation Valves

## 1.10.1 PWR Main Steam Isolation Valves

### 1.10.1.1 PWR MSIV FAIL TO OPEN

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Main Steam Stop Valve |
| **Failure Mode :** | Fail to open on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 19.30
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9244300 | 0.9777250 | 0.9869320 | 0.9996320 | 0.9875310 | 3.0046E+01 | 6.8452E-01 |
| $\alpha_2$ | 3.66E-04 | 2.23E-02 | 1.31E-02 | 7.56E-02 | 1.25E-02 | 6.8452E-01 | 3.0046E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9333660 | 0.9735300 | 0.9785610 | 0.9964880 | 0.9832360 | 5.8880E+01 | 1.6009E+00 |
| $\alpha_2$ | 1.60E-03 | 2.00E-02 | 1.50E-02 | 5.55E-02 | 1.26E-02 | 1.2087E+00 | 5.9272E+01 |
| $\alpha_3$ | 5.95E-06 | 6.49E-03 | 2.32E-03 | 2.71E-02 | 4.19E-03 | 3.9222E-01 | 6.0089E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9367670 | 0.9709510 | 0.9744670 | 0.9931150 | 0.9826110 | 8.4986E+01 | 2.5426E+00 |
| $\alpha_2$ | 2.42E-03 | 1.83E-02 | 1.48E-02 | 4.63E-02 | 9.48E-03 | 1.6031E+00 | 8.5925E+01 |
| $\alpha_3$ | 1.02E-04 | 7.48E-03 | 4.20E-03 | 2.60E-02 | 6.32E-03 | 6.5431E-01 | 8.6874E+01 |
| $\alpha_4$ | 2.18E-07 | 3.26E-03 | 7.34E-04 | 1.51E-02 | 1.58E-03 | 2.8517E-01 | 8.7243E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9451450 | 0.9707840 | 0.9728700 | 0.9893000 | 0.9834900 | 1.4457E+02 | 4.3509E+00 |
| $\alpha_2$ | 3.65E-03 | 1.63E-02 | 1.42E-02 | 3.62E-02 | 6.35E-03 | 2.4267E+00 | 1.4649E+02 |
| $\alpha_3$ | 7.82E-04 | 8.66E-03 | 6.58E-03 | 2.36E-02 | 6.35E-03 | 1.2899E+00 | 1.4763E+02 |
| $\alpha_4$ | 1.91E-05 | 3.56E-03 | 1.71E-03 | 1.34E-02 | 3.18E-03 | 5.3069E-01 | 1.4839E+02 |
| $\alpha_5$ | 1.13E-15 | 6.96E-04 | 5.10E-06 | 4.03E-03 | 6.36E-04 | 1.0358E-01 | 1.4882E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9483500 | 0.9712970 | 0.9730280 | 0.9883350 | 0.9848740 | 1.7493E+02 | 5.1694E+00 |
| $\alpha_2$ | 3.14E-03 | 1.37E-02 | 1.20E-02 | 3.03E-02 | 3.98E-03 | 2.4736E+00 | 1.7763E+02 |
| $\alpha_3$ | 9.05E-04 | 8.07E-03 | 6.34E-03 | 2.12E-02 | 5.31E-03 | 1.4543E+00 | 1.7865E+02 |
| $\alpha_4$ | 1.40E-04 | 4.59E-03 | 2.93E-03 | 1.47E-02 | 3.98E-03 | 8.2662E-01 | 1.7927E+02 |
| $\alpha_5$ | 3.00E-07 | 1.75E-03 | 4.66E-04 | 7.89E-03 | 1.59E-03 | 3.1600E-01 | 1.7978E+02 |
| $\alpha_6$ | 2.32E-16 | 5.49E-04 | 3.04E-06 | 3.19E-03 | 2.65E-04 | 9.8837E-02 | 1.8000E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9527130 | 0.9715000 | 0.9727030 | 0.9861680 | 0.9863220 | 2.5165E+02 | 7.3825E+00 |
| $\alpha_2$ | 3.69E-03 | 1.26E-02 | 1.13E-02 | 2.56E-02 | 2.39E-03 | 3.2519E+00 | 2.5578E+02 |
| $\alpha_3$ | 1.23E-03 | 7.35E-03 | 6.13E-03 | 1.77E-02 | 3.99E-03 | 1.9046E+00 | 2.5713E+02 |
| $\alpha_4$ | 4.21E-04 | 4.87E-03 | 3.67E-03 | 1.34E-02 | 3.99E-03 | 1.2623E+00 | 2.5777E+02 |
| $\alpha_5$ | 4.28E-05 | 2.65E-03 | 1.53E-03 | 9.07E-03 | 2.39E-03 | 6.8587E-01 | 2.5835E+02 |
| $\alpha_6$ | 1.04E-08 | 9.30E-04 | 1.51E-04 | 4.55E-03 | 7.98E-04 | 2.4098E-01 | 2.5879E+02 |
| $\alpha_7$ | 1.16E-38 | 1.42E-04 | 1.53E-11 | 6.50E-04 | 1.14E-04 | 3.6871E-02 | 2.5900E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9553120 | 0.9723180 | 0.9733440 | 0.9858070 | 0.9876590 | 2.9596E+02 | 8.4260E+00 |
| $\alpha_2$ | 3.50E-03 | 1.13E-02 | 1.03E-02 | 2.28E-02 | 1.40E-03 | 3.4541E+00 | 3.0093E+02 |
| $\alpha_3$ | 1.12E-03 | 6.43E-03 | 5.39E-03 | 1.53E-02 | 2.80E-03 | 1.9572E+00 | 3.0243E+02 |
| $\alpha_4$ | 5.00E-04 | 4.66E-03 | 3.63E-03 | 1.24E-02 | 3.50E-03 | 1.4199E+00 | 3.0297E+02 |
| $\alpha_5$ | 1.29E-04 | 3.05E-03 | 2.05E-03 | 9.36E-03 | 2.80E-03 | 9.2713E-01 | 3.0346E+02 |
| $\alpha_6$ | 4.74E-06 | 1.56E-03 | 6.83E-04 | 6.11E-03 | 1.40E-03 | 4.7636E-01 | 3.0391E+02 |
| $\alpha_7$ | 7.67E-12 | 5.07E-04 | 2.34E-05 | 2.78E-03 | 4.00E-04 | 1.5427E-01 | 3.0423E+02 |
| $\alpha_8$ | 1.38E-38 | 1.22E-04 | 1.41E-11 | 5.57E-04 | 4.99E-05 | 3.7024E-02 | 3.0435E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9875310 | 0.9832360 | 0.9826110 | 0.9834900 | 0.9848740 | 0.9863220 | 0.9876590 |
| $\alpha_2$ | 1.25E-02 | 1.26E-02 | 9.48E-03 | 6.35E-03 | 3.98E-03 | 2.39E-03 | 1.40E-03 |
| $\alpha_3$ | | 4.19E-03 | 6.32E-03 | 6.35E-03 | 5.31E-03 | 3.99E-03 | 2.80E-03 |
| $\alpha_4$ | | | 1.58E-03 | 3.18E-03 | 3.98E-03 | 3.99E-03 | 3.50E-03 |
| $\alpha_5$ | | | | 6.36E-04 | 1.59E-03 | 2.39E-03 | 2.80E-03 |
| $\alpha_6$ | | | | | 2.65E-04 | 7.98E-04 | 1.40E-03 |
| $\alpha_7$ | | | | | | 1.14E-04 | 4.00E-04 |
| $\alpha_8$ | | | | | | | 4.99E-05 |

PWR Main Steam Isolation Valves

PWR MSIV FAIL TO OPEN

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.88E-01 | 9.83E-01 | 9.83E-01 | 9.83E-01 | 9.85E-01 | 9.86E-01 | 9.88E-01 |
| Beta | 1.25E-02 | 1.68E-02 | 1.74E-02 | 1.65E-02 | 1.51E-02 | 1.37E-02 | 1.23E-02 |
| Gamma | | 2.50E-01 | 4.55E-01 | 6.15E-01 | 7.37E-01 | 8.25E-01 | 8.87E-01 |
| Delta | | | 2.00E-01 | 3.75E-01 | 5.24E-01 | 6.46E-01 | 7.44E-01 |
| Epsilon | | | | 1.67E-01 | 3.18E-01 | 4.53E-01 | 5.71E-01 |
| Mu | | | | | 1.43E-01 | 2.76E-01 | 3.98E-01 |
| Upsilon | | | | | | 1.25E-01 | 2.43E-01 |
| Sigma | | | | | | | 1.11E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 19.30 | 28.95 | 38.60 | 48.25 | 57.90 | 67.55 | 77.20 |
| $N_1$ | 0.5000 | 0.3750 | 0.2500 | 0.1563 | 0.0938 | 0.0547 | 0.0313 |
| $N_2$ | 0.2500 | 0.3750 | 0.3750 | 0.3125 | 0.2344 | 0.1641 | 0.1094 |
| $N_3$ | | 0.1250 | 0.2500 | 0.3125 | 0.3125 | 0.2734 | 0.2188 |
| $N_4$ | | | 0.0625 | 0.1563 | 0.2344 | 0.2734 | 0.2734 |
| $N_5$ | | | | 0.0313 | 0.0938 | 0.1641 | 0.2188 |
| $N_6$ | | | | | 0.0156 | 0.0547 | 0.1094 |
| $N_7$ | | | | | | 0.0078 | 0.0313 |
| $N_8$ | | | | | | | 0.0039 |

## 1.10.1.2 PWR MSIV FAIL TO CLOSE

| | |
|---|---|
| **System :** | Main steam |
| **Component :** | Main Steam Stop Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | PWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 28.30
Total Number of Common-Cause Failure Events: 4

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8762750 | 0.9567710 | 0.9684440 | 0.9972900 | 0.9548290 | 2.3633E+01 | 1.0678E+00 |
| $\alpha_2$ | 2.71E-03 | 4.32E-02 | 3.16E-02 | 1.24E-01 | 4.52E-02 | 1.0678E+00 | 2.3633E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8891090 | 0.9479300 | 0.9537080 | 0.9869590 | 0.9234760 | 4.8260E+01 | 2.6509E+00 |
| $\alpha_2$ | 8.93E-03 | 4.34E-02 | 3.75E-02 | 9.79E-02 | 6.79E-02 | 2.2087E+00 | 4.8702E+01 |
| $\alpha_3$ | 1.73E-05 | 8.69E-03 | 3.56E-03 | 3.47E-02 | 8.64E-03 | 4.4222E-01 | 5.0469E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8892480 | 0.9400750 | 0.9440080 | 0.9774600 | 0.9010300 | 6.9693E+01 | 4.4426E+00 |
| $\alpha_2$ | 1.35E-02 | 4.46E-02 | 4.05E-02 | 8.95E-02 | 7.94E-02 | 3.3031E+00 | 7.0832E+01 |
| $\alpha_3$ | 3.90E-04 | 1.15E-02 | 7.53E-03 | 3.63E-02 | 1.72E-02 | 8.5431E-01 | 7.3281E+01 |
| $\alpha_4$ | 2.57E-07 | 3.85E-03 | 8.68E-04 | 1.79E-02 | 2.39E-03 | 2.8517E-01 | 7.3850E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9160930 | 0.9504890 | 0.9527610 | 0.9771360 | 0.9067120 | 1.2512E+02 | 6.5175E+00 |
| $\alpha_2$ | 9.46E-03 | 2.86E-02 | 2.62E-02 | 5.57E-02 | 5.15E-02 | 3.7600E+00 | 1.2788E+02 |
| $\alpha_3$ | 3.12E-03 | 1.61E-02 | 1.37E-02 | 3.73E-02 | 3.59E-02 | 2.1232E+00 | 1.2951E+02 |
| $\alpha_4$ | 2.16E-05 | 4.03E-03 | 1.94E-03 | 1.51E-02 | 4.89E-03 | 5.3069E-01 | 1.3111E+02 |
| $\alpha_5$ | 1.28E-15 | 7.87E-04 | 5.77E-06 | 4.57E-03 | 9.80E-04 | 1.0358E-01 | 1.3153E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9230000 | 0.9533110 | 0.9552020 | 0.9771540 | 0.9166830 | 1.5149E+02 | 7.4193E+00 |
| $\alpha_2$ | 5.75E-03 | 1.99E-02 | 1.80E-02 | 4.09E-02 | 2.46E-02 | 3.1680E+00 | 1.5574E+02 |
| $\alpha_3$ | 4.87E-03 | 1.82E-02 | 1.63E-02 | 3.84E-02 | 4.66E-02 | 2.8987E+00 | 1.5601E+02 |
| $\alpha_4$ | 2.58E-04 | 5.90E-03 | 4.00E-03 | 1.80E-02 | 9.17E-03 | 9.3772E-01 | 1.5797E+02 |
| $\alpha_5$ | 3.40E-07 | 1.99E-03 | 5.28E-04 | 8.94E-03 | 2.49E-03 | 3.1600E-01 | 1.5859E+02 |
| $\alpha_6$ | 2.63E-16 | 6.22E-04 | 3.45E-06 | 3.62E-03 | 4.14E-04 | 9.8837E-02 | 1.5881E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9352350 | 0.9586090 | 0.9599140 | 0.9775420 | 0.9254650 | 2.2425E+02 | 9.6826E+00 |
| $\alpha_2$ | 5.45E-03 | 1.63E-02 | 1.50E-02 | 3.19E-02 | 1.69E-02 | 3.8232E+00 | 2.3011E+02 |
| $\alpha_3$ | 3.46E-03 | 1.27E-02 | 1.14E-02 | 2.66E-02 | 3.09E-02 | 2.9741E+00 | 2.3096E+02 |
| $\alpha_4$ | 1.33E-03 | 8.06E-03 | 6.70E-03 | 1.94E-02 | 2.06E-02 | 1.8846E+00 | 2.3205E+02 |
| $\alpha_5$ | 6.05E-05 | 3.09E-03 | 1.84E-03 | 1.04E-02 | 4.63E-03 | 7.2287E-01 | 2.3321E+02 |
| $\alpha_6$ | 1.15E-08 | 1.03E-03 | 1.67E-04 | 5.04E-03 | 1.26E-03 | 2.4098E-01 | 2.3369E+02 |
| $\alpha_7$ | 1.28E-38 | 1.58E-04 | 1.70E-11 | 7.20E-04 | 1.80E-04 | 3.6871E-02 | 2.3390E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9399540 | 0.9608570 | 0.9619710 | 0.9779650 | 0.9325320 | 2.6458E+02 | 1.0778E+01 |
| $\alpha_2$ | 4.89E-03 | 1.44E-02 | 1.32E-02 | 2.78E-02 | 1.23E-02 | 3.9516E+00 | 2.7141E+02 |
| $\alpha_3$ | 2.55E-03 | 1.00E-02 | 8.87E-03 | 2.15E-02 | 2.08E-02 | 2.7622E+00 | 2.7260E+02 |
| $\alpha_4$ | 1.60E-03 | 7.98E-03 | 6.83E-03 | 1.83E-02 | 2.14E-02 | 2.1987E+00 | 2.7316E+02 |
| $\alpha_5$ | 3.27E-04 | 4.31E-03 | 3.18E-03 | 1.21E-02 | 9.71E-03 | 1.1858E+00 | 2.7417E+02 |
| $\alpha_6$ | 6.19E-06 | 1.77E-03 | 7.93E-04 | 6.87E-03 | 2.48E-03 | 4.8866E-01 | 2.7487E+02 |
| $\alpha_7$ | 8.48E-12 | 5.60E-04 | 2.59E-05 | 3.07E-03 | 6.37E-04 | 1.5427E-01 | 2.7520E+02 |
| $\alpha_8$ | 1.52E-38 | 1.34E-04 | 1.56E-11 | 6.16E-04 | 7.93E-05 | 3.7024E-02 | 2.7532E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9548290 | 0.9234760 | 0.9010300 | 0.9067120 | 0.9166830 | 0.9254650 | 0.9325320 |
| $\alpha_2$ | 4.52E-02 | 6.79E-02 | 7.94E-02 | 5.15E-02 | 2.46E-02 | 1.69E-02 | 1.23E-02 |
| $\alpha_3$ | | 8.64E-03 | 1.72E-02 | 3.59E-02 | 4.66E-02 | 3.09E-02 | 2.08E-02 |
| $\alpha_4$ | | | 2.39E-03 | 4.89E-03 | 9.17E-03 | 2.06E-02 | 2.14E-02 |
| $\alpha_5$ | | | | 9.80E-04 | 2.49E-03 | 4.63E-03 | 9.71E-03 |
| $\alpha_6$ | | | | | 4.14E-04 | 1.26E-03 | 2.48E-03 |
| $\alpha_7$ | | | | | | 1.80E-04 | 6.37E-04 |
| $\alpha_8$ | | | | | | | 7.93E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.55E-01 | 9.23E-01 | 9.01E-01 | 9.07E-01 | 9.17E-01 | 9.25E-01 | 9.33E-01 |
| Beta | 4.52E-02 | 7.65E-02 | 9.90E-02 | 9.33E-02 | 8.33E-02 | 7.45E-02 | 6.75E-02 |
| Gamma | | 1.13E-01 | 1.98E-01 | 4.48E-01 | 7.04E-01 | 7.73E-01 | 8.17E-01 |
| Delta | | | 1.22E-01 | 1.41E-01 | 2.06E-01 | 4.63E-01 | 6.22E-01 |
| Epsilon | | | | 1.67E-01 | 2.40E-01 | 2.27E-01 | 3.76E-01 |
| Mu | | | | | 1.43E-01 | 2.37E-01 | 2.47E-01 |
| Upsilon | | | | | | 1.25E-01 | 2.24E-01 |
| Sigma | | | | | | | 1.11E-01 |

PWR Main Steam Isolation Valves

PWR MSIV FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 11.32 | 16.98 | 22.64 | 28.30 | 33.96 | 39.62 | 45.28 |
| $N_1$ | 2.0667 | 1.7250 | 0.9167 | 0.6563 | 0.5938 | 0.5797 | 0.5713 |
| $N_2$ | 0.6333 | 1.3750 | 2.0750 | 1.6458 | 0.9288 | 0.7354 | 0.6069 |
| $N_3$ | | 0.1750 | 0.4500 | 1.1458 | 1.7569 | 1.3429 | 1.0238 |
| $N_4$ | | | 0.0625 | 0.1563 | 0.3455 | 0.8957 | 1.0522 |
| $N_5$ | | | | 0.0313 | 0.0938 | 0.2011 | 0.4775 |
| $N_6$ | | | | | 0.0156 | 0.0547 | 0.1217 |
| $N_7$ | | | | | | 0.0078 | 0.0313 |
| $N_8$ | | | | | | | 0.0039 |

# 1.10.2 BWR Main Steam Isolation Valves

## 1.10.2.1 BWR MSIV FAIL TO OPEN

**Component :** Main Steam Stop Valve
**Failure Mode :** Fail to open on demand
**Plant Type :** BWR
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 3.50
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8513580 | 0.9625750 | 0.9842830 | 0.9999310 | 1.0000000 | 1.1176E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.04E-05 | 3.74E-02 | 1.57E-02 | 1.49E-01 | 0.00E+00 | 4.3452E-01 | 1.1176E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9022300 | 0.9656380 | 0.9747930 | 0.9977110 | 0.9999280 | 3.0940E+01 | 1.1010E+00 |
| $\alpha_2$ | 8.33E-04 | 2.60E-02 | 1.70E-02 | 8.21E-02 | 7.22E-05 | 8.3376E-01 | 3.1207E+01 |
| $\alpha_3$ | 2.94E-07 | 8.34E-03 | 1.69E-03 | 3.96E-02 | 0.00E+00 | 2.6722E-01 | 3.1774E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9110910 | 0.9627760 | 0.9687980 | 0.9938470 | 0.9998920 | 4.7986E+01 | 1.8553E+00 |
| $\alpha_2$ | 2.05E-03 | 2.46E-02 | 1.86E-02 | 6.79E-02 | 1.08E-04 | 1.2283E+00 | 4.8613E+01 |
| $\alpha_3$ | 9.16E-06 | 8.11E-03 | 3.02E-03 | 3.35E-02 | 0.00E+00 | 4.0431E-01 | 4.9437E+01 |
| $\alpha_4$ | 1.93E-08 | 4.47E-03 | 6.13E-04 | 2.24E-02 | 0.00E+00 | 2.2267E-01 | 4.9619E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9313770 | 0.9653120 | 0.9683150 | 0.9889800 | 0.9998270 | 9.8475E+01 | 3.5386E+00 |
| $\alpha_2$ | 4.00E-03 | 2.07E-02 | 1.77E-02 | 4.79E-02 | 1.73E-04 | 2.1146E+00 | 9.9899E+01 |
| $\alpha_3$ | 4.68E-04 | 9.58E-03 | 6.62E-03 | 2.88E-02 | 0.00E+00 | 9.7738E-01 | 1.0104E+02 |
| $\alpha_4$ | 2.41E-06 | 3.67E-03 | 1.24E-03 | 1.56E-02 | 0.00E+00 | 3.7439E-01 | 1.0164E+02 |
| $\alpha_5$ | 5.85E-21 | 7.09E-04 | 4.01E-07 | 4.10E-03 | 0.00E+00 | 7.2277E-02 | 1.0194E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9350450 | 0.9654900 | 0.9679680 | 0.9874670 | 0.9998200 | 1.1972E+02 | 4.2792E+00 |
| $\alpha_2$ | 3.72E-03 | 1.81E-02 | 1.55E-02 | 4.10E-02 | 1.80E-04 | 2.2397E+00 | 1.2176E+02 |
| $\alpha_3$ | 6.49E-04 | 9.21E-03 | 6.74E-03 | 2.62E-02 | 0.00E+00 | 1.1418E+00 | 1.2286E+02 |
| $\alpha_4$ | 4.27E-05 | 4.78E-03 | 2.50E-03 | 1.72E-02 | 0.00E+00 | 5.9222E-01 | 1.2341E+02 |
| $\alpha_5$ | 7.49E-09 | 1.79E-03 | 2.43E-04 | 8.98E-03 | 0.00E+00 | 2.2220E-01 | 1.2378E+02 |
| $\alpha_6$ | 1.14E-18 | 6.71E-04 | 1.17E-06 | 3.92E-03 | 0.00E+00 | 8.3237E-02 | 1.2392E+02 |

BWR Main Steam Isolation Valves

BWR MSIV FAIL TO OPEN

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9432010 | 0.9667270 | 0.9683250 | 0.9848010 | 0.9997530 | 1.8728E+02 | 6.4458E+00 |
| $\alpha_2$ | 4.49E-03 | 1.59E-02 | 1.43E-02 | 3.30E-02 | 2.47E-04 | 3.0886E+00 | 1.9064E+02 |
| $\alpha_3$ | 1.14E-03 | 8.42E-03 | 6.80E-03 | 2.12E-02 | 0.00E+00 | 1.6312E+00 | 1.9209E+02 |
| $\alpha_4$ | 2.56E-04 | 5.10E-03 | 3.53E-03 | 1.53E-02 | 0.00E+00 | 9.8887E-01 | 1.9274E+02 |
| $\alpha_5$ | 1.32E-05 | 2.69E-03 | 1.28E-03 | 1.02E-02 | 0.00E+00 | 5.2177E-01 | 1.9320E+02 |
| $\alpha_6$ | 3.47E-10 | 9.62E-04 | 8.21E-05 | 5.05E-03 | 0.00E+00 | 1.8628E-01 | 1.9354E+02 |
| $\alpha_7$ | 0.00E+00 | 1.50E-04 | 1.31E-13 | 5.65E-04 | 0.00E+00 | 2.9071E-02 | 1.9370E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9463270 | 0.9675410 | 0.9688920 | 0.9841570 | 0.9997300 | 2.2243E+02 | 7.4620E+00 |
| $\alpha_2$ | 4.38E-03 | 1.46E-02 | 1.32E-02 | 2.95E-02 | 2.70E-04 | 3.3457E+00 | 2.2655E+02 |
| $\alpha_3$ | 1.12E-03 | 7.56E-03 | 6.19E-03 | 1.87E-02 | 0.00E+00 | 1.7384E+00 | 2.2815E+02 |
| $\alpha_4$ | 3.53E-04 | 4.99E-03 | 3.65E-03 | 1.42E-02 | 0.00E+00 | 1.1465E+00 | 2.2875E+02 |
| $\alpha_5$ | 5.61E-05 | 3.08E-03 | 1.81E-03 | 1.04E-02 | 0.00E+00 | 7.0833E-01 | 2.2918E+02 |
| $\alpha_6$ | 9.03E-07 | 1.60E-03 | 5.23E-04 | 6.83E-03 | 0.00E+00 | 3.6696E-01 | 2.2953E+02 |
| $\alpha_7$ | 7.08E-14 | 5.35E-04 | 9.62E-06 | 3.05E-03 | 0.00E+00 | 1.2297E-01 | 2.2977E+02 |
| $\alpha_8$ | 1.33E-42 | 1.44E-04 | 2.05E-12 | 6.09E-04 | 0.00E+00 | 3.3124E-02 | 2.2986E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 0.9999280 | 0.9998920 | 0.9998270 | 0.9998200 | 0.9997530 | 0.9997300 |
| $\alpha_2$ | 0.00E+00 | 7.22E-05 | 1.08E-04 | 1.73E-04 | 1.80E-04 | 2.47E-04 | 2.70E-04 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 7.22E-05 | 1.08E-04 | 1.73E-04 | 1.80E-04 | 2.47E-04 | 2.70E-04 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

BWR Main Steam Isolation Valves

BWR MSIV FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 0.88 | 1.31 | 1.75 | 2.19 | 2.63 | 3.06 | 3.50 |
| $N_1$ | 0.0499 | 0.0748 | 0.0996 | 0.1243 | 0.1489 | 0.1735 | 0.1980 |
| $N_2$ | 0.0000 | 0.0001 | 0.0002 | 0.0004 | 0.0005 | 0.0008 | 0.0010 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.10.2.2 BWR MSIV FAIL TO CLOSE

| | |
|---|---|
| **Component :** | Main Steam Stop Valve |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Plant Type :** | BWR |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 9.00
Total Number of Common-Cause Failure Events: 2

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8651700 | 0.9648640 | 0.9838790 | 0.9998860 | 0.9849080 | 1.3157E+01 | 4.7912E-01 |
| $\alpha_2$ | 1.16E-04 | 3.51E-02 | 1.61E-02 | 1.35E-01 | 1.51E-02 | 4.7912E-01 | 1.3157E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9036240 | 0.9647480 | 0.9731720 | 0.9970110 | 0.9693660 | 3.3792E+01 | 1.2348E+00 |
| $\alpha_2$ | 1.34E-03 | 2.76E-02 | 1.93E-02 | 8.25E-02 | 3.06E-02 | 9.6756E-01 | 3.4059E+01 |
| $\alpha_3$ | 2.69E-07 | 7.63E-03 | 1.54E-03 | 3.62E-02 | 0.00E+00 | 2.6722E-01 | 3.4760E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9095910 | 0.9604830 | 0.9660640 | 0.9922520 | 0.9532640 | 5.1600E+01 | 2.1230E+00 |
| $\alpha_2$ | 3.32E-03 | 2.78E-02 | 2.22E-02 | 7.16E-02 | 4.67E-02 | 1.4960E+00 | 5.2227E+01 |
| $\alpha_3$ | 8.49E-06 | 7.53E-03 | 2.80E-03 | 3.11E-02 | 0.00E+00 | 4.0431E-01 | 5.3319E+01 |
| $\alpha_4$ | 1.79E-08 | 4.14E-03 | 5.69E-04 | 2.08E-02 | 0.00E+00 | 2.2267E-01 | 5.3500E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9285140 | 0.9626750 | 0.9655350 | 0.9870620 | 0.9367570 | 1.0277E+02 | 3.9846E+00 |
| $\alpha_2$ | 5.71E-03 | 2.40E-02 | 2.11E-02 | 5.22E-02 | 6.32E-02 | 2.5606E+00 | 1.0419E+02 |
| $\alpha_3$ | 4.47E-04 | 9.16E-03 | 6.33E-03 | 2.75E-02 | 0.00E+00 | 9.7738E-01 | 1.0578E+02 |
| $\alpha_4$ | 2.31E-06 | 3.51E-03 | 1.18E-03 | 1.49E-02 | 0.00E+00 | 3.7439E-01 | 1.0638E+02 |
| $\alpha_5$ | 5.59E-21 | 6.77E-04 | 3.83E-07 | 3.92E-03 | 0.00E+00 | 7.2277E-02 | 1.0668E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9307480 | 0.9618040 | 0.9641580 | 0.9848090 | 0.9196190 | 1.2460E+02 | 4.9483E+00 |
| $\alpha_2$ | 6.03E-03 | 2.25E-02 | 2.00E-02 | 4.71E-02 | 8.04E-02 | 2.9088E+00 | 1.2664E+02 |
| $\alpha_3$ | 6.21E-04 | 8.81E-03 | 6.45E-03 | 2.51E-02 | 0.00E+00 | 1.1418E+00 | 1.2841E+02 |
| $\alpha_4$ | 4.09E-05 | 4.57E-03 | 2.39E-03 | 1.65E-02 | 0.00E+00 | 5.9222E-01 | 1.2896E+02 |
| $\alpha_5$ | 7.17E-09 | 1.72E-03 | 2.33E-04 | 8.59E-03 | 0.00E+00 | 2.2220E-01 | 1.2933E+02 |
| $\alpha_6$ | 1.09E-18 | 6.43E-04 | 1.12E-06 | 3.75E-03 | 0.00E+00 | 8.3237E-02 | 1.2947E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9389120 | 0.9630990 | 0.9646360 | 0.9820470 | 0.9020120 | 1.9268E+02 | 7.3825E+00 |
| $\alpha_2$ | 6.97E-03 | 2.01E-02 | 1.85E-02 | 3.87E-02 | 9.80E-02 | 4.0253E+00 | 1.9604E+02 |
| $\alpha_3$ | 1.10E-03 | 8.15E-03 | 6.58E-03 | 2.06E-02 | 0.00E+00 | 1.6312E+00 | 1.9843E+02 |
| $\alpha_4$ | 2.48E-04 | 4.94E-03 | 3.42E-03 | 1.48E-02 | 0.00E+00 | 9.8887E-01 | 1.9907E+02 |
| $\alpha_5$ | 1.28E-05 | 2.61E-03 | 1.23E-03 | 9.86E-03 | 0.00E+00 | 5.2177E-01 | 1.9954E+02 |
| $\alpha_6$ | 3.36E-10 | 9.31E-04 | 7.95E-05 | 4.89E-03 | 0.00E+00 | 1.8628E-01 | 1.9988E+02 |
| $\alpha_7$ | 0.00E+00 | 1.45E-04 | 1.27E-13 | 5.47E-04 | 0.00E+00 | 2.9071E-02 | 2.0003E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9411920 | 0.9632360 | 0.9645350 | 0.9808530 | 0.8837210 | 2.2823E+02 | 8.7110E+00 |
| $\alpha_2$ | 7.32E-03 | 1.94E-02 | 1.81E-02 | 3.60E-02 | 1.16E-01 | 4.5947E+00 | 2.3235E+02 |
| $\alpha_3$ | 1.09E-03 | 7.34E-03 | 6.00E-03 | 1.81E-02 | 0.00E+00 | 1.7384E+00 | 2.3520E+02 |
| $\alpha_4$ | 3.43E-04 | 4.84E-03 | 3.54E-03 | 1.38E-02 | 0.00E+00 | 1.1465E+00 | 2.3579E+02 |
| $\alpha_5$ | 5.44E-05 | 2.99E-03 | 1.76E-03 | 1.01E-02 | 0.00E+00 | 7.0833E-01 | 2.3623E+02 |
| $\alpha_6$ | 8.77E-07 | 1.55E-03 | 5.07E-04 | 6.62E-03 | 0.00E+00 | 3.6696E-01 | 2.3657E+02 |
| $\alpha_7$ | 6.87E-14 | 5.19E-04 | 9.33E-06 | 2.95E-03 | 0.00E+00 | 1.2297E-01 | 2.3682E+02 |
| $\alpha_8$ | 1.29E-42 | 1.40E-04 | 1.99E-12 | 5.91E-04 | 0.00E+00 | 3.3124E-02 | 2.3691E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9849080 | 0.9693660 | 0.9532640 | 0.9367570 | 0.9196190 | 0.9020120 | 0.8837210 |
| $\alpha_2$ | 1.51E-02 | 3.06E-02 | 4.67E-02 | 6.32E-02 | 8.04E-02 | 9.80E-02 | 1.16E-01 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.85E-01 | 9.69E-01 | 9.53E-01 | 9.37E-01 | 9.20E-01 | 9.02E-01 | 8.84E-01 |
| Beta | 1.51E-02 | 3.06E-02 | 4.67E-02 | 6.32E-02 | 8.04E-02 | 9.80E-02 | 1.16E-01 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

BWR Main Steam Isolation Valves

BWR MSIV FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 2.25 | 3.38 | 4.50 | 5.63 | 6.75 | 7.88 | 9.00 |
| $N_1$ | 0.6607 | 0.8571 | 0.9643 | 0.9821 | 0.9107 | 0.7500 | 0.5000 |
| $N_2$ | 0.0446 | 0.1339 | 0.2679 | 0.4464 | 0.6696 | 0.9375 | 1.2500 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.11 Generators

## 1.11.1 Emergency Diesel Generators

### 1.11.1.1 EMERGENCY DIESEL GENERATOR SPAR:DGN-FS

| | |
|---|---|
| **System :** | Emergency power supply |
| **Component :** | Generator |
| **Failure Mode :** | Fail to start |
| **Component Group :** | Emergency Diesel Generator |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 197.90
Total Number of Common-Cause Failure Events: 4

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9733480 | 0.9877110 | 0.9891910 | 0.9970130 | 0.9892000 | 2.1175E+02 | 2.6345E+00 |
| $\alpha_2$ | 2.99E-03 | 1.23E-02 | 1.08E-02 | 2.67E-02 | 1.08E-02 | 2.6345E+00 | 2.1175E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9783850 | 0.9890700 | 0.9900250 | 0.9964770 | 0.9915860 | 3.3127E+02 | 3.6609E+00 |
| $\alpha_2$ | 1.54E-03 | 7.09E-03 | 6.13E-03 | 1.59E-02 | 5.06E-03 | 2.3737E+00 | 3.3256E+02 |
| $\alpha_3$ | 3.44E-04 | 3.84E-03 | 2.91E-03 | 1.05E-02 | 3.35E-03 | 1.2872E+00 | 3.3364E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9801470 | 0.9891730 | 0.9898880 | 0.9957630 | 0.9924730 | 4.4777E+02 | 4.9011E+00 |
| $\alpha_2$ | 1.48E-03 | 5.96E-03 | 5.25E-03 | 1.29E-02 | 3.64E-03 | 2.7001E+00 | 4.4997E+02 |
| $\alpha_3$ | 3.73E-04 | 3.26E-03 | 2.57E-03 | 8.53E-03 | 2.65E-03 | 1.4763E+00 | 4.5119E+02 |
| $\alpha_4$ | 3.16E-05 | 1.60E-03 | 9.52E-04 | 5.38E-03 | 1.24E-03 | 7.2467E-01 | 4.5195E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9801170 | 0.9881460 | 0.9886820 | 0.9943520 | 0.9928130 | 5.9747E+02 | 7.1675E+00 |
| $\alpha_2$ | 2.10E-03 | 6.32E-03 | 5.79E-03 | 1.24E-02 | 3.38E-03 | 3.8222E+00 | 6.0082E+02 |
| $\alpha_3$ | 5.17E-04 | 3.12E-03 | 2.60E-03 | 7.54E-03 | 1.81E-03 | 1.8894E+00 | 6.0275E+02 |
| $\alpha_4$ | 1.29E-04 | 1.87E-03 | 1.36E-03 | 5.37E-03 | 1.50E-03 | 1.1334E+00 | 6.0350E+02 |
| $\alpha_5$ | 1.08E-07 | 5.33E-04 | 1.46E-04 | 2.38E-03 | 4.96E-04 | 3.2248E-01 | 6.0432E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9809500 | 0.9882090 | 0.9886560 | 0.9939430 | 0.9929180 | 7.1773E+02 | 8.5639E+00 |
| $\alpha_2$ | 2.16E-03 | 5.97E-03 | 5.52E-03 | 1.13E-02 | 3.46E-03 | 4.3325E+00 | 7.2196E+02 |
| $\alpha_3$ | 4.54E-04 | 2.66E-03 | 2.22E-03 | 6.37E-03 | 1.31E-03 | 1.9334E+00 | 7.2436E+02 |
| $\alpha_4$ | 1.88E-04 | 1.88E-03 | 1.45E-03 | 5.05E-03 | 1.28E-03 | 1.3665E+00 | 7.2493E+02 |
| $\alpha_5$ | 1.95E-05 | 9.96E-04 | 5.91E-04 | 3.35E-03 | 8.28E-04 | 7.2330E-01 | 7.2557E+02 |
| $\alpha_6$ | 5.11E-10 | 2.87E-04 | 3.31E-05 | 1.46E-03 | 2.07E-04 | 2.0824E-01 | 7.2609E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9892000 | 0.9915860 | 0.9924730 | 0.9928130 | 0.9929180 |
| $\alpha_2$ | 1.08E-02 | 5.06E-03 | 3.64E-03 | 3.38E-03 | 3.46E-03 |
| $\alpha_3$ | | 3.35E-03 | 2.65E-03 | 1.81E-03 | 1.31E-03 |
| $\alpha_4$ | | | 1.24E-03 | 1.50E-03 | 1.28E-03 |
| $\alpha_5$ | | | | 4.96E-04 | 8.28E-04 |
| $\alpha_6$ | | | | | 2.07E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.89E-01 | 9.92E-01 | 9.92E-01 | 9.93E-01 | 9.93E-01 |
| Beta | 1.08E-02 | 8.41E-03 | 7.53E-03 | 7.19E-03 | 7.08E-03 |
| Gamma | | 3.98E-01 | 5.17E-01 | 5.29E-01 | 5.12E-01 |
| Delta | | | 3.19E-01 | 5.25E-01 | 6.39E-01 |
| Epsilon | | | | 2.48E-01 | 4.47E-01 |
| Mu | | | | | 2.00E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 197.90 | 296.85 | 395.80 | 494.75 | 593.70 |
| $N_1$ | 3.6000 | 4.8600 | 5.8320 | 6.5610 | 7.0859 |
| $N_2$ | 2.2000 | 1.5400 | 1.4720 | 1.7080 | 2.0933 |
| $N_3$ | | 1.0200 | 1.0720 | 0.9120 | 0.7916 |
| $N_4$ | | | 0.5020 | 0.7590 | 0.7743 |
| $N_5$ | | | | 0.2502 | 0.5011 |
| $N_6$ | | | | | 0.1250 |

## 1.11.1.2 EMERGENCY DIESEL GENERATOR SPAR:DGN-LR

| | |
|---|---|
| **System :** | Emergency power supply |
| **Component :** | Generator |
| **Failure Mode :** | Fail to Load/Run |
| **Component Group :** | Emergency Diesel Generator |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 209.70
Total Number of Common-Cause Failure Events: 3

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9791800 | 0.9940090 | 0.9966350 | 0.9999200 | 0.9977620 | 1.0877E+02 | 6.5552E-01 |
| $\alpha_2$ | 8.18E-05 | 5.99E-03 | 3.37E-03 | 2.08E-02 | 2.24E-03 | 6.5552E-01 | 1.0877E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9758210 | 0.9901870 | 0.9919470 | 0.9985320 | 0.9956010 | 1.7670E+02 | 1.7511E+00 |
| $\alpha_2$ | 9.53E-04 | 8.28E-03 | 6.53E-03 | 2.16E-02 | 4.36E-03 | 1.4775E+00 | 1.7697E+02 |
| $\alpha_3$ | 6.78E-08 | 1.53E-03 | 3.20E-04 | 7.22E-03 | 4.33E-05 | 2.7362E-01 | 1.7818E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9735840 | 0.9871960 | 0.9885000 | 0.9963500 | 0.9935050 | 2.4150E+02 | 3.1323E+00 |
| $\alpha_2$ | 2.32E-03 | 1.01E-02 | 8.85E-03 | 2.24E-02 | 6.38E-03 | 2.4822E+00 | 2.4215E+02 |
| $\alpha_3$ | 2.76E-06 | 1.74E-03 | 6.81E-04 | 7.08E-03 | 1.13E-04 | 4.2661E-01 | 2.4421E+02 |
| $\alpha_4$ | 4.09E-09 | 9.13E-04 | 1.25E-04 | 4.57E-03 | 4.07E-06 | 2.2347E-01 | 2.4441E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9737510 | 0.9856220 | 0.9865480 | 0.9943250 | 0.9941970 | 3.4018E+02 | 4.9625E+00 |
| $\alpha_2$ | 2.61E-03 | 9.13E-03 | 8.20E-03 | 1.88E-02 | 4.23E-03 | 3.1513E+00 | 3.4199E+02 |
| $\alpha_3$ | 3.92E-04 | 3.94E-03 | 3.04E-03 | 1.06E-02 | 1.56E-03 | 1.3608E+00 | 3.4378E+02 |
| $\alpha_4$ | 7.68E-07 | 1.10E-03 | 3.72E-04 | 4.64E-03 | 1.47E-05 | 3.7799E-01 | 3.4476E+02 |
| $\alpha_5$ | 1.82E-21 | 2.10E-04 | 1.20E-07 | 1.21E-03 | 4.07E-07 | 7.2377E-02 | 3.4507E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9752900 | 0.9859250 | 0.9866950 | 0.9939170 | 0.9946680 | 4.0959E+02 | 5.8475E+00 |
| $\alpha_2$ | 2.16E-03 | 7.58E-03 | 6.80E-03 | 1.56E-02 | 3.09E-03 | 3.1483E+00 | 4.1229E+02 |
| $\alpha_3$ | 5.67E-04 | 4.04E-03 | 3.28E-03 | 1.01E-02 | 1.82E-03 | 1.6786E+00 | 4.1376E+02 |
| $\alpha_4$ | 3.22E-05 | 1.72E-03 | 1.01E-03 | 5.81E-03 | 4.15E-04 | 7.1442E-01 | 4.1472E+02 |
| $\alpha_5$ | 2.33E-09 | 5.37E-04 | 7.31E-05 | 2.69E-03 | 2.38E-06 | 2.2290E-01 | 4.1521E+02 |
| $\alpha_6$ | 3.38E-19 | 2.00E-04 | 3.50E-07 | 1.17E-03 | 0.00E+00 | 8.3237E-02 | 4.1535E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9977620 | 0.9956010 | 0.9935050 | 0.9941970 | 0.9946680 |
| $\alpha_2$ | 2.24E-03 | 4.36E-03 | 6.38E-03 | 4.23E-03 | 3.09E-03 |
| $\alpha_3$ | | 4.33E-05 | 1.13E-04 | 1.56E-03 | 1.82E-03 |
| $\alpha_4$ | | | 4.07E-06 | 1.47E-05 | 4.15E-04 |
| $\alpha_5$ | | | | 4.07E-07 | 2.38E-06 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.98E-01 | 9.96E-01 | 9.94E-01 | 9.94E-01 | 9.95E-01 |
| Beta | 2.24E-03 | 4.40E-03 | 6.50E-03 | 5.80E-03 | 5.33E-03 |
| Gamma | | 9.84E-03 | 1.81E-02 | 2.72E-01 | 4.21E-01 |
| Delta | | | 3.46E-02 | 9.56E-03 | 1.86E-01 |
| Epsilon | | | | 2.70E-02 | 5.70E-03 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 96.86 | 145.29 | 193.72 | 242.15 | 290.58 |
| $N_1$ | 1.6680 | 1.8582 | 1.6415 | 1.8682 | 2.0684 |
| $N_2$ | 0.2210 | 0.6438 | 1.2541 | 1.0371 | 0.9091 |
| $N_3$ | | 0.0064 | 0.0223 | 0.3834 | 0.5368 |
| $N_4$ | | | 0.0008 | 0.0036 | 0.1222 |
| $N_5$ | | | | 0.0001 | 0.0007 |
| $N_6$ | | | | | 0.0000 |

## 1.11.1.3 EMERGENCY DIESEL GENERATOR SPAR:DGN-FR

| | |
|---|---|
| **System :** | Emergency power supply |
| **Component :** | Generator |
| **Failure Mode :** | Fail to Run (Normally running equipment) |
| **Component Group :** | Emergency Diesel Generator |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 140.20
Total Number of Common-Cause Failure Events: 4

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9660900 | 0.9868990 | 0.9896050 | 0.9984490 | 0.9897360 | 1.1303E+02 | 1.5005E+00 |
| $\alpha_2$ | 1.55E-03 | 1.31E-02 | 1.04E-02 | 3.39E-02 | 1.03E-02 | 1.5005E+00 | 1.1303E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9721900 | 0.9877210 | 0.9894200 | 0.9974310 | 0.9923890 | 1.8357E+02 | 2.2821E+00 |
| $\alpha_2$ | 9.64E-04 | 8.11E-03 | 6.42E-03 | 2.10E-02 | 4.34E-03 | 1.5065E+00 | 1.8435E+02 |
| $\alpha_3$ | 1.04E-04 | 4.17E-03 | 2.58E-03 | 1.37E-02 | 3.28E-03 | 7.7562E-01 | 1.8508E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9742860 | 0.9874770 | 0.9887270 | 0.9963790 | 0.9935500 | 2.5129E+02 | 3.1869E+00 |
| $\alpha_2$ | 1.07E-03 | 6.99E-03 | 5.75E-03 | 1.72E-02 | 2.67E-03 | 1.7794E+00 | 2.5270E+02 |
| $\alpha_3$ | 1.58E-04 | 3.67E-03 | 2.48E-03 | 1.12E-02 | 2.56E-03 | 9.3381E-01 | 2.5354E+02 |
| $\alpha_4$ | 5.47E-06 | 1.86E-03 | 8.08E-04 | 7.28E-03 | 1.22E-03 | 4.7367E-01 | 2.5400E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9743300 | 0.9858850 | 0.9867800 | 0.9943750 | 0.9941540 | 3.5238E+02 | 5.0451E+00 |
| $\alpha_2$ | 1.84E-03 | 7.49E-03 | 6.59E-03 | 1.62E-02 | 2.18E-03 | 2.6766E+00 | 3.5475E+02 |
| $\alpha_3$ | 4.24E-04 | 3.97E-03 | 3.09E-03 | 1.05E-02 | 1.71E-03 | 1.4172E+00 | 3.5601E+02 |
| $\alpha_4$ | 4.77E-05 | 2.11E-03 | 1.28E-03 | 6.98E-03 | 1.47E-03 | 7.5389E-01 | 3.5667E+02 |
| $\alpha_5$ | 4.68E-10 | 5.52E-04 | 5.54E-05 | 2.86E-03 | 4.85E-04 | 1.9738E-01 | 3.5723E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9757860 | 0.9861470 | 0.9868920 | 0.9939550 | 0.9945610 | 4.2420E+02 | 5.9589E+00 |
| $\alpha_2$ | 1.73E-03 | 6.63E-03 | 5.88E-03 | 1.41E-02 | 1.98E-03 | 2.8500E+00 | 4.2731E+02 |
| $\alpha_3$ | 4.17E-04 | 3.51E-03 | 2.78E-03 | 9.11E-03 | 1.19E-03 | 1.5095E+00 | 4.2865E+02 |
| $\alpha_4$ | 1.12E-04 | 2.28E-03 | 1.57E-03 | 6.87E-03 | 1.26E-03 | 9.8062E-01 | 4.2918E+02 |
| $\alpha_5$ | 3.20E-06 | 1.10E-03 | 4.76E-04 | 4.31E-03 | 8.12E-04 | 4.7300E-01 | 4.2969E+02 |
| $\alpha_6$ | 1.73E-12 | 3.39E-04 | 1.26E-05 | 1.88E-03 | 2.02E-04 | 1.4574E-01 | 4.3001E+02 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9897360 | 0.9923890 | 0.9935500 | 0.9941540 | 0.9945610 |
| $\alpha_2$ | 1.03E-02 | 4.34E-03 | 2.67E-03 | 2.18E-03 | 1.98E-03 |
| $\alpha_3$ | | 3.28E-03 | 2.56E-03 | 1.71E-03 | 1.19E-03 |
| $\alpha_4$ | | | 1.22E-03 | 1.47E-03 | 1.26E-03 |
| $\alpha_5$ | | | | 4.85E-04 | 8.12E-04 |
| $\alpha_6$ | | | | | 2.02E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.90E-01 | 9.92E-01 | 9.94E-01 | 9.94E-01 | 9.95E-01 |
| Beta | 1.03E-02 | 7.61E-03 | 6.45E-03 | 5.85E-03 | 5.44E-03 |
| Gamma | | 4.30E-01 | 5.86E-01 | 6.27E-01 | 6.36E-01 |
| Delta | | | 3.22E-01 | 5.34E-01 | 6.56E-01 |
| Epsilon | | | | 2.48E-01 | 4.46E-01 |
| Mu | | | | | 1.99E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 101.96 | 152.95 | 203.93 | 254.91 | 305.89 |
| $N_1$ | 0.8280 | 1.0692 | 1.2247 | 1.3122 | 1.3666 |
| $N_2$ | 1.0660 | 0.6728 | 0.5513 | 0.5624 | 0.6108 |
| $N_3$ | | 0.5084 | 0.5295 | 0.4398 | 0.3677 |
| $N_4$ | | | 0.2510 | 0.3795 | 0.3884 |
| $N_5$ | | | | 0.1251 | 0.2508 |
| $N_6$ | | | | | 0.0625 |

# 1.12 Vacuum Breakers

## 1.12.1 BWR Pressure Suppression Vacuum Breakers

### 1.12.1.1 CONTAINMENT VACUUM RELIEF CHECK FAIL TO OPEN

| | |
|---|---|
| **System :** | Vapor suppression |
| **Component :** | Vacuum Breaker |
| **Failure Mode :** | Fail to open on demand |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 7.50
Total Number of Common-Cause Failure Events: 1

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8612040 | 0.9606120 | 0.9783400 | 0.9996040 | 0.9636300 | 1.4663E+01 | 6.0122E-01 |
| $\alpha_2$ | 3.94E-04 | 3.94E-02 | 2.17E-02 | 1.39E-01 | 3.64E-02 | 6.0122E-01 | 1.4663E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8927750 | 0.9570640 | 0.9649780 | 0.9942240 | 0.9245850 | 3.5685E+01 | 1.6009E+00 |
| $\alpha_2$ | 3.52E-03 | 3.58E-02 | 2.78E-02 | 9.52E-02 | 7.54E-02 | 1.3337E+00 | 3.5952E+01 |
| $\alpha_3$ | 2.52E-07 | 7.17E-03 | 1.45E-03 | 3.40E-02 | 0.00E+00 | 2.6722E-01 | 3.7019E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8945600 | 0.9494600 | 0.9546940 | 0.9864480 | 0.8823530 | 5.3636E+01 | 2.8551E+00 |
| $\alpha_2$ | 8.18E-03 | 3.94E-02 | 3.41E-02 | 8.89E-02 | 1.18E-01 | 2.2281E+00 | 5.4263E+01 |
| $\alpha_3$ | 8.07E-06 | 7.16E-03 | 2.66E-03 | 2.96E-02 | 0.00E+00 | 4.0431E-01 | 5.6087E+01 |
| $\alpha_4$ | 1.70E-08 | 3.94E-03 | 5.40E-04 | 1.97E-02 | 0.00E+00 | 2.2267E-01 | 5.6268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9237230 | 0.9587720 | 0.9615280 | 0.9844100 | 0.9036610 | 1.0554E+02 | 4.5383E+00 |
| $\alpha_2$ | 6.52E-03 | 2.53E-02 | 2.24E-02 | 5.37E-02 | 6.42E-02 | 2.7809E+00 | 1.0730E+02 |
| $\alpha_3$ | 1.11E-03 | 1.19E-02 | 9.11E-03 | 3.23E-02 | 3.21E-02 | 1.3107E+00 | 1.0877E+02 |
| $\alpha_4$ | 2.24E-06 | 3.40E-03 | 1.15E-03 | 1.44E-02 | 0.00E+00 | 3.7439E-01 | 1.0970E+02 |
| $\alpha_5$ | 5.42E-21 | 6.57E-04 | 3.71E-07 | 3.80E-03 | 0.00E+00 | 7.2277E-02 | 1.1001E+02 |

CONTAINMENT VACUUM RELIEF CHECK FAIL TO OPEN
**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9294330 | 0.9604510 | 0.9627350 | 0.9836660 | 0.9183750 | 1.2819E+02 | 5.2786E+00 |
| $\alpha_2$ | 5.00E-03 | 2.01E-02 | 1.78E-02 | 4.32E-02 | 3.63E-02 | 2.6836E+00 | 1.3078E+02 |
| $\alpha_3$ | 1.54E-03 | 1.19E-02 | 9.55E-03 | 3.02E-02 | 3.63E-02 | 1.5862E+00 | 1.3188E+02 |
| $\alpha_4$ | 9.38E-05 | 5.27E-03 | 3.09E-03 | 1.79E-02 | 9.07E-03 | 7.0332E-01 | 1.3277E+02 |
| $\alpha_5$ | 6.96E-09 | 1.66E-03 | 2.26E-04 | 8.34E-03 | 0.00E+00 | 2.2220E-01 | 1.3325E+02 |
| $\alpha_6$ | 1.06E-18 | 6.24E-04 | 1.09E-06 | 3.64E-03 | 0.00E+00 | 8.3237E-02 | 1.3339E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9636300 | 0.9245850 | 0.8823530 | 0.9036610 | 0.9183750 |
| $\alpha_2$ | 3.64E-02 | 7.54E-02 | 1.18E-01 | 6.42E-02 | 3.63E-02 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 3.21E-02 | 3.63E-02 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 9.07E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.64E-01 | 9.25E-01 | 8.82E-01 | 9.04E-01 | 9.18E-01 |
| Beta | 3.64E-02 | 7.54E-02 | 1.18E-01 | 9.63E-02 | 8.16E-02 |
| Gamma | | 0.00E+00 | 0.00E+00 | 3.33E-01 | 5.56E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 2.00E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 3.75 | 5.63 | 7.50 | 9.38 | 11.25 |
| $N_1$ | 0.6667 | 0.5000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.1667 | 0.5000 | 1.0000 | 0.6667 | 0.4444 |
| $N_3$ | | 0.0000 | 0.0000 | 0.3333 | 0.4444 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.1111 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.13 AC Power Distribution Breakers

## 1.13.1 480 Vac Circuit Breakers

### 1.13.1.1 480 V CIRCUIT BREAKERS FAIL TO OPEN

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Fail to open on demand |
| **Component Group :** | 480 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 12.20
Total Number of Common-Cause Failure Events: 3

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8574060 | 0.9632090 | 0.9835270 | 0.9998990 | 0.9844030 | 1.2177E+01 | 4.6512E-01 |
| $\alpha_2$ | 1.03E-04 | 3.68E-02 | 1.65E-02 | 1.43E-01 | 1.56E-02 | 4.6512E-01 | 1.2177E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9021370 | 0.9647150 | 0.9734900 | 0.9972530 | 0.9713440 | 3.2368E+01 | 1.1839E+00 |
| $\alpha_2$ | 1.13E-03 | 2.72E-02 | 1.85E-02 | 8.30E-02 | 2.71E-02 | 9.1226E-01 | 3.2640E+01 |
| $\alpha_3$ | 3.37E-07 | 8.10E-03 | 1.69E-03 | 3.82E-02 | 1.52E-03 | 2.7162E-01 | 3.3280E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9098200 | 0.9612840 | 0.9670770 | 0.9929170 | 0.9605090 | 4.9794E+01 | 2.0055E+00 |
| $\alpha_2$ | 2.67E-03 | 2.63E-02 | 2.05E-02 | 6.99E-02 | 3.54E-02 | 1.3628E+00 | 5.0437E+01 |
| $\alpha_3$ | 1.16E-05 | 8.10E-03 | 3.14E-03 | 3.30E-02 | 3.96E-03 | 4.1941E-01 | 5.1380E+01 |
| $\alpha_4$ | 1.93E-08 | 4.31E-03 | 5.95E-04 | 2.16E-02 | 1.58E-04 | 2.2327E-01 | 5.1576E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298630 | 0.9639350 | 0.9668600 | 0.9879950 | 0.9516930 | 1.0064E+02 | 3.7654E+00 |
| $\alpha_2$ | 4.71E-03 | 2.21E-02 | 1.91E-02 | 4.97E-02 | 4.08E-02 | 2.3062E+00 | 1.0210E+02 |
| $\alpha_3$ | 5.13E-04 | 9.67E-03 | 6.77E-03 | 2.87E-02 | 6.89E-03 | 1.0098E+00 | 1.0340E+02 |
| $\alpha_4$ | 2.50E-06 | 3.61E-03 | 1.23E-03 | 1.53E-02 | 5.53E-04 | 3.7699E-01 | 1.0403E+02 |
| $\alpha_5$ | 6.05E-21 | 6.93E-04 | 3.97E-07 | 4.01E-03 | 2.13E-05 | 7.2377E-02 | 1.0433E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9331270 | 0.9638210 | 0.9662340 | 0.9862570 | 0.9446800 | 1.2222E+02 | 4.5878E+00 |
| $\alpha_2$ | 4.52E-03 | 1.96E-02 | 1.71E-02 | 4.31E-02 | 4.41E-02 | 2.4854E+00 | 1.2432E+02 |
| $\alpha_3$ | 7.36E-04 | 9.44E-03 | 7.02E-03 | 2.64E-02 | 9.97E-03 | 1.1975E+00 | 1.2561E+02 |
| $\alpha_4$ | 4.44E-05 | 4.72E-03 | 2.50E-03 | 1.70E-02 | 1.22E-03 | 5.9902E-01 | 1.2621E+02 |
| $\alpha_5$ | 7.51E-09 | 1.76E-03 | 2.39E-04 | 8.79E-03 | 7.16E-05 | 2.2260E-01 | 1.2659E+02 |
| $\alpha_6$ | 1.11E-18 | 6.56E-04 | 1.15E-06 | 3.83E-03 | 0.00E+00 | 8.3237E-02 | 1.2672E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9415240 | 0.9652780 | 0.9668410 | 0.9836880 | 0.9390090 | 1.9011E+02 | 6.8384E+00 |
| $\alpha_2$ | 5.22E-03 | 1.72E-02 | 1.56E-02 | 3.46E-02 | 4.56E-02 | 3.3822E+00 | 1.9357E+02 |
| $\alpha_3$ | 1.26E-03 | 8.71E-03 | 7.11E-03 | 2.16E-02 | 1.30E-02 | 1.7150E+00 | 1.9523E+02 |
| $\alpha_4$ | 2.64E-04 | 5.09E-03 | 3.54E-03 | 1.52E-02 | 2.14E-03 | 1.0027E+00 | 1.9595E+02 |
| $\alpha_5$ | 1.32E-05 | 2.66E-03 | 1.26E-03 | 1.00E-02 | 2.02E-04 | 5.2307E-01 | 1.9643E+02 |
| $\alpha_6$ | 3.44E-10 | 9.46E-04 | 8.09E-05 | 4.97E-03 | 1.55E-05 | 1.8638E-01 | 1.9676E+02 |
| $\alpha_7$ | 0.00E+00 | 1.48E-04 | 1.29E-13 | 5.56E-04 | 0.00E+00 | 2.9071E-02 | 1.9692E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9445330 | 0.9660020 | 0.9673240 | 0.9829570 | 0.9346470 | 2.2555E+02 | 7.9381E+00 |
| $\alpha_2$ | 5.11E-03 | 1.58E-02 | 1.44E-02 | 3.11E-02 | 4.59E-02 | 3.6798E+00 | 2.2981E+02 |
| $\alpha_3$ | 1.28E-03 | 7.94E-03 | 6.58E-03 | 1.92E-02 | 1.58E-02 | 1.8534E+00 | 2.3163E+02 |
| $\alpha_4$ | 3.71E-04 | 5.01E-03 | 3.69E-03 | 1.42E-02 | 3.26E-03 | 1.1703E+00 | 2.3232E+02 |
| $\alpha_5$ | 5.63E-05 | 3.05E-03 | 1.80E-03 | 1.03E-02 | 4.11E-04 | 7.1133E-01 | 2.3278E+02 |
| $\alpha_6$ | 8.94E-07 | 1.57E-03 | 5.15E-04 | 6.73E-03 | 2.74E-05 | 3.6716E-01 | 2.3312E+02 |
| $\alpha_7$ | 6.97E-14 | 5.27E-04 | 9.47E-06 | 3.00E-03 | 0.00E+00 | 1.2297E-01 | 2.3337E+02 |
| $\alpha_8$ | 1.31E-42 | 1.42E-04 | 2.02E-12 | 6.00E-04 | 0.00E+00 | 3.3124E-02 | 2.3345E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9844030 | 0.9713440 | 0.9605090 | 0.9516930 | 0.9446800 | 0.9390090 | 0.9346470 |
| $\alpha_2$ | 1.56E-02 | 2.71E-02 | 3.54E-02 | 4.08E-02 | 4.41E-02 | 4.56E-02 | 4.59E-02 |
| $\alpha_3$ | | 1.52E-03 | 3.96E-03 | 6.89E-03 | 9.97E-03 | 1.30E-02 | 1.58E-02 |
| $\alpha_4$ | | | 1.58E-04 | 5.53E-04 | 1.22E-03 | 2.14E-03 | 3.26E-03 |
| $\alpha_5$ | | | | 2.13E-05 | 7.16E-05 | 2.02E-04 | 4.11E-04 |
| $\alpha_6$ | | | | | 0.00E+00 | 1.55E-05 | 2.74E-05 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

480 V CIRCUIT BREAKERS FAIL TO OPEN

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.84E-01 | 9.71E-01 | 9.61E-01 | 9.52E-01 | 9.45E-01 | 9.39E-01 | 9.35E-01 |
| Beta | 1.56E-02 | 2.87E-02 | 3.95E-02 | 4.83E-02 | 5.53E-02 | 6.10E-02 | 6.54E-02 |
| Gamma | | 5.30E-02 | 1.04E-01 | 1.55E-01 | 2.03E-01 | 2.52E-01 | 2.98E-01 |
| Delta | | | 3.82E-02 | 7.69E-02 | 1.14E-01 | 1.54E-01 | 1.90E-01 |
| Epsilon | | | | 3.70E-02 | 5.56E-02 | 9.21E-02 | 1.19E-01 |
| Mu | | | | | 0.00E+00 | 7.14E-02 | 6.25E-02 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 1.53 | 2.29 | 3.05 | 3.81 | 4.58 | 5.34 | 6.10 |
| $N_1$ | 0.4013 | 0.5234 | 0.6081 | 0.6641 | 0.6984 | 0.7167 | 0.7233 |
| $N_2$ | 0.0306 | 0.0786 | 0.1347 | 0.1920 | 0.2462 | 0.2944 | 0.3351 |
| $N_3$ | | 0.0044 | 0.0151 | 0.0324 | 0.0557 | 0.0838 | 0.1150 |
| $N_4$ | | | 0.0006 | 0.0026 | 0.0068 | 0.0138 | 0.0238 |
| $N_5$ | | | | 0.0001 | 0.0004 | 0.0013 | 0.0030 |
| $N_6$ | | | | | 0.0000 | 0.0001 | 0.0002 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.13.1.2 480 V CIRCUIT BREAKERS FAIL TO CLOSE

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Component Group :** | 480 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 48.20
Total Number of Common-Cause Failure Events: 1

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8946290 | 0.9730650 | 0.9882370 | 0.9999270 | 0.9960820 | 1.6601E+01 | 4.5952E-01 |
| $\alpha_2$ | 6.94E-05 | 2.69E-02 | 1.18E-02 | 1.05E-01 | 3.92E-03 | 4.5952E-01 | 1.6601E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9185560 | 0.9708280 | 0.9782260 | 0.9977840 | 0.9925070 | 3.9013E+01 | 1.1723E+00 |
| $\alpha_2$ | 9.03E-04 | 2.25E-02 | 1.52E-02 | 6.90E-02 | 7.30E-03 | 9.0326E-01 | 3.9282E+01 |
| $\alpha_3$ | 2.52E-07 | 6.69E-03 | 1.37E-03 | 3.17E-02 | 1.89E-04 | 2.6902E-01 | 3.9916E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9231590 | 0.9671750 | 0.9721710 | 0.9940750 | 0.9892790 | 5.8657E+01 | 1.9908E+00 |
| $\alpha_2$ | 2.24E-03 | 2.24E-02 | 1.74E-02 | 5.96E-02 | 1.02E-02 | 1.3567E+00 | 5.9291E+01 |
| $\alpha_3$ | 8.57E-06 | 6.78E-03 | 2.57E-03 | 2.78E-02 | 5.61E-04 | 4.1141E-01 | 6.0236E+01 |
| $\alpha_4$ | 1.59E-08 | 3.67E-03 | 5.03E-04 | 1.84E-02 | 0.00E+00 | 2.2267E-01 | 6.0425E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9366560 | 0.9675000 | 0.9701630 | 0.9892270 | 0.9864070 | 1.1171E+02 | 3.7525E+00 |
| $\alpha_2$ | 4.27E-03 | 2.00E-02 | 1.73E-02 | 4.50E-02 | 1.25E-02 | 2.3106E+00 | 1.1315E+02 |
| $\alpha_3$ | 4.41E-04 | 8.62E-03 | 6.00E-03 | 2.58E-02 | 1.14E-03 | 9.9528E-01 | 1.1447E+02 |
| $\alpha_4$ | 2.13E-06 | 3.24E-03 | 1.09E-03 | 1.38E-02 | 0.00E+00 | 3.7439E-01 | 1.1509E+02 |
| $\alpha_5$ | 5.17E-21 | 6.26E-04 | 3.54E-07 | 3.62E-03 | 0.00E+00 | 7.2277E-02 | 1.1539E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9394480 | 0.9672890 | 0.9694890 | 0.9876020 | 0.9839070 | 1.3550E+02 | 4.5823E+00 |
| $\alpha_2$ | 4.16E-03 | 1.79E-02 | 1.57E-02 | 3.93E-02 | 1.42E-02 | 2.5071E+00 | 1.3758E+02 |
| $\alpha_3$ | 6.32E-04 | 8.41E-03 | 6.21E-03 | 2.37E-02 | 1.89E-03 | 1.1775E+00 | 1.3890E+02 |
| $\alpha_4$ | 3.78E-05 | 4.23E-03 | 2.21E-03 | 1.53E-02 | 0.00E+00 | 5.9222E-01 | 1.3949E+02 |
| $\alpha_5$ | 6.63E-09 | 1.59E-03 | 2.15E-04 | 7.95E-03 | 0.00E+00 | 2.2220E-01 | 1.3986E+02 |
| $\alpha_6$ | 1.01E-18 | 5.94E-04 | 1.04E-06 | 3.47E-03 | 0.00E+00 | 8.3237E-02 | 1.4000E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9457110 | 0.9677780 | 0.9692400 | 0.9848640 | 0.9817680 | 2.0559E+02 | 6.8450E+00 |
| $\alpha_2$ | 4.95E-03 | 1.61E-02 | 1.46E-02 | 3.24E-02 | 1.54E-02 | 3.4253E+00 | 2.0901E+02 |
| $\alpha_3$ | 1.14E-03 | 7.97E-03 | 6.49E-03 | 1.99E-02 | 2.85E-03 | 1.6937E+00 | 2.1074E+02 |
| $\alpha_4$ | 2.33E-04 | 4.65E-03 | 3.22E-03 | 1.40E-02 | 0.00E+00 | 9.8887E-01 | 2.1145E+02 |
| $\alpha_5$ | 1.21E-05 | 2.46E-03 | 1.16E-03 | 9.28E-03 | 0.00E+00 | 5.2177E-01 | 2.1191E+02 |
| $\alpha_6$ | 3.16E-10 | 8.77E-04 | 7.49E-05 | 4.60E-03 | 0.00E+00 | 1.8628E-01 | 2.1225E+02 |
| $\alpha_7$ | 0.00E+00 | 1.37E-04 | 1.20E-13 | 5.15E-04 | 0.00E+00 | 2.9071E-02 | 2.1241E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9482890 | 0.9683070 | 0.9695460 | 0.9841050 | 0.9800000 | 2.4323E+02 | 7.9610E+00 |
| $\alpha_2$ | 4.89E-03 | 1.49E-02 | 1.36E-02 | 2.93E-02 | 1.60E-02 | 3.7447E+00 | 2.4745E+02 |
| $\alpha_3$ | 1.17E-03 | 7.32E-03 | 6.06E-03 | 1.78E-02 | 4.00E-03 | 1.8384E+00 | 2.4935E+02 |
| $\alpha_4$ | 3.23E-04 | 4.56E-03 | 3.34E-03 | 1.30E-02 | 0.00E+00 | 1.1465E+00 | 2.5004E+02 |
| $\alpha_5$ | 5.13E-05 | 2.82E-03 | 1.66E-03 | 9.54E-03 | 0.00E+00 | 7.0833E-01 | 2.5048E+02 |
| $\alpha_6$ | 8.27E-07 | 1.46E-03 | 4.78E-04 | 6.25E-03 | 0.00E+00 | 3.6696E-01 | 2.5082E+02 |
| $\alpha_7$ | 6.48E-14 | 4.90E-04 | 8.80E-06 | 2.79E-03 | 0.00E+00 | 1.2297E-01 | 2.5107E+02 |
| $\alpha_8$ | 1.21E-42 | 1.32E-04 | 1.88E-12 | 5.57E-04 | 0.00E+00 | 3.3124E-02 | 2.5116E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9960820 | 0.9925070 | 0.9892790 | 0.9864070 | 0.9839070 | 0.9817680 | 0.9800000 |
| $\alpha_2$ | 3.92E-03 | 7.30E-03 | 1.02E-02 | 1.25E-02 | 1.42E-02 | 1.54E-02 | 1.60E-02 |
| $\alpha_3$ | | 1.89E-04 | 5.61E-04 | 1.14E-03 | 1.89E-03 | 2.85E-03 | 4.00E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.96E-01 | 9.93E-01 | 9.89E-01 | 9.86E-01 | 9.84E-01 | 9.82E-01 | 9.80E-01 |
| Beta | 3.92E-03 | 7.49E-03 | 1.07E-02 | 1.36E-02 | 1.61E-02 | 1.82E-02 | 2.00E-02 |
| Gamma | | 2.52E-02 | 5.23E-02 | 8.35E-02 | 1.18E-01 | 1.56E-01 | 2.00E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

480 V CIRCUIT BREAKERS FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 6.03 | 9.04 | 12.05 | 15.06 | 18.08 | 21.09 | 24.10 |
| $N_1$ | 0.3250 | 0.4179 | 0.4714 | 0.4911 | 0.4821 | 0.4500 | 0.4000 |
| $N_2$ | 0.0250 | 0.0696 | 0.1286 | 0.1964 | 0.2679 | 0.3375 | 0.4000 |
| $N_3$ | | 0.0018 | 0.0071 | 0.0179 | 0.0357 | 0.0625 | 0.1000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.13.1.3 480 V CIRCUIT BREAKERS SPURIOUS ACTUATION

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Spurious operation open or close |
| **Component Group :** | 480 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 42.20
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9669310 | 0.9917830 | 0.9966990 | 0.9999840 | 1.0000000 | 5.2446E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.47E-05 | 8.22E-03 | 3.30E-03 | 3.31E-02 | 0.00E+00 | 4.3452E-01 | 5.2446E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9565670 | 0.9848900 | 0.9890400 | 0.9990100 | 1.0000000 | 7.1755E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.60E-04 | 1.14E-02 | 7.39E-03 | 3.64E-02 | 0.00E+00 | 8.3366E-01 | 7.2022E+01 |
| $\alpha_3$ | 1.28E-07 | 3.67E-03 | 7.36E-04 | 1.74E-02 | 0.00E+00 | 2.6722E-01 | 7.2589E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9504890 | 0.9794320 | 0.9828630 | 0.9966420 | 1.0000000 | 8.8336E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.12E-03 | 1.36E-02 | 1.02E-02 | 3.77E-02 | 0.00E+00 | 1.2281E+00 | 8.8963E+01 |
| $\alpha_3$ | 5.03E-06 | 4.48E-03 | 1.66E-03 | 1.85E-02 | 0.00E+00 | 4.0431E-01 | 8.9787E+01 |
| $\alpha_4$ | 1.06E-08 | 2.47E-03 | 3.37E-04 | 1.24E-02 | 0.00E+00 | 2.2267E-01 | 8.9968E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9504910 | 0.9750650 | 0.9772670 | 0.9921220 | 1.0000000 | 1.3836E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.86E-03 | 1.49E-02 | 1.27E-02 | 3.45E-02 | 0.00E+00 | 2.1142E+00 | 1.3978E+02 |
| $\alpha_3$ | 3.36E-04 | 6.89E-03 | 4.75E-03 | 2.07E-02 | 0.00E+00 | 9.7738E-01 | 1.4092E+02 |
| $\alpha_4$ | 1.73E-06 | 2.64E-03 | 8.88E-04 | 1.12E-02 | 0.00E+00 | 3.7439E-01 | 1.4152E+02 |
| $\alpha_5$ | 4.20E-21 | 5.09E-04 | 2.88E-07 | 2.95E-03 | 0.00E+00 | 7.2277E-02 | 1.4183E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9505740 | 0.9738180 | 0.9757310 | 0.9905280 | 1.0000000 | 1.5914E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.81E-03 | 1.37E-02 | 1.18E-02 | 3.12E-02 | 0.00E+00 | 2.2392E+00 | 1.6118E+02 |
| $\alpha_3$ | 4.91E-04 | 6.99E-03 | 5.11E-03 | 1.99E-02 | 0.00E+00 | 1.1418E+00 | 1.6228E+02 |
| $\alpha_4$ | 3.24E-05 | 3.62E-03 | 1.90E-03 | 1.31E-02 | 0.00E+00 | 5.9222E-01 | 1.6283E+02 |
| $\alpha_5$ | 5.68E-09 | 1.36E-03 | 1.84E-04 | 6.81E-03 | 0.00E+00 | 2.2220E-01 | 1.6320E+02 |
| $\alpha_6$ | 8.62E-19 | 5.09E-04 | 8.90E-07 | 2.97E-03 | 0.00E+00 | 8.3237E-02 | 1.6334E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9526440 | 0.9723030 | 0.9736480 | 0.9873780 | 1.0000000 | 2.2625E+02 | 6.4450E+00 |
| $\alpha_2$ | 3.73E-03 | 1.33E-02 | 1.19E-02 | 2.75E-02 | 0.00E+00 | 3.0878E+00 | 2.2961E+02 |
| $\alpha_3$ | 9.44E-04 | 7.01E-03 | 5.66E-03 | 1.77E-02 | 0.00E+00 | 1.6312E+00 | 2.3106E+02 |
| $\alpha_4$ | 2.13E-04 | 4.25E-03 | 2.94E-03 | 1.28E-02 | 0.00E+00 | 9.8887E-01 | 2.3171E+02 |
| $\alpha_5$ | 1.10E-05 | 2.24E-03 | 1.06E-03 | 8.48E-03 | 0.00E+00 | 5.2177E-01 | 2.3217E+02 |
| $\alpha_6$ | 2.89E-10 | 8.01E-04 | 6.83E-05 | 4.20E-03 | 0.00E+00 | 1.8628E-01 | 2.3251E+02 |
| $\alpha_7$ | 0.00E+00 | 1.25E-04 | 1.09E-13 | 4.70E-04 | 0.00E+00 | 2.9071E-02 | 2.3267E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9539690 | 0.9722010 | 0.9733640 | 0.9864490 | 1.0000000 | 2.6093E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.75E-03 | 1.25E-02 | 1.13E-02 | 2.52E-02 | 0.00E+00 | 3.3447E+00 | 2.6505E+02 |
| $\alpha_3$ | 9.58E-04 | 6.48E-03 | 5.30E-03 | 1.60E-02 | 0.00E+00 | 1.7384E+00 | 2.6665E+02 |
| $\alpha_4$ | 3.02E-04 | 4.27E-03 | 3.12E-03 | 1.22E-02 | 0.00E+00 | 1.1465E+00 | 2.6724E+02 |
| $\alpha_5$ | 4.80E-05 | 2.64E-03 | 1.55E-03 | 8.93E-03 | 0.00E+00 | 7.0833E-01 | 2.6768E+02 |
| $\alpha_6$ | 7.74E-07 | 1.37E-03 | 4.47E-04 | 5.85E-03 | 0.00E+00 | 3.6696E-01 | 2.6802E+02 |
| $\alpha_7$ | 6.07E-14 | 4.58E-04 | 8.24E-06 | 2.61E-03 | 0.00E+00 | 1.2297E-01 | 2.6827E+02 |
| $\alpha_8$ | 1.14E-42 | 1.23E-04 | 1.76E-12 | 5.21E-04 | 0.00E+00 | 3.3124E-02 | 2.6836E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

480 V CIRCUIT BREAKERS SPURIOUS ACTUATION

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 42.20 | 42.20 | 42.20 | 42.20 | 42.20 | 42.20 | 42.20 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.13.2 4160 vac and 6.9Kva Distribution Circuit Breakers

### 1.13.2.1 ACP 4160 AND 6.9 CIRCUIT BREAKERS FAIL TO OPEN SPAR: CRB-CC

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Fail to open on demand |
| **Component Group :** | 4160 - 6900 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 16.10
Total Number of Common-Cause Failure Events: 2

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8699270 | 0.9661810 | 0.9845710 | 0.9998930 | 0.9875910 | 1.3628E+01 | 4.7702E-01 |
| $\alpha_2$ | 1.09E-04 | 3.38E-02 | 1.54E-02 | 1.30E-01 | 1.24E-02 | 4.7702E-01 | 1.3628E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9058520 | 0.9656470 | 0.9739180 | 0.9971220 | 0.9750400 | 3.4512E+01 | 1.2278E+00 |
| $\alpha_2$ | 1.28E-03 | 2.69E-02 | 1.87E-02 | 8.05E-02 | 2.49E-02 | 9.6026E-01 | 3.4780E+01 |
| $\alpha_3$ | 2.66E-07 | 7.49E-03 | 1.52E-03 | 3.55E-02 | 5.90E-05 | 2.6752E-01 | 3.5472E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9115860 | 0.9614580 | 0.9669550 | 0.9925130 | 0.9622640 | 5.2575E+01 | 2.1076E+00 |
| $\alpha_2$ | 3.17E-03 | 2.71E-02 | 2.15E-02 | 6.99E-02 | 3.75E-02 | 1.4793E+00 | 5.3203E+01 |
| $\alpha_3$ | 8.55E-06 | 7.42E-03 | 2.77E-03 | 3.06E-02 | 1.94E-04 | 4.0561E-01 | 5.4277E+01 |
| $\alpha_4$ | 1.76E-08 | 4.07E-03 | 5.58E-04 | 2.04E-02 | 0.00E+00 | 2.2267E-01 | 5.4460E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9296570 | 0.9633470 | 0.9661740 | 0.9873600 | 0.9492900 | 1.0400E+02 | 3.9569E+00 |
| $\alpha_2$ | 5.51E-03 | 2.34E-02 | 2.06E-02 | 5.12E-02 | 5.03E-02 | 2.5299E+00 | 1.0543E+02 |
| $\alpha_3$ | 4.47E-04 | 9.08E-03 | 6.28E-03 | 2.73E-02 | 3.63E-04 | 9.8038E-01 | 1.0698E+02 |
| $\alpha_4$ | 2.28E-06 | 3.47E-03 | 1.17E-03 | 1.47E-02 | 0.00E+00 | 3.7439E-01 | 1.0758E+02 |
| $\alpha_5$ | 5.53E-21 | 6.69E-04 | 3.79E-07 | 3.88E-03 | 0.00E+00 | 7.2277E-02 | 1.0788E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9319670 | 0.9625690 | 0.9649000 | 0.9851910 | 0.9361010 | 1.2610E+02 | 4.9037E+00 |
| $\alpha_2$ | 5.76E-03 | 2.18E-02 | 1.94E-02 | 4.60E-02 | 6.33E-02 | 2.8582E+00 | 1.2815E+02 |
| $\alpha_3$ | 6.24E-04 | 8.76E-03 | 6.42E-03 | 2.49E-02 | 6.03E-04 | 1.1477E+00 | 1.2986E+02 |
| $\alpha_4$ | 4.05E-05 | 4.52E-03 | 2.37E-03 | 1.63E-02 | 1.02E-05 | 5.9232E-01 | 1.3041E+02 |
| $\alpha_5$ | 7.09E-09 | 1.70E-03 | 2.30E-04 | 8.50E-03 | 0.00E+00 | 2.2220E-01 | 1.3078E+02 |
| $\alpha_6$ | 1.08E-18 | 6.35E-04 | 1.11E-06 | 3.71E-03 | 0.00E+00 | 8.3237E-02 | 1.3092E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9398470 | 0.9637380 | 0.9652650 | 0.9824310 | 0.9226780 | 1.9444E+02 | 7.3160E+00 |
| $\alpha_2$ | 6.68E-03 | 1.96E-02 | 1.80E-02 | 3.78E-02 | 7.64E-02 | 3.9484E+00 | 1.9781E+02 |
| $\alpha_3$ | 1.11E-03 | 8.14E-03 | 6.58E-03 | 2.05E-02 | 8.97E-04 | 1.6413E+00 | 2.0011E+02 |
| $\alpha_4$ | 2.46E-04 | 4.90E-03 | 3.39E-03 | 1.47E-02 | 2.66E-05 | 9.8917E-01 | 2.0077E+02 |
| $\alpha_5$ | 1.27E-05 | 2.59E-03 | 1.22E-03 | 9.77E-03 | 0.00E+00 | 5.2177E-01 | 2.0123E+02 |
| $\alpha_6$ | 3.33E-10 | 9.23E-04 | 7.88E-05 | 4.85E-03 | 0.00E+00 | 1.8628E-01 | 2.0157E+02 |
| $\alpha_7$ | 0.00E+00 | 1.44E-04 | 1.26E-13 | 5.42E-04 | 0.00E+00 | 2.9071E-02 | 2.0173E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9421670 | 0.9639310 | 0.9652210 | 0.9812980 | 0.9090370 | 2.3028E+02 | 8.6169E+00 |
| $\alpha_2$ | 6.98E-03 | 1.88E-02 | 1.74E-02 | 3.51E-02 | 8.97E-02 | 4.4843E+00 | 2.3441E+02 |
| $\alpha_3$ | 1.10E-03 | 7.34E-03 | 6.02E-03 | 1.81E-02 | 1.24E-03 | 1.7541E+00 | 2.3714E+02 |
| $\alpha_4$ | 3.40E-04 | 4.80E-03 | 3.51E-03 | 1.37E-02 | 4.72E-05 | 1.1471E+00 | 2.3775E+02 |
| $\alpha_5$ | 5.40E-05 | 2.97E-03 | 1.74E-03 | 1.00E-02 | 0.00E+00 | 7.0833E-01 | 2.3819E+02 |
| $\alpha_6$ | 8.69E-07 | 1.54E-03 | 5.03E-04 | 6.57E-03 | 0.00E+00 | 3.6696E-01 | 2.3853E+02 |
| $\alpha_7$ | 6.82E-14 | 5.15E-04 | 9.26E-06 | 2.93E-03 | 0.00E+00 | 1.2297E-01 | 2.3877E+02 |
| $\alpha_8$ | 1.28E-42 | 1.39E-04 | 1.98E-12 | 5.86E-04 | 0.00E+00 | 3.3124E-02 | 2.3886E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9875910 | 0.9750400 | 0.9622640 | 0.9492900 | 0.9361010 | 0.9226780 | 0.9090370 |
| $\alpha_2$ | 1.24E-02 | 2.49E-02 | 3.75E-02 | 5.03E-02 | 6.33E-02 | 7.64E-02 | 8.97E-02 |
| $\alpha_3$ | | 5.90E-05 | 1.94E-04 | 3.63E-04 | 6.03E-04 | 8.97E-04 | 1.24E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 1.02E-05 | 2.66E-05 | 4.72E-05 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.88E-01 | 9.75E-01 | 9.62E-01 | 9.49E-01 | 9.36E-01 | 9.23E-01 | 9.09E-01 |
| Beta | 1.24E-02 | 2.50E-02 | 3.77E-02 | 5.07E-02 | 6.39E-02 | 7.73E-02 | 9.10E-02 |
| Gamma | | 2.36E-03 | 5.15E-03 | 7.17E-03 | 9.60E-03 | 1.19E-02 | 1.41E-02 |
| Delta | | | 0.00E+00 | 0.00E+00 | 1.67E-02 | 2.88E-02 | 3.68E-02 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

ACP 4160 AND 6.9 CIRCUIT BREAKERS FAIL TO OPEN SPAR: CRB-CC

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 2.68 | 4.03 | 5.37 | 6.71 | 8.05 | 9.39 | 10.73 |
| $N_1$ | 0.7025 | 0.9272 | 1.0688 | 1.1281 | 1.1061 | 1.0036 | 0.8214 |
| $N_2$ | 0.0425 | 0.1266 | 0.2512 | 0.4157 | 0.6190 | 0.8606 | 1.1396 |
| $N_3$ | | 0.0003 | 0.0013 | 0.0030 | 0.0059 | 0.0101 | 0.0157 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0001 | 0.0003 | 0.0006 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.13.2.2 ACP 4160 AND 6.9 CIRCUIT BREAKERS FAIL TO CLOSE SPAR: CRB-OO

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Fail to close (reseat) on demand |
| **Component Group :** | 4160 - 6900 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 59.80
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9751720 | 0.9938350 | 0.9975270 | 0.9999880 | 1.0000000 | 7.0046E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.10E-05 | 6.17E-03 | 2.47E-03 | 2.48E-02 | 0.00E+00 | 4.3452E-01 | 7.0046E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9649640 | 0.9878300 | 0.9911930 | 0.9992040 | 1.0000000 | 8.9355E+01 | 1.1009E+00 |
| $\alpha_2$ | 2.89E-04 | 9.22E-03 | 5.94E-03 | 2.93E-02 | 0.00E+00 | 8.3366E-01 | 8.9622E+01 |
| $\alpha_3$ | 1.03E-07 | 2.95E-03 | 5.92E-04 | 1.40E-02 | 0.00E+00 | 2.6722E-01 | 9.0189E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9585110 | 0.9827910 | 0.9856790 | 0.9971970 | 1.0000000 | 1.0594E+02 | 1.8551E+00 |
| $\alpha_2$ | 9.36E-04 | 1.14E-02 | 8.54E-03 | 3.16E-02 | 0.00E+00 | 1.2281E+00 | 1.0657E+02 |
| $\alpha_3$ | 4.20E-06 | 3.75E-03 | 1.39E-03 | 1.55E-02 | 0.00E+00 | 4.0431E-01 | 1.0739E+02 |
| $\alpha_4$ | 8.88E-09 | 2.07E-03 | 2.82E-04 | 1.03E-02 | 0.00E+00 | 2.2267E-01 | 1.0757E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9559140 | 0.9778160 | 0.9797820 | 0.9930000 | 1.0000000 | 1.5596E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.54E-03 | 1.33E-02 | 1.13E-02 | 3.07E-02 | 0.00E+00 | 2.1142E+00 | 1.5738E+02 |
| $\alpha_3$ | 2.98E-04 | 6.13E-03 | 4.23E-03 | 1.84E-02 | 0.00E+00 | 9.7738E-01 | 1.5852E+02 |
| $\alpha_4$ | 1.54E-06 | 2.35E-03 | 7.89E-04 | 9.97E-03 | 0.00E+00 | 3.7439E-01 | 1.5912E+02 |
| $\alpha_5$ | 3.74E-21 | 4.53E-04 | 2.56E-07 | 2.62E-03 | 0.00E+00 | 7.2277E-02 | 1.5943E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9553410 | 0.9763630 | 0.9781000 | 0.9914630 | 1.0000000 | 1.7674E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.54E-03 | 1.24E-02 | 1.06E-02 | 2.82E-02 | 0.00E+00 | 2.2392E+00 | 1.7878E+02 |
| $\alpha_3$ | 4.43E-04 | 6.31E-03 | 4.61E-03 | 1.80E-02 | 0.00E+00 | 1.1418E+00 | 1.7988E+02 |
| $\alpha_4$ | 2.92E-05 | 3.27E-03 | 1.71E-03 | 1.18E-02 | 0.00E+00 | 5.9222E-01 | 1.8043E+02 |
| $\alpha_5$ | 5.13E-09 | 1.23E-03 | 1.66E-04 | 6.15E-03 | 0.00E+00 | 2.2220E-01 | 1.8080E+02 |
| $\alpha_6$ | 7.78E-19 | 4.60E-04 | 8.04E-07 | 2.68E-03 | 0.00E+00 | 8.3237E-02 | 1.8094E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9559450 | 0.9742500 | 0.9755060 | 0.9882740 | 1.0000000 | 2.4385E+02 | 6.4450E+00 |
| $\alpha_2$ | 3.47E-03 | 1.23E-02 | 1.11E-02 | 2.56E-02 | 0.00E+00 | 3.0878E+00 | 2.4721E+02 |
| $\alpha_3$ | 8.77E-04 | 6.52E-03 | 5.26E-03 | 1.65E-02 | 0.00E+00 | 1.6312E+00 | 2.4866E+02 |
| $\alpha_4$ | 1.98E-04 | 3.95E-03 | 2.73E-03 | 1.19E-02 | 0.00E+00 | 9.8887E-01 | 2.4931E+02 |
| $\alpha_5$ | 1.02E-05 | 2.08E-03 | 9.86E-04 | 7.88E-03 | 0.00E+00 | 5.2177E-01 | 2.4977E+02 |
| $\alpha_6$ | 2.68E-10 | 7.44E-04 | 6.35E-05 | 3.91E-03 | 0.00E+00 | 1.8628E-01 | 2.5011E+02 |
| $\alpha_7$ | 0.00E+00 | 1.16E-04 | 1.02E-13 | 4.37E-04 | 0.00E+00 | 2.9071E-02 | 2.5027E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9567850 | 0.9739120 | 0.9750110 | 0.9872950 | 1.0000000 | 2.7853E+02 | 7.4610E+00 |
| $\alpha_2$ | 3.51E-03 | 1.17E-02 | 1.06E-02 | 2.37E-02 | 0.00E+00 | 3.3447E+00 | 2.8265E+02 |
| $\alpha_3$ | 8.99E-04 | 6.08E-03 | 4.97E-03 | 1.50E-02 | 0.00E+00 | 1.7384E+00 | 2.8425E+02 |
| $\alpha_4$ | 2.84E-04 | 4.01E-03 | 2.93E-03 | 1.14E-02 | 0.00E+00 | 1.1465E+00 | 2.8484E+02 |
| $\alpha_5$ | 4.51E-05 | 2.48E-03 | 1.46E-03 | 8.38E-03 | 0.00E+00 | 7.0833E-01 | 2.8528E+02 |
| $\alpha_6$ | 7.26E-07 | 1.28E-03 | 4.20E-04 | 5.49E-03 | 0.00E+00 | 3.6696E-01 | 2.8562E+02 |
| $\alpha_7$ | 5.69E-14 | 4.30E-04 | 7.73E-06 | 2.45E-03 | 0.00E+00 | 1.2297E-01 | 2.8587E+02 |
| $\alpha_8$ | 1.07E-42 | 1.16E-04 | 1.65E-12 | 4.89E-04 | 0.00E+00 | 3.3124E-02 | 2.8596E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 59.80 | 59.80 | 59.80 | 59.80 | 59.80 | 59.80 | 59.80 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

### 1.13.2.3 ACP 4160 AND 6.9 CIRCUIT BREAKERS SPURIOUS OP SPAR: CRB-CO

| | |
|---|---|
| **System :** | Plant ac power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Spurious operation open or close |
| **Component Group :** | 4160 - 6900 Volt |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 34.50
Total Number of Common-Cause Failure Events: 3

#### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8873580 | 0.9699960 | 0.9855150 | 0.9998620 | 0.9878150 | 1.6569E+01 | 5.1252E-01 |
| $\alpha_2$ | 1.40E-04 | 3.00E-02 | 1.45E-02 | 1.13E-01 | 1.22E-02 | 5.1252E-01 | 1.6569E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9113590 | 0.9667450 | 0.9741620 | 0.9967340 | 0.9753380 | 3.8801E+01 | 1.3347E+00 |
| $\alpha_2$ | 1.64E-03 | 2.66E-02 | 1.92E-02 | 7.68E-02 | 2.46E-02 | 1.0673E+00 | 3.9068E+01 |
| $\alpha_3$ | 2.36E-07 | 6.66E-03 | 1.35E-03 | 3.16E-02 | 2.11E-05 | 2.6742E-01 | 3.9868E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9144750 | 0.9616040 | 0.9665900 | 0.9916710 | 0.9625990 | 5.8150E+01 | 2.3219E+00 |
| $\alpha_2$ | 4.06E-03 | 2.80E-02 | 2.30E-02 | 6.92E-02 | 3.74E-02 | 1.6943E+00 | 5.8778E+01 |
| $\alpha_3$ | 7.62E-06 | 6.70E-03 | 2.49E-03 | 2.76E-02 | 4.81E-05 | 4.0491E-01 | 6.0067E+01 |
| $\alpha_4$ | 1.59E-08 | 3.68E-03 | 5.04E-04 | 1.84E-02 | 0.00E+00 | 2.2267E-01 | 6.0249E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9296580 | 0.9625100 | 0.9651600 | 0.9862920 | 0.9495530 | 1.1079E+02 | 4.3153E+00 |
| $\alpha_2$ | 6.71E-03 | 2.51E-02 | 2.24E-02 | 5.27E-02 | 5.04E-02 | 2.8899E+00 | 1.1222E+02 |
| $\alpha_3$ | 4.17E-04 | 8.50E-03 | 5.88E-03 | 2.56E-02 | 9.09E-05 | 9.7878E-01 | 1.1413E+02 |
| $\alpha_4$ | 2.14E-06 | 3.25E-03 | 1.10E-03 | 1.38E-02 | 0.00E+00 | 3.7439E-01 | 1.1473E+02 |
| $\alpha_5$ | 5.18E-21 | 6.28E-04 | 3.55E-07 | 3.63E-03 | 0.00E+00 | 7.2277E-02 | 1.1503E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9308660 | 0.9609780 | 0.9631660 | 0.9836140 | 0.9362390 | 1.3404E+02 | 5.4430E+00 |
| $\alpha_2$ | 7.47E-03 | 2.44E-02 | 2.21E-02 | 4.89E-02 | 6.36E-02 | 3.4008E+00 | 1.3608E+02 |
| $\alpha_3$ | 5.80E-04 | 8.20E-03 | 6.00E-03 | 2.33E-02 | 1.42E-04 | 1.1444E+00 | 1.3834E+02 |
| $\alpha_4$ | 3.80E-05 | 4.25E-03 | 2.22E-03 | 1.53E-02 | 5.48E-06 | 5.9232E-01 | 1.3889E+02 |
| $\alpha_5$ | 6.66E-09 | 1.59E-03 | 2.16E-04 | 7.98E-03 | 0.00E+00 | 2.2220E-01 | 1.3926E+02 |
| $\alpha_6$ | 1.01E-18 | 5.97E-04 | 1.04E-06 | 3.48E-03 | 0.00E+00 | 8.3237E-02 | 1.3940E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9404460 | 0.9637370 | 0.9651920 | 0.9820650 | 0.9417840 | 2.0392E+02 | 7.6731E+00 |
| $\alpha_2$ | 6.82E-03 | 1.94E-02 | 1.79E-02 | 3.71E-02 | 4.85E-02 | 4.1114E+00 | 2.0748E+02 |
| $\alpha_3$ | 1.39E-03 | 8.67E-03 | 7.18E-03 | 2.11E-02 | 9.68E-03 | 1.8355E+00 | 2.0976E+02 |
| $\alpha_4$ | 2.34E-04 | 4.67E-03 | 3.24E-03 | 1.40E-02 | 9.48E-06 | 9.8907E-01 | 2.1060E+02 |
| $\alpha_5$ | 1.21E-05 | 2.47E-03 | 1.17E-03 | 9.32E-03 | 0.00E+00 | 5.2177E-01 | 2.1107E+02 |
| $\alpha_6$ | 3.18E-10 | 8.80E-04 | 7.52E-05 | 4.62E-03 | 0.00E+00 | 1.8628E-01 | 2.1141E+02 |
| $\alpha_7$ | 0.00E+00 | 1.37E-04 | 1.20E-13 | 5.17E-04 | 0.00E+00 | 2.9071E-02 | 2.1156E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9440000 | 0.9649640 | 0.9661950 | 0.9817210 | 0.9455740 | 2.4135E+02 | 8.7629E+00 |
| $\alpha_2$ | 6.17E-03 | 1.71E-02 | 1.58E-02 | 3.24E-02 | 3.91E-02 | 4.2796E+00 | 2.4583E+02 |
| $\alpha_3$ | 1.53E-03 | 8.26E-03 | 6.99E-03 | 1.93E-02 | 1.37E-02 | 2.0650E+00 | 2.4805E+02 |
| $\alpha_4$ | 3.62E-04 | 4.75E-03 | 3.51E-03 | 1.34E-02 | 1.69E-03 | 1.1869E+00 | 2.4893E+02 |
| $\alpha_5$ | 5.15E-05 | 2.83E-03 | 1.66E-03 | 9.59E-03 | 0.00E+00 | 7.0833E-01 | 2.4940E+02 |
| $\alpha_6$ | 8.30E-07 | 1.47E-03 | 4.80E-04 | 6.28E-03 | 0.00E+00 | 3.6696E-01 | 2.4975E+02 |
| $\alpha_7$ | 6.51E-14 | 4.92E-04 | 8.84E-06 | 2.80E-03 | 0.00E+00 | 1.2297E-01 | 2.4999E+02 |
| $\alpha_8$ | 1.22E-42 | 1.32E-04 | 1.89E-12 | 5.60E-04 | 0.00E+00 | 3.3124E-02 | 2.5008E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9878150 | 0.9753380 | 0.9625990 | 0.9495530 | 0.9362390 | 0.9417840 | 0.9455740 |
| $\alpha_2$ | 1.22E-02 | 2.46E-02 | 3.74E-02 | 5.04E-02 | 6.36E-02 | 4.85E-02 | 3.91E-02 |
| $\alpha_3$ | | 2.11E-05 | 4.81E-05 | 9.09E-05 | 1.42E-04 | 9.68E-03 | 1.37E-02 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 5.48E-06 | 9.48E-06 | 1.69E-03 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 9.88E-01 | 9.75E-01 | 9.63E-01 | 9.50E-01 | 9.36E-01 | 9.42E-01 | 9.46E-01 |
| Beta | 1.22E-02 | 2.47E-02 | 3.74E-02 | 5.04E-02 | 6.38E-02 | 5.82E-02 | 5.44E-02 |
| Gamma | | 8.55E-04 | 1.29E-03 | 1.80E-03 | 2.32E-03 | 1.67E-01 | 2.82E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 3.70E-02 | 9.78E-04 | 1.10E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

ACP 4160 AND 6.9 CIRCUIT BREAKERS SPURIOUS OP SPAR: CRB-CO

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 5.45 | 8.17 | 10.89 | 13.61 | 16.34 | 19.06 | 21.78 |
| $N_1$ | 0.8732 | 1.0762 | 1.1241 | 1.0173 | 0.7561 | 0.8076 | 0.8387 |
| $N_2$ | 0.0780 | 0.2336 | 0.4662 | 0.7757 | 1.1616 | 1.0236 | 0.9349 |
| $N_3$ | | 0.0002 | 0.0006 | 0.0014 | 0.0026 | 0.2043 | 0.3266 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0001 | 0.0002 | 0.0404 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.14 DC Power System - Batteries, Chargers, and Breakers

## 1.14.1 Batteries

### 1.14.1.1 DC POWER BATTERY NO OUTPUT SPAR:BAT-LP

**System :** dc power
**Component :** Battery
**Failure Mode :**
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 50.60
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9714550 | 0.9929090 | 0.9971570 | 0.9999860 | 1.0000000 | 6.0846E+01 | 4.3452E-01 |
| $\alpha_2$ | 1.27E-05 | 7.09E-03 | 2.85E-03 | 2.85E-02 | 0.00E+00 | 4.3452E-01 | 6.0846E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9610260 | 0.9864520 | 0.9901830 | 0.9991130 | 1.0000000 | 8.0155E+01 | 1.1009E+00 |
| $\alpha_2$ | 3.23E-04 | 1.03E-02 | 6.62E-03 | 3.26E-02 | 0.00E+00 | 8.3366E-01 | 8.0422E+01 |
| $\alpha_3$ | 1.15E-07 | 3.29E-03 | 6.59E-04 | 1.56E-02 | 0.00E+00 | 2.6722E-01 | 8.0989E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9546710 | 0.9811840 | 0.9843330 | 0.9969320 | 1.0000000 | 9.6736E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.02E-03 | 1.25E-02 | 9.35E-03 | 3.45E-02 | 0.00E+00 | 1.2281E+00 | 9.7363E+01 |
| $\alpha_3$ | 4.60E-06 | 4.10E-03 | 1.52E-03 | 1.70E-02 | 0.00E+00 | 4.0431E-01 | 9.8187E+01 |
| $\alpha_4$ | 9.71E-09 | 2.26E-03 | 3.08E-04 | 1.13E-02 | 0.00E+00 | 2.2267E-01 | 9.8368E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9532340 | 0.9764580 | 0.9785440 | 0.9925670 | 1.0000000 | 1.4676E+02 | 3.5382E+00 |
| $\alpha_2$ | 2.70E-03 | 1.41E-02 | 1.20E-02 | 3.26E-02 | 0.00E+00 | 2.1142E+00 | 1.4818E+02 |
| $\alpha_3$ | 3.17E-04 | 6.50E-03 | 4.49E-03 | 1.96E-02 | 0.00E+00 | 9.7738E-01 | 1.4932E+02 |
| $\alpha_4$ | 1.63E-06 | 2.49E-03 | 8.38E-04 | 1.06E-02 | 0.00E+00 | 3.7439E-01 | 1.4992E+02 |
| $\alpha_5$ | 3.97E-21 | 4.81E-04 | 2.72E-07 | 2.78E-03 | 0.00E+00 | 7.2277E-02 | 1.5023E+02 |

Batteries
DC POWER BATTERY NO OUTPUT SPAR:BAT-LP
**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9529700 | 0.9750980 | 0.9769220 | 0.9910010 | 1.0000000 | 1.6754E+02 | 4.2787E+00 |
| $\alpha_2$ | 2.67E-03 | 1.30E-02 | 1.12E-02 | 2.97E-02 | 0.00E+00 | 2.2392E+00 | 1.6958E+02 |
| $\alpha_3$ | 4.67E-04 | 6.65E-03 | 4.86E-03 | 1.89E-02 | 0.00E+00 | 1.1418E+00 | 1.7068E+02 |
| $\alpha_4$ | 3.08E-05 | 3.45E-03 | 1.80E-03 | 1.24E-02 | 0.00E+00 | 5.9222E-01 | 1.7123E+02 |
| $\alpha_5$ | 5.40E-09 | 1.29E-03 | 1.75E-04 | 6.48E-03 | 0.00E+00 | 2.2220E-01 | 1.7160E+02 |
| $\alpha_6$ | 8.20E-19 | 4.84E-04 | 8.47E-07 | 2.83E-03 | 0.00E+00 | 8.3237E-02 | 1.7174E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 50.60 | 50.60 | 50.60 | 50.60 | 50.60 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.14.2 Battery Chargers

### 1.14.2.1 DC POWER BATTERY CHARGER LOSS OF FUNCTION SPAR: BCH-FC

**System :** dc power
**Component :** Battery Charger
**Failure Mode :**

**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 0.00
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8386830 | 0.9593170 | 0.9828300 | 0.9999250 | 1.0000000 | 1.0246E+01 | 4.3452E-01 |
| $\alpha_2$ | 7.70E-05 | 4.07E-02 | 1.72E-02 | 1.61E-01 | 0.00E+00 | 4.3452E-01 | 1.0246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8979020 | 0.9640890 | 0.9736330 | 0.9976040 | 1.0000000 | 2.9555E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.71E-04 | 2.72E-02 | 1.78E-02 | 8.57E-02 | 0.00E+00 | 8.3366E-01 | 2.9822E+01 |
| $\alpha_3$ | 3.08E-07 | 8.72E-03 | 1.77E-03 | 4.13E-02 | 0.00E+00 | 2.6722E-01 | 3.0389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9077330 | 0.9613450 | 0.9675780 | 0.9936050 | 1.0000000 | 4.6136E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.13E-03 | 2.56E-02 | 1.93E-02 | 7.04E-02 | 0.00E+00 | 1.2281E+00 | 4.6763E+01 |
| $\alpha_3$ | 9.52E-06 | 8.42E-03 | 3.13E-03 | 3.48E-02 | 0.00E+00 | 4.0431E-01 | 4.7587E+01 |
| $\alpha_4$ | 2.01E-08 | 4.64E-03 | 6.37E-04 | 2.32E-02 | 0.00E+00 | 2.2267E-01 | 4.7768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9298110 | 0.9645110 | 0.9675740 | 0.9887220 | 1.0000000 | 9.6161E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.09E-03 | 2.12E-02 | 1.81E-02 | 4.90E-02 | 0.00E+00 | 2.1142E+00 | 9.7585E+01 |
| $\alpha_3$ | 4.79E-04 | 9.80E-03 | 6.78E-03 | 2.95E-02 | 0.00E+00 | 9.7738E-01 | 9.8722E+01 |
| $\alpha_4$ | 2.47E-06 | 3.76E-03 | 1.27E-03 | 1.59E-02 | 0.00E+00 | 3.7439E-01 | 9.9325E+01 |
| $\alpha_5$ | 5.99E-21 | 7.25E-04 | 4.10E-07 | 4.20E-03 | 0.00E+00 | 7.2277E-02 | 9.9627E+01 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9335790 | 0.9647030 | 0.9672350 | 0.9871780 | 1.0000000 | 1.1694E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.80E-03 | 1.85E-02 | 1.59E-02 | 4.20E-02 | 0.00E+00 | 2.2392E+00 | 1.1898E+02 |
| $\alpha_3$ | 6.64E-04 | 9.42E-03 | 6.89E-03 | 2.68E-02 | 0.00E+00 | 1.1418E+00 | 1.2008E+02 |
| $\alpha_4$ | 4.37E-05 | 4.89E-03 | 2.56E-03 | 1.76E-02 | 0.00E+00 | 5.9222E-01 | 1.2063E+02 |
| $\alpha_5$ | 7.67E-09 | 1.83E-03 | 2.49E-04 | 9.18E-03 | 0.00E+00 | 2.2220E-01 | 1.2100E+02 |
| $\alpha_6$ | 1.16E-18 | 6.87E-04 | 1.20E-06 | 4.01E-03 | 0.00E+00 | 8.3237E-02 | 1.2114E+02 |

DC POWER BATTERY CHARGER LOSS OF FUNCTION SPAR: BCH-FC

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.14.2.2 DC POWER BATTERY CHARGER NO OUTPUT SPAR:BCH-LP

**System :** dc power
**Component :** Battery Charger
**Failure Mode :**
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 253.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9933610 | 0.9983550 | 0.9993480 | 0.9999940 | 1.0000000 | 2.6375E+02 | 4.3452E-01 |
| $\alpha_2$ | 2.91E-06 | 1.64E-03 | 6.55E-04 | 6.64E-03 | 0.00E+00 | 4.3452E-01 | 2.6375E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9887990 | 0.9961260 | 0.9972130 | 0.9997480 | 1.0000000 | 2.8305E+02 | 1.1009E+00 |
| $\alpha_2$ | 9.15E-05 | 2.93E-03 | 1.88E-03 | 9.36E-03 | 0.00E+00 | 8.3366E-01 | 2.8332E+02 |
| $\alpha_3$ | 3.26E-08 | 9.40E-04 | 1.88E-04 | 4.46E-03 | 0.00E+00 | 2.6722E-01 | 2.8388E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9850910 | 0.9938470 | 0.9949020 | 0.9990030 | 1.0000000 | 2.9964E+02 | 1.8551E+00 |
| $\alpha_2$ | 3.33E-04 | 4.07E-03 | 3.04E-03 | 1.13E-02 | 0.00E+00 | 1.2281E+00 | 3.0027E+02 |
| $\alpha_3$ | 1.50E-06 | 1.34E-03 | 4.93E-04 | 5.55E-03 | 0.00E+00 | 4.0431E-01 | 3.0109E+02 |
| $\alpha_4$ | 3.16E-09 | 7.39E-04 | 1.00E-04 | 3.70E-03 | 0.00E+00 | 2.2267E-01 | 3.0127E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9799990 | 0.9899820 | 0.9908880 | 0.9968540 | 1.0000000 | 3.4966E+02 | 3.5382E+00 |
| $\alpha_2$ | 1.14E-03 | 5.99E-03 | 5.08E-03 | 1.39E-02 | 0.00E+00 | 2.1142E+00 | 3.5108E+02 |
| $\alpha_3$ | 1.34E-04 | 2.77E-03 | 1.90E-03 | 8.35E-03 | 0.00E+00 | 9.7738E-01 | 3.5222E+02 |
| $\alpha_4$ | 6.94E-07 | 1.06E-03 | 3.56E-04 | 4.50E-03 | 0.00E+00 | 3.7439E-01 | 3.5282E+02 |
| $\alpha_5$ | 1.68E-21 | 2.05E-04 | 1.15E-07 | 1.18E-03 | 0.00E+00 | 7.2277E-02 | 3.5313E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9783400 | 0.9885820 | 0.9894370 | 0.9958990 | 1.0000000 | 3.7044E+02 | 4.2787E+00 |
| $\alpha_2$ | 1.22E-03 | 5.98E-03 | 5.12E-03 | 1.36E-02 | 0.00E+00 | 2.2392E+00 | 3.7248E+02 |
| $\alpha_3$ | 2.13E-04 | 3.05E-03 | 2.22E-03 | 8.70E-03 | 0.00E+00 | 1.1418E+00 | 3.7358E+02 |
| $\alpha_4$ | 1.41E-05 | 1.58E-03 | 8.25E-04 | 5.71E-03 | 0.00E+00 | 5.9222E-01 | 3.7413E+02 |
| $\alpha_5$ | 2.47E-09 | 5.93E-04 | 8.02E-05 | 2.97E-03 | 0.00E+00 | 2.2220E-01 | 3.7450E+02 |
| $\alpha_6$ | 3.75E-19 | 2.22E-04 | 3.88E-07 | 1.29E-03 | 0.00E+00 | 8.3237E-02 | 3.7464E+02 |

DC POWER BATTERY CHARGER NO OUTPUT SPAR:BCH-LP

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 253.50 | 253.50 | 253.50 | 253.50 | 253.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

# 1.14.3 DC Power Distribution Circuit Breakers

## 1.14.3.1 DC POWER BREAKER FAIL TO OPEN

**System :** dc power
**Component :** Circuit Breaker
**Failure Mode :** Fail to open on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 1.50
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8581890 | 0.9643270 | 0.9850590 | 0.9999350 | 1.0000000 | 1.1746E+01 | 4.3452E-01 |
| $\alpha_2$ | 6.69E-05 | 3.57E-02 | 1.49E-02 | 1.42E-01 | 0.00E+00 | 4.3452E-01 | 1.1746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9025780 | 0.9657640 | 0.9748880 | 0.9977200 | 1.0000000 | 3.1055E+01 | 1.1009E+00 |
| $\alpha_2$ | 8.29E-04 | 2.59E-02 | 1.69E-02 | 8.18E-02 | 0.00E+00 | 8.3366E-01 | 3.1322E+01 |
| $\alpha_3$ | 2.93E-07 | 8.31E-03 | 1.69E-03 | 3.94E-02 | 0.00E+00 | 2.6722E-01 | 3.1889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9104790 | 0.9625170 | 0.9685780 | 0.9938040 | 1.0000000 | 4.7636E+01 | 1.8551E+00 |
| $\alpha_2$ | 2.06E-03 | 2.48E-02 | 1.87E-02 | 6.83E-02 | 0.00E+00 | 1.2281E+00 | 4.8263E+01 |
| $\alpha_3$ | 9.23E-06 | 8.17E-03 | 3.04E-03 | 3.37E-02 | 0.00E+00 | 4.0431E-01 | 4.9087E+01 |
| $\alpha_4$ | 1.95E-08 | 4.50E-03 | 6.18E-04 | 2.25E-02 | 0.00E+00 | 2.2267E-01 | 4.9268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9308380 | 0.9650370 | 0.9680620 | 0.9888920 | 1.0000000 | 9.7661E+01 | 3.5382E+00 |
| $\alpha_2$ | 4.03E-03 | 2.09E-02 | 1.78E-02 | 4.83E-02 | 0.00E+00 | 2.1142E+00 | 9.9085E+01 |
| $\alpha_3$ | 4.72E-04 | 9.66E-03 | 6.68E-03 | 2.90E-02 | 0.00E+00 | 9.7738E-01 | 1.0022E+02 |
| $\alpha_4$ | 2.43E-06 | 3.70E-03 | 1.25E-03 | 1.57E-02 | 0.00E+00 | 3.7439E-01 | 1.0082E+02 |
| $\alpha_5$ | 5.90E-21 | 7.14E-04 | 4.04E-07 | 4.14E-03 | 0.00E+00 | 7.2277E-02 | 1.0113E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9343810 | 0.9651340 | 0.9676320 | 0.9873370 | 1.0000000 | 1.1844E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.75E-03 | 1.82E-02 | 1.57E-02 | 4.15E-02 | 0.00E+00 | 2.2392E+00 | 1.2048E+02 |
| $\alpha_3$ | 6.56E-04 | 9.30E-03 | 6.81E-03 | 2.65E-02 | 0.00E+00 | 1.1418E+00 | 1.2158E+02 |
| $\alpha_4$ | 4.32E-05 | 4.83E-03 | 2.53E-03 | 1.74E-02 | 0.00E+00 | 5.9222E-01 | 1.2213E+02 |
| $\alpha_5$ | 7.57E-09 | 1.81E-03 | 2.46E-04 | 9.07E-03 | 0.00E+00 | 2.2220E-01 | 1.2250E+02 |
| $\alpha_6$ | 1.15E-18 | 6.78E-04 | 1.19E-06 | 3.96E-03 | 0.00E+00 | 8.3237E-02 | 1.2264E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9426990 | 0.9664310 | 0.9680420 | 0.9846650 | 1.0000000 | 1.8555E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.53E-03 | 1.61E-02 | 1.44E-02 | 3.33E-02 | 0.00E+00 | 3.0878E+00 | 1.8891E+02 |
| $\alpha_3$ | 1.15E-03 | 8.50E-03 | 6.86E-03 | 2.14E-02 | 0.00E+00 | 1.6312E+00 | 1.9036E+02 |
| $\alpha_4$ | 2.58E-04 | 5.15E-03 | 3.57E-03 | 1.55E-02 | 0.00E+00 | 9.8887E-01 | 1.9101E+02 |
| $\alpha_5$ | 1.34E-05 | 2.72E-03 | 1.29E-03 | 1.03E-02 | 0.00E+00 | 5.2177E-01 | 1.9147E+02 |
| $\alpha_6$ | 3.50E-10 | 9.70E-04 | 8.29E-05 | 5.09E-03 | 0.00E+00 | 1.8628E-01 | 1.9181E+02 |
| $\alpha_7$ | 0.00E+00 | 1.51E-04 | 1.33E-13 | 5.70E-04 | 0.00E+00 | 2.9071E-02 | 1.9197E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9458180 | 0.9672320 | 0.9685940 | 0.9840060 | 1.0000000 | 2.2023E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.42E-03 | 1.47E-02 | 1.33E-02 | 2.97E-02 | 0.00E+00 | 3.3447E+00 | 2.2435E+02 |
| $\alpha_3$ | 1.13E-03 | 7.63E-03 | 6.25E-03 | 1.89E-02 | 0.00E+00 | 1.7384E+00 | 2.2595E+02 |
| $\alpha_4$ | 3.57E-04 | 5.04E-03 | 3.68E-03 | 1.43E-02 | 0.00E+00 | 1.1465E+00 | 2.2654E+02 |
| $\alpha_5$ | 5.66E-05 | 3.11E-03 | 1.83E-03 | 1.05E-02 | 0.00E+00 | 7.0833E-01 | 2.2698E+02 |
| $\alpha_6$ | 9.12E-07 | 1.61E-03 | 5.28E-04 | 6.89E-03 | 0.00E+00 | 3.6696E-01 | 2.2732E+02 |
| $\alpha_7$ | 7.15E-14 | 5.40E-04 | 9.71E-06 | 3.07E-03 | 0.00E+00 | 1.2297E-01 | 2.2757E+02 |
| $\alpha_8$ | 1.34E-42 | 1.45E-04 | 2.07E-12 | 6.15E-04 | 0.00E+00 | 3.3124E-02 | 2.2766E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

DC Power Distribution Circuit Breakers
DC POWER BREAKER FAIL TO OPEN

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.14.3.2 DC POWER BREAKER FAIL TO CLOSE

**System :** dc power
**Component :** Circuit Breaker
**Failure Mode :** Fail to close (reseat) on demand
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 9.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9116630 | 0.9779210 | 0.9909360 | 0.9999560 | 1.0000000 | 1.9246E+01 | 4.3452E-01 |
| $\alpha_2$ | 4.05E-05 | 2.21E-02 | 9.06E-03 | 8.83E-02 | 0.00E+00 | 4.3452E-01 | 1.9246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9207320 | 0.9722390 | 0.9797180 | 0.9981670 | 1.0000000 | 3.8555E+01 | 1.1009E+00 |
| $\alpha_2$ | 6.69E-04 | 2.10E-02 | 1.37E-02 | 6.65E-02 | 0.00E+00 | 8.3366E-01 | 3.8822E+01 |
| $\alpha_3$ | 2.37E-07 | 6.74E-03 | 1.36E-03 | 3.20E-02 | 0.00E+00 | 2.6722E-01 | 3.9389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9220800 | 0.9674500 | 0.9727570 | 0.9946390 | 1.0000000 | 5.5136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.79E-03 | 2.15E-02 | 1.63E-02 | 5.94E-02 | 0.00E+00 | 1.2281E+00 | 5.5763E+01 |
| $\alpha_3$ | 8.00E-06 | 7.09E-03 | 2.63E-03 | 2.93E-02 | 0.00E+00 | 4.0431E-01 | 5.6587E+01 |
| $\alpha_4$ | 1.69E-08 | 3.91E-03 | 5.36E-04 | 1.96E-02 | 0.00E+00 | 2.2267E-01 | 5.6768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9355510 | 0.9674490 | 0.9702750 | 0.9896710 | 1.0000000 | 1.0516E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.75E-03 | 1.95E-02 | 1.66E-02 | 4.50E-02 | 0.00E+00 | 2.1142E+00 | 1.0658E+02 |
| $\alpha_3$ | 4.39E-04 | 8.99E-03 | 6.21E-03 | 2.70E-02 | 0.00E+00 | 9.7738E-01 | 1.0772E+02 |
| $\alpha_4$ | 2.26E-06 | 3.44E-03 | 1.16E-03 | 1.46E-02 | 0.00E+00 | 3.7439E-01 | 1.0832E+02 |
| $\alpha_5$ | 5.49E-21 | 6.65E-04 | 3.76E-07 | 3.85E-03 | 0.00E+00 | 7.2277E-02 | 1.0863E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9381170 | 0.9671430 | 0.9695070 | 0.9880770 | 1.0000000 | 1.2594E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.53E-03 | 1.72E-02 | 1.48E-02 | 3.91E-02 | 0.00E+00 | 2.2392E+00 | 1.2798E+02 |
| $\alpha_3$ | 6.17E-04 | 8.77E-03 | 6.41E-03 | 2.50E-02 | 0.00E+00 | 1.1418E+00 | 1.2908E+02 |
| $\alpha_4$ | 4.07E-05 | 4.55E-03 | 2.38E-03 | 1.64E-02 | 0.00E+00 | 5.9222E-01 | 1.2963E+02 |
| $\alpha_5$ | 7.13E-09 | 1.71E-03 | 2.31E-04 | 8.55E-03 | 0.00E+00 | 2.2220E-01 | 1.3000E+02 |
| $\alpha_6$ | 1.08E-18 | 6.39E-04 | 1.12E-06 | 3.73E-03 | 0.00E+00 | 8.3237E-02 | 1.3014E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9448370 | 0.9676930 | 0.9692440 | 0.9852520 | 1.0000000 | 1.9305E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.36E-03 | 1.55E-02 | 1.39E-02 | 3.20E-02 | 0.00E+00 | 3.0878E+00 | 1.9641E+02 |
| $\alpha_3$ | 1.10E-03 | 8.18E-03 | 6.60E-03 | 2.06E-02 | 0.00E+00 | 1.6312E+00 | 1.9786E+02 |
| $\alpha_4$ | 2.48E-04 | 4.96E-03 | 3.43E-03 | 1.49E-02 | 0.00E+00 | 9.8887E-01 | 1.9851E+02 |
| $\alpha_5$ | 1.29E-05 | 2.62E-03 | 1.24E-03 | 9.88E-03 | 0.00E+00 | 5.2177E-01 | 1.9897E+02 |
| $\alpha_6$ | 3.37E-10 | 9.34E-04 | 7.97E-05 | 4.90E-03 | 0.00E+00 | 1.8628E-01 | 1.9931E+02 |
| $\alpha_7$ | 0.00E+00 | 1.46E-04 | 1.28E-13 | 5.49E-04 | 0.00E+00 | 2.9071E-02 | 1.9947E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9475310 | 0.9682770 | 0.9695950 | 0.9845210 | 1.0000000 | 2.2773E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.28E-03 | 1.42E-02 | 1.29E-02 | 2.88E-02 | 0.00E+00 | 3.3447E+00 | 2.3185E+02 |
| $\alpha_3$ | 1.09E-03 | 7.39E-03 | 6.05E-03 | 1.83E-02 | 0.00E+00 | 1.7384E+00 | 2.3345E+02 |
| $\alpha_4$ | 3.45E-04 | 4.87E-03 | 3.56E-03 | 1.39E-02 | 0.00E+00 | 1.1465E+00 | 2.3404E+02 |
| $\alpha_5$ | 5.48E-05 | 3.01E-03 | 1.77E-03 | 1.02E-02 | 0.00E+00 | 7.0833E-01 | 2.3448E+02 |
| $\alpha_6$ | 8.83E-07 | 1.56E-03 | 5.11E-04 | 6.67E-03 | 0.00E+00 | 3.6696E-01 | 2.3482E+02 |
| $\alpha_7$ | 6.92E-14 | 5.23E-04 | 9.40E-06 | 2.98E-03 | 0.00E+00 | 1.2297E-01 | 2.3507E+02 |
| $\alpha_8$ | 1.30E-42 | 1.41E-04 | 2.01E-12 | 5.95E-04 | 0.00E+00 | 3.3124E-02 | 2.3516E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

DC Power Distribution Circuit Breakers
DC POWER BREAKER FAIL TO CLOSE

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 | 9.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

## 1.14.3.3 DC POWER BREAKER SPURIOUS ACTUATION

| | |
|---|---|
| **System :** | dc power |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Spurious operation open or close |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 14.00
Total Number of Common-Cause Failure Events: 0

### *ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9294220 | 0.9823940 | 0.9928250 | 0.9999650 | 1.0000000 | 2.4246E+01 | 4.3452E-01 |
| $\alpha_2$ | 3.20E-05 | 1.76E-02 | 7.18E-03 | 7.06E-02 | 0.00E+00 | 4.3452E-01 | 2.4246E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9294880 | 0.9753470 | 0.9820230 | 0.9983720 | 1.0000000 | 4.3555E+01 | 1.1009E+00 |
| $\alpha_2$ | 5.92E-04 | 1.87E-02 | 1.21E-02 | 5.91E-02 | 0.00E+00 | 8.3366E-01 | 4.3822E+01 |
| $\alpha_3$ | 2.10E-07 | 5.98E-03 | 1.21E-03 | 2.84E-02 | 0.00E+00 | 2.6722E-01 | 4.4389E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9282810 | 0.9700750 | 0.9749830 | 0.9950760 | 1.0000000 | 6.0136E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.64E-03 | 1.98E-02 | 1.49E-02 | 5.47E-02 | 0.00E+00 | 1.2281E+00 | 6.0763E+01 |
| $\alpha_3$ | 7.35E-06 | 6.52E-03 | 2.42E-03 | 2.69E-02 | 0.00E+00 | 4.0431E-01 | 6.1587E+01 |
| $\alpha_4$ | 1.55E-08 | 3.59E-03 | 4.92E-04 | 1.80E-02 | 0.00E+00 | 2.2267E-01 | 6.1768E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9383530 | 0.9688800 | 0.9715890 | 0.9901320 | 1.0000000 | 1.1016E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.58E-03 | 1.86E-02 | 1.59E-02 | 4.30E-02 | 0.00E+00 | 2.1142E+00 | 1.1158E+02 |
| $\alpha_3$ | 4.20E-04 | 8.60E-03 | 5.94E-03 | 2.58E-02 | 0.00E+00 | 9.7738E-01 | 1.1272E+02 |
| $\alpha_4$ | 2.16E-06 | 3.29E-03 | 1.11E-03 | 1.40E-02 | 0.00E+00 | 3.7439E-01 | 1.1332E+02 |
| $\alpha_5$ | 5.25E-21 | 6.36E-04 | 3.59E-07 | 3.68E-03 | 0.00E+00 | 7.2277E-02 | 1.1363E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9403810 | 0.9683580 | 0.9706390 | 0.9885240 | 1.0000000 | 1.3094E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.40E-03 | 1.66E-02 | 1.42E-02 | 3.77E-02 | 0.00E+00 | 2.2392E+00 | 1.3298E+02 |
| $\alpha_3$ | 5.94E-04 | 8.44E-03 | 6.18E-03 | 2.40E-02 | 0.00E+00 | 1.1418E+00 | 1.3408E+02 |
| $\alpha_4$ | 3.92E-05 | 4.38E-03 | 2.29E-03 | 1.58E-02 | 0.00E+00 | 5.9222E-01 | 1.3463E+02 |
| $\alpha_5$ | 6.87E-09 | 1.64E-03 | 2.23E-04 | 8.23E-03 | 0.00E+00 | 2.2220E-01 | 1.3500E+02 |
| $\alpha_6$ | 1.04E-18 | 6.16E-04 | 1.08E-06 | 3.59E-03 | 0.00E+00 | 8.3237E-02 | 1.3514E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9461730 | 0.9684830 | 0.9699980 | 0.9856130 | 1.0000000 | 1.9805E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.25E-03 | 1.51E-02 | 1.35E-02 | 3.12E-02 | 0.00E+00 | 3.0878E+00 | 2.0141E+02 |
| $\alpha_3$ | 1.07E-03 | 7.98E-03 | 6.44E-03 | 2.01E-02 | 0.00E+00 | 1.6312E+00 | 2.0286E+02 |
| $\alpha_4$ | 2.42E-04 | 4.84E-03 | 3.35E-03 | 1.45E-02 | 0.00E+00 | 9.8887E-01 | 2.0351E+02 |
| $\alpha_5$ | 1.25E-05 | 2.55E-03 | 1.21E-03 | 9.64E-03 | 0.00E+00 | 5.2177E-01 | 2.0397E+02 |
| $\alpha_6$ | 3.29E-10 | 9.11E-04 | 7.78E-05 | 4.78E-03 | 0.00E+00 | 1.8628E-01 | 2.0431E+02 |
| $\alpha_7$ | 0.00E+00 | 1.42E-04 | 1.24E-13 | 5.35E-04 | 0.00E+00 | 2.9071E-02 | 2.0447E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9486090 | 0.9689370 | 0.9702290 | 0.9848460 | 1.0000000 | 2.3273E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.19E-03 | 1.39E-02 | 1.26E-02 | 2.82E-02 | 0.00E+00 | 3.3447E+00 | 2.3685E+02 |
| $\alpha_3$ | 1.07E-03 | 7.24E-03 | 5.92E-03 | 1.79E-02 | 0.00E+00 | 1.7384E+00 | 2.3845E+02 |
| $\alpha_4$ | 3.38E-04 | 4.77E-03 | 3.49E-03 | 1.36E-02 | 0.00E+00 | 1.1465E+00 | 2.3904E+02 |
| $\alpha_5$ | 5.37E-05 | 2.95E-03 | 1.73E-03 | 9.98E-03 | 0.00E+00 | 7.0833E-01 | 2.3948E+02 |
| $\alpha_6$ | 8.65E-07 | 1.53E-03 | 5.00E-04 | 6.54E-03 | 0.00E+00 | 3.6696E-01 | 2.3982E+02 |
| $\alpha_7$ | 6.78E-14 | 5.12E-04 | 9.21E-06 | 2.91E-03 | 0.00E+00 | 1.2297E-01 | 2.4007E+02 |
| $\alpha_8$ | 1.27E-42 | 1.38E-04 | 1.97E-12 | 5.83E-04 | 0.00E+00 | 3.3124E-02 | 2.4016E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

DC Power Distribution Circuit Breakers
DC POWER BREAKER SPURIOUS ACTUATION

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 | 14.00 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.15 Reactor Protection System, Reactor Trip Breakers

## 1.15.1 Reactor Trip Breakers

### 1.15.1.1 REACTOR TRIP BREAKERS FAIL TO OPEN

| | |
|---|---|
| **System :** | Reactor protection |
| **Component :** | Circuit Breaker |
| **Failure Mode :** | Fail to open on demand |
| **Component Group :** | Reactor Trip Breaker |
| **Start Date :** | 1997/01/01 |
| **Data Version :** | 2010/12/31 |

Total Number of Independent Failure Events: 4.50
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8858260 | 0.9713760 | 0.9881340 | 0.9999430 | 1.0000000 | 1.4746E+01 | 4.3452E-01 |
| $\alpha_2$ | 5.30E-05 | 2.86E-02 | 1.19E-02 | 1.14E-01 | 0.00E+00 | 4.3452E-01 | 1.4746E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9107480 | 0.9686860 | 0.9770720 | 0.9979200 | 1.0000000 | 3.4055E+01 | 1.1009E+00 |
| $\alpha_2$ | 7.57E-04 | 2.37E-02 | 1.55E-02 | 7.49E-02 | 0.00E+00 | 8.3366E-01 | 3.4322E+01 |
| $\alpha_3$ | 2.68E-07 | 7.60E-03 | 1.54E-03 | 3.61E-02 | 0.00E+00 | 2.6722E-01 | 3.4889E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9155110 | 0.9646590 | 0.9703930 | 0.9941670 | 1.0000000 | 5.0636E+01 | 1.8551E+00 |
| $\alpha_2$ | 1.94E-03 | 2.34E-02 | 1.77E-02 | 6.45E-02 | 0.00E+00 | 1.2281E+00 | 5.1263E+01 |
| $\alpha_3$ | 8.69E-06 | 7.70E-03 | 2.86E-03 | 3.18E-02 | 0.00E+00 | 4.0431E-01 | 5.2087E+01 |
| $\alpha_4$ | 1.83E-08 | 4.24E-03 | 5.82E-04 | 2.13E-02 | 0.00E+00 | 2.2267E-01 | 5.2268E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9328030 | 0.9660430 | 0.9689890 | 0.9892170 | 1.0000000 | 1.0066E+02 | 3.5382E+00 |
| $\alpha_2$ | 3.91E-03 | 2.03E-02 | 1.73E-02 | 4.69E-02 | 0.00E+00 | 2.1142E+00 | 1.0208E+02 |
| $\alpha_3$ | 4.58E-04 | 9.38E-03 | 6.48E-03 | 2.82E-02 | 0.00E+00 | 9.7738E-01 | 1.0322E+02 |
| $\alpha_4$ | 2.36E-06 | 3.59E-03 | 1.21E-03 | 1.53E-02 | 0.00E+00 | 3.7439E-01 | 1.0382E+02 |
| $\alpha_5$ | 5.73E-21 | 6.94E-04 | 3.92E-07 | 4.02E-03 | 0.00E+00 | 7.2277E-02 | 1.0413E+02 |

REACTOR TRIP BREAKERS FAIL TO OPEN

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9359280 | 0.9659660 | 0.9684130 | 0.9876440 | 1.0000000 | 1.2144E+02 | 4.2787E+00 |
| $\alpha_2$ | 3.66E-03 | 1.78E-02 | 1.53E-02 | 4.05E-02 | 0.00E+00 | 2.2392E+00 | 1.2348E+02 |
| $\alpha_3$ | 6.40E-04 | 9.08E-03 | 6.64E-03 | 2.59E-02 | 0.00E+00 | 1.1418E+00 | 1.2458E+02 |
| $\alpha_4$ | 4.21E-05 | 4.71E-03 | 2.47E-03 | 1.70E-02 | 0.00E+00 | 5.9222E-01 | 1.2513E+02 |
| $\alpha_5$ | 7.39E-09 | 1.77E-03 | 2.40E-04 | 8.86E-03 | 0.00E+00 | 2.2220E-01 | 1.2550E+02 |
| $\alpha_6$ | 1.12E-18 | 6.62E-04 | 1.16E-06 | 3.86E-03 | 0.00E+00 | 8.3237E-02 | 1.2564E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9435720 | 0.9669480 | 0.9685360 | 0.9849040 | 1.0000000 | 1.8855E+02 | 6.4450E+00 |
| $\alpha_2$ | 4.46E-03 | 1.58E-02 | 1.42E-02 | 3.28E-02 | 0.00E+00 | 3.0878E+00 | 1.9191E+02 |
| $\alpha_3$ | 1.13E-03 | 8.37E-03 | 6.75E-03 | 2.11E-02 | 0.00E+00 | 1.6312E+00 | 1.9336E+02 |
| $\alpha_4$ | 2.54E-04 | 5.07E-03 | 3.51E-03 | 1.52E-02 | 0.00E+00 | 9.8887E-01 | 1.9401E+02 |
| $\alpha_5$ | 1.32E-05 | 2.68E-03 | 1.27E-03 | 1.01E-02 | 0.00E+00 | 5.2177E-01 | 1.9447E+02 |
| $\alpha_6$ | 3.45E-10 | 9.55E-04 | 8.16E-05 | 5.01E-03 | 0.00E+00 | 1.8628E-01 | 1.9481E+02 |
| $\alpha_7$ | 0.00E+00 | 1.49E-04 | 1.31E-13 | 5.61E-04 | 0.00E+00 | 2.9071E-02 | 1.9497E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9465160 | 0.9676580 | 0.9690050 | 0.9842160 | 1.0000000 | 2.2323E+02 | 7.4610E+00 |
| $\alpha_2$ | 4.36E-03 | 1.45E-02 | 1.31E-02 | 2.93E-02 | 0.00E+00 | 3.3447E+00 | 2.2735E+02 |
| $\alpha_3$ | 1.12E-03 | 7.54E-03 | 6.17E-03 | 1.86E-02 | 0.00E+00 | 1.7384E+00 | 2.2895E+02 |
| $\alpha_4$ | 3.52E-04 | 4.97E-03 | 3.63E-03 | 1.42E-02 | 0.00E+00 | 1.1465E+00 | 2.2954E+02 |
| $\alpha_5$ | 5.59E-05 | 3.07E-03 | 1.80E-03 | 1.04E-02 | 0.00E+00 | 7.0833E-01 | 2.2998E+02 |
| $\alpha_6$ | 9.00E-07 | 1.59E-03 | 5.21E-04 | 6.80E-03 | 0.00E+00 | 3.6696E-01 | 2.3032E+02 |
| $\alpha_7$ | 7.06E-14 | 5.33E-04 | 9.59E-06 | 3.03E-03 | 0.00E+00 | 1.2297E-01 | 2.3057E+02 |
| $\alpha_8$ | 1.32E-42 | 1.44E-04 | 2.05E-12 | 6.07E-04 | 0.00E+00 | 3.3124E-02 | 2.3066E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 | 1.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

Reactor Trip Breakers
REACTOR TRIP BREAKERS FAIL TO OPEN

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| Adj. Ind. Events | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 | 4.50 |
| $N_1$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_3$ | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_5$ | | | | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 | 0.0000 | 0.0000 |
| $N_7$ | | | | | | 0.0000 | 0.0000 |
| $N_8$ | | | | | | | 0.0000 |

# 1.16 Air Compressors

## 1.16.1 Motor-Driven Air Compressors

### 1.16.1.1 MOTOR DRIVEN AIR COMPRESSOR FAIL TO START

**Component :** Compressor
**Failure Mode :** Fail to start
**Component Group :** Motor Driven
**Start Date :** 1998/01/01
**Data Version :** 2010/12/31

## Total Number of Independent Failure Events: 217.60
## Total Number of Common-Cause Failure Events: 2

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9791990 | 0.9936620 | 0.9960890 | 0.9998490 | 0.9969830 | 1.2038E+02 | 7.6782E-01 |
| $\alpha_2$ | 1.53E-04 | 6.34E-03 | 3.91E-03 | 2.08E-02 | 3.02E-03 | 7.6782E-01 | 1.2038E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9750620 | 0.9892730 | 0.9908910 | 0.9979580 | 0.9939470 | 1.9376E+02 | 2.1009E+00 |
| $\alpha_2$ | 1.49E-03 | 9.36E-03 | 7.75E-03 | 2.27E-02 | 6.05E-03 | 1.8337E+00 | 1.9403E+02 |
| $\alpha_3$ | 4.73E-08 | 1.36E-03 | 2.72E-04 | 6.47E-03 | 0.00E+00 | 2.6722E-01 | 1.9559E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9719390 | 0.9855940 | 0.9867890 | 0.9951750 | 0.9908930 | 2.6374E+02 | 3.8551E+00 |
| $\alpha_2$ | 3.52E-03 | 1.21E-02 | 1.09E-02 | 2.47E-02 | 9.11E-03 | 3.2281E+00 | 2.6437E+02 |
| $\alpha_3$ | 1.69E-06 | 1.51E-03 | 5.56E-04 | 6.25E-03 | 0.00E+00 | 4.0431E-01 | 2.6719E+02 |
| $\alpha_4$ | 3.56E-09 | 8.32E-04 | 1.13E-04 | 4.17E-03 | 0.00E+00 | 2.2267E-01 | 2.6737E+02 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9736570 | 0.9851800 | 0.9860350 | 0.9937800 | 0.9927010 | 3.6816E+02 | 5.5383E+00 |
| $\alpha_2$ | 2.84E-03 | 9.23E-03 | 8.37E-03 | 1.86E-02 | 4.87E-03 | 3.4475E+00 | 3.7025E+02 |
| $\alpha_3$ | 5.98E-04 | 4.40E-03 | 3.55E-03 | 1.11E-02 | 2.43E-03 | 1.6441E+00 | 3.7205E+02 |
| $\alpha_4$ | 6.56E-07 | 1.00E-03 | 3.36E-04 | 4.26E-03 | 0.00E+00 | 3.7439E-01 | 3.7332E+02 |
| $\alpha_5$ | 1.59E-21 | 1.93E-04 | 1.09E-07 | 1.12E-03 | 0.00E+00 | 7.2277E-02 | 3.7363E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9758880 | 0.9860360 | 0.9867480 | 0.9937490 | 0.9939100 | 4.4334E+02 | 6.2787E+00 |
| $\alpha_2$ | 1.97E-03 | 6.96E-03 | 6.24E-03 | 1.44E-02 | 2.71E-03 | 3.1281E+00 | 4.4649E+02 |
| $\alpha_3$ | 8.20E-04 | 4.52E-03 | 3.81E-03 | 1.06E-02 | 2.71E-03 | 2.0307E+00 | 4.4759E+02 |
| $\alpha_4$ | 5.25E-05 | 1.81E-03 | 1.15E-03 | 5.83E-03 | 6.77E-04 | 8.1442E-01 | 4.4880E+02 |
| $\alpha_5$ | 2.06E-09 | 4.94E-04 | 6.68E-05 | 2.48E-03 | 0.00E+00 | 2.2220E-01 | 4.4940E+02 |
| $\alpha_6$ | 3.13E-19 | 1.85E-04 | 3.23E-07 | 1.08E-03 | 0.00E+00 | 8.3237E-02 | 4.4954E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9969830 | 0.9939470 | 0.9908930 | 0.9927010 | 0.9939100 |
| $\alpha_2$ | 3.02E-03 | 6.05E-03 | 9.11E-03 | 4.87E-03 | 2.71E-03 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 2.43E-03 | 2.71E-03 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 6.77E-04 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.97E-01 | 9.94E-01 | 9.91E-01 | 9.93E-01 | 9.94E-01 |
| Beta | 3.02E-03 | 6.05E-03 | 9.11E-03 | 7.30E-03 | 6.09E-03 |
| Gamma | | 0.00E+00 | 0.00E+00 | 3.33E-01 | 5.56E-01 |
| Delta | | | 0.00E+00 | 0.00E+00 | 2.00E-01 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 108.80 | 163.20 | 217.60 | 272.00 | 326.40 |
| $N_1$ | 1.3333 | 1.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 0.3333 | 1.0000 | 2.0000 | 1.3333 | 0.8889 |
| $N_3$ | | 0.0000 | 0.0000 | 0.6667 | 0.8889 |
| $N_4$ | | | 0.0000 | 0.0000 | 0.2222 |
| $N_5$ | | | | 0.0000 | 0.0000 |
| $N_6$ | | | | | 0.0000 |

## 1.16.1.2 MOTOR DRIVEN AIR COMPRESSOR FAIL TO RUN

| | |
|---|---|
| **Component :** | Compressor |
| **Failure Mode :** | Fail to Run (Normally running equipment) |
| **Component Group :** | Motor Driven |
| **Start Date :** | 1998/01/01 |
| **Data Version :** | 2010/12/31 |

## Total Number of Independent Failure Events: 580.00
## Total Number of Common-Cause Failure Events: 3

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9883980 | 0.9945890 | 0.9952160 | 0.9986240 | 0.9953410 | 5.0876E+02 | 2.7678E+00 |
| $\alpha_2$ | 1.37E-03 | 5.41E-03 | 4.78E-03 | 1.16E-02 | 4.66E-03 | 2.7678E+00 | 5.0876E+02 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9899010 | 0.9947450 | 0.9951640 | 0.9981680 | 0.9959990 | 7.7634E+02 | 4.1009E+00 |
| $\alpha_2$ | 9.42E-04 | 3.63E-03 | 3.22E-03 | 7.74E-03 | 2.67E-03 | 2.8337E+00 | 7.7761E+02 |
| $\alpha_3$ | 1.41E-04 | 1.62E-03 | 1.22E-03 | 4.48E-03 | 1.33E-03 | 1.2672E+00 | 7.7917E+02 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9914600 | 0.9953610 | 0.9956700 | 0.9981970 | 0.9969960 | 1.0418E+03 | 4.8551E+00 |
| $\alpha_2$ | 4.31E-04 | 2.13E-03 | 1.82E-03 | 4.88E-03 | 1.00E-03 | 2.2281E+00 | 1.0444E+03 |
| $\alpha_3$ | 3.04E-04 | 1.82E-03 | 1.51E-03 | 4.38E-03 | 1.50E-03 | 1.9043E+00 | 1.0448E+03 |
| $\alpha_4$ | 1.35E-05 | 6.90E-04 | 4.10E-04 | 2.32E-03 | 5.01E-04 | 7.2267E-01 | 1.0459E+03 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9916730 | 0.9951470 | 0.9953930 | 0.9977880 | 0.9975950 | 1.3408E+03 | 6.5383E+00 |
| $\alpha_2$ | 4.66E-04 | 1.94E-03 | 1.70E-03 | 4.24E-03 | 4.01E-04 | 2.6142E+00 | 1.3447E+03 |
| $\alpha_3$ | 3.35E-04 | 1.65E-03 | 1.41E-03 | 3.79E-03 | 1.00E-03 | 2.2274E+00 | 1.3451E+03 |
| $\alpha_4$ | 1.03E-04 | 1.02E-03 | 7.87E-04 | 2.74E-03 | 8.02E-04 | 1.3744E+00 | 1.3460E+03 |
| $\alpha_5$ | 4.82E-08 | 2.39E-04 | 6.53E-05 | 1.07E-03 | 2.00E-04 | 3.2228E-01 | 1.3470E+03 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9924610 | 0.9955010 | 0.9957000 | 0.9978450 | 0.9979950 | 1.6105E+03 | 7.2786E+00 |
| $\alpha_2$ | 3.51E-04 | 1.54E-03 | 1.34E-03 | 3.41E-03 | 1.67E-04 | 2.4892E+00 | 1.6153E+03 |
| $\alpha_3$ | 2.24E-04 | 1.25E-03 | 1.05E-03 | 2.95E-03 | 5.85E-04 | 2.0168E+00 | 1.6158E+03 |
| $\alpha_4$ | 1.54E-04 | 1.06E-03 | 8.64E-04 | 2.64E-03 | 7.52E-04 | 1.7172E+00 | 1.6161E+03 |
| $\alpha_5$ | 1.71E-05 | 5.24E-04 | 3.38E-04 | 1.66E-03 | 4.18E-04 | 8.4720E-01 | 1.6169E+03 |
| $\alpha_6$ | 2.29E-10 | 1.29E-04 | 1.48E-05 | 6.56E-04 | 8.35E-05 | 2.0824E-01 | 1.6176E+03 |

*ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9953410 | 0.9959990 | 0.9969960 | 0.9975950 | 0.9979950 |
| $\alpha_2$ | 4.66E-03 | 2.67E-03 | 1.00E-03 | 4.01E-04 | 1.67E-04 |
| $\alpha_3$ | | 1.33E-03 | 1.50E-03 | 1.00E-03 | 5.85E-04 |
| $\alpha_4$ | | | 5.01E-04 | 8.02E-04 | 7.52E-04 |
| $\alpha_5$ | | | | 2.00E-04 | 4.18E-04 |
| $\alpha_6$ | | | | | 8.35E-05 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.95E-01 | 9.96E-01 | 9.97E-01 | 9.98E-01 | 9.98E-01 |
| Beta | 4.66E-03 | 4.00E-03 | 3.00E-03 | 2.40E-03 | 2.00E-03 |
| Gamma | | 3.33E-01 | 6.67E-01 | 8.33E-01 | 9.17E-01 |
| Delta | | | 2.50E-01 | 5.00E-01 | 6.82E-01 |
| Epsilon | | | | 2.00E-01 | 4.00E-01 |
| Mu | | | | | 1.67E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 497.85 | 746.78 | 995.71 | 1244.64 | 1493.56 |
| $N_1$ | 0.6667 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $N_2$ | 2.3333 | 2.0000 | 1.0000 | 0.5000 | 0.2500 |
| $N_3$ | | 1.0000 | 1.5000 | 1.2500 | 0.8750 |
| $N_4$ | | | 0.5000 | 1.0000 | 1.1250 |
| $N_5$ | | | | 0.2500 | 0.6250 |
| $N_6$ | | | | | 0.1250 |

# 2 No Data (Prior Only)

### 2.1.1.1 No Data

The section labeled No Data (Prior Only) shows the prior used in the CCF database. This is the result of calculating an application without any data, which is the same as calculating an application with all the events in the CCF database. These CCF parameters may be used for those cases where there is no reasonable set of data to approximate the intended event.

# 2.2 Generic Distributions

## 2.2.1 Generic Demand CCF Distribution

### 2.2.1.1 ALL CCF DEMAND BASED EVENTS 1997 TO CURRENT SPAR: CCF-DEM

**Failure Mode :** Fail to close (reseat) on demand
Fail to Open/Close Mode Unspecified (demand based)
Fail to open on demand
Fail to start
Fail to Load/Run
Fail to stop
**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 2821.80
Total Number of Common-Cause Failure Events: 95

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9679280 | 0.9760020 | 0.9762900 | 0.9830830 | 0.9761660 | 1.0674E+03 | 2.6245E+01 |
| $\alpha_2$ | 1.69E-02 | 2.40E-02 | 2.37E-02 | 3.21E-02 | 2.38E-02 | 2.6245E+01 | 1.0674E+03 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9689110 | 0.9755070 | 0.9756980 | 0.9814460 | 0.9757250 | 1.5955E+03 | 4.0060E+01 |
| $\alpha_2$ | 1.15E-02 | 1.62E-02 | 1.60E-02 | 2.17E-02 | 1.60E-02 | 2.6557E+01 | 1.6090E+03 |
| $\alpha_3$ | 4.95E-03 | 8.26E-03 | 8.06E-03 | 1.22E-02 | 8.25E-03 | 1.3503E+01 | 1.6221E+03 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9689330 | 0.9747150 | 0.9748630 | 0.9799950 | 0.9750170 | 2.1153E+03 | 5.4874E+01 |
| $\alpha_2$ | 1.13E-02 | 1.54E-02 | 1.53E-02 | 2.00E-02 | 1.52E-02 | 3.3455E+01 | 2.1367E+03 |
| $\alpha_3$ | 3.95E-03 | 6.50E-03 | 6.35E-03 | 9.57E-03 | 6.46E-03 | 1.4109E+01 | 2.1561E+03 |
| $\alpha_4$ | 1.61E-03 | 3.37E-03 | 3.22E-03 | 5.64E-03 | 3.34E-03 | 7.3097E+00 | 2.1629E+03 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9721560 | 0.9770540 | 0.9771730 | 0.9815520 | 0.9775280 | 2.6748E+03 | 6.2818E+01 |
| $\alpha_2$ | 8.03E-03 | 1.11E-02 | 1.10E-02 | 1.46E-02 | 1.07E-02 | 3.0426E+01 | 2.7072E+03 |
| $\alpha_3$ | 4.24E-03 | 6.55E-03 | 6.43E-03 | 9.28E-03 | 6.43E-03 | 1.7939E+01 | 2.7197E+03 |
| $\alpha_4$ | 2.18E-03 | 3.91E-03 | 3.79E-03 | 6.06E-03 | 3.92E-03 | 1.0711E+01 | 2.7269E+03 |
| $\alpha_5$ | 4.45E-04 | 1.37E-03 | 1.25E-03 | 2.70E-03 | 1.39E-03 | 3.7417E+00 | 2.7339E+03 |

Generic Demand CCF Distribution

ALL CCF DEMAND BASED EVENTS 1997 TO CURRENT SPAR: CCF-DEM

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9745600 | 0.9788530 | 0.9789530 | 0.9828180 | 0.9793970 | 3.2045E+03 | 6.9231E+01 |
| $\alpha_2$ | 6.15E-03 | 8.63E-03 | 8.53E-03 | 1.14E-02 | 8.25E-03 | 2.8242E+01 | 3.2455E+03 |
| $\alpha_3$ | 3.83E-03 | 5.84E-03 | 5.74E-03 | 8.19E-03 | 5.70E-03 | 1.9120E+01 | 3.2546E+03 |
| $\alpha_4$ | 2.22E-03 | 3.80E-03 | 3.70E-03 | 5.72E-03 | 3.76E-03 | 1.2439E+01 | 3.2613E+03 |
| $\alpha_5$ | 1.09E-03 | 2.27E-03 | 2.16E-03 | 3.78E-03 | 2.28E-03 | 7.4165E+00 | 3.2663E+03 |
| $\alpha_6$ | 1.10E-04 | 6.15E-04 | 5.17E-04 | 1.46E-03 | 6.12E-04 | 2.0134E+00 | 3.2717E+03 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9761660 | 0.9757250 | 0.9750170 | 0.9775280 | 0.9793970 |
| $\alpha_2$ | 2.38E-02 | 1.60E-02 | 1.52E-02 | 1.07E-02 | 8.25E-03 |
| $\alpha_3$ | | 8.25E-03 | 6.46E-03 | 6.43E-03 | 5.70E-03 |
| $\alpha_4$ | | | 3.34E-03 | 3.92E-03 | 3.76E-03 |
| $\alpha_5$ | | | | 1.39E-03 | 2.28E-03 |
| $\alpha_6$ | | | | | 6.12E-04 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.76E-01 | 9.76E-01 | 9.75E-01 | 9.78E-01 | 9.79E-01 |
| Beta | 2.38E-02 | 2.43E-02 | 2.50E-02 | 2.25E-02 | 2.06E-02 |
| Gamma | | 3.40E-01 | 3.92E-01 | 5.22E-01 | 6.00E-01 |
| Delta | | | 3.41E-01 | 4.52E-01 | 5.38E-01 |
| Epsilon | | | | 2.62E-01 | 4.35E-01 |
| Mu | | | | | 2.12E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1015.04 | 1522.55 | 2030.07 | 2537.59 | 3045.11 |
| $N_1$ | 42.0650 | 43.3744 | 39.0866 | 41.0323 | 42.4318 |
| $N_2$ | 25.8106 | 25.7231 | 32.2268 | 28.3118 | 26.0027 |
| $N_3$ | | 13.2362 | 13.7050 | 16.9613 | 17.9781 |
| $N_4$ | | | 7.0870 | 10.3371 | 11.8469 |
| $N_5$ | | | | 3.6694 | 7.1943 |
| $N_6$ | | | | | 1.9302 |

## 2.2.2 Generic Rate CCF Distribution

### 2.2.2.1 ALL CCF RATE BASED EVENTS 1997 TO CURRENT SPAR: CCF-RATE

**Failure Mode :**

Spurious operation open or close
Fail to Run (Normally running equipment)
Filter media allows the pass through of debris
Failure of Control Function Only
High dP across filter
Fail to Run >1 Hour (Standby equipment)
Fail to control flow
Fail to Run less than 1 Hour
Fail to Operate (General operation failure, rate based)

Loss of heat transfer capabilities in heat exchangers

No flow/plugged

**Start Date :** 1997/01/01
**Data Version :** 2010/12/31

Total Number of Independent Failure Events: 2433.50
Total Number of Common-Cause Failure Events: 99

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9546190 | 0.9640470 | 0.9643150 | 0.9725600 | 0.9640900 | 1.1169E+03 | 4.1654E+01 |
| $\alpha_2$ | 2.74E-02 | 3.60E-02 | 3.57E-02 | 4.54E-02 | 3.59E-02 | 4.1654E+01 | 1.1169E+03 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9582460 | 0.9657470 | 0.9659280 | 0.9726330 | 0.9657760 | 1.6645E+03 | 5.9037E+01 |
| $\alpha_2$ | 1.45E-02 | 1.97E-02 | 1.95E-02 | 2.55E-02 | 1.95E-02 | 3.3908E+01 | 1.6896E+03 |
| $\alpha_3$ | 1.02E-02 | 1.46E-02 | 1.44E-02 | 1.96E-02 | 1.47E-02 | 2.5129E+01 | 1.6984E+03 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9618670 | 0.9681350 | 0.9682740 | 0.9739420 | 0.9682810 | 2.2088E+03 | 7.2699E+01 |
| $\alpha_2$ | 1.10E-02 | 1.50E-02 | 1.48E-02 | 1.94E-02 | 1.47E-02 | 3.4148E+01 | 2.2474E+03 |
| $\alpha_3$ | 6.89E-03 | 1.01E-02 | 9.92E-03 | 1.37E-02 | 1.01E-02 | 2.2953E+01 | 2.2585E+03 |
| $\alpha_4$ | 4.27E-03 | 6.84E-03 | 6.69E-03 | 9.90E-03 | 6.88E-03 | 1.5598E+01 | 2.2659E+03 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9665110 | 0.9717760 | 0.9718820 | 0.9766630 | 0.9720370 | 2.7911E+03 | 8.1064E+01 |
| $\alpha_2$ | 7.42E-03 | 1.03E-02 | 1.02E-02 | 1.36E-02 | 9.92E-03 | 2.9626E+01 | 2.8425E+03 |
| $\alpha_3$ | 5.93E-03 | 8.55E-03 | 8.44E-03 | 1.16E-02 | 8.51E-03 | 2.4566E+01 | 2.8476E+03 |
| $\alpha_4$ | 3.54E-03 | 5.62E-03 | 5.50E-03 | 8.09E-03 | 5.69E-03 | 1.6139E+01 | 2.8560E+03 |
| $\alpha_5$ | 2.08E-03 | 3.74E-03 | 3.62E-03 | 5.78E-03 | 3.85E-03 | 1.0733E+01 | 2.8614E+03 |

Generic Rate CCF Distribution

ALL CCF RATE BASED EVENTS 1997 TO CURRENT SPAR: CCF-RATE

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9701220 | 0.9746820 | 0.9747770 | 0.9789330 | 0.9750480 | 3.3448E+03 | 8.6882E+01 |
| $\alpha_2$ | 5.07E-03 | 7.29E-03 | 7.19E-03 | 9.83E-03 | 6.88E-03 | 2.5014E+01 | 3.4067E+03 |
| $\alpha_3$ | 4.91E-03 | 7.10E-03 | 7.00E-03 | 9.60E-03 | 7.01E-03 | 2.4348E+01 | 3.4073E+03 |
| $\alpha_4$ | 3.55E-03 | 5.44E-03 | 5.34E-03 | 7.65E-03 | 5.46E-03 | 1.8666E+01 | 3.4130E+03 |
| $\alpha_5$ | 1.67E-03 | 3.03E-03 | 2.94E-03 | 4.72E-03 | 3.08E-03 | 1.0408E+01 | 3.4213E+03 |
| $\alpha_6$ | 1.25E-03 | 2.46E-03 | 2.37E-03 | 4.00E-03 | 2.53E-03 | 8.4458E+00 | 3.4232E+03 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| $\alpha_1$ | 0.9640900 | 0.9657760 | 0.9682810 | 0.9720370 | 0.9750480 |
| $\alpha_2$ | 3.59E-02 | 1.95E-02 | 1.47E-02 | 9.92E-03 | 6.88E-03 |
| $\alpha_3$ | | 1.47E-02 | 1.01E-02 | 8.51E-03 | 7.01E-03 |
| $\alpha_4$ | | | 6.88E-03 | 5.69E-03 | 5.46E-03 |
| $\alpha_5$ | | | | 3.85E-03 | 3.08E-03 |
| $\alpha_6$ | | | | | 2.53E-03 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| 1-Beta | 9.64E-01 | 9.66E-01 | 9.68E-01 | 9.72E-01 | 9.75E-01 |
| Beta | 3.59E-02 | 3.42E-02 | 3.17E-02 | 2.80E-02 | 2.50E-02 |
| Gamma | | 4.29E-01 | 5.35E-01 | 6.45E-01 | 7.24E-01 |
| Delta | | | 4.05E-01 | 5.28E-01 | 6.12E-01 |
| Epsilon | | | | 4.03E-01 | 5.06E-01 |
| Mu | | | | | 4.51E-01 |

| Avg. Impact Vector | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 |
|---|---|---|---|---|---|
| Adj. Ind. Events | 1064.99 | 1597.48 | 2129.98 | 2662.47 | 3194.97 |
| $N_1$ | 41.6641 | 37.4219 | 32.6854 | 32.5040 | 32.9120 |
| $N_2$ | 41.2199 | 33.0742 | 32.9199 | 27.5114 | 22.7750 |
| $N_3$ | | 24.8618 | 22.5482 | 23.5890 | 23.2064 |
| $N_4$ | | | 15.3758 | 15.7646 | 18.0733 |
| $N_5$ | | | | 10.6611 | 10.1861 |
| $N_6$ | | | | | 8.3626 |

## 2.2.3 CCF Prior Distribution

### 2.2.3.1 No Data (Prior Only)

**Data Version :** 2007/12/31

Total Number of Independent Failure Events: 0
Total Number of Common-Cause Failure Events: 0

*ALPHA FACTOR DISTRIBUTIONS*

***CCCG = 2***

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.8993200 | 0.9742690 | 0.9887700 | 0.9999290 | ---- | 1.7418E+01 | 4.6002E-01 |
| $\alpha_2$ | 6.65E-05 | 2.57E-02 | 1.12E-02 | 1.00E-01 | ---- | 4.6002E-01 | 1.7418E+01 |

**CCCG = 3**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9306240 | 0.9755060 | 0.9819700 | 0.9982830 | ---- | 4.5105E+01 | 1.1325E+00 |
| $\alpha_2$ | 6.61E-04 | 1.87E-02 | 1.23E-02 | 5.84E-02 | ---- | 8.6476E-01 | 4.5372E+01 |
| $\alpha_3$ | 2.07E-07 | 5.79E-03 | 1.17E-03 | 2.74E-02 | ---- | 2.6776E-01 | 4.5969E+01 |

**CCCG = 4**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9380870 | 0.9740820 | 0.9782970 | 0.9956540 | ---- | 7.0868E+01 | 1.8856E+00 |
| $\alpha_2$ | 1.43E-03 | 1.70E-02 | 1.28E-02 | 4.69E-02 | ---- | 1.2400E+00 | 7.1513E+01 |
| $\alpha_3$ | 9.66E-06 | 5.89E-03 | 2.32E-03 | 2.38E-02 | ---- | 4.2870E-01 | 7.2324E+01 |
| $\alpha_4$ | 9.21E-09 | 2.98E-03 | 3.83E-04 | 1.50E-02 | ---- | 2.1695E-01 | 7.2536E+01 |

**CCCG = 5**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9521790 | 0.9760740 | 0.9782400 | 0.9925770 | ---- | 1.4106E+02 | 3.4576E+00 |
| $\alpha_2$ | 2.59E-03 | 1.41E-02 | 1.19E-02 | 3.30E-02 | ---- | 2.0400E+00 | 1.4247E+02 |
| $\alpha_3$ | 3.01E-04 | 6.59E-03 | 4.50E-03 | 2.00E-02 | ---- | 9.5369E-01 | 1.4356E+02 |
| $\alpha_4$ | 2.21E-06 | 2.67E-03 | 9.37E-04 | 1.12E-02 | ---- | 3.8684E-01 | 1.4413E+02 |
| $\alpha_5$ | 5.61E-20 | 5.33E-04 | 5.18E-07 | 3.10E-03 | ---- | 7.7129E-02 | 1.4444E+02 |

**CCCG = 6**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9553700 | 0.9762820 | 0.9779970 | 0.9913440 | ---- | 1.7893E+02 | 4.3470E+00 |
| $\alpha_2$ | 2.60E-03 | 1.24E-02 | 1.07E-02 | 2.81E-02 | ---- | 2.2804E+00 | 1.8099E+02 |
| $\alpha_3$ | 4.16E-04 | 6.13E-03 | 4.45E-03 | 1.75E-02 | ---- | 1.1245E+00 | 1.8215E+02 |
| $\alpha_4$ | 3.82E-05 | 3.40E-03 | 1.85E-03 | 1.20E-02 | ---- | 6.2471E-01 | 1.8265E+02 |
| $\alpha_5$ | 1.60E-08 | 1.32E-03 | 2.18E-04 | 6.46E-03 | ---- | 2.4272E-01 | 1.8303E+02 |
| $\alpha_6$ | 1.26E-20 | 4.07E-04 | 3.05E-07 | 2.36E-03 | ---- | 7.4722E-02 | 1.8320E+02 |

**CCCG = 7**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9603690 | 0.9769760 | 0.9781320 | 0.9896440 | ---- | 2.6720E+02 | 6.2971E+00 |
| $\alpha_2$ | 3.14E-03 | 1.12E-02 | 1.00E-02 | 2.33E-02 | ---- | 3.0721E+00 | 2.7042E+02 |
| $\alpha_3$ | 6.66E-04 | 5.55E-03 | 4.40E-03 | 1.43E-02 | ---- | 1.5182E+00 | 2.7197E+02 |
| $\alpha_4$ | 1.58E-04 | 3.48E-03 | 2.37E-03 | 1.06E-02 | ---- | 9.5310E-01 | 2.7254E+02 |
| $\alpha_5$ | 1.00E-05 | 1.93E-03 | 9.22E-04 | 7.26E-03 | ---- | 5.2795E-01 | 2.7296E+02 |
| $\alpha_6$ | 4.58E-10 | 7.08E-04 | 6.75E-05 | 3.68E-03 | ---- | 1.9373E-01 | 2.7330E+02 |
| $\alpha_7$ | 5.03E-44 | 1.17E-04 | 8.41E-13 | 4.81E-04 | ---- | 3.2027E-02 | 2.7346E+02 |

**CCCG = 8**

| Alpha Factor | 5th% | Mean | Median | 95th% | MLE | a | b |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.9622170 | 0.9773660 | 0.9783580 | 0.9891370 | ---- | 3.1221E+02 | 7.2302E+00 |
| $\alpha_2$ | 3.13E-03 | 1.04E-02 | 9.45E-03 | 2.12E-02 | ---- | 3.3414E+00 | 3.1609E+02 |
| $\alpha_3$ | 6.67E-04 | 5.04E-03 | 4.06E-03 | 1.28E-02 | ---- | 1.6130E+00 | 3.1782E+02 |
| $\alpha_4$ | 1.86E-04 | 3.26E-03 | 2.30E-03 | 9.62E-03 | ---- | 1.0438E+00 | 3.1839E+02 |
| $\alpha_5$ | 3.88E-05 | 2.20E-03 | 1.28E-03 | 7.47E-03 | ---- | 7.0280E-01 | 3.1873E+02 |
| $\alpha_6$ | 5.77E-07 | 1.13E-03 | 3.63E-04 | 4.86E-03 | ---- | 3.6184E-01 | 3.1907E+02 |
| $\alpha_7$ | 1.19E-13 | 3.98E-04 | 8.44E-06 | 2.25E-03 | ---- | 1.2739E-01 | 3.1931E+02 |
| $\alpha_8$ | 5.47E-36 | 1.25E-04 | 5.43E-11 | 6.01E-04 | ---- | 4.0005E-02 | 3.1940E+02 |

## *ALPHA FACTOR and MGL PARAMETERS*

| Alpha Factor | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| $\alpha_1$ | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 | 0.0000000 |
| $\alpha_2$ | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_3$ | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_4$ | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_5$ | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_6$ | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| $\alpha_7$ | | | | | | 0.00E+00 | 0.00E+00 |
| $\alpha_8$ | | | | | | | 0.00E+00 |

| MGL Parameter | CCCG=2 | CCCG=3 | CCCG=4 | CCCG=5 | CCCG=6 | CCCG=7 | CCCG=8 |
|---|---|---|---|---|---|---|---|
| 1-Beta | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 | 1.00E+00 |
| Beta | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Gamma | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Delta | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Epsilon | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Mu | | | | | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| Upsilon | | | | | | 0.00E+00 | 0.00E+00 |
| Sigma | | | | | | | 0.00E+00 |

# 3 Glossary

***Application***
A particular set of CCF events selected from the CCF database for use in a specific study.

***Average Impact Vector***
An average over the impact vectors for different hypotheses regarding the number of components failed in an event.

***Available***
The component is available if it is capable of performing its function according to a specified success criterion.

***Basic Event***
An event in a reliability logic model that represents the state in which a component or group of components is unavailable and does not require further development in terms of contributing causes.

***Common Cause Event***
A dependent failure in which two or more component fault states exist simultaneously, or within a short time interval, and are a direct result of a shared cause.

***Common Cause Basic Event***
In system modeling, a basic event that represents the unavailability of a specific set of components because of shared causes that are not explicitly represented in the system logic model as other basic events.

***Common Cause Component Group***
A group of (usually similar [in mission, manufacturer, maintenance, environment, etc.]) components that are considered to have a high potential for failure due to the same cause or causes.

***Common Cause Failure Model***
The basis for quantifying the frequency of common cause events. Examples include the beta factor, alpha factor, and basic parameter, and the binomial failure rate models.

***Complete Common Cause Failure***
A CCF in which all redundant components are failed simultaneously as a direct result of a shared cause; i.e., the component degradation value equals 1.0 for all components, and both the timing factor and the shared cause factor are equal to 1.0.

***Component***
An element of plant hardware designed to provide a particular function.

***Component Boundary***
The component boundary encompasses the set of piece parts that are considered to form the component.

***Component Degradation Value (p)***
The assessed probability ($0.0 = p = 1.0$) that a functionally or physically degraded component would fail to complete the mission.

### *Component State*
Component state defines the component status in regard to its intended function. Two general categories of component states are defined as available and unavailable.

### *Timing Factor (q)*
The probability (0.0 = q = 1.0) that two or more component failures (or degraded states) separated in time represent a CCF. This can be viewed as an indication of the strength-of-coupling in synchronizing failure times.

### *Unavailable*
The component is unavailable if the component is unable to perform its intended function according to a stated success criterion. Two subsets of unavailable states are failure and functionally unavailable.

### *Exposed Population*
The set of components within the plant that are potentially affected by the CCF under consideration.

### *Failure*
The component is not capable of performing its specified operation according to a success criterion.

### *Functionally Unavailable*
The component is capable of operation, but the function normally provided by the component is unavailable due to lack of proper input, lack of support function from a source outside the component (i.e., motive power, actuation signal), maintenance, testing, the improper interference of a person, etc.

### *Potentially Unavailable*
The component is capable of performing its function according to a success criterion, but an incipient or degraded condition exists. (N.B., potentially unavailable is not synonymous with hypothetical.)

### *Defense*
Any operational, maintenance, and design measures taken to diminish the frequency and/or consequences of CCFs.

### *Degraded*
The component is in such a state that it exhibits reduced performance but insufficient degradation to declare the component unavailable according to the specified success criterion.

### *Impact Vector*
An assessment of the impact an event would have on a common cause component group. The impact is usually measured as the number of failed components out of a set of similar components in the common cause component group.

### *Incipient*
The component is in a condition that, if left unremedied, could ultimately lead to a degraded or unavailable state.

### *Reliability Logic Model*
A logical representation of the combinations of component states that could lead to

system failure. A fault tree is an example of a system logic model.

### *Root Cause*
The most basic reason for a component failure, which, if corrected, could prevent recurrence. The identified root cause may vary depending on the particular defensive strategy adopted against the failure mechanism.

### *Shared Cause Factor/Mechanism*
A set of causes and factors characterizing why and how a failure is systematically induced in several components.

### *Failure Mechanism*
The history describing the events and influences leading to a given failure.

### *Failure Mode*
A description of component failure in terms of the component function that was actually or potentially unavailable.

### *Failure Mode Applicability*
The analyst's probability that the specified component failure mode for a given event is appropriate to the particular application.

### *Mapping*
The impact vector of an event must be "mapped up" or "mapped down" when the exposed population of the target plant is higher or lower than that of the original plant that experienced the CCF. The end result of mapping an impact vector is an adjusted impact vector applicable to the target plant.

### *Mapping up Factor*
A factor used to adjust the impact vector of an event when the exposed population of the target plan is higher than that of the original plant that experienced the CCF.

### *Potential Common Cause Failure*
Any common cause event in which at least one component degradation value is less than 1.0.

### *Proximate Cause*
A characterization of the condition that is readily identified as leading to failure of the component. It might alternatively be characterized as a symptom.

### *Shared-Cause Factor (c)*
A number that reflects the analyst's uncertainty ($0.0 = c = 1.0$) about the existence of coupling among the failures of two or more components, i.e., whether a shared cause of failure can be clearly identified.

### *Shock*
A shock is an event that occurs at a random point in time and acts on the system; i.e., all the components in the system simultaneously. There are two kinds of shocks distinguished by the potential impact of the shock event, i.e., lethal and non-lethal.

### *System*
The entity that encompasses an interacting collection of components to provide a particular function or functions.